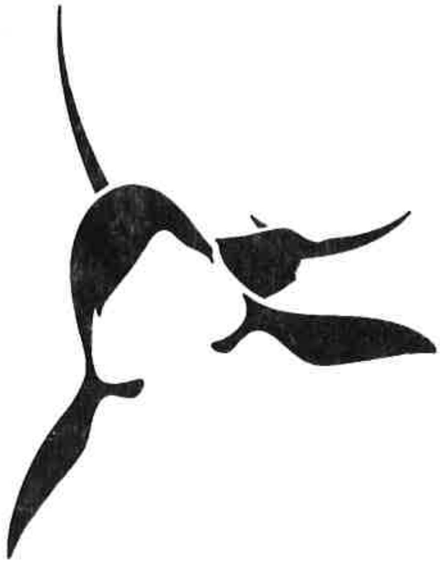
EUROPEAN RESEARCH ON CETACEANS - 12

PROCEEDINGS OF THE TWELFTH ANNUAL CONFERENCE OF THE EUROPEAN CETACEAN SOCIETY,

MONACO

20-24 JANUARY 1998



EDITORS: P.G.H. EVANS AND E.C.M. PARSONS

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Proceedings of the Twelfth Annual Conference
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INTRODUCTION

For the first time in their histories, the European Cetacean Society and the Society for Marine Mammalogy joined forces to organise the first World Marine Mammal Science Conference, in Monaco between 20th and 24th January 1998.

This represents the Twelfth Annual Conference of the ECS. In line with previous years, the Proceedings that follow comprise those papers on subjects relating to European marine mammals or from ECS members. The conference was attended by around 1,200 persons from 55 countries. Its success was largely due to the efforts of Anne Collet (ably supported by Isabelle Deval, Bellou Kuhn, Olivier Van Canneyt, Cyril Hue, Eric Poncelet and Karine Le Coq) who devoted much of the previous two years to ensuring that the conference ran moothly. Many others also played a crucial role: the SMM board particularly Ian Stirling, Roger Gentry and Dan Odell; the ECS board particularly Christina Lockyer, Greg Donovan and Ursula Siebert; the chairs and members of abstract Review committees; ECS & SMM student volunteers lead by Paula Moreno and Leah Gerber; and last but by no means least, Terry Odell. A list of those participating in the various committees follows this introduction.

We gratefully acknowledge the contribution to the conference made by the following organisations: Air-France, Argos, Art Graphic 89, Centre de Recherche sur les Mammiferes Marins de La Rochelle, Centre des Congres Auditorium Monte-Carlo (CCAM), Heli-Air, Hotel Loews, Insituto Centrale per la Ricerca al Mare (ICRAM), International Whaling Commission, MAAF Assurances, Marineland Antibes, Ministere de l'Amenagement du Territoire et de l'Environnement (France), Musee Oceanographique (Monaco), North Atlantic Marine Mammal Commission (NAMMCO), Office of Naval Research (ONREUR & ONR), Sea World Inc., Sir Speedy, SPA/RAC (UNEP/MAP) and Ville de La Rochelle.

For the first time, all summaries contributed to the Proceedings have been peer reviewed, and the editors would like to thank in particular those reviewers who gave up their time to give expert comment: John Baker, Juan Balbuena, Giovanni Bearzi, Harald Benke, Ray Bernor, Arne Bjorge, David Bohaska, Jim Boran, Oliver Chappell, Peter Corkeron, Mariano Domingo, Dagmar Fertl, Jaume Forcada, Caterina Fortuna, Alexandre Gannier, Joe Geraci, Guido Gnone, John Goold, Jonathan Gordon, John Harwood, Mads-Peter Heide-Jorgensen, Denise Herzing, Lex Hiby, Rus Hoelzel, Vincent Janik, Tom Jefferson, Paul Jepson, Robin Law, Justin Matthews, Colin McLeod, Michel Milinkovitch, Vic Peddemors, Michela Podesta', Toni Raga, Vincent Ridoux, Ursula Siebert, Chris Smeenk, Rene Swift, Sean Twiss, Ben Wilson, Bernd Wursig, Kerstin Young, and Margherita Zanardelli.

Contributions have been arranged broadly by subject. Those extended summaries which have been accepted after review appear first in each subject category, followed by half-page abstracts (including those who did not wish to submit extended summaries). Each set is arranged alphabetically by first author. For the benefit of contributors to future Proceedings, instructions are given at the back of this volume.

An enormous amount of effort has gone into the editing and production of these Proceedings. In this connection, I should like to thank my co-editor Chris Parsons, along with Anna Colbert and Rachel King for their invaluable help in typing, editing, and lay-out. Together, hundreds of hours have been spent towards the final production, whilst Toni Raga has been responsible for organising its printing in Valencia.

Peter G.H. Evans

POST SCRIPT

Christina Lockyer, as chairman of the ECS, would like to express the Society's great appreciation of Peter Evans' continued efficient and successful efforts in editing and producing the Proceedings.

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CONSERVATION

YOU SEE ME, I SEE YOU: THE EFFECTS OF ECO-TOURISM ON THE GREY SEAL BREEDING SITE AT DONNA NOOK, LINCOLNSHIRE, UK.

Damian C. Lidgard

Department of Zoology and Animal Ecology, University College, Cork, Ireland

INTRODUCTION Despite the increase in marine mammal watching throughout the world, the effects of human disturbance on marine mammal populations remain largely unknown. Donna Nook is a National Nature Reserve on the east coast of England and is home to a breeding colony of grey seal (*Halichoerus grypus*) (Brown and Booth, 1991). The colony is divided between a sand-bar and the top-shore which lies 2 km from the sand-bar and the Mean Low Water Mark. Each year, an estimated 10,000 people visit the colony during the short 7 week breeding season (Fairhurst, 1993).

Females at the top-shore rookery do not feed and remain close to their pup during the intense 2 to 3-week lactation period (*pers.obs.*). Since the transfer of energy from mother to pup is a closed system, extraneous behavioural activities associated with human disturbance may lower the efficiency of energy transfer and thus lower the pup growth rate and weaning mass. In light of the increasing number of visitors to the reserve, a study was conducted to determine the effects of human disturbance on the maternal performance of grey seals.

METHODS The study area was situated at the top-shore rookery. A fence, which ran parallel along the top-shore, prevented public access to the rookery although late in the season seals moved beyond the fence and were accessible to the public. Two-thirds of the study area was designated as the control, low disturbed, area and lay between an access path, 20 m from the fence, and the sea. The high disturbed area encompassed the access path and a small area of established dune beyond the fence.

Visitors in the study area were counted during 68 one-hour observation sessions using scan sampling, from 7th November to 10th December 1995. Eighteen focal mother-pup pairs from the low and high disturbed areas were studied from birth to weaning to measure the duration of lactation. Of these, 14 pups were used to obtain growth rates by taking a weight at 3 to 7 days after birth and on the day of weaning. Pups were weighed in a canvas bag attached to a 100kg scale (accurate to ±1kg) and hoisted with a wooden pole using one or two people. Pup ages were calculated from known birth dates and pup sex noted. Pup mass gain was calculated using linear regression and the data analysed using the Mann Whitney *U*-test. All values given are ± standard error.

RESULTS The number of visitors in the study area was lowest during the early season (07 to 18 November) and highest during the end of the season (30 November to 10 December) (Fig. 1). Thirteen females gave birth early in the season and 5 later in the season (25 to 30 November). Eight of the 13 early breeders pupped in the low disturbed area and 4 of the 5 late breeders pupped in the high disturbed area (Table 1). Early breeders had a significantly longer lactation period compared with late breeders (Table 2).

Pups born in the low disturbed area had a larger weaning mass and higher growth rate compared with pups born in the high disturbed area (Table 3), although these differences were not significant. Pups born in the early season when visitor attendance was at its lowest had a significantly larger weaning mass and higher growth rate compared with pups born later in the season when visitor attendance was at its highest (Table 2, Figs. 1 and 2).

DISCUSSION Maternal performance was lower in those females that pupped in the high disturbed area in the late part of the season when visitor attendance was at its highest. Human disturbance may increase the time females spend in defence of their pup and/or disrupt suckling bouts. Since females at Donna Nook do not feed during lactation, this may lead to a lower mass transfer efficiency between mother and pup and to the observed decrease in mass gain and weaning mass and ultimately contribute to a lower survival post-weaning (Coulson and Hickling, 1964). Disturbance may also contribute to premature weaning since late breeders had a shorter lactation period compared with early breeders.

These effects may be partially shadowed by the natural temporal variation in maternal size and its influence on pup mass gain (Anderson and Fedak, 1987; Iverson *et al.*, 1993), and the contributing effects of male harassment during the late part of the season (Boness *et.al.*, 1995). Based on this study, visitor management would be more effective during the late part of the season when females are most sensitive to the effects of human disturbance.

ACKNOWLEDGEMENTS I would like to thank John Harwood (SMRU) for granting permits, Andrew Humberstone for assistance in the field, and Barry Wilkinson (LTNC) for permission to conduct this study on a Trust reserve. This project was funded by the British Ecological Society: Small Ecological Grant (No. 1172).

REFERENCES

Anderson, S.S. and Fedak, M.A. 1987. Grey seal, *Halichoerus grypus*, energetics: females invest more in male offspring. *J. Zool.*, Lond. 211: 667-679.

Boness, D.J.; Bowen, W.D. and Iverson, S.J. 1995. Does male harassment of females contribute to reproductive synchrony in the grey seal by affecting maternal performance? *Behav Ecol Sociobiol.*, 36: 1-10.

Brown, R. and Booth, V. 1991. *Donna Nook Management Plan*. Lincolnshire Trust for Nature Conservation.

Coulson, J.C. and Hickling, G. 1964. The breeding biology of the grey seal, *Halichoerus grypus*, (Fab.), on the Farne Islands, Northumberland. *J.Anim.Ecol.*, 33: 485-512.

Fairhurst, J. 1993. *Warden's Report for Donna Nook Nature Reserve*. Lincolnshire Trust for Nature Conservation.

Iverson, S.J., Bowen, W.D., Boness, D.J., and Oftedal, O.T. 1993. The effects of maternal size and milk energy output on pup growth in grey seals (*Halichoerus grypus*). *Physiol Zool.*, 66(1): 61-88.

Table 1. Number of females giving birth during the early and late season in the low and high disturbed areas.

	Early Breeder (07 to 18 Nov.)	**Late Breeder (25 to 30 Nov.)**
Low Disturbed Area	8	1
High Disturbed Area	5	4

Table 2. Lactation period, weaning mass and growth rate of pups born in the early or late season.

	EARLY	**LATE**	**P VALUE**
Lactation Period (days)	15.8 ± 0.25 n=13	14.2 ± 0.37 n=5	$p < 0.05$
Weaning Mass (kg)	55.5 ± 1.92 n=9	39.6 ± 4.14 n=5	$p < 0.05$
Growth Rate (kg/day)	2.18 ± 0.1 n=9	1.33 ± 0.19 n=5	$p < 0.05$

Table 3. Lactation period, weaning mass and growth rate of pups born in areas of low or high disturbance.

	LOW DISTURBANCE	**HIGH DISTURBANCE**	**P VALUE**
Lactation Period (days)	15.4 ± 0.44 n=9	15.3 ± 0.33 n=9	NS
Weaning Mass (kg)	54.5 ± 2.53 n=8	43.5 ± 4.63 n=6	NS
Growth Rate (kg/day)	2.12 ± 0.12 n=8	1.54 ± 0.24 n=6	NS

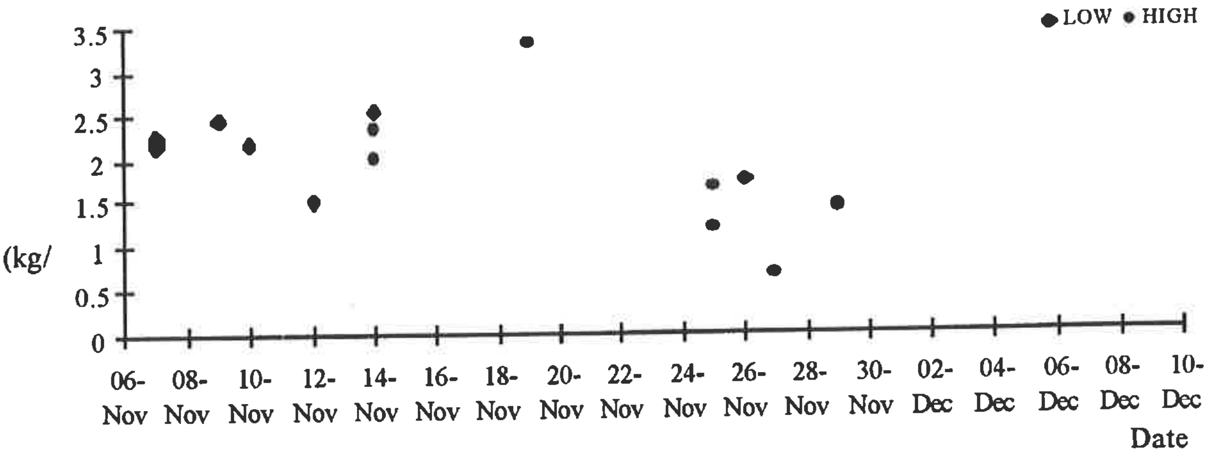

Fig. 1: Rate of mass gain and date of birth for grey seal pups born in low or disturbed areas, at Donna Nook, England.

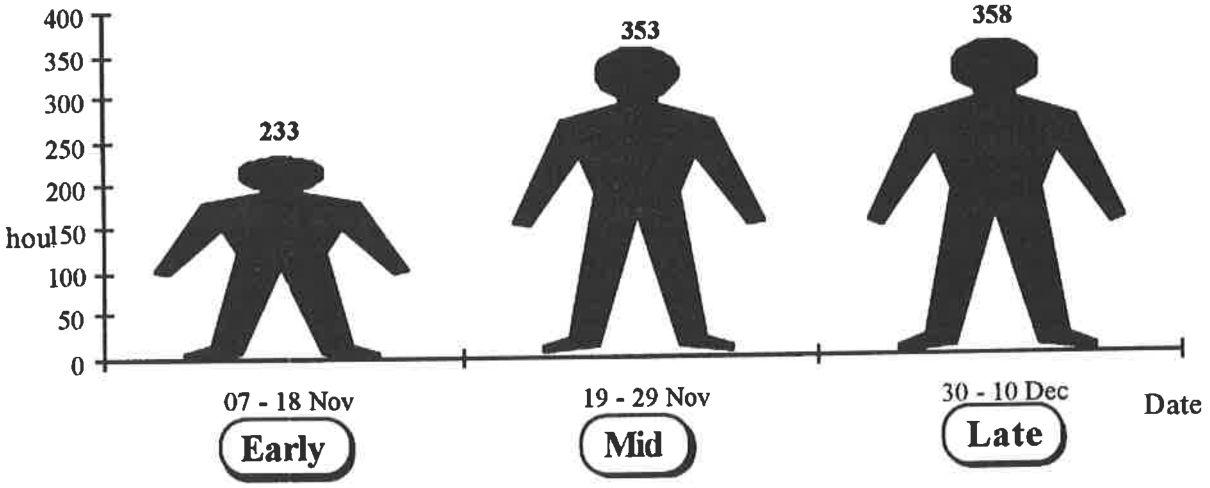

Fig 2: Number of people in study area for early, mid and late seas

A SUMMARY OF INDO-PACIFIC HUMP-BACKED DOLPHIN MORTALITY IN HONG KONG: IMPLICATIONS FOR THE CONSERVATION OF THE POPULATION

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INTRODUCTION The first published record of a cetacean stranding in Hong Kong (in 1955) was made by Romer (1958) and remained the only published account of Hong Kong's marine mammals until 1973, when an official scheme to report cetacean sightings and strandings was initiated by the Agriculture and Fisheries Department of the Hong Kong Government. The most common cetacean stranded in Hong Kong is the Indo-Pacific hump-backed dolphin (*Sousa chinensis*), a species which is present in Hong Kong's waters all year round (Parsons *et al.*, 1995). Populations of this species are considered to be at risk of extirpation in many areas due to their close proximity to human activities (Reeves and Leatherwood, 1994), and there has been concern over the viability of the population in Hong Kong (Parsons and Hoffmann, 1996).

A detailed analysis of cetacean strandings can provide a wealth of information. The stranding network in operation within Hong Kong has enabled investigations into the variety and relative abundance of cetacean species inhabiting the area, if local cetaceans are contaminated by anthropogenic pollutants, and whether or not cetacean populations are threatened by disease or human activities. This paper updates information on Indo-Pacific hump-backed dolphin mortality in Hong Kong and discusses the conclusions drawn from research upon these strandings.

MATERIALS AND METHODS Initially, historical stranding records were collated from a variety of sources, notably from Agriculture and Fisheries Department (AFD) stranding records. From December 1993 onwards, a dedicated programme was set up to record and examine cetaceans stranded upon the Hong Kong coastline. This programme was run through the AFD and stranding protocols were drafted by the AFD, in collaboration with researchers at the Swire Institute of Marine Science (SWIMS), and circulated to Government departments which were likely to come into contact with stranded cetaceans, namely, the Royal Hong Kong Marine Police and the Urban Services Department (responsible for refuse removal on public swimming beaches). Bilingual posters were produced and distributed to suitable locations: yacht clubs, Country Park wardens' offices and visitor centres, lifeguard stations and ferry terminals. From September 1995 onwards, the Ocean Park Conservation Foundation joined AFD and SWIMS in the co-ordination and examination of cetacean stranding events.

Necropsies of stranded cetaceans were undertaken according to the protocols and methodologies outlined by Geraci and Lounsbury (1993).

Spatial and temporal distribution of strandings Indo-Pacific hump-backed dolphin strandings were predominantly reported from the waters north of Lantau Island (Fig. 1), a pattern which is also apparent from sightings of live animals (Leatherwood and Jefferson, 1997; Jefferson and Leatherwood, 1997).

Strandings reported from the waters to the south and to the east of Lantau Island, occurring mostly during the summer. This coincides with sightings of live hump-backed dolphins, which frequent these southern and eastern waters during the summer and autumn (Parsons, 1997a; Jefferson and Leatherwood, 1997). This appearance of dolphins in southern waters is linked to changes in local hydrography, as dolphin abundance south of Lantau Island is correlated with changes in salinity and water temperature (Parsons, 1997a).

There is a distinct increase in the number of reported hump-backed dolphin strandings between May and September (Fig. 2; Parsons, 1998a). This seasonal increase could be due to:

1- An increase in the number of people visiting beaches and areas where strandings might occur and, hence, an increase in reports. However, heavy summer monsoon rains are common in the summer and it is unlikely that people will be flocking to beaches.
2- Local changes in dolphin abundance and habitat use.
3- A change in the distribution of dolphins in other regions of the Pearl River Delta, i.e., an influx of animals into Hong Kong from neighbouring waters.

Jefferson (1998) reported an influx of non-resident individuals into South Lantau waters, presumably animals which dwell in Chinese waters outside of Hong Kong's boundaries for the rest of the year. Therefore the latter hypothesis is probably the explanation for this increase in summer strandings.

Trace metal contamination Concentrations of trace metals were determined from liver, kidney and blubber tissue excised from stranded hump-backed dolphins. These tissues were freeze dried and approximately 0.5 g of dried tissue was digested in 5 ml of concentrated nitric acid at room temperature for 24 hours, and at 100oC for 24 hours. The digest was then filtered and made up to 50 ml with de-ionised water. Trace metal levels were determined by inductively-coupled plasma emission spectroscopy on a Perkin-Elmer 400 spectrograph with a Perkin-Elmer AS-90 automated sampler.

Trace metal concentrations in hump-backed dolphin tissues were generally low (Table 1). However, concentrations of mercury in some animals were shown to be high, with a level of 906 g.g-1 (dry weight) determined from the liver of one animal, a level which is high enough to cause damage to tissue damage (Wageman and Muir, 1984; Rawson *et al.*, 1993). Therefore, mercury contamination is a possible health risk to Hong Kong's hump-backed dolphins.

Potential prey species from areas of high dolphin abundance have also been tested for trace metals (Parsons, 1997a) and concentrations of metals were shown to be high, particularly levels of lead and cadmium, in addition to the aforementioned element mercury, with concentrations (dry weight) of up to 180, 16.6 and 66 g.g-1 respectively. This suggests that the hump-backed dolphins are ingesting large amounts of potentially toxic trace metals.

Organochlorine contamination Blubber samples were also excised from stranded carcasses in order to examine the tissues for organochlorine compounds (Parsons and Chan, 1998). Approximately 10 g of blubber was homogenised, eluted with solvents and applied to a gas chromatography-ion trap mass spectrometer with the methodology outlined in Parsons and Chan (1998). A total of 63 PCBs and 17 chlorinated pesticides were screened in the sample.

Concentrations of the organochlorine pesticides mirex, chlordane, dieldrin and cyclohexanes were low (Table 2). In addition PCB concentrations were also generally low, but in some animals PCBs had accumulated to potentially health-threatening levels, i.e., 125 g.g-1 lipid weight. However, concentrations of DDT and its metabolites in the tissues were of more concern. The concentrations were, in fact, amongst some of the highest recorded from small cetaceans world-wide (Fig. 3).

This level of organochlorine contamination undoubtedly has an impact on the health of Hong Kong's cetaceans. Organochlorine poisoning can be lethal. DDT, in particular, can kill by direct action on the mammalian nervous system. In addition, organochlorines in smaller concentrations can still be lethal as they are immuno-suppressive and can result in an increase in disease-related mortality (Vos and Luster, 1989). Moreover, the chemicals could adversely affect cetacean populations by the disruption of reproductive systems due to the fact that the structure of the organochlorine molecule resembles that of various reproductive hormones and, as such, has been linked with still-births, abortions, neonate mortality and impaired growth in several mammal species (Aulerich and Ringer, 1977; Bleavins *et al.*, 1980; Aulerich *et al.*, 1985).

Organochlorines are especially problematic for young animals (Clark, 1978) as adult females can pass on their organochlorine burden to their offspring. Organochlorines are lipophilic and can, therefore, be passed on to neonatal animals via lactation (Subramanian *et al.* 1987; Cockcroft *et al.*, 1989; Morris *et al.* 1989).

In addition to the blubber analysed, milk extracted from the stomach of a cetacean calf was also analysed for organochlorines (Parsons and Chan, 1998) and high concentrations were identified (500-1000g.l-1 PCB and 3740-7500 g.l-1 DDT). This demonstrates that organochlorine transfer via lactation is occurring in Hong Kong and, moreover, that the amount being ingested by calves is substantial.

Considering that the World Health Organisation tolerable daily intake limits for PCB and DDT are 1 g.kg-1.day-1 and 20g.kg-1.day-1, respectively, the daily recommended intake of these two organochlorines could, thus, be exceeded if a hump-backed dolphin calf ingested more than 1ml of milk a day (Parsons, 1997a). In recent years, neonate mortality has been relatively high (Parsons, 1998a; Jefferson, 1998) and this is probably attributable to organochlorine poisoning.

In fact, preliminary analyses of blubber taken from recently stranded hump-backed dolphin calves suggest that the situation is escalating, with DDT concentrations of 150-200 g.g-1 lipid weight reported (Tanabe in Jefferson,1997).

CONCLUSIONS In addition to the above results from the post-mortem examination of strandings, it has become apparent that in recent years a high proportion of animals may have died as the result of anthropogenic activities, i.e., collisions with boats and entanglements in fishing gear (Parsons, 1997a; Jefferson 1998). Considering that Hong Kong is one of the busiest ports in the world and possesses an intensive coastal fisheries fleet, with such a density of human activity it is hardly surprising that dolphin mortalities ensue.

The number of hump-backed dolphin strandings reported in Hong Kong's territorial waters has increased notably in recent years (Fig. 4). This may be partially due to an increased awareness of the need to report strandings, but it may also reflect an increase in mortality.

Hong Kong's Indo-Pacific hump-backed dolphins face multiple threats, namely pollution, whether it be sewage, trace metal or, especially, organochlorine pollution, in addition to fisheries by-catches and casualties caused by shipping and other vessel traffic. These threats undoubtedly work together to reduce the viability of Hong Kong's dolphins.

However, although these factors may already be a grave problem, it is estimated that the population of Hong Kong will double in the next thirty years. Expansion will undoubtedly be accompanied by an escalation in the amount of anthropogenic pollutants discharged into Hong Kong's waters, and general environmental decrepitude. Considering this, it is hard to envisage the long-term survival of Hong Kong's Indo-Pacific hump-backed dolphins unless major action is taken to both reduce pollution and to prevent environmental destruction.

ACKNOWLEDGEMENTS This project was funded by the Agriculture and Fisheries Department of the Hong Kong Government. We wish to thank Raymond C.C. Lay and Daniel Y.K. Chan for allowing access to their stranding records. We also wish to thank Les Simms, Tom Jefferson and Lindsay Porter for their assistance with the stranding network; the staff of CINE, McGill University for their assistance with the organochlorine analysis and, finally, Sarah Clark, Tom Jefferson and Robin Law for kindly reviewing this paper.

REFERENCES

Aulerich, R.J. and Ringer, R.K. 1977. Current status of PCB toxicity to mink, and effect on their reproduction. *Arch. Environ. Contam. Toxicol.*, 6: 279-292.

Aulerich, R.J., Bursian, S.J., Breslin, W.J., Olson, B.A. and Ringer, R.K. 1985. Toxicological manifestations of 2,4,5,2',4',5'-, 2,3,4,2',3',6'-, and 3,4,5,3',4',5'-hexachlorobiphenyl and Arochlor 1254 in mink. *J. Toxicol. Environ. Health*, 15: 63-79.

Bleavins, M.R., Aulerich, R.J., and Ringer, R.K. 1980. Polychlorinated biphenyls (Arochlors 1016 and 1242): effects on survival and reproduction in mink and ferrets. *Arch. Environ. Contam. Toxicol.*, 11: 305-312.

Clark, D.R., Kunz, T.H. and Kaiser, T.E. 1978. Insecticides applied to a nursery colony of little brown bats (*Myotis lucifugus*): lethal concentrations in brain tissues. *J. Mammal.*, 59: 84-91.

Cockcroft, V.G., De Kock, A.C., Lord, A.D. and Ross, G.J.B. 1989. Organochlorines in bottlenose dolphins from the east coast of southern Africa. *S. Afr. J. Mar. Sci.*, 8: 207-217.

Cockcroft, V.G., De Kock, A.C., Ross, G.J.B. and Lord, D.A. 1990. Organochlorines in common dolphins caught in shark nets during the Natal 'sardine run'. *S. Afr. J. Zoo.*, 25: 144-148.

De Kock, A.C. 1989. *Chlorinated hydrocarbons as chemical tracers of marine contamination.* PhD Thesis. Port Elizabeth University, South Africa.

Geraci, J.R. 1989. *Clinical investigation of the 1987-88 mass mortality of bottlenose dolphins along the U.S. Central and South Atlantic coast.* Unpublished report to the National Marine Fisheries Service and U.S. Navy, Office of Naval Research and the U.S. Marine Mammal Commission.

Geraci, J.R. and Lounsbury, V.J. 1993. *Marine Mammals Ashore- A Field Guide for Strandings.* Texas A& M Sea Grant Publications, Galveston, Texas.

Jefferson, T.A. 1997. *Multi-disciplinary research program on the Indo-Pacific hump-backed dolphin population. Sixth quarterly report.* Unpublished report to the Agriculture & Fisheries Department of the Hong Kong Government. [Available from AFD, 393 Canton Road, Jordan, Hong Kong]

Jefferson, T.A. 1998. *Population biology of the Indo-Pacific hump-backed dolphin* (Sousa chinensis *Osbeck, 1765) in Hong Kong waters: final report.* Ocean Park Conservation Foundation, Hong Kong. [Available from OPCF, Ocean Park, Aberdeen, Hong Kong]

Jefferson, T.A. and Leatherwood, S. 1997. Distribution and abundance of Indo-Pacific hump-backed dolphins (*Sousa chinensis*) in Hong Kong waters. *Asian Mar. Biol.*, 14: 93-110.

Leatherwood, S. and Jefferson, T.A. 1997. Dolphins and development in Hong Kong: a case study in conflict. *IBI Rep.*, 7: 57-69.

Loganathan, B.G., Tanabe, S., Tanaka, H., Watanabe, S., Miyazaki, N., Amano, M. and Tatsukawa, R. 1990. Comparison of organochlorine residue levels in the striped dolphin from Western North Pacific, 1978-79 and 1986. *Mar. Pollut. Bull.*, 21: 435-439.

Martineau, D., Beland, P., Desjardins, C. and Lagace, A. 1987. Levels of organochlorine chemicals in tissues of beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Quebec, Canada. *Arch. Environ. Contam. Toxicol.*, 16: 137-147.

Morris, R., Law, R., Allchin, C., Kelly, C. and Fileman, C. 1989. Metals and organochlorines in dolphins and porpoises of Cardigan Bay, West Wales. *Mar. Pollut. Bull.*, 20: 512-523.

Muir, D.C.G., Wagemann, R., Grift, N.P., Norstrom, R.J., Simon, M., and Lien, J. 1988. Organochlorine chemical and heavy metal contaminants in white-beaked dolphins (*Lagenorhynchus albirostris*) and Pilot whales (*Globicephala melaena*) from the coast of Newfoundland, Canada. *Arch. Environ. Contam. Toxicol.*, 17: 613-629.

Osbeck, P. 1765. *Reise nach Ostidien und China.* Koppe, Rostock.

Parsons, E.C.M. 1997a. *Hong Kong's cetaceans: the biology, ecology and behaviour of* Sousa chinensis *and* Neophocaena phocaenoides. PhD Thesis. The University of Hong Kong., Hong Kong.

Parsons, E.C.M. 1997b. *Sewage pollution in Hong Kong: implications for the health and conservation of local cetaceans.* Unpublished report to Friends of the Earth, Hong Kong. [Available from Friends of the Earth, 53-55 Lockhart Road, 2/F, Wanchai, Hong Kong].

Parsons, E.C.M. 1998a. Strandings of small cetaceans in Hong Kong's territorial waters. *J. Mar. Biol. Assoc. UK*, 78: 1039-1042.

Parsons, E.C.M. 1998b. Trace metal pollution in Hong Kong: implications for the health of Hong Kong's Indo-Pacific hump-backed dolphins (*Sousa chinensis*). *Sci. Total Environ.*, 214: 175-184.

Parsons, E.C.M and Hoffmann, C.C. 1996. The conservation status of Hong Kong's cetaceans. Pp. 12-14. In *European Research on Cetaceans - 10.* Proc. 10th Ann. Conf. ECS, Lisbon, Portugal (Ed. P.G.H. Evans). European Cetacean Society, Kiel, Germany.

Parsons, E.C.M. and Chan, H.M. 1998. Organochlorines in Indo-Pacific hump-backed dolphins (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) from Hong Kong. Pp. 423-437. In *The Marine Biology of the South China Sea* III (Ed. B. Morton). Hong Kong University Press, Hong Kong.

Parsons, E.C.M., Felley, M.J. and Porter, L.J. 1995. An annotated checklist of cetaceans recorded from Hong Kong's territorial waters. *Asian Mar. Biol.*, 12: 79-100.

Rawson, A.J., Patton, G.W., Hofmann, S., Pietra, G.G. and Johns, L. 1993. Liver abnormalities associated with chronic mercury accumulation in stranded Atlantic bottlenose dolphins. *Ecotoxicol. Environ. Safety* 25: 41-47.

Reeves, R.R. and Leatherwood, S. 1994. *Dolphins, Porpoises and Whales. An 1994-1998 Action Plan for the Conservation of Cetaceans.* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Romer, J.D. 1958. Cetaceans recorded from within or near Hong Kong territorial waters. *Hong Kong Uni. Fish. J.*, 2: 127-129.

Subramanian, A., Tanabe, S., and Tatsukawa, R. 1987. Age and size trends and male-female differences of PCBs and DDE in Dalli-type Dall's porpoises, *Phocoenoides dalli* of the north-western North Pacific. *Proc. Natl. Instit. Polar Res. Symp. Polar Biol.*, 1: 205-216.

Tanabe, S., Mori, T., Tatsukawa, R. and Miyazaki, N. 1983. Global pollution of marine mammals by PCBs, DDTs, HCHs (BHCs). *Chemosphere*, 12: 1269-1275.

Tanabe, S., Subramanian, A.N., Ramesh, A., Kumaran, P.L., Miyazaki, N. and Tatsukawa, R. 1993. Persistent organochlorine residues in dolphins from the Bay of Bengal, South India. *Mar. Pollut. Bull.*, 26: 311-316.

Vos, J.G. and Luster, M.I. 1989. Immune alterations. Pp. 295-324. In *Halogenated biphenyls, terphenyls, napthalenes, dibenzodioxins and related products* (Ed. R.D. Kimborough and A.A. Jensen). Elsevier, Amsterdam.

Wagemann, R. and Muir, D.C.G. 1984. Concentrations of heavy metals and organochlorines in marine mammals of northern waters; overview and evaluation. *Can. Tech. Rep. Fish. Aquatic Sci. No. 1279.*

Table 1. The range of trace metal concentrations recorded from the tissues of hump-backed dolphins stranded in Hong Kong (g.g-1 dry weight), n.d. denotes trace metals in non-detectable concentrations (<0.9 g.g-1 dry weight) (Parsons, 1998b).

TISSUE		As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Pb	Se	Sn	Zn
Liver (n = 11)	Mean	2.3	2.2	n.d.	0.06	14.1	142	0.8	0.4	3.6	23.3	2.6	100
	Range	n.d. - 12.9	n.d. - 23.2	n.d.	n.d. - 0.65	0.93 - 30.6	n.d. - 906	n.d. - 1.6	n.d. - 1.3	n.d. - 8.6	n.d. - 131	n.d. - 8.9	24.1 - 243
	S.D.	*4.5*	*7.0*	-	*0.20*	*9.1*	*302*	*0.5*	*0.5*	*3.5*	*40.6*	*3.6*	*63.3*
	S.E.	*1.4*	*2.1*	-	*0.06*	*2.7*	*91.2*	*0.1*	*0.1*	*1.0*	*12.2*	*1.1*	*19.1*
Kidney (n = 8)	Mean	6.0	12.1	n.d.	n.d.	12.3	4.5	0.09	0.4	3.4	10.0	2.1	98
	Range	n.d. - 12.1	n.d. - 84.1	n.d.	n.d.	7.0 - 23.6	n.d. - 35.8	n.d. - 0.8	n.d. - 0.9	n.d. - 13.1	n.d. - 21.3	n.d. - 8.7	53.4 - 234
	S.D.	*4.4*	*29.1*	-	-	*5.1*	*12.7*	*0.3*	*0.5*	*4.7*	*6.7*	*2.9*	*59.6*
	S.E.	*1.6*	*10.3*	-	-	*1.8*	*4.5*	*0.04*	*0.2*	*1.7*	*2.4*	*1.0*	*21.1*
Blubber (n = 8)	Mean	2.8	n.d.	0.3	0.8	0.9	n.d.	0.3	0.4	3.8	3.3	0.8	9.2
	Range	n.d. - 18.3	n.d.	n.d. - 1.1	n.d. - 2.7	n.d - 2.7	n.d.	n.d. - 1.1	n.d. - 1.2	n.d. - 12.1	n.d. - 15.6	n.d. - 3.5	2.00 - 18.24
	S.D.	*6.4*	-	*0.5*	*1.2*	*0.8*	-	*0.5*	*0.5*	*3.8*	*5.3*	*1.2*	*5.8*
	S.E.	*2.2*	-	*0.2*	*0.4*	*0.3*	-	*0.2*	*0.2*	*1.3*	*1.9*	*0.4*	*2.1*

Table 2. Organochlorine concentrations in hump-backed dolphins stranded in Hong Kong (g.g-1 lipid weight) (Parsons and Chan, 1998).

SAMPLE NO	AGE (GLGs)	LIPID %	PCB	CHLORO BENZENE	LINDANE	CHLORDANE	DIELDRIN	MIREX	DDT
SC93-25/5	1	79	0.59	0.08	0.08	0.15	0.07	0.01	13.7
SC94-28/4	-	5.1	125	1.84	0.74	24.9	2.34	2.01	381
SC95-28/5	6	16	15.2	0.15	5.76	1.10	0.83	0.18	328
SC95-11/2	11	67	22.4	0.03	0.22	0.42	0.14	0.05	96.1
SC95-2/4	14	67	0.19	0.00	0.04	0.01	1.08	0.00	1.00
SC95-22/6	< 1	49	2.45	0.16	0.28	0.11	0.14	0.03	21.3
SC95-14/9	17+	24	6.02	0.06	0.04	0.27	0.37	0.32	32.4
SC96-25/5	< 1	61	2.82	0.24	0.20	0.16	0.26	0.03	26.7

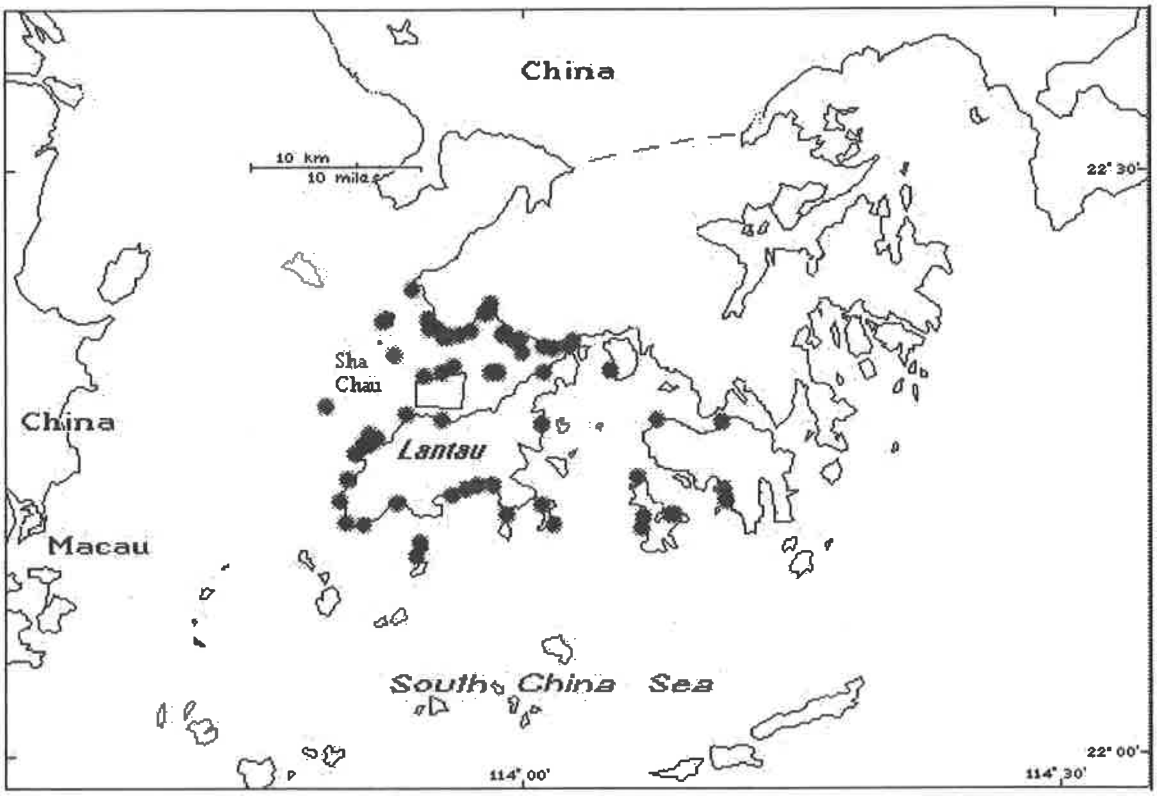

Fig. 1. Map of Hong Kong showing the location of *Sousa chinensis* strandings

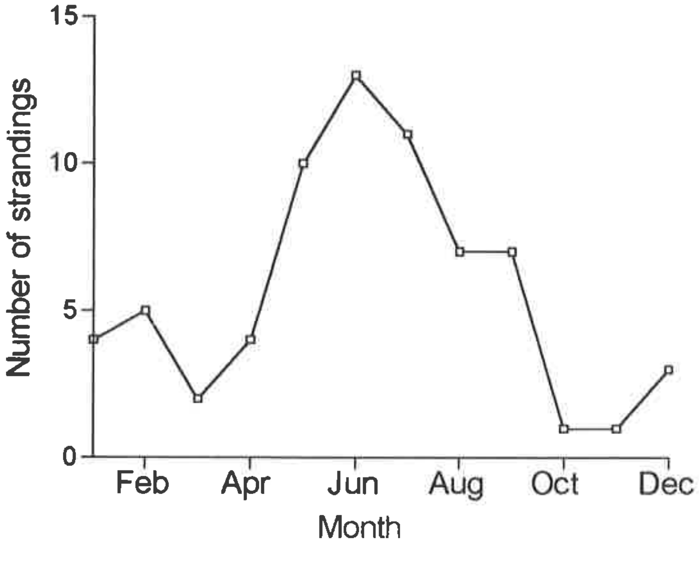

Fig. 2. The number of dolphin strandings reported each month [1973-1997]

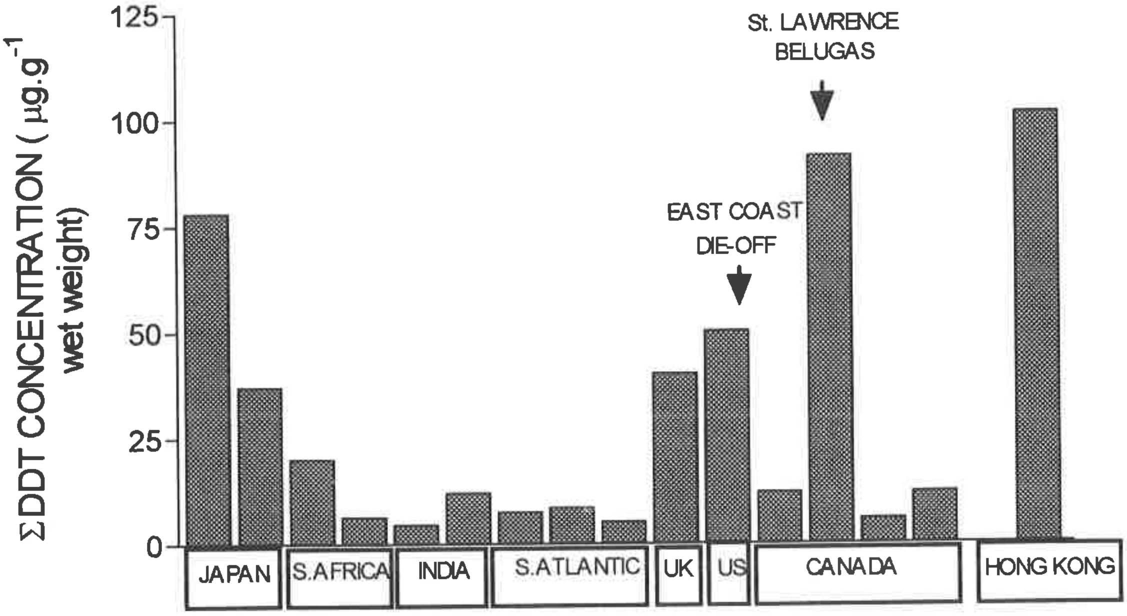

Fig. 3. A comparison of mean DDT concentrations determined in Hong Kong's Indo-Pacific hump-backed dolphins and cetaceans from other regions of the world (sources: Lognathan *et al.*, 1990; Cockcroft *et al.*, 1989,1990; De Kock, 1989; Geraci, 1989; Martineau *et al.*, 1987; Morris *et al.*, 1989; Muir *et al.*, 1988; Parsons and Chan, 1998; Tanabe *et al.*, 1983, 1993).

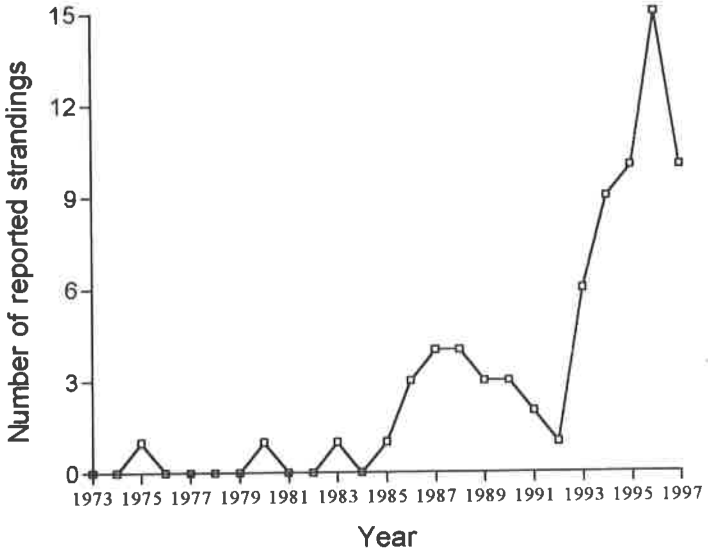

Fig. 4. Graph showing the increase in the number of strandings reported annually in Hong Kong (it should be noted that the graph shows reported strandings, not confirmed strandings and the accuracy of some stranding reports may be questionable).

APPLICATION OF LINKED NUMERICAL MODELS TO THE SIMULATION OF OIL-SPILL EFFECTS ON MARINE MAMMALS

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INTRODUCTION The Minerals Management Service (MMS) of the U.S. Department of the Interior (DOI) regulates Outer Continental Shelf oil and gas activities. The bureau assures compliance with several environmental laws, such as the Endangered Species Act and the Marine Mammal Protection Act. One responsibility is to assess the effects of oil spills on protected species. These analyses help decisionmakers evaluate the environmental impacts of offshore activities. The authors hypothesize that more systematic and consistent analyses could be achieved using linked numerical models.

We used an existing modelthe Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME)to simulate spill events that could affect marine mammals. The DOI issued the current NRDAM/CME (version 2.4) as a regulatory "simplified procedure" (43 CFR 11 Subpart D) for estimating damages from oil spills. NRDAM/CME links together physical, chemical, and biological information. This methodology of linked numerical submodels has been used for over a decade and represents the most objective, internally consistent, comprehensive approach to environmental impact assessment available (61 FR 20560).

MATERIALS AND METHODS NRDAM/CME is a tool for assessing natural resource damages resulting from minor spills of hazardous substances or oils in coastal and marine environments (Applied Science Associates, Inc. et al., 1996). The model treats each spill as an isolated event and does not account for cumulative effects. The model is supported by a geographical information system (GIS), which supplies spatially gridded environmental and biotic information. Detailed databases provide the environmental and biotic information for the physical fates, biological effects, and restoration submodels. We employed the model as a tool to estimate the potential effects of hypothetical surface oil spills on coastal and marine resources, not as a tool to conduct damage assessment. Therefore, we used the results of the physical fates and biological effects submodels.

The model allows the user to supply the following event-specific information:

Σ material spilled
Σ amount spilled
Σ time of spill
Σ duration of spill
Σ location of spill
Σ wind time series
Σ background and tidal currents

The physical fates submodel computes the dynamic distribution of the spilled substance in the environment. Computations continue until all environmental exposure levels are below minimum thresholds. This submodel creates a time series file of surface slick coverage and concentrations of the spilled substance in the water column, on the bottom, and along the shoreline. When the physical fates submodel computations cease, this time series file is used as input to the biological effects submodel. The biological effects submodel computes:

direct lethal effects on
-- mammals
-- birds

- reptiles
- eggs, larvae, juvenile and adult fish and shellfish
- lower-trophic level biota

indirect and long-term effects
- resulting from food loss
- involving the eventual loss of mammals, birds, and reptiles as a result of lost broods
- involving the eventual loss of fish and shellfish as a result of lost eggs, larvae, and juveniles

NRDAM/CME also generates a graphic image of the spill simulation. We screen captured the images, imported them into ARC/INFO 7.1.1, and provided geo-referencing. The images were then integrated with U.S. Geological Survey Digital Line Graph Data (DLG).

Four spill scenarios are exhibited here (Table 1). Two spills are hypothetical spills off Alaska; one in the Beaufort Sea, the other in the Gulf of Alaska. The other two spills represent historical spills in the Gulf of Mexico, off the State of Louisiana. The size of the spills represent the average "Size 3" ($\geq$1,000 bbl) oil spill from any source (7,000 bbl) and the average size of a large spill from all U.S. tanker traffic (26,000 bbl). These data were derived from more than 30 years of spill event records maintained by MMS (MMS Worldwide Tanker Spill Database, 1998; MMS OCS Spill Database, Technical Information Management System, 1998).

RESULTS & DISCUSSION Results from the model runs (Tables 2-5, Figs. 1-4) were consistent in predicting the level of impact to marine mammals from oil spills. Mortality from toxic contamination and loss of food resources are quantified as the main oil-spill effects. These numbers can allow analysts to provide discrete quantification of impacts rather than ambiguous qualifiers such as "moderate" or "few immediate deaths."

Expanding databases and evolving technology would likely continue improving comprehensive interdisciplinary modeling efforts such as the NRDAM/CME. The NRDAM/CME can be a useful management tool for decisionmaking and responding to environmental laws such as the Endangered Species Act.

REFERENCES

Applied Science Associates, Inc., A.T. Kearney, Inc., and Hagler Bailly Consulting, Inc. 1996. *The CERCLA Type A Natural Resource Damage Assessment Model for Coastal and Marine Environments.* Code of Federal Regulations (CFR). 1997. Title 11, Subpart D. Office of the Federal Register, National Archives and Records Administration. Washington, D.C.. Pp. 228-230.

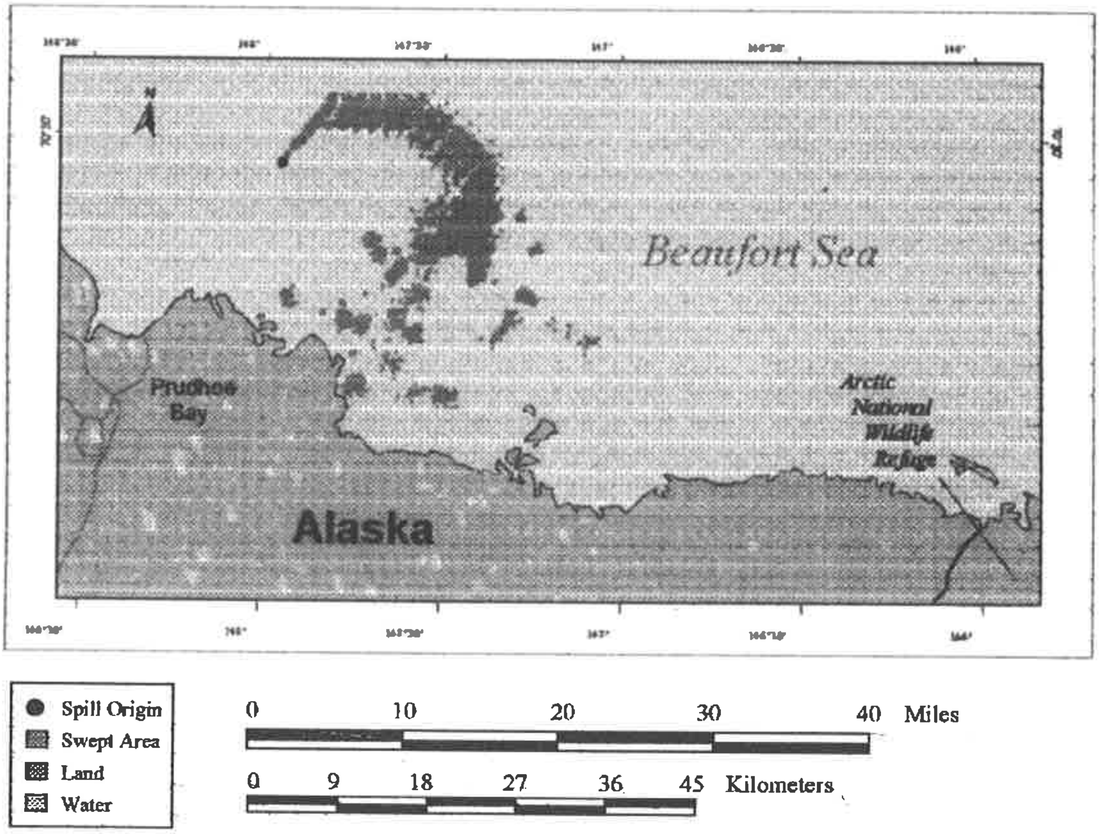
Federal Register (FR). 1996. *Office of the Federal Register. National Archives and Records Administration.* Washington, D.C., Vol. 61, P. 20560.

Table 1. Spill Scenarios

Scenario	Material Spilled	Amount Spilled	Time of Spill	Duration of Spill	Location of Spill	Winds
Beaufort Sea	Prudhoe Bay crudelow volatiles	7,000 bbl	12:00 am August 30, 1997	6 hours	70° 29'N. lat. 147° 58'W. long.	12 knots random
Gulf of Alaska	Prudhoe Bay crudelow volatiles	30,000 bbl	12:00 am July 15, 1997	6 hours	60° 20'N. lat. 146° 50'W. long.	15 knots random
Gulf of Mexico Main Pass Area	South Louisiana crude	30,000 bbl	12:00 am February 10, 1997	49 hours	29° 23'N. lat. 88° 59'W. long.	Stochastic
Gulf of Mexico South Timbalier Area	South Louisiana crude	7,000 bbl	12:00 am January 26, 1973	6 hours	29° 01'N. lat. 90° 11'W. long.	Stochastic

Table 2. Beaufort Sea Mammal and Other Wildlife Kills

Total Mammal Kills		Other Wildlife Kills	
Baleen Whales	0.014	Waterfowl	3691.461
Toothed Whales	0.089	Seabirds	43.549
Harbor Seals	1.706		
Walrus	0.727		
Polar Bear	7.272		

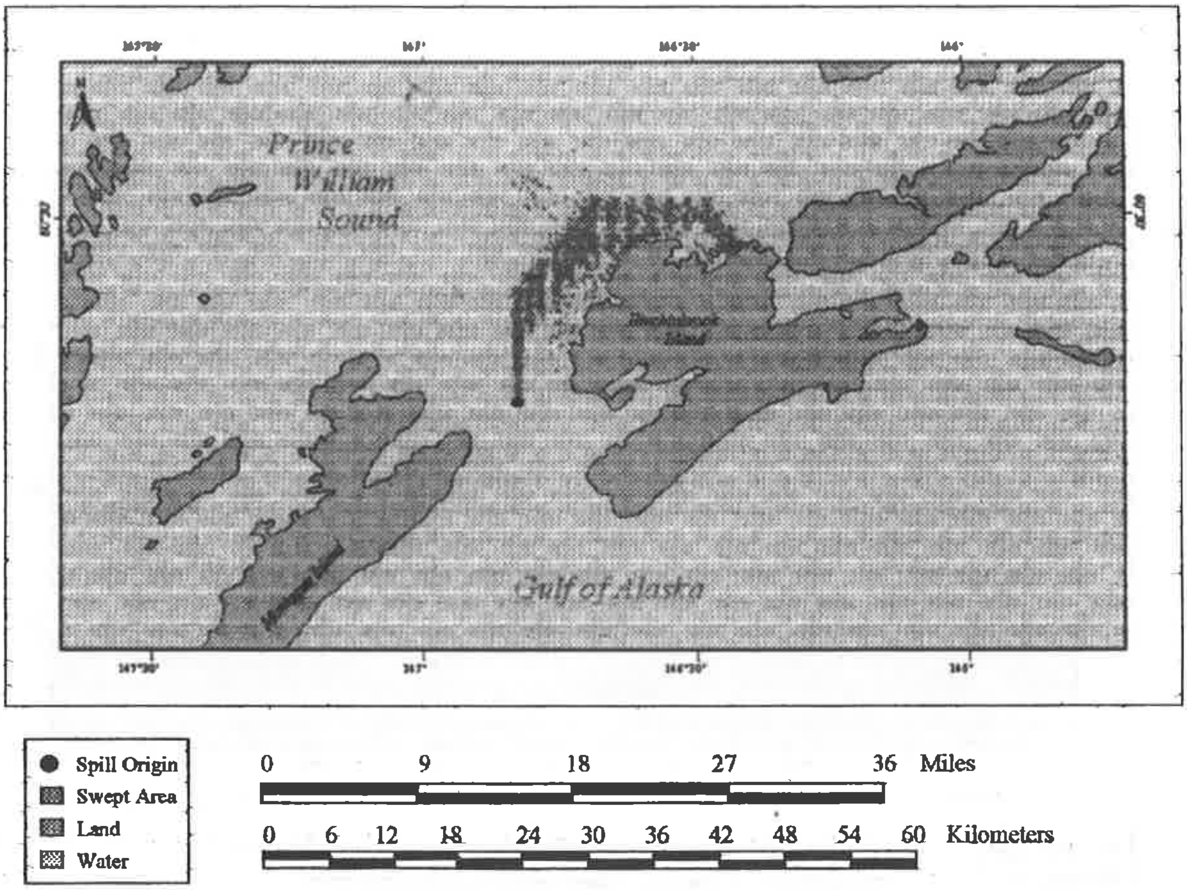


Projection: Universal Transverse Mercator (UTM) Zone 6
Data Sources: United States Geological Survey, Digital Line Graph (DLG) Data @ 1:2,000,000.
Spill data from NRDAM/CME

Fig. 1. Oil-Spill Map for the Beaufort Sea Spill Scenario

Table 3. Gulf of Alaska Mammal and Other Wildlife Kills

Total Mammal	Kills	Other Wildlife Kills	
Baleen Whales	0.002	Waterfowl	418.458
Toothed Whales	0.004	Seabirds	2937.713
Dolphins, Porpoises	0.023	Raptors	24.433
Sea Lions	0.528	Pelagic Fish (adults)	0.281
Harbor Seals	0.618	Pelagic Fish (young of year)	987.914
Sea Otters	188.499	Demersal Fish (adults)	1404.272
		Demersal Fish (young of year)	7733.608
		Crustaceans (adults)	2.478
		Crustaceans (young of year)	1515.624
		Cephalopods	2.375



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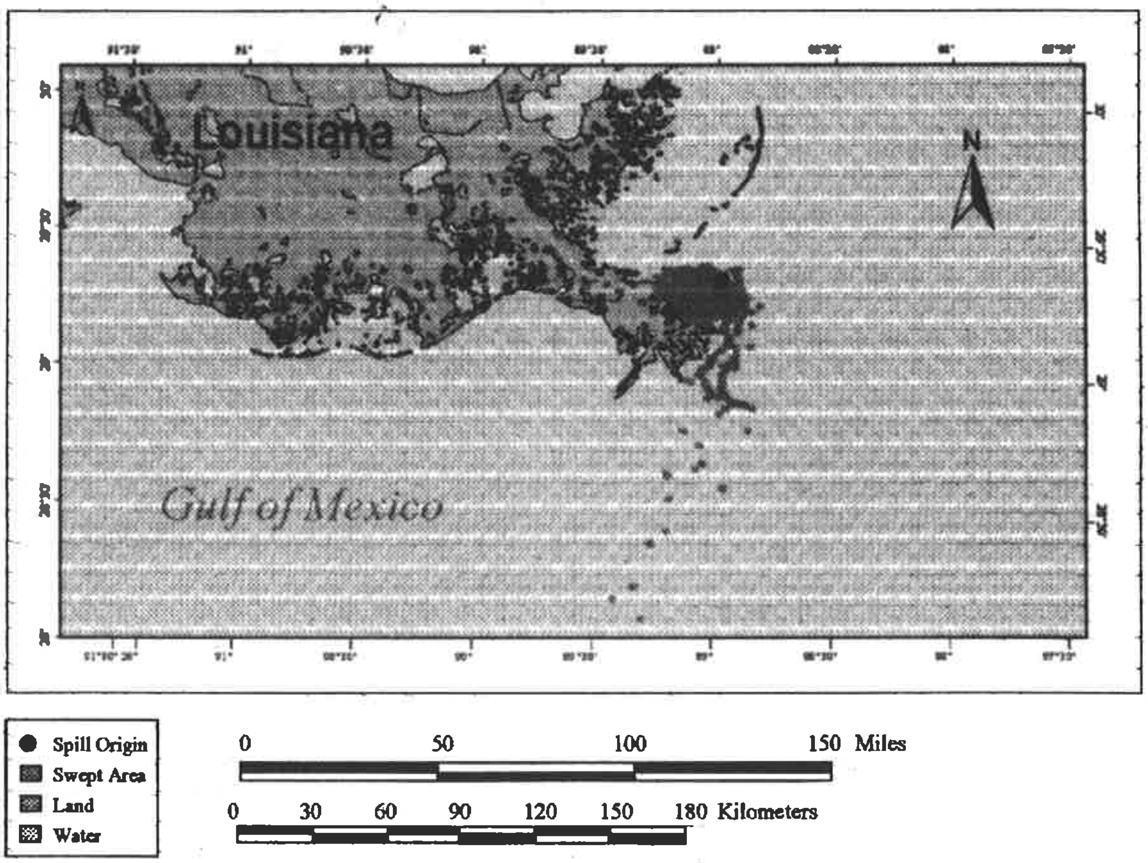
Spill data from NRDAM/CME

Fig. 2. Oil-Spill Map for the Gulf of Alaska Spill Scenario

Table 4. Gulf of Mexico Main Pass Area Mammal and Other Wildlife Kills

Total Mammal Kills		Other Wildlife Kills	
Toothed Whales	.031	Waterfowl	15930.530
Dolphins, Porpoises	2.787	Seabirds	389.508
Muskrat, Nutria	11.256	Wading Birds	5600.404
		Shorebirds	119.943
		Sea Turtles	1.446
		Pelagic Fish (adults)	1714.981
		Demersal Fish (adults)	599.966
		Demersal Fish (young of year)	1053.748
		Crustaceans (adults)	.079
		Crustaceans (young of year)	5.520
		Cephalopods	.920
		Molluscs	.004

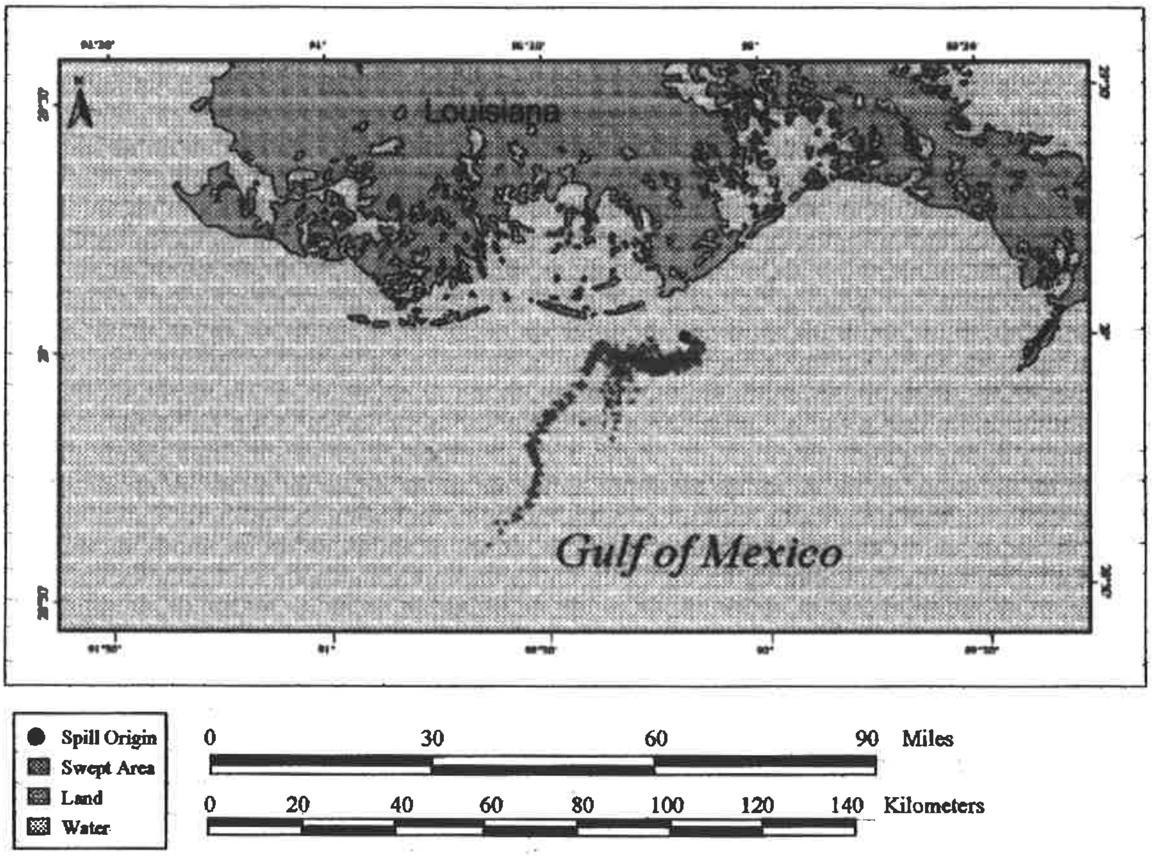


Projection: Universal Transverse Mercator (UTM) Zone 16
Data Sources: United States Geological Survey, Digital Line Graph (DLG) Data @ 1:2,000,000.
Spill data from NRDAM/CME.

Fig. 3. Oil-Spill Map for the Gulf of Mexico Main Pass Area Spill Scenario

Table 5. Gulf of Mexico South Timbalier Area Mammal and Other Wildlife Kills

Total Mammal Kills		Other Wildlife Kills	
Muskrat, Nutria	0.003	Waterfowl	786.642
		Seabirds	427.291
		Wading Birds	0.281
		Shorebirds	0.080



Projection: Universal Transverse Mercator (UTM) Zone 15
Data Sources: United States Geological Survey, Digital Line Graph (DLG) Data @ 1:2,000,000.
Spill data from NRDAM/CME

Fig. 4. Oil-Spill Map for the Gulf of Mexico South Timbalier Area Spill Scenario

SEAL WATCHING IN THE UK AND REPUBLIC OF IRELAND

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INTRODUCTION Tourism has been described as the world's largest business (Miller, 1993) rising at a rate of roughly 4% annually, while 'nature-based' tourism grows by 30% each year. Wildlife watching is not just a lucrative industry. It is also potentially compatible with sustainable development providing a platform for promoting conservation through environmental education and the raising of awareness. It is important, however, that the risk of anthropogenic disturbance to the subject animal or habitat is minimised.

Pinnipeds are the subject of direct exploitation for pelts and meat, and culling aimed at reducing competition in fisheries. However, they are also good subjects for 'nature-based' tourism often hauling out in coastal sites or ice, where they may be viewed either from land or boat.

Pinnipeds require a consistently abundant and accessible food source and they depend on suitable sites on which to haul out. These sites are particularly significant, and provide a safe location in which the animals can rest, moult, mate (in some species), and most importantly, to give birth and nurse their offspring. There is evidence to suggest that disturbance of some pinnipeds e.g. grey seals at breeding sites, may decrease pup survival (Summers and Harwood, 1978; Wilkinson and Bester, 1988; Wilson and Corpe, 1996), and change maternal behaviour and performance (Lidgard, 1996). In this species, the most common cause of pup mortality is a failure of the mother-pup bond, leading to starvation and increased mortality (Anderson, *et al*, 1979).

UK populations of common (*Phoca vitulina vitulina*) and grey (*Halichoerus grypus*) seals represent large proportions of world totals (40% and 40% respectively). Little is known of the extent of the pinniped watching industry in the UK. The aim of this short study, funded by the International Fund for Animal Welfare, was to investigate the size of the industry in the UK and Republic of Ireland, provide an overview of the methods used to watch seals, and assess the economics of the industry.

METHODS: Postal survey A postal survey of operators in England, Wales, Northern Ireland and Republic of Ireland, was conducted to complement a previous wildlife tourism study in Scotland. A simple economic assessment of the total revenue created by the UK seal watch industry was also carried out using information on seal watch prices, visitor numbers and multiplication factors appropriate for whale watching in Europe (Hoyt, 1997). Legislation relevant to seals in the UK was also reviewed.

METHODS: Visits A subset of seal watch operators were visited. Visits were planned to cover a range of localities and habitats. Before each seal watch trip, the operator was informed that a study of methods was being conducted. Operators were aware of the presence of an observer so it is possible that their behaviour was altered. Details of trips were 'scored' on forms after each trip. Parameters scored on forms included whether seals were PRIMARY if the trip specifically travelled to the haulout site and then immediately back to shore or MAJOR if seals are part of a more general wildlife watching experience. Speed of approach and departure was scored as FAST, MEDIUM or SLOW. Skill of boat handling when in close proximity to the seals was scored as GOOD, MEDIUM or BAD, related to the author's experience of boat handling in the presence of whales and dolphins, and included factors such as keeping engine revs low, drifting and type of manoeuvring. Distance was estimated by eye. The percentage of animals flushed from the haulout was also noted. According to a study in Northern

Ireland, less than 30% of animals in a colony showed vigilant behaviour when undisturbed (Wilson and Corpe, 1996). If the vigilance level exceeded 30% of animals it was noted on the form. Other information about operators was collected if possible.

RESULTS: POSTAL There are at least 117 seal watch establishments in the UK & Ireland. Many offer general wildlife watching tours with the importance of seal watching fluctuating with time of year. Most operators use displacement-hulled boats powered by inboard engines. In 1996, the number of visitors watching seals in the UK & Ireland was estimated to be c. 0.5 million and the total gross revenue of the industry was estimated at £36 million per annum. Employment created by the seal watch industry was extrapolated to be 193 full-time, 322 part-time/seasonal and 152 voluntary posts. Pupping and breeding sites were common destinations of the tours. Only five of the 20 respondents to the postal survey provide onshore background briefings, and five others provide 'on vessel' talks. Seal watching in the UK is presently not controlled by legislation.

RESULTS: VISITS The closest approaches observed during visits were in the range of 4 – 30m. This is very much less than the 100m recommended by some literature (Allen *et al*, 1984). In this very small sample of five seal watching trips, distance did not necessarily seem to predict whether the seals showed signs of disturbance. Although approach distance does affect seal disturbance there are obviously other factors involved such as boat type, style of approach and habituation to a regular boat or trip. It may be difficult to provide an entertaining tour for visitors whilst keeping at a distance of 100-150m and provision of binoculars may help, especially during the breeding season.

Three of the 5 operators visited provided 'on-vessel' talks, which included some aspect of seal ecology. Most were based on reproductive aspects of seal biology and none included details about distribution, conservation, diet or behaviour. None of the trips provided a leaflet on seal biology, an 'onshore' talk or visitor centre. Educational aspect of the tours could be improved. The opportunity to promote seal conservation, general marine ecology and awareness has yet to be exploited.

CONCLUSIONS There are several different ways in which to watch seals, with boat-based trips to haulout sites being very popular. Pinnipeds may be susceptible to disturbance during the pupping season. The seal watch industry must incorporate appropriate management if it is to operate effectively and with no detrimental consequences for the seals. Legislative management of seal watching is, at present, non-existent. There are at least 117 seal watch operators in UK/Ireland at present, and undoubtedly many more. Simple extrapolations suggest that around a half a million people went seal watching in 1996, generating total revenues of over £36 million ($60 million). Therefore, the seal watch industry is potentially lucrative. Nature-based tourism may be an opportunity to educate the public in wildlife biology and conservation education in seal watching in the UK and the Republic of Ireland is, at present, deficient.

RECOMMENDATIONS

1) In order to improve the educational quality of seal watch tours, operators should be provided with material concerning both seal biology and general marine ecology and conservation, for their own use and use by visitors, e.g. leaflets.
2) Training should be offered to operators and staff, which should include wildlife ecology, seamanship and first aid.
3) Further, more detailed, studies of the economics of seal watching in the UK and Republic of Ireland would be useful to assess the total economic impact of the industry.
4) There is a lack of legislation to cover aspects of seal watching in the UK and Republic of Ireland increasing potential for disturbance of seal populations. Effective and enforceable guidelines should be set into practice and all parties utilising all areas

important to a seal population and community should be involved in introducing these.

5) Advertising by operators may be more effective if at a national level although expansion of the industry may have detrimental effects to seal populations if legislative management is not in place before this is done.

The full report resulting from this study can be obtained from The International Fund for Animal Welfare, Warren Court, Park Rd, Crowborough, East Sussex, UK, TN6 2GA.

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REFERENCES

Allen, S.G., Ainley, D.G. and Page, G.W. 1984. The effects of disturbance on harbor seal haulout patterns at Bolinas Lagoon, California. *Fish. Bull.*, 82 (3): 493–500.

Anderson, S.S., Baker, J.R., Prime, J.H. and Baird, A. 1979. Mortality in Grey seal pups: incidence and causes. *J. Zool., Lond.*, 189: 407–417.

Baines, M. E., Earl, S.J., Pierpoint, C.L.J. and Poole, J. 1995. The West Wales Grey Seal Census. *Countryside Council for Wales Contract Science Report 131.*

Hoyt, E. 1997. The Potential of Whale Watching in Europe. Whale and Dolphin Conservation Society, Bath, UK. 36pp.

Kovacs, K. M. and Innes, S. 1990. The impact of Tourism on Harp Seals (*Phoca groenlandica*) in the Gulf of St. Lawrence, Canada. *Applied Animal Behaviour Science* 26: 15–26.

Lidgard, D.C. 1996. *The effects of human disturbance on the maternal behaviour and performance of grey seals* (Halichoerus grypus) *at Donna Nook, Lincolnshire, UK.* Prelim. Rep., Brit. Ecol. Soc.

Miller, M.L. 1993. The Rise of Coastal and Marine Tourism. *Ocean & Coastal Management*, 20: 181–199.

Summers, C.F. and Harwood, J. 1978. Indirect effects of grey seal culls. *Int. Counc. Expl. Sea Mar. Mamm. Comm.*, 4: 1-6.

Scottish Tourism and Environment Taskforce. 1997. *Review of Wildlife Tourism in Scotland. Full Report.* A report commissioned by the Tourism and Environment Taskforce and the LIFE Programme with support from the Scottish Tourist Board.

Wilkinson, J.S. and Bester, M.N. 1988. Is onshore human activity a factor in the decline of the southern elephant seal? *S. Afr. J. Antarct. Res.*, 18: 14-17.

Wilson, S.C. and Corpe, H.M. 1996. *An investigation into the* status quo *of the harbour seals of Co. Down, Northern Ireland.* Environment and Heritage Service, Northern Ireland, Res. Rep. 1. May 1996.

PRE-EPIZOOTIC HARBOUR SEAL POPULATION TRENDS IN THE WADDEN SEA: A REVIEW OF HISTORICAL CENSUS DATA

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The harbour seal population in the European Wadden Sea has been depressed by excessive hunting and disturbance until the mid 1970s, but temporarily recovered until 1988, when a virus epizootic killed more than 50% of the seals. Population trends prior to this incisive event were studied by reviewing aerial census data supplied by the respective survey teams in The Netherlands, Lower Saxony and Schleswig-Holstein (Germany), and Denmark.

Data were screened for methodological consistency and analysed by log-linear regression procedures. Maximum numbers of non-pups (*i.e.* adults and subadults) recorded during or prior to the whelping season were considered as a pre-whelping index of population size.

Counts meeting standard quality requirements exhibit remarkably low variance. Numbers stagnated from mid to late 1970s, but increased exponentially at 0.095±0.002 SE during 1979-87, which rate is also evident in numbers of pups in 1980-87 (0.097±0.005 SE). This is somewhat lower than rates of increase recorded in harbour seal populations elsewhere (0.11-0.12). The 1980-87 period was further characterised by a ratio of counted pups vs. non-pups of 23%, whereas prior to 1979 this ratio was 27%.

It is concluded that the onset of population increase was the result of a distinct rise in juvenile survival, which had been estimated at only 35-40% in 1975-78. The decline of the per capita birth rate, occasionally misinterpreted as a density-related drop of fertility, is thus recognised as purely arithmetic, *i.e.* as a decrease in the proportion of adults through improved recruitment to the subadult section.

GREY SEAL MOTHERS EXPERIENCE SIZE-DEPENDENT CONSEQUENCES OF REPRODUCTIVE EXPENDITURE FOR PUPPING SUCCESS

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The way that maternal resources are allocated during each reproductive episode and over the course of a female's lifetime is critical in determining the maternal contribution to reproductive success.

Although there are few studies which have looked at the effects of maternal reproductive expenditure in one year on her expenditure and pupping success in the following year, we hypothesised that (a) mother's postpartum mass (MPPM) would explain most variation in maternal expenditure and pupping success would be greatest in larger females; (b) maternal expenditure in one year would not affect pupping success in the following year.

Known females from the established colony on North Rona, Scotland were immobilised, weighed at the start and end of lactation over the period 1978-1995. Grey seals in the UK do not feed during lactation therefore relative maternal reproductive expenditure was estimated by calculating the proportion of MPPM lost during the lactation period. Production of a pup weighing a minimum of 30kg at weaning was defined as a pupping success, all other cases were failures.

The mean MPPM for mothers during the study was 190±23 kg. Mothers expended an average of 39.1±0.6% of MPPM during lactation (range 4.8 - 47.5%).

(a) MPPM and individual identity were significant predictors of maternal expenditure in GLM models ($p<0.001$, $p<0.05$ respectively). In any year, pupping success was greatest for mothers that were of average or larger than average MPPM and relative expenditures.

(b) There was a compensatory relationship between relative maternal expenditure in one year and MPPM the following year: when expenditure was smaller than average in the first year, MPPM increased between years and vice versa. However, mothers with small MPPMs in one year had higher rates of pupping success the following year than average and large sized mothers. Mothers with low expenditures in one year had lowest pupping success subsequently. Although subsequent pupping success rate for high expenditure mothers was lower than for mothers with average expenditures the difference was just non-significant, suggesting that larger sample sizes may indicate that high maternal expenditures incur a cost in future pupping success.

JUST TAKE TWO ASPIRIN: IS THE VOLUNTARY APPROACH AN EFFECTIVE PRESCRIPTION FOR THE MANAGEMENT OF DOLPHIN WATCHING IN SCOTLAND?

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Whale watching has become increasingly popular world-wide. A number of countries try to manage this activity, with varying degrees of success, through voluntary or statutory codes of conduct based on the precautionary approach. Growing interest in the small population of bottlenose dolphins in the Moray Firth in Scotland has led to an increase in dolphin watching boats in this area, rising from one in 1990 and peaking at nine in 1996. Although it is an offence under British and European law to deliberately disturb cetaceans, there is no legislation that specifically governs boat-based whale watching.

In 1995, a voluntary code of conduct and accreditation scheme for commercial dolphin watching boats was implemented in the Moray Firth. The first scheme of its type in the UK, the project has been running on a trial basis for three years. Its objectives are to reduce potential impacts of dolphin watching boats on the dolphins and to encourage sustainable development of high quality, low environmental impact cetacean watching in the Moray Firth.

In its first year, four of the six wildlife cruise operators joined the scheme. In 1996, all 9 commercial operators became accredited and in 1997, six of the eight trip boats were accredited. A 1996 survey of accredited boat operators indicated that the more experienced operators tend to believe the dolphins can look after themselves and that experienced operators do not need a prescribed code to operate in a sustainable way. This view has triggered the defection of at least one operator. The survey expressed doubts about how closely some of the operators adhered to the new code. It was suggested that more intensive monitoring and enforcement could be counter-productive.

The accreditation scheme on trial in Scotland illustrates a still fragile voluntary approach to reducing disturbance to cetaceans. Legislation supporting a licensing system for dolphin watching boats must be a more equitable and effective way to manage sustainable cetacean watching.

INVESTIGATING STOCK STRUCTURE FOR PROPER MANAGEMENT OF MARINE MAMMALS: IS ONE METHOD GOOD ENOUGH?

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Harbour porpoises have declined drastically in Swedish waters, most notably in the Baltic Sea where the abundance is estimated to be less than 1,000 animals. The low abundance and year round bycatches in the Baltic led us to test the hypothesis of separate stocks in Swedish waters. As the number of specimens from the Baltic was limited, three separate methods were used to improve the chances of detecting differences between animals bycaught in the Baltic Sea and the Kattegat-Skagerrak Seas. In two of the methods specimens were also included from the west coast of Norway for comparison.

Skulls of 103 specimens were morphometrically compared using 19 measurements. Females showed separation between the Baltic and the Kattegat-Skagerrak Seas. Males did not show differences, indicating that they move around between areas to a greater extent than females.

Mitochondrial DNA (mtDNA) of 65 harbour porpoises was analysed with nine restriction enzymes. Analyses of the heterogeneity in the frequency distribution of haplotypes revealed significant differences between all three areas. Furthermore, indices of haplotypic and nucleotide diversity were low which is indicative of severely depleted populations.

Patterns of chlorinated aromatic contaminants (DDTs, PCBs, non-ortho PCBs and PCDD/Fs) were compared in 48 male harbour porpoises. Animals sampled off the west coast of Norway were found to have a significantly different contaminant pattern than animals from the Baltic and Kattegat-Skagerrak Seas, whereas specimens from the latter two areas did not show conclusive differences.

The skull morphometric and the mtDNA demonstrated differences in stock structure between areas and the existence of a separate stock of porpoises in the Baltic. The contaminant method could only identify the Norwegian sample as separate from the two Swedish. Although the mtDNA showed that separate stocks exist, it did not detect that Baltic males move around and also risk entanglement in Kattegat-Skagerrak Seas. Furthermore, different methods added other significant information for management; *e.g.* the mtDNA showed that animals had very low variability and contaminants that animals from the Baltic had the highest levels of several contaminants. In conclusion, a single method would not have been enough for proper management of porpoises in Swedish waters.

BYCATCH REMOVAL RATE OF HARBOUR PORPOISE IN THE SWEDISH SKAGERRAK SEA

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The harbour porpoise in Swedish waters is threatened; numbers have declined drastically since the 1960s, and a pilot observer project revealed an alarmingly high bycatch rate. To estimate the yearly removal rate of porpoises in the Swedish Skagerrak Sea, an observer programme was conducted during two-month periods in spring, autumn and winter from March 1996 to February 1997. The programme was part of the EU-project "Assessment and Reduction of the By-catch of Small Cetaceans (BY-CARE)". Observers were randomly assigned to fishing boats using bottom set gill-nets for cod and pollock. The sample unit was the observed haul of each net in a string. The observed gear types corresponded to 58% of the bycatches in the Skagerrak Sea in a collection of bycaught animals 1989-91.

The observers monitored hauls of 1,981 (n=972), 257 (n=121) and 406 km net*hours fished (n=171) in spring, autumn and winter, respectively. This effort corresponded to 9% of the total yearly effort of the observed fishery. The documented bycatch rates were 40 porpoises per 10,000km net*hours fished in spring, 39 in autumn and 0 in winter. By multiplying the bycatch rates with total fishing effort per season a yearly bycatch of 113 porpoises (95% C.I.=53-173) was obtained. The ratio between this bycatch and an abundance estimate of 4,785 porpoises, derived from a SCANS density estimate, and the sea surface area of the Swedish Skagerrak Sea, results in a 2.4% removal rate of porpoises in bottom set gill-nets for cod and pollock only.

In addition, bycatches in the Skagerrak Sea have also been documented in bottom set gill-nets for lumpsucker, hake, dogfish, flatfish, crab and herring, drift-nets for mackerel and bottom trawls for Norwegian lobster, shrimp and herring. Thus, it is likely that the total removal rate exceeds 4%, the estimated maximum growth rate of a harbour porpoise population.

The results of the observer programme indicate that the removal rate is not sustainable and that immediate actions should be taken to reduce the bycatch level of porpoises in Swedish waters. With limited resources available, main priority should be given to solving rather than documenting the bycatch problem further.

DISTRIBUTION AND STATUS OF THE MEDITERRANEAN MONK SEAL IN GREECE 1990-1996

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The presence of the endangered Mediterranean monk seal (*Monachus monachus*) in Greek waters was dilucidated by visiting most of the country islands, as well as promising trenches in the mainland, and by direct interviews with local fishermen. Methods used in the past were mainly mailed interviews which are subject to conspicuous biases.

Causes of mortality were quantified by collecting data on 107 death events. Present and past suitability of breeding caves were evaluated by means of surveys and monitoring of a big sample of territory, including most of the Cyclades islands in the Aegean Sea.

The census of such a sparse seal population is technically impossible. Hence, for the evaluation of the population size an estimate of the very minimum population in the surveyed areas was obtained by means of interviews with selected locals. Seals in a sample of three Cycladic islands, with a notorious population, were censused by direct observation; the difference found in that sample between the number of seals censused and the lower one estimated by the interview method was extrapolated to the estimation for other Country areas, in order to obtain a less underestimated value for them. Population censuses available for Zakynthos and Sporades islands were added to obtain the total value for all the country.

Results show that the species is still present along most of its former range known in the 70's. Mortality, both before and after its legal protection in 1981, is mainly by direct killing but entanglement in trammel nets has increased (before 1981: direct killing 80%, entanglement 10%, natural-unknown 10%, n=41; after 1981: direct killing 47%, entanglement 21%, natural-unknown 32%, n-66). Most of the breeding caves are still tactically used. The surviving population in Greece might be at least 234 individuals, and it possibly reaches 300 seals, pups not included in the calculations.

CHANGES IN GREY SEAL PUP PRODUCTION IN SCOTLAND: MONITORING USING AERIAL PHOTOGRAPHY

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A time series of pup production estimates can provide valuable insights into the responses of pinniped populations to natural or anthropogenic changes in their local environment. Pup production can also be used to determine total population size, a statistic frequently required in fisheries management decisions.

Pup production at the 40 main grey seal (*Halichoerus grypus*) breeding sites in Scotland, has been monitored annually since 1960 using aerial photography. Colonies are surveyed 3 to 7 times at approximately 11 day intervals through the pupping season. Total pup production at each colony is derived from counts of pups, classified as white coated, moulted or dead and either sucking or not sucking. A model describing the numbers of pups ashore, assuming a lognormal frequency distribution of birth dates, and incorporating empirical estimates of age at moult, age at leaving, pup mortality, age-related proportion of time spent sucking and error in pup classification, is fitted to the classified counts to produce a maximum likelihood estimate of total production.

Pup production at Scottish breeding sites, currently estimated to be 31,000 or 37% of the world production, has been increasing at about 4% per annum since the early 1960s and has more than doubled since 1984. Different sites have increased at different rates. The relatively new sites in the Monach Isles have accounted for all the increase in production in the Outer Hebrides since the mid 1970s, while production at long established sites has remained static or has declined. In Orkney, one recent site increased from <50 pups to 1000 pups per annum in 6 years. Between 1992 and 1995, pup production in the Outer Hebrides increased by 2% p.a. while in Orkney production increased by 7% p.a.

Reasons for the selection, and timing of colonisation, of new sites are poorly understood. Most have lost their human inhabitants within the past 2-4 decades. Most recent sites incorporate wide open beaches allowing easy access; pup mortality at these sites appears to be lower than at older, long-established sites. At least at present, Scottish grey seal population growth does not appear to be food or space limited.

EFFECT OF DISTURBANCE ON PUP WEANING MASS IN SOUTHERN ELEPHANT SEALS

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Quantifying the effects of disturbance on breeding biology of southern elephant seals (*Mirounga leonina*) is considered necessary for management and monitoring of human impacts on (Sub)Antarctic ecosystems. We monitored a number of potential behavioural and physiological measures of disturbance. It was hypothesised that disturbance would have a negative effect on the mother-pup energy transfer resulting in lower masses of pups at weaning. This paper describes the effect of handling on pup weaning mass.

On Macquarie Island, 30 mother-pup pairs were given different degrees of experimental disturbance. Three experimental groups of 8, 4, and 6 pairs were captured, respectively, 3, 4, and 5 times throughout the lactation period around days 2, 11, (14, 18), and 21 post partum; a control group of 12 pairs was only captured on the 21st day post partum, one of the last days of lactation. Captures included anaesthetising the mother and physically restraining the pup, taking blood and milk samples, and measuring weight and length.

Weaning masses of pups, corrected for maternal length, were significantly different among the four groups (Kruskal-Wallis H=11.9, df=3, $P<0.01$). Remarkably, this difference was largely due to the most intensely treated group captured five times (mean 98 kg ± 18 S.D.); weaning masses did not vary significantly (Kruskal-Wallis H=1.8, df=2, $P>0.05$) between the control group (mean 125 kg ± 29 S.D.) and the experimental groups captured 3 times (mean 119 ± 15 S.D.) and 4 times (mean 125 ± 16 S.D.). As there is evidence of an association between weaning mass and juvenile survival (C.R. McMahon, pers. comm.), the effect observed would imply an adverse fitness effect of disturbance.

Additional data on behaviour, blood stress parameters, milk composition, and survival rate are needed to study the mechanism by which disturbance may affect weaning mass and survivorship and to what extent.

SURVIVAL IN POST-WEANED GREY SEAL PUPS IN RELATION TO WEANING MASS

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The aim of this study was to estimate the survival of a cohort of post-weaned grey seals (*Halichoerus grypus*) during their first year of life and determine whether survival is related to size at weaning. 250 pups born at the Isle of May, Scotland in 1996 (approximately 25% of the birth cohort) were tagged using a specifically designed passive head tag. The tags were glued to the head of the seal and will float when detached. We assume tags will become detached when the animal dies or moults next season, so tags recovered before the moult represent dead animals. The tags were individually numbered and colour coded according to three weight categories (<35kg n=100, 35-40kg n=85 and >40kg n=65). Tag recoveries and live resightings from regular trips to three major grey seal haul-out sites on the east coast of the UK have provided information to estimate initial survival in each group.

Data from 11 weaned pups fitted with satellite relay data loggers between 1993 and 1995 indicated there was no significant relationship between the proportion of time spent hauled out, after leaving the breeding beach, and mass. Consequently, the probability of sighting a tagged animal hauled out appeared to be independent of size.

Re-sightings of the different colour tags on live animals (number seen as a proportion of those tagged in each size class) were 0.33 (<35kg), 0.20 (35-40kg) and 0.34 (>40kg). This resulted in survival estimates for the first 6 months of life (based on a single mark continuous recovery model) of 0.47, 95% CI.=0.41-0.54 for the <35kg class, 0.43, 95% C.I.=0.37-0.51 for the 35-40kg class, and 0.52, 95% C.I.=0.43-0.63 for the >40kg class. Thus, there was no significant effect of mass on survival.

Tag recovery data showed that the overall survival in the first 6 months of life was 0.24 (95%C.I.=0.21-0.26). There was no significant difference in survival between the small and large size classes (<35kg 0.29, 95%C.I.=0.25-0.34; >40kg 0.28 95%C.I.=0.22-0.35). However, pups in the middle class had a significantly higher survival rate (0.52, 95%C.I.=0.45-0.60).

TRADITIONAL VERSUS PRECAUTIONARY APPROACHES TO THE MANAGEMENT OF COASTAL CETACEANS

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Traditionally, marine resources have been managed on a basis where controls on new developments are implemented only when harmful effects on other interests can be demonstrated. This approach poses particular problems for the conservation of coastal cetaceans because potential threats are diverse and likely to interact, and the problems inherent in monitoring cetacean populations result in low power to detect any effects. Recognition of these problems has led to the development of integrated coastal management programmes in many countries and the endorsement of precautionary management principles in many national and international agreements. In practice, however, a number of factors may prevent application of precautionary rather than traditional management approaches. Politically, there often remains a demand for scientific "proof" of a problem before controls are implemented and many scientists remain reluctant to deviate from the traditional approach to minimising Type I statistical error.

We illustrate these problems using a case study from the Moray Firth, Scotland. This estuarine area will soon be designated and managed as a site to conserve bottlenose dolphins under the European Community's "Habitats Directive". The population is small, isolated and faces a wide range of potential threats: oil extraction, waste disposal, military training, fisheries, transport, and recreation. We combine the results of population surveys to monitor abundance, power analyses and population viability analyses to explore the consequences of adopting either traditional or precautionary approaches to management. In doing so, we aim to show how this framework could be developed to provide a scientific basis for illustrating the level of precaution required for the management of activities which may impact upon coastal cetacean populations.

CONSERVING GENETIC DIVERSITY IN MARINE MAMMAL POPULATIONS: THE CASE OF THE MEDITERRANEAN MONK SEAL

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Small and fragmented populations of all species are at risk of losing genetic diversity through genetic drift, inbreeding depression, selection and a number of processes which occur at the molecular level. We review the way in which each of these factors can affect genetic diversity in marine mammal populations, evaluate their relative importance, and consider what the consequences of loss of genetic diversity might be.

Drift alone is unlikely to be responsible for the low levels of genetic diversity observed in some marine mammal populations. We use a proposal to translocate part of the surviving population of Mediterranean monk seals (*Monachus monachus*) from the west coast of Africa to the Canary Islands to illustrate how mathematical models can be used to evaluate the likely success of management actions. If a small translocation had taken place before the mass mortality which seriously affected this population in May and June of 1997, it would have had little effect on the parent population, so long as that population was stationary or increasing, and would have reduced the risk of extinction for the entire population from a single catastrophic event. However, the probability of a new population becoming established is small. Even if a translocated population can be established successfully, it is likely to have less genetic diversity than the parent population unless a substantial number of animals are translocated.

FINE SCALE DISTRIBUTION OF BOTTLENOSE DOLPHINS IN THE MORAY FIRTH, SCOTLAND

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The Moray Firth, Scotland, is home to a resident population of approximately 130 bottlenose dolphins (*Tursiops truncatus*). Boat based photo-identification surveys conducted since 1990 showed that, within the main part of the population's range, a small area was used by over 60% of the population in a single year and was the only area used consistently year round. This is located at the entrance to the Cromarty Firth, a deep narrow channel of approximately 6 km^2. The reason why this small area is favoured by the dolphins is unclear.

The entrance to the Cromarty firth is an area also used for human activities including shipping, spoil dumping and fish farming. In order to minimise potential impacts from these human activities and provide effective protection for the dolphin population, more detailed information on their spatial and temporal use of this area is required.

The primary objectives of this study were to examine the fine scale habitat use and behaviour of the dolphins with respect to seasonal, tidal and diurnal changes within the entrance to the Cromarty Firth.

Observations were made from a 70 m high headland overlooking the survey area. The positions of dolphins were obtained using an electronic theodolite and their behaviour was recorded on video. These tracks of dolphins allowed information on behaviour and habitat use to be linked. Furthermore, regular samples using the video camera provided a distribution map of dolphin surfacings based on cue-counting. Results have provided information necessary for the management of this population, whilst this new technique offers an objective method for investigating patterns of fine scale habitat use by inshore cetaceans.

MARINE BLASTING: NEW AND IMPROVED APPROACH TO MINIMISE MARINE MAMMALS AND SEA TURTLE IMPACT

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For the last decade there has been growing concern about the effect of man-made sounds in the ocean on the marine life, specially in coastal zones. During 5th March and 1st May, 1997, a series of 37 blasting activities, using an average of 1468.8 lbs. of explosive each, occurred in conjunction with the construction of the Ponce Deep Ocean Sewage Outfall Pipeline, at the bay of Ponce, Puerto Rico. A resourceful disposition and distribution of charges, along with an innovative combination of different surveillance devices provide a successful and safety protection area for marine mammals and sea turtles. Sound pressures level less than 10 PSI were recorded at distances of 70 meters from the blasting point. Pre and post blasting surveillance activities were carried out, combining a bottom scanner and a specially constructed side scan sonar, as well as visual recognition, covering an average of 0.66 nm of radii from the blasting point.

Although several marine mammals (72) and sea turtles (33) were observed, no animals were confirmed injured or killed during the entire blasting activity. For all purposes, it was judicious environmentally and economically to consider the ecological components in advance and include them into the design of this kind of project. Mankind enhanced ecological consciousness, and the pursuits of economical development do not have to contradict each other as is still widely (but erroneously) believed. Ultimately, they must converge for an ecological and economical balance.

SPATIO-TEMPORAL MODELLING OF EASTERN TROPICAL PACIFIC DOLPHIN ABUNDANCE

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Incidental mortality of dolphins during tuna purse seine operations in the eastern tropical Pacific (ETP) Ocean has negatively affected populations of spotted and spinner dolphins. Estimates of trends in abundance of ETP dolphin populations are used to assess their current status. At present trend estimates are obtained using post-stratification techniques applied to sightings data collected since 1975 by observers on board tuna vessels. If the precision of these estimates can be improved, current trends in the populations will be identified earlier. To improve the precision and to explore dolphin distribution and movements we used generalised additive models (GAMs) containing environmental and spatio-temporal covariates to separately model encounter rate and mean school size. Annual estimates of relative abundance were obtained from the fitted density surfaces, and trends estimated using a GAM fitted to the annual abundance estimates (1975-1990).

Results from the spatio-temporal model suggest a significant increase in relative abundance since the early 1980s for the eastern spinner dolphin stock, with a substantial increase in the precision of the estimate for 1990. For the north-eastern offshore spotted dolphin stock, a significant decline in abundance since the mid 1970s was observed, with no apparent trend in the late 1980s-1990. However, data from the early years are limited, and comparisons with that period should be treated with caution. Analyses of model residuals do not suggest any apparent patterns, but the models tend to perform poorly near the outer regions of the nominal stock areas. The use of 'structural zeros' to improve model robustness will be reviewed. Preliminary results from a simulation study to evaluate model performance will be reported.

THE SITUATION OF THE MEDITERRANEAN MONK SEALS ON THE TURKISH COASTS

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The Mediterranean monk seal *Monachus monachus* (Hermann, 1779) is a highly endangered species, remaining only in ex-Sahara on the Atlantic coast of Eastern Africa and in the Eastern Mediterranean Sea. In the Turkish waters, this species has been under the legal protection since 1977. However, it is important to continuously monitor the status of the species to implement more effective protection measures. For this reason, the status of the Mediterranean monk seals in the Turkish coasts of the Black Sea, Marmara Sea, Aegean Sea, and Mediterranean Sea was studied from 1986 to 1996 for 10 years. Direct censuses were made, as well as the first hand information was collected from the fishermen. During this study, 44 individuals were identified for all the Turkish waters: two individuals in the Black Sea, two in the Marmara Sea, 28 in the Aegean Sea, and 12 the Mediterranean Sea. Except for the two individuals in the Bodrum Peninsula and the three individuals in the Sicilian Basin, all monk seals were single animals. This means that the seal populations lost their colony peculiarities. Main causes of the decline of the monk seals in Turkey are deliberate killings, overfishing and loss of habitats. Twenty four seal deaths were reported during the study period. Twelve of them were deliberately killed, six of them were drowned in the nets and the reason for six deaths was not determined.

CAN PARASITES HELP CETACEANS? PARASITES AS BIOLOGICAL TAGS OF FRANCISCANA IN SOUTH AMERICAN WATERS

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Parasites suffer from a severe problem of public relationship. Often perceived as unpleasant and disgusting, they have been neglected in ecological studies despite they represent a fundamental part of the living world. Furthermore, parasites are relevant to host conservation programmes because they can provide useful and valuable information about host populations, particularly on stock identity, migration and social structure. Not surprisingly, the use of parasites as biological tags of marine mammals has increased over the last ten years. In this study we compared the helminth fauna of the franciscana (*Pontoporia blainvillei*) in several locations of Argentina, Uruguay and Brazil, in order to identify host ecological stocks along the entire geographical range. This is particularly important because franciscana populations currently suffer from a heavy mortality by fishing, but the actual impact is uncertain as the population status of the franciscana is poorly known. Data on helminths of 46 franciscanas collected during the austral spring 1988-89 in Buenos Aires province (Argentina) were compared with previous information from dolphins off Punta del Diablo (Uruguay). We found both qualitative and quantitative differences in parasite faunas, which suggests that at least some ecological segregation exists between franciscanas north and south of La Plata Estuary. This conclusion is further supported by recent helminthological evidence from southern Brazilian waters. We conclude that franciscanas may not move between these areas at least during spring, coinciding with their reproductive period. The ever increasing demand for conservation of marine mammals requires the integration of a wide array of data. A plea is made for further multidisciplinary studies including genetic, meristic and parasitological information.

BREEDING GROUND OF HARBOUR PORPOISES (*PHOCOENA PHOCOENA*) IN THE NORTH SEA OFF SCHLESWIG-HOLSTEIN (GERMANY) AND ITS IMPLICATION FOR MANAGEMENT

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The occurrence of harbour porpise calves was studied in the coastal waters of Schleswig-Holstein, Germany. Between 1990 and October 1996 all stranded harbour porpoises along the North Sea coast of SchleswigHolstein were investigated. 71.6% of the 197 stranded porpoises younger than one year were found on the island of Sylt and 7.6% on the neighbouring island of Amrum, whereas a significant higher proportion of presumably subadult harbour porpoises aged between 1 and 4 years stranded on beaches south of Sylt than on this island. In addition to collecting stranding data, the area was investigated by aerial survey. 15.8% of the sighted porpoises in the Sylt area were calves, whereas the average calf proportion for the whole North Sea during the 1994 SCANS survey was only 5.4%. The significant higher proportion of calves off Sylt demonstrates the importance of these coastal waters as a breeding and nursing area for harbour porpoises. Therefore, the area should be protected, at least during the summer months, when harbour porpoise calves are most vulnerable to disturbances.

ARGOS SECOND AND THIRD GENERATIONS ARGOS SYSTEM EVOLUTION FOR ANIMAL TRACKING

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The Argos Data Collection and Location Satellite System is operated under a partnership agreement between NOAA (National Oceanographic and Atmospheric Administration - USA) and CNES (Centre National d'Etudes Spatiales - France) to provide a worlwide in-situ environmental data collection and Doppler-derived location service. One of the most significant use of Argos involves the location and collection of data associated with scientific programmes that study animals (birds, marine and terrestrial animals) all over the world. Recently an independent survey of the major international users was conducted to obtain their perspective on Argos system capabilities. Further clarification of Argos system User requirements was obtained through responses to an extensive Argos questionnaire. The results of the survey indicated that certain Argos system Users' requirements could only be addressed through modification of the satellite instrument along with associated changes in ground segment management. The User requirements are summarised as follows: * Improve Satellite Coverage * Increase Data Volume transmission capability * Improve Satellite Receiver Sensitivity to reduce platform power requirements or enhance transmission performance * Allow to control platforms remotely by having a two-way communication capability with the satellite. The desirability of many of these improvements was anticipated by Argos, and this paper will present plans for the second generation (Argos-2) beginning in 1996. Enhancements (under discussion during 1997) decided for the third Argos generation beginning in 2002 are under discussion and are presented.

REMOTE SENSING OF HARBOUR PORPOISE BEHAVIOUR IN RELATION TO GILLNETTING ACTIVITY IN DANISH WATERS.

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An estimated 5-10,000 harbour porpoises are taken annually as by-catch in the Danish gillnet fishery. Concern has been expressed that this by-catch may not be sustainable. An abundance of about 300,000 harbour porpoises has been estimated in the North Sea and adjacent waters.

Preliminary studies on population structure suggest the existence of several sub-populations, that could well be affected very differently by the geographically concentrated fishery. However, the specific impact of the by-catch on each of these sub-populations is not known. Similarly, the reason why harbour porpoises become entangled in these gillnets is not well known either. Studies on harbour porpoises migrations and preferred habitats as well as studies on the behaviour of these animals around gillnets are therefore essential in order to understand the processes that govern susceptibility to by-catch.

To address this problem we mounted satellite-linked-time-depth-recorders on two harbour porpoises to study their movements and diving behaviour. The porpoises were by-caught in pound nets in April 1997 in the Danish Belt seas. Within 26 days a subadult male moved more than 800 km to the south-east of Norway, frequently diving to the seabed throughout the day. The maximum depth and duration was 166 m and 7 mins, respectively.

An adult female accompanied by a one year old calf moved forth and back along the western and northern coast of Sjælland for 38 days until contact was lost. This animal too, examined the seabed frequently to a maximum of 44 metre and with a dive duration up to 9 minutes.

The general picture from these results shows that subadult males are capable of moving extensive distances within a short time. The adult female accompanied by its calf, moving in a well defined coastal route, gives an impression of a 'home-range'. Within this 'home-range' some of the highest densities of gillnets in the Danish waters are found during the spring.

FISH-INDUCED ANAEMIA IN SCOTTISH HARBOUR SEALS; A CLUE TO DECLINES IN BERING SEA PINNIPED AND SEABIRD POPULATIONS?

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Since the mid-1970s, populations of several pinniped and seabird species have been declining in the Bering Sea and Gulf of Alaska. A number of potential causes including competition with fisheries, incidental takes, disease, and pollution have been proposed, but no clear primary reason for the declines has yet emerged.

In NE Scotland, between-year variations in the availability of over-wintering clupeids (herring and sprat) have allowed us to assess the consequences of variations in diet composition in a population of harbour seals. Recent analyses suggest that, as reported for farmed mink and foxes in the 1960s, seals experienced a fish-induced anaemia when they switched from clupeid prey to alternative species such as gadoids and sand eels. As in mink, we found diet-related differences in juvenile growth and there is evidence of a recent decrease in population growth rates. While differing in pattern and temporal scale, changes from a clupeid to a gadoid dominated prey community in Scottish waters have parallels with that reported for the Bering Sea.

Previous studies of the effects of changes in prey availability on Bering Sea top predators have focused on the energetic consequences of differences in diet composition. Here, we outline our evidence for an additional physiological cost to prey switching in Scottish harbour seals, and discuss the potential role of differences in prey nutritional quality for the dynamics of declining populations of Bering Sea pinniped and seabirds.

DISTRIBUTION
&
SURVEYS

FIRST RESULTS ON THE DISTRIBUTION OF CETACEANS IN THE SOCIETY ISLANDS (FRENCH POLYNESIA)

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INTRODUCTION The hydrobiological situation of the Central Tropical Pacific is dominated by superficial biomass levels of less than 0.1 g.Chla.m^{-3} (Rancher and Rougerie, 1993), if one excepts a narrow equatorial band, where moderate primary production occurs (Longhurst and Pauly, 1987). More than 20 species of cetaceans may frequent the waters of the Society Islands, at least seasonally (Leatherwood and Reeves, 1985; Evans, 1987). Poole (1993) listed a serie of 17 species, by analysing reports obtained from various sources, including himself: 15 are odontocetes and two are mysticetes. If cetaceans are said to be common around Polynesia, it remains to describe their distribution and relative abundance in response to a very oligotrophic ecosystem. French Polynesia alone comprises five archipelagoes extending over 20° of latitude and 20° of longitude. We present here the results obtained from data collected during two different surveys in 1996 and 1997 in the waters of the Society Islands.

MATERIAL AND METHODS A dedicated survey program was organised on a 12 m auxiliary sailboat in March-April 1996, in October-November 1996 and from March to May 1997 around the Society Islands. The same field protocol was adopted during the three sub-surveys: sampling was essentially done on diesel propulsion (speed 5 kts), taking place with wind speed less or equal to 10 knots. Sampling effort did not include short bouts inside the barrier reef and searching started and ended outside of the passes. Two or three observers shared the frontal sector, searching with naked eyes. Cetaceans were positioned upon detection, radial distance and bearing estimates were recorded, and were thereafter approached for species determination and school size estimate. This survey program covered the 0-50 miles area around the main islands of the Societies, from Tahiti to Maupiti, with an effective effort of 1,963 km, representing 246 hours of searching effort.

The other survey took place in December 1996 on the 85 m oceanographic vessel R/V "L'Atalante", belonging to IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer). It was organised by the Université Française du Pacifique and consisted in an extensive geophysical sampling of a large area known as «Savannah seamounts», some 100 miles southwest of Tahiti. One observer was searching with naked-eye from the upper deck (15m above the surface), the vessel cruising at 10 kts. The searching was interrupted when the wind speed exceeded 15 knots.This was a passing mode survey and species identificaton was done with a 10x56 binoculars. Mission specific material included very noisy underwater devices (airguns and sonar) that caused any cetaceans to rush off the vessel trackline. An effective effort of 2,166 km was achieved during this geophysical survey, representing 118 hrs of sighting effort.

The species identification was sometimes aided by microscope observation of fine grain colour slides. Sighting rates were estimated for delphinids for each survey with *Distance* software, by only taking account of the survey effort with wind speed lower than 10 knots (Laake *et al.*, 1994). For both surveys, the area of study was stratified into an inshore stratum (within 15 milles from shore) and an offshore stratum (more than the 15 milles off shore). Confidence intervals were estimated on the basis of log-normal distribution. The diversity of odontocetes was evaluated with the Shannon-Weaver index (Frontier and Pichod-Viale, 1995):

$$H = - \sum (N_i/N_t) \, Log^2 \, (N_i/N_t)$$

where N_i is the number of observed individuals belonging to the species i and N_t is the total number of observed cetaceans.

RESULTS A total of 58 groups of cetaceans were observed, including one species of mysticete (*Megaptera novaeangliae*), two species of beaked whale (*Mesoplodon densirostris*) and (*Ziphius cavirostris*) and eight species of delphinid (*Stenella longirostris, Steno bredanensis, Peponocephala electra, Lagenodelphis hosei, Tursiops truncatus, Globicephala macrorhynchus, S. attenuata, Feresa attenuata*). From the total, 10 sightings were off-effort: six of spinner dolphin, three of humpback whale and one of bottlenose dolphin. 39 sightings on nine species were made during the small boat surveys (Table 1). Eight sightings on six species were made during the geophysical survey (Table 2).

The humpback whale was observed in groups of 1-2 animals during its breeding season (July-November), generally very close to the reef barrier (less than 1 km). It was only observed in the Windward Islands (Tahiti, Moorea and Maiao). Beaked whales were sighted less than three miles from the reef (*M.densirostris*) or farther in the inshore stratum (*Z.cavirostris*) in groups of 2-4 individuals.

From the total of 39 delphinid schools sighted in-effort, three were seen offshore during the geophysical survey, including the only sightings of pygmy killer whale (10-12 animals) and pan-tropical spotted dolphin (about 70-100 individuals). The majority of the dolphins were sighted inshore, usually less than 5 milles from the reef. The spinner dolphin was the most common species seen during both surveys, with a total of 17 schools observed in-effort and a mean school size of 25.9 individuals. Fifteen sightings were made during the dedicated cruises and two during the geophysical survey. All sightings were obtained inshore. The second most frequent species is the rough-toothed dolphin, with nine sightings (including 8 during the dedicated surveys). This is a wide-ranging dolphin, mostly occuring in groups of 1 to 15 individuals (mean 5.6), always in the inshore stratum but sometimes at a distance of six miles from the barrier reef. Its distribution range includes all the islands from Bora Bora to Tahiti.

The melon-headed whale and Fraser's dolphin were observed four times in mixed schools during the dedicated survey (totalling 150-200 animals), with a higher number of melon-headed whales (mean school size 80 individuals) than Fraser's dolphins (mean school size 42 individuals). These inshore agregations also included rough-toothed dolphins on two occasions. One large group of Fraser's dolphins (about 100 dolphins) was also seen offshore during the geophysical cruise. Two groups of short-finned pilot whales were observed inshore: one during the dedicated survey (35 animals), and one during the geophysical survey (7 individuals). With one on-effort sighting in the Leeward Islands, the bottlenose dolphin is the least frequently observed of the inshore dolphins. The only sighting of pygmy killer whale was a school seen close to the bow during the geophysical cruise, while the air gun system was switched off.

With 10 species of odontocetes obtained in 44 in-effort sightings, the index of diversity of Shannon-Weaver is 2.41, which is about 72% of the maximum possible value.

During the dedicated survey, the sighting rate was of 0.0 group/mile for the offshore stratum against 1.62 10^{-2} group/mile (CV=26%) for the inshore stratum. For the geophysical survey, the figures were of 1.01 10-2 group/mille (CV=51%) for the inshore stratum and 0.08 10^{-2} group/mile (CV=61%) for the offshore stratum. Pairwise T-test comparisons show that inshore and offshore strata are significantly different for both surveys. This situation is also visible on an histogram, where 40 sightings out of 58 were made at less than two miles from the shore line of the reef barrier (Figure 1).

DISCUSSION These results are broadly similar to those published by Poole (1993), but this author lists eight species that we did not observe, and does not mention one species that we saw. The randomness of sampling work may account for the differences. It is also true that species identification in tropical waters can be sometimes problematic even for very experienced observers: therefore, reports from amateur may be regarded with prudence. With ten species sighted for an effort of 2,000 miles, the local odontocete population displays diversity, while the mysticete population is only represented by the humpback whale. The high Shannon index of diversity (2.41) may reflect a high degree of stability in the trophic conditions. The absence of sperm whale from our records is most surprising if one considers the ancient whaling history of Polynesia (Dodge, 1971; Townshend, 1935): our surveys were essentially made without hydrophone. Additional data obtained in October 1997 includes one sighting of *Physeter macrocephalus* and one of *Grampus griseus* (unpublished data).

The other striking feature is the distribution of cetaceans favouring the inshore stratum: for the odontocetes, it may be explained by the availability of food resources. In the open ocean around the Societies, there is a mixed superficial layer of about 100-150m, above a transition layer of 200-400m thickness (Rancher and Rougerie, 1995): this hydrological situation is not favourable to the feeding of cetaceans unless they are deep divers. Several reasons may explain the affinity of cetaceans for inshore waters: the islands are volcanic cones with slopes of about 10-20°. A small scale productivity increase around the islands may evolve from eddies linked to the current flow around the islands, or from local nutrient inputs due to rivers and rainfall, or from less understood phenomenon (Rougerie and Wauthy, 1986).

The seasonal thermal contrast in superficial waters (from 24-25°C in August to 29-30°C in March) may cause some seasonal variation in the cetacean population. If we except the obvious case of the humpback whale, our data are not numerous enough to imagine such a change. If the spinner and rough-toothed dolphins are clearly present year-long, the seasonal absence of other delphinids (melon-headed whale, Fraser's dolphin) from our records appears to be largely incidental, as confirmed by other cetologists observations (Jay Sweeney and Kristi West, *pers. comm.*). We clearly need new sets of data to study this seasonal aspect.

CONCLUSIONS The particular structure of the cetacean population of the Society islands, as shown by this study, features a high diversity and an accentuated spatial segregation, favouring the inshore waters. Other archipelagoes of French Polynesia may display distinct situations.

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REFERENCES

Dodge, E.S., 1971. *Baleiniers à Tahiti.* Société des Océanistes (Musée de l'Homme, Paris), vol. 11: 32pp.

Evans P.G.H., 1987. *The Natural History of Whales and Dolphins.* Christopher Helm books, London. 343pp.

Frontier S. and Pichod-Viale, D., 1995. *Ecosystèmes: structure, fonctionnement, évolution.* Masson, Paris. 447pp.

Laake, J.L., Buckland, S.T., Anderson, D.R. and Burnham, K.P. 1994. *DISTANCE User's Guide V2.1.* Colorado Co-operative Fish and Wildlife Research Unit, Colorado State University, Fort Collins. 72pp.

Leatherwood, S. and Reeves, R. 1985. *The Sierra Club Handbook on Cetaceans.* Sierra Club, San Francisco. 302pp.

Longhurst, A.R. and Pauly, D. 1987. *Ecology of Tropical Oceans.* Academic Press, San Diego. 407pp.

Poole, M. 1993. A sighting/stranding network in French Polynesia, 1988-1993. Abstract from the Tenth Bienn. Conf. Biol. Marine Mammals, Galveston, USA.

Rancher, J. and Rougerie, F. 1993. *Hydropol-situations océaniques du pacifique central sud.* Editions S.M.S.R., Montlhéry. 91pp.

Rougerie, F. and Wauthy, B. 1986. Le concept d'endo-upwelling dans le fonctionnement des atolls-oasis. *Oceanologica acta* 9 (2): 133-148.

Townshend, C.H. 1935. The distribution of certain whales as shown by logbooks records of American whaleships. *Scientific Contribution of the New York Zoological Society, Zoologica*, 19 (1): 1-50.

Table 1 Sightings made during the small boat survey.

species	dedicated survey inshore stratum	dedicated survey offshore stratum
Megaptera novaeangliae	3	0
Mesoplodon densirostris	2	0
Ziphius cavirostris	1	0
Stenella longirostris	15	0
Steno bredanensis	8	0
Peponocephala electra	4	0
Lagenodelphis hosei	4	0
Tursiops truncatus	1	0
Globicephala macrorhynchus	1	0

Table 2 Sightings made during the oceanographic survey (December 1996).

species	oceanographic survey inshore stratum	oceanographic survey offshore stratum
Stenella longirostris	2	0
Steno bredanensis	1	0
Lagenodelphis hosei	0	1
Globicephala macrorhynchus	1	0
Stenella attenuata	0	1
Feresa attenuata	0	1
unidentified dolphin	1	0

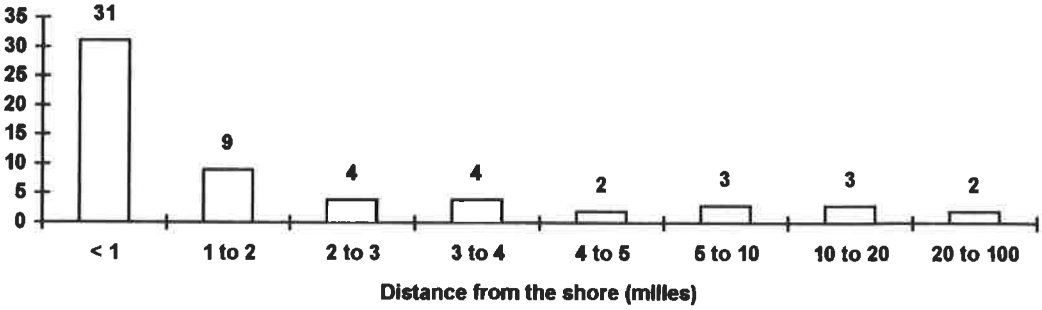

Figure 1: Number of sightings and distance from the shore or reef barrier line.

STRANDINGS OF CETACEANS ALONG THE COASTS OF CRIMEAN PENINSULA IN 1989-1996

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INTRODUCTION Three species of cetaceans are known in the Black Sea: the harbour porpoise (*Phocoena phocoena*), the bottlenose dolphin (*Tursiops truncatus*) and the common dolphin (*Delphinus delphis*). The contemporary status of their populations is not sufficiently clear (Klinowska, 1991; Birkun *et al.*, 1992; Buckland *et al.*, 1992; Birkun and Krivokhizhin, 1996). There is a scarcity of scientific data on cetacean population abundance, their distribution, migrations, biology, genetics, threats, pathology, and even taxonomy. In particular, the most accurate currently is the CIESM's *Atlas préliminaire de distribution des cétacés de Méditerranée* (Beaubrun, 1995) does not present any maps on dolphins and porpoise occurrence in the north half of the Black Sea. Undoubtedly, this is a consequence of poor information exchange between eastern and western cetologists not long ago. Moreover, the results of annual, more or less regular (every spring and autumn), observations in that area are not summarised yet, although four research institutes in Russia, Ukraine and Georgia collected numerous data during 1967-1989. Then, surveys were ceased completely because of lack of funding, but a study of cetacean strandings began just at that time in the Crimea.

METHODS Since February 1989, cetacean strandings were recorded along the Crimean coasts of the Black Sea. The entire length of the coastline permanently explored was about 650 km: from Karkinit Bay in the north-west to the Kerch Strait in the east. The stranding network was established here on the base of existing coastal frontier outposts and numerous voluntary assistants, mainly local inhabitants interested in wildlife conservation. The network was strengthened by a few specialist monthly patrols of two control coastal parcels 30 and 35 km long.

In addition, 120-180 km of Azov Sea's coastline were examined each year. An active search of stranded animals has been conducted annually in June since 1990 by two groups of trained volunteers travelling on foot along Kazantip Bay (southern coast of the Sea), and three special expeditions were organised in April 1994, May 1995, and May 1996 to Arabat Spit (western coast).

The strandings were recorded in correspondence with the following scheme: date and geographical point of finding, animal species, sex, external measurements, and state of carcass preservation. In most cases, postmortems and tissue sampling were examined by specialists for cause of death and disease investigation. The *Black Sea Geographic Information System* (Version 2.0, BSEP/UNDP, 1997) was used for mapping strandings in accordance with the CIESM protocol (1996).

RESULTS AND DISCUSSION A total of 817 strandings were recorded. Although this number is not absolute because of obvious imperfections in the methodology, some figures and conclusions presented below could be interesting for consideration.

Black Sea strandings

Black Sea strandings (552 cases; 100) were represented by harbour porpoises (321; 58), common dolphins (93; 17), bottlenose dolphins (45; 8), and unidentified small cetaceans (93; 17), but there are no suspicions that unidentified animals could be representatives of another species than *Ph. phocoena*, *T. truncatus* and *D. delphis*.

Among known cetaceans (459; 100), the harbour porpoises were predominant (70), whereas common dolphins (20) and bottlenose dolphins (10) constituted the minority.

Peaks in Black Sea harbour porpoise strandings were recorded in 1989 (46 cases), 1990 (225), and 1995 (33). Only 17 *Phocoena* strandings were found during all the other five years combined (Fig. 1).

Distinct peaks of common dolphin strandings were observed in 1990 (39 cases) and 1994 (27) (Fig. 2). Moreover, in 1994, the number of *Delphinus* strandings was predominant in comparison with harbour porpoise (one animal) and bottlenose dolphin (four animals).

Only one more or less sharp peak in bottlenose dolphins strandings was registered in 1990 (20 from 45 *Tursiops* carcasses recorded during eight years) (Fig. 3).

So, it is very likely that in 1990 the mass mortality event affected cetaceans of all three Black Sea species. The second precisely known die-off, which took place in 1994, concerned only common dolphins. The harbour porpoise also showed a probable increase in mortality in 1989 and 1995.

In accordance with the data of monthly dynamics, most harbour porpoise strandings were recorded in spring with a marked peak in April; and numbers of common dolphin strandings increased in April and July-August. Meantime, bottlenose dolphin strandings showed no prominent fluctuations during a year. The above-mentioned seasonal peaks correspond with mass mortality events in spring 1990 (harbour porpoises and common dolphins) and in summer 1994 (common dolphins).

The origin of the first die-off observed in 1990 is not clearly known (Birkun *et al.*, 1992; Birkun and Krivokhizhin, 1993). The majority of stranded harbour porpoises were immature individuals about one metre long (Fig. 4). All necropsied porpoises had severe lung nematodosis complicated by suppurative broncho-pneumonia, and histological signs of secondary immunodeficiency, but common dolphins and bottlenose dolphins usually had no lung disease.

The common dolphin die-off recorded in 1994 was studied more thoroughly (Birkun *et al.*, 1996). It was supposed that some viral infection has affected Black Sea *Delphinus* population, and now the *Morbillivirus* aetiology has been distinctly shown in two animals (Birkun *et al.*, 1999).

Azov Sea strandings

Azov Sea strandings (265 cases; 100) were represented by harbour porpoises (231 cases; 87), bottlenose dolphins (3 cases; 1), and unidentified cetaceans (31 cases; 12). No evidence of common dolphin occurrence in this Sea is known till now.

During the warm season (May - October), the level of cetacean strandings depends on the widespread use in this region of bottom-set gill nets for sturgeon and turbot. Most summer strandings were suspected to be by-catches.

Carcasses of bottlenose dolphins also had marks of by-catch. The presence of this species in the Sea of Azov seems important in itself because, before 1997, there was only a single publication on the existence of*Tursiops* in this area (Tzalkin, 1940; Birkun *et al.*, 1997).

In late autumn 1993 the harbour porpoise die-off occurred in the south-west corner of the Azov Sea. Because of unfavourable weather conditions, cetaceans were captured in an ice trap (Birkun and Krivokhizhin, 1997).

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REFERENCES

Beaubrun, P.C. 1995. *Atlas préliminaire de distribution des cétacés de Méditerranée.* CIESM, Musée Océanographique, Monaco. 87pp.

Birkun, A., Jr., Krivokhizhin, S, Shvatsky, A., Miloserdova, N., Radygin,G., Pavlov,V., Nikitina,V., Goldin, E., Artov, A., Suremkina, A., Zhivkova, E., Plebansky,V. 1992. Present status and future of Black Sea dolphins. Pp: 47-53. In: *European Research on Cetaceans - 6*: Proc. 6th Ann. Conf. ECS, San Remo, 20-22 February, 1992 (Ed. P.G.H. Evans). European Cetacean Society, Cambridge, England. 454pp.

Birkun, A., Jr. and Krivokhizhin, S. 1993. Is there any progress in the protection of Black Sea cetaceans? Pp. 288-293. In: *European Research on cetaceans - 7*: Proc. 7th Ann. Conf. ECS, Inverness, 18-21 February, 1993 (Ed. P.G.H. Evans). European Cetacean Society, Cambridge, England. 306pp.

Birkun, A., Jr. and Krivokhizhin, S. 1997. Sudden ice formation - a cause of harbour porpoise die-offs in the Sea of Azov. In: *European Research on Cetaceans - 11*: Proc. 11th Ann. Conf. ECS, Stralsund, 1997. European Cetacean Society, Kiel, Germany. 314pp.

Birkun, A., Jr. and Krivokhizhin, S. 1996. Present state and causes of Black Sea cetacean populations suppression. I. Dynamics of numbers, biotic and non-biotic limiting factors. *Vestnic Zoologii*, 3: 36-42 (In Russian).

Birkun, A., Jr., Krivokhizhin, S., and Pavlov, V. 1997. New data on the existence of bottlenose dolphins in the Sea of Azov. Pp. 200-203. In: *European Research on Cetaceans - 10*: Proc. 10th Ann. Conf. ECS, Lisbon, 11-13 March, 1996 (Ed. P.G.H. Evans). European Cetacean Society, Kiel, Germany. 334pp.

Birkun, A., Jr., Krivokhizhin, S. and Stanenis, A. 1996. The Black Sea common dolphin epizootic in 1994. Pp.266-268. In *European Research on Cetaceans* - 9: Proc. 9th Ann. Conf. ECS, Lugano, 9-11 February, 1995 (Ed. P.G.H. Evans). European Cetacean Society, Kiel, Germany. 306pp.

Birkun, A., Jr., Kuiken, T., Haines, D.M., Joiris, C.R., Krivokhizhin, S., Osterhaus, A.D.M.E., Siebert, U. and Van de Bildt, M. 1999. Evidence of morbilliviral disease in Black Sea common dolphins. (this volume)

Buckland, S.T., Smith, T.D., and Cattanach, K.L. 1992. Status of small cetacean populations in the Black Sea: review of current information and suggestions for future research. *Rep. Int. Whal. Commn.*, 42: 513-516.

CIESM Protocol on cetacen sightings in the Mediterranean and Black Seas. 1996. Unpublished issue of the meeting of CIESM Marine Mammal Specialist Group, Monaco, 12-13 January 1996. 10pp.

Klinowska, M. 1991. *Dolphins, Porpoises and Whales of the World. The IUCN Red Data Book.* IUCN, Gland. 429pp.

Tzalkin, V.I. 1940. Certain observations on biology of Azov and Black Sea dolphins. *Bull.Moscow Soc. Naturalists*, Biol.Div., 49: 61-70 (In Russian).

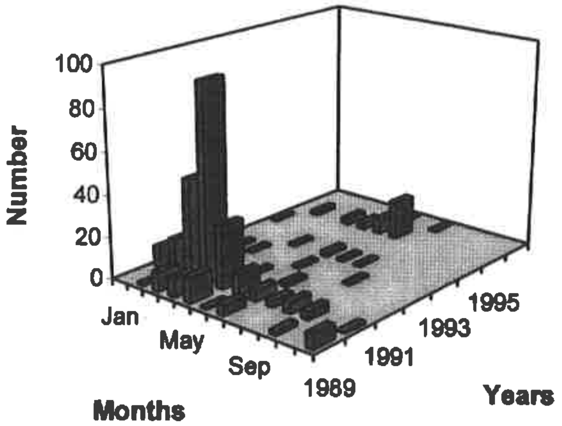

Fig. 1. Annual and monthly dynamics of harbour porpoises strandings

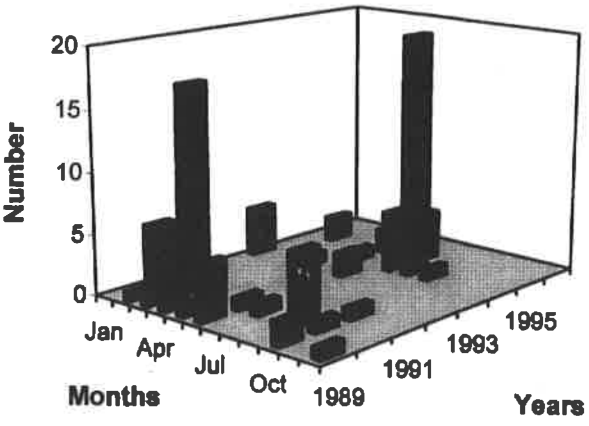

Fig. 2. Annual and monthly dynamics of commo dolphins strandings

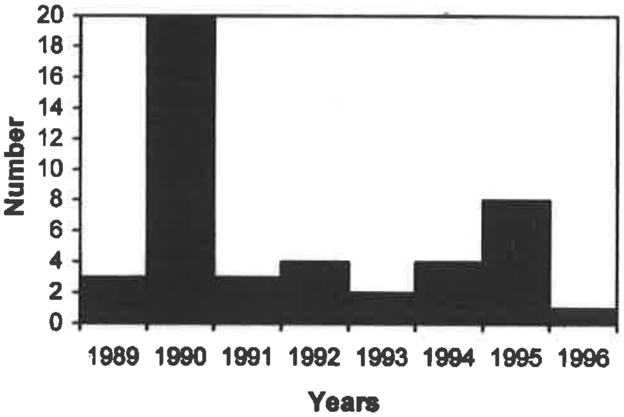

Fig. 3. Annual dynamics of bottlenose dolphins strandings

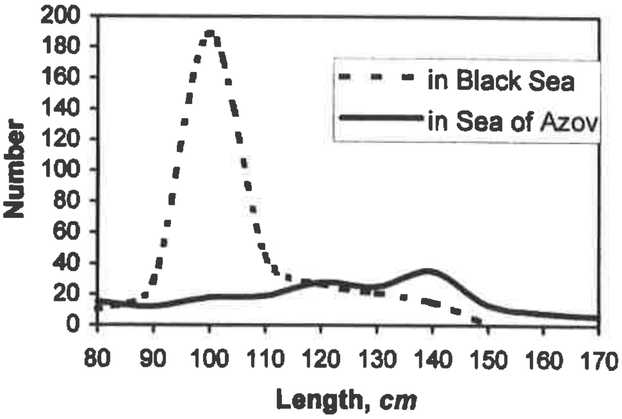

Fig. 4. Body length of stranded harbour porpoise

CETACEAN SIGHTINGS AND INTERACTIONS WITH FISHERIES IN THE ARCHIPELAGO PONTINO CAMPANO, SOUTHERN TYRRHENIAN SEA, 1991-1995

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INTRODUCTION: We chose this area because in the past it has never been the object of a detailed systematic cetacean study. This is a preliminary report of five years observations. The purpose of this project was to initiate a longterm study on cetaceans in a sample area, to record the most common species, analyse seasonal variation in their presence, verify the existence of resident cetaceans, and study interactions with fisheries.

METHODS: The archipelago Pontino Campano comprises nine volcanic islands, forming three distinct groups, old eruptive centres, separated from each other by about 40 km.

During the research we adopted two different methods: between June 1991 and June 1993, data were collected by ferries, cargo and fishing boats sailing in the area. The recordings were discontinuous but enable us to find out the winter presence of cetaceans in the area. From 1993 to 1995, in order to obtain more information, we used a 15 m. sailing boat, "Barbarian", equipped for high seas navigation with a GPS, recording databases, and a hydrophone system. A constant watch was kept for cetaceans and all sightings noted with their position, group size, behaviour, associated species, presence of juveniles, sea state, and wind strength. Trips were conducted daily from dawn to sunset, and from May to October. No trip was started in conditions greater than sea state 5. Travel was always made by sail.

RESULTS: A total of 330 sightings, including 3,494 individuals of seven cetacean species, were recorded during the period of the research. We tried to quantify the observers' effort from 1993 to 1995. Besides recording all dependent variables (sea state, light conditions, observation height, boat and cetacean behaviour), a sightings frequency was calculated by dividing the number of individuals by the travelled distance (km.). These indices varied between 0.09 (1993), 0.12 (1994) and 0.13 (1995) (mean frequency 1.11).

Striped dolphins (*Stenella coeruleoalba*) were the most frequent cetacean encountered, with a total of 183 sightings, comprising 2,557 individuals. The great majority were sightings of groups of 6-10 individuals (mean group size =13.97) with a maximum group of 350 animals, and concentrated in the southern waters of the islands, at an average depth of 700 m. The number of sightings increased to a peak in the month of September. In the same month, we recorded the highest concentration of juveniles in striped dolphin groups.

Bottlenose dolphins (*Tursiops truncatus*) were distributed in coastal waters particularly at the mouth of the river Volturno and around Ventotene and Ischia islands at an average depth of 100 m. A total of 68 sightings comprising 501 individuals were recorded during the study. Most sightings were groups of 2-5 individuals (mean group size =7.36) with a maximum group size of 100 individuals. Sightings frequency increase to a peak in June, with the highest concentration of juveniles recorded from May to August. A resident group of 15 individuals had been photo-identified and studied since 1993: the group comprised four females, six males, one subadult and four juveniles. The home range of this group extended from Ischia to Ponza, but the most frequent observations were made around Ventotene.

Sperm whales (*Physeter macrocephalus*) were recorded during the survey, with 29 sightings of 39 individuals. Sightings were largely confined to the southern waters of the islands at an average depth of 700 m.; most sightings were of single animals (mean group size =1.34) and with greatest frequency in August and September. They were recorded near the coast at night, during the breeding season of "European flying squids" (*Ommastrephes sagittatus*) making use of the high concentration of squids near fishermen's lights.

Risso's dolphins (*Grampus griseus*) were relatively uncommon, with 13 sightings of 101 individuals. They were encountered very close to the shore of the islands, in groups of 7-10 individuals (mean group size 7.76) with a maximum of 15 individuals. Sightings occurred in all years, decreasing in winter and increasing in September. Juveniles were recorded in April, May, June and September.

Long finned pilot whales (*Globicephala melas*) were rarely encountered in the area, with six sightings comprising 64 individuals. They were observed most frequently in groups of 6 (mean group size = 10.66) with a maximum of 35 individuals and were most abundant in October, in south-westerly waters of the islands. Photo-ID studies revealed the seasonal presence of recognisable individuals in a single location (around Ventotene).

Common dolphins (*Delphinus delphis*) were the rarest cetaceans in the area, with only four sightings of seven individuals. They were always in association with large groups of striped dolphin. Two juveniles were recorded near Ponza, swimming near their mother. In 1996 (data still being analysed) one sighting of 15 individuals of common dolphins was recorded without any association with striped dolphin.

Fin whales (*Balaenoptera physalus*) were recorded throughout the area with 16 sightings of 28 individuals. The majority were sightings of single animals (mean group size =1.75), with a maximum group size of three individuals. They were most abundant in summer time, from May to September. The number of juveniles reached a peak in the month of September.

Unidentified. They were recorded mainly in 1991-1993 during the ferry-census for a total of 12 sightings, comprising 197 individuals.

Interactions with fisheries were recorded in the area involving illuminated handlines for squids, surface longlines, trawling nets, bottom gillnets and drift nets.

Illuminated handlines for squids. Interactions occurred with striped dolphin, Risso's dolphin, long finned pilot whale, and sperm whale. In all cases, opportunistic feeding was completed by small groups of 2-5, or single animals (sperm whale); cetaceans waited near the fishing boats until the gear's light had attracted a great number of squids under the boats, and then they quickly swam to catch their prey; this technique may be repeated several times in one night.

Surface longlines. One interaction was recorded with a sperm whale. We found an abandoned gear in which a decomposed sperm whale was entangled, probably drowned in the course of capturing his prey.

Trawling nets. Interactions were recorded with striped and bottlenosed dolphins, in both cases involving an opportunistic feeding by small groups of 2-5; by making long dives, dolphins fed all around and within the net, especially at the end of the haul.

Bottom gillnets are used in the area only by artisanal fishermen. Around the islands of Ventotene and Ischia, interactions were recorded with bottlenose dolphins: every year, in the months of March, May and September, they were observed preying from the nets. Dolphins made long dives around the net and produced large rips to catch their prey.

Drift nets are used throughout the area especially in June, July, and August. Interactions recorded were with striped dolphin and sperm whale: we found on the high sea, two specimens of striped dolphin without their tails (sometimes fishermen cut the tail to more easily extract the cetacean from the net); a juvenile sperm whale, probably caught, was found dead near Naples with an oblique cut from throat to tail. In 1995, we spent 28 nights from June to August, the boat adrift, between about 55 swordfish boats that were in the area. Our aim was to record the vocalisations of any cetaceans in difficulty. Every night, from Ponza to Capri (about 120 km.), fishermen set two interrupted barrages (exactly along 1,000 m. and 700 m. depth contours): the boats are co-ordinated by radio, and the nets set one after another, leaving a minimal security distance between the boats; drift nets were set at 20:30 hours and retrieved at 03:00 hours. During 243 hours of workable underwater listening, we never heard a click: cetacean biosonar regularly entered our hearing range at 05:30 hours and disappeared at 21:00 hours.

CONCLUSIONS: Five years of observations have enabled us to establish the rich variety of cetacean species around the archipelago Pontino-Campano: seven species were identified in total: one baleen whale, three toothed whales, and three small dolphins. We also verified the existence of resident bottlenose dolphins and a seasonal presence of five photo-identified individuals of long finned pilot whale around Ventotene island.

Our main objective is to make a long-term study in a sample area of the Mediterranean Sea. Long-term study provides a powerful way for developing an understanding of the social lives of long-lived animals such cetaceans, besides which we are interested in improving our knowledge of fisheries interactions so that a conservation programme can be initiated despite all the difficulties involved. Of course in general, several years will be necessary to adequately conduct analyses of such observations.

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REFERENCES

Cagnolaro, L., Di Natale, A., and Notarbartolo Di Sciara, G. 1983. Cetacei. Guida per il riconoscimento delle specie animali delle acque lagunari e costiere italiane, *C.N.R.*, 9: 1-185.

Di Natale, A. 1992 A impact of fisheries on cetaceans in the Mediterranean Sea. P. 18. In: *European Research on Cetaceans -6*. (Editor P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb 1992. European Cetacean Society, Cambridge, UK. 254pp.

Marini, L., Consiglio, C., Angradi, A.M., and Sanna, A. 1993. Cetaceans in the Central Tyrrhenian Sea: third (and last?) year of sightings survey Preliminary results. Pp. 148-149. In: *European Research on Cetaceans - 7*. (Editor P.G.H. Evans). Proc. 7th Ann. Conf. ECS, Inverness, Scotland, 18-21 Feb 1993. European Cetacean Society, Cambridge, UK. 306pp.

Notarbartolo Di Sciara, G. and Demma, M., 1994. *Guida dei mammiferi marini del Mediterraneo*. Franco Muzzio editore, Padova. 262pp.

Podestà, M., Bortolotto, A., Borri, M., and Cagnolaro, L. 1997. Ten years of activity of the Italian Centro Studi Cetacei. Pp. 83-86. In: *European Research on Cetaceans -11*. (Editors P.G.H. Evans, E.C.M. Parsons and S.L. Clark). Proc. 11th Ann. Conf. ECS, Straslund, Germany, 10-12 March 1997. European Cetacean Society, Kiel, Germany. 314pp.

CETACEAN SURVEYS AROUND THE MALTESE ISLANDS & MALTES SEA-USER CETACEAN QUESTIONNAIRE STUDY

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INTRODUCTION: Why carry out cetacean research around the Maltese Islands? 1) Although cetaceans have been studied around Sicily and some areas in the central Mediterranean (Notarbartolo di Sciara *et al.*, 1993), and have been sighted around the Maltese Islands for many years by various individuals or organisations, no scientific cetacean survey has ever focused on the region around these islands before;

2) Combined with the lack of scientific data is an increased threat faced by these cetaceans including pollution, increased ship and vessel traffic, over-fishing by Maltese fishermen and those from neighbouring countries, there is poor local knowledge of these mammals and the inappropriate laws protecting them. In order to promote effective cetacean protection around the Maltese Islands, knowledge of species abundance and seasonality of both resident and transient cetaceans in these waters is necessary;

3) Since little is known of the complete distribution and large-scale movements of most Mediterranean cetacean species, the Maltese Islands are well situated to investigate possible movements between the eastern and western parts of the Mediterranean Sea as well as for studying the status of cetaceans in the central and southern Mediterranean. These first cetacean research surveys aimed at starting to improve the knowledge available on cetaceans in this region of the Mediterreanean Sea.

SURVEY METHODS Rigorous surveys were conducted to obtain information on cetacean population status in the Mediterranean Sea around the Maltese Islands (Hiby and Hammond, 1989). Between June and November 1997, 20 surveys, each averaging c. 148 km (80 nm) were undertaken for a total distance of 2,780 km (or 1,500 nm) (on effort), and a total observation time of 130 hours.

Random line transects were selected around the Maltese islands and were surveyed by boat and by plane. This was required since no previous survey had been undertaken, and sighting records gave very few indications towards any area of cetacean concentration. Vessel speed during observations varied between 6 to 10 knots, with an average of 8 knots (15 km/hr). Aircraft speed was kept at 100 knots (185 km/hr) and at an elevation of 153 m.

In each survey, two trained observers were always present besides the crew members. Both long and short surveys were undertaken, respectively focusing on regions distant and close to the Maltese coast. Special effort was taken not to disturb any cetacean encountered and cetaceans were never approached unless they chose to do so. This often limited species identification. Wind speed conditions during these surveys varied between Beaufort 2 and 4, with an average of Beaufort 3 (5.4 ms^{-1}). Indeed, only three test surveys were undertaken at a wind speed ranging between Beaufort 4 to 5 and these were aerial surveys.

Once a sighting was established, close observation with binoculars (Nikon 12x50 CF) for identification was undertaken, followed by careful observations to count the number and seek differences in size and coloration among the individuals. Photos were also taken (Nikon 75-200mm lens) to allow photo-identification in future surveys. GPS readings were regularly taken during the trips and on sightings, to confirm survey tracks, and to register sighting positions. The results are given in Tables 1-3. To avoid a stop/start after the confirmation of each sighting (Kishino and Kasamatsu 1987; Hiby and

Hammond, 1989; Forcada *et al.*, 1994), the track-line was rejoined by following a convergent course instead of returning to the exact sighting position. This avoided possible repeated sightings of the same schools. Sightings when not on effort were excluded in the analyses.

Sighting frequency for all cetaceans sighted for each survey was calculated, as described by Notarbartolo di Sciara *et.al.* (1993), *i.e.* the sighting frequency was calculated by dividing the number of school sightings made during each bout by the duration (in hrs) of that bout (these sighting frequencies are illustrated in Tables 1 and 2). Another estimate of sighting rate was calculated by considering distance rather than time (results shown in Table 2).

Following Burnham *et al.* (1987), density and abundance estimates are presented for the most commonly sighted species (*Tursiops truncatus*) in an extended research area and period from 1997 to 1998. The estimates shown in Tables 4 to 6 were obtained using the Distance computer software (Laake *et al.* 1998). The analysis was stratified according to platform (boat or plane) type.

SURVEY RESULTS: The results obtained for each survey is given in Tables 1-3. Tables 4-6 include more results obtained during the extended research project between 1997 to 1998, so as to give the first indications of the density and abundance of one of the more commonly encountered species around the coasts of the Maltese Islands, *i.e. Tursiops truncatus*. Results are given according to platform type (sea and aerial surveys) and as overall combined estimates.

DISCUSSION OF FIELD RESULTS These preliminary results indicate that cetaceans are indeed present and relatively abundant in the central region of the Mediterranean. Some species such as the bottlenose dolphins seem to be more abundant throughout the year, followed by common dolphins and striped dolphins. As sample sizes will increase with ongoing surveys, it will be possible to obtain increasingly better estimates of all the cetacean species encountered around the Maltese Islands. Also important are the photo-ID studies currently being undertaken to start distinguishing between transient and resident groups/populations around these islands.

Results also indicate a possible local cetacean association with fisheries of economic importance and seasonality in variation of sighting frequency and abundance. In particular an association has been observed between striped dolphins and tuna during June and July, and between common dolphin and dolphin-fish from August - November. Indeed, in this field study, larger groups of dolphins were seen in cases of association with fishing activities. Also important is the stranding of a striped dolphin calf in June, and of a young common dolphin in October. These seem to corroborate the presence of particular dolphin species in different fishing seasons. Further research will be undertaken in future fishing seasons to build upon these results. From a conservation point of view, the observed associations may be the cause of competition between local fishermen and local cetaceans, and the negative attitude towards cetaceans expressed by some local fishermen. Local awareness and careful monitoring is thus required for the safeguard of cetaceans in this region.

MALTESE SEA-USER QUESTIONNAIRE STUDY One of the main concerns for cetacean conservation is the role played by man. Too often, researchers may find themselves dealing with detailed ecological research with little time to assess the local social basis of some of the important problems facing cetaceans which include increased vessel traffic and interference, and over-exploitation of marine resources. In a highly densely populated island such as Malta, it seemed more important to consider this issue, and try to assess the links between field research results and social attitude by means of a questionnaire. The questionnaire dealt with both cetaceans and marine life in general. Around the Maltese Islands, the fishermen's role in cetacean presence has been considered important, too often at the expense of other factors playing important roles such as the role of fish stock assessment through time.

METHODS IN QUESTIONNAIRE STUDY The cetacean questionnaire was posted or handed to a group of sea-users in Malta, Gozo and Comino consisting of: fishermen, yachtsmen and sailing boat owners, boat divers, occasional marine researchers, and other occasional sea-users such as sea-cruising organisations. From a total of 300 questionnaires distributed, 100 were valid for analyses. Out of the 19 questions presented in the questionnaire to the sample, several questions were included to check for the reliability and validity of the answers given. The distribution of the above categoroes of individuals is illustrated in Fig. 1. What makes this sample a good representation of reality is the long experience (>15years) at sea by many of the individuals that replied, and the balance between the activity types. Although individuals were free to refrain from giving details of their identity when participating, most questionnaires returned with participants' names and addresses.

RESULTS The results obtained with this sample for some of the questions are highlighted in Figs. 1-5. Among the individuals sampled, the fishermen (both full-timers and part-timers) were by far the most frequent sea-users with an overall average of 73 days at sea in summer, 47 days in autumn, 34 days in winter, and 48 days in spring. They also indicated that individuals with the longest period at sea had an average of 23 years experience. These fishermen also proved to be the group within the sample to have experienced the greatest number of sightings of dolphins, whales, sharks, and sea-turtles. This would be expected for three main reasons: (1) the time and experience spent at sea; (2) their relationship with the sea which is closely linked with fish stocks; and (3) their active capture of these fish may often involve capture of other marine organisms as by-catches. This definitely confirms that fishermen can greatly contribute to our local marine knowledge and preservation. Most fishermen showed willingness to contribute toward cetacean research in more than one way.

DISCUSSION OF QUESTIONNAIRE STUDY RESULTS The replies of fishermen to this questionnaire increasingly added weight, as one approached questions relating to local fish stock and local fish catch status, and the requirement of local marine research, education, and conservation. A clear predominance of low fish stock and low fish catch replies from these fishermen went hand in hand with a clear interest and wish for marine research by these same fishermen. These two results are a strong indication that the local marine life is in depletion, and that even fishermen are realising and seeking scientific research as an aid to improving the local marine condition. Many fishermen fear such an impoverishment of the sea that may jeopardise their own profession and that of their children. When asked to prioritise the three activities which should be applied most to marine life including cetaceans, conservation, education and research were all considered important, to the point that almost equal numbers of fishermen opted for each of these activities as a priority.

Most fishermen again showed an awareness for cetacean protection by replying positively to questions which dealt with whether cetaceans should be saved from fishing nets by voluntary groups, and whether cetaceans should be effectively protected. Not all fishermen sampled here consider the sea as only a natural resource available for exploitation, but on the contrary, equal numbers considered the sea as a source of pleasure, as a source of adventure, and as one of the last natural environments left for the Maltese people.

After reviewing the "fishermen" category of individuals sampled here, it is interesting to see how the overall sample consisting of five categories (Fig. 1) replied to some of the most important questions. As expected, most of these individuals go to sea during the summer months with some (mostly fishermen) going to sea in the other seasons when weather permits (Fig. 2). When asked to give indications of their sighting experience and frequency, dolphins were the ones sighted most often, followed by sea turtles, sharks, and whales in decreasing order of sighting frequency (Fig. 3). When asked to specify the mode of sighting, the most frequent reply stated that dolphins were sighted alive usually in the vicinity of the vessel on which the individual was based (Fig. 4).

Dolphins were considered a joy to see in 49% of the cases, and as important to the marine environment in another 36% of the cases, with only 12% (mostly fishermen) considering dolphins a trouble, and 3% as of no interest (Fig. 5). When considering the entire sample, there is again an almost equal division between considering conservation, education, and research as most important for marine life including cetaceans. Most of the replies revealed that the sea is sought because it is a source of pleasure, but also because it is one of the last natural environments for the Maltese people. Less frequent replies included consideration of the sea as a source of economic importance and as a source of adventure. The unexpected low consideration of the sea's economic value is striking but may be understood when considering that only a portion of the sample (the fishermen) really could consider the sea as of direct economic importance. This result conveys the fact that too often the sea is considered for its uneconomical merits which consequently makes it more vulnerable to exploitation without financial aid given for marine conservation research, management, and monitoring.

CONCLUSIONS Both the results of field surveys and questionnaire surveys indicate that various cetacean species occur in the central and southern Mediterranean region. Ongoing research in this region will add more valuable information on relative cetacean species abundance, density and distribution in an area of the Mediterranean which is still lagging in cetacean research. The questionnaire results indicated some current hazards for these species which include decreased resources such as fish stocks and undisturbed space due to increased vessel traffic, fish exploitation, and pollution in this region of the Mediterranean. Cetacean species need to be monitored and protected more effectively by integrating biological research, with those socio-economic parameters found to influence the cetacean environment. This preliminary study has considered some of these integrating factors, and highlights the need for more work in this direction.

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REFERENCES

Forcada, J., Aguilar, A., Hammond, P.S., Pastor, X., and Aguilar, R. 1994. Distribution and numbers of striped dolphins in the western Mediterranean Sea after the 1990 epizootic outbreak. *Marine Mammal Science* 10(2): 137-150.

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating abundance of cetaceans. Pp. 47-80. In: *The Comprehensive Assessment of Whale Stocks: the early years.* Rep. int Whal. Commn, Spec. Issue, 11 (Ed. G.P. Donovan). Interenational Whaling Commission, Cambridge. 210pp.

Kishino, H. and Kasamatsu, F. 1987. Comparison of closing and passing mode. *Rep. int.Whal.Commn*, 37: 253-258.

Notarbartolo di Sciara G., Venturino M. C., Zanardelli M., Bearzi G., Borsani, F.J., and Cavalloni B. 1993. Cetaceans in the central Mediterranean Sea: distribution and sighting frequencies. *Boll. Zool.*, 60:131-138.

Laake, T.L., Derry, J.L., Buckland, J.F., Borchers, S. T., Anderson, D. L., Burnham, D. R., Strindberg, K.P., Hedley, S., Burt, S.L., Marques, M.L., Pollard, F., and Fewster, R.M. 1998. *Distance 3.5, User's Guide.* Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.

Table 1. Results of surveys of cetaceans in Maltese region

Survey	*Line-transects (km)*	*Platform*	*Sightings*	*No. of individuals sighted*	*Sighting frequency*
1	42	boat	0	-	0
2	426	boat	6	1; 3; 1*; 3; 6; 15	16.7
3	46	boat	1	3	33.3
4	145	aircraft	0	-	0
5	74	boat	0	-	0
6	278	aircraft	0	-	0
7	167	aircraft	0	-	0
8	195	boat	1	5	7.7
9	63	boat	1	2	23.5
10	28	boat	1	1*	53.0
11	102	boat	1	6	14.6
12	84	boat	1	4	17.9
13	250	aircraft	3	2; 8; 20	150.0
14	111	aircraft	0	-	0
15	107	boat	0	-	0
16	111	boat	1	12	13.3
17	130	boat	1	2	11.4
18	120	boat	1	20	12.3
19	195	aircraft	0	-	0
20	102	boat	1	10	14.6

(*=whale-like unidentified cetacean)

Table 2. Summary Statistics (from Table 1)

Overall cetacean mean group size per sighting = 6 (S.D. = 5.3)

Mean cetacean sighting frequency per duration of sea bout = 15.59 (S.D.=14.17)

Mean cetacean sighting frequency per duration of aerial bout = 25.00 (S.D.=61.24)

Overall average rate of cetacean sightings around the Maltese Islands per distance surveyed (for the period June to November 1997) = 1 cetacean sighting per 146 kms, or 0.007 cetacean sightings per km.

Average rate of cetacean sightings using a boat = 1 cetacean sighting per 89 kms surveyed, or 0.011 cetacean sighting per km surveyed.

Average rate of cetacean sightings using an aircraft = 1 cetacean sighting per 383 kms surveyed, or 0.003 cetacean sightings per km surveyed.

Species sighted in the preliminary surveys (1997) around the Maltese Islands, in order of sighting frequency:

1. *Tursiops truncatus* (Bottlenose dolphin) 9 encounters school size range: 2-12
2. *Dephinus delphis* (Common dolphin) 3 encounters : 2-20
3. *Stenella coeruleoalba* (Striped dolphin) 3 encounters : 2-15
4. *Grampus griseus* (Risso's dolphin) 1 encounter : 2
5. *Steno bedanensis* (Rough toothed dolphin) 1 encounter : 1
6. Unidentified whales 2 encounters : 1

Table 3. Cetaceans Sighted & Cetacean Associations with Fisheries of Economic Importance

Note: Since this field study period encompassed two important local fishing seasons that are the tuna (*Thunnus thynnus*) fishing season (June-July) and the dolphin fish (*Coryphaena hippurus*) season (August-November), the possible associations between cetaceans observed and presence of fish of economic importance were recorded:

Number of Sightings in period June-July = 7
Out of these, 5 sightings (most commonly sighted species: *Tursiops truncatus* and *Stenella coeruleoalba*) were found in association with tuna presence.

Number of Sightings in period August-November = 12
Out of these, 7 sightings (most commonly sighted species *Delphinus delphis, Tursiops truncatus* and *Stenella coeruleoalba*) were found to be associated with dolphin-fish presence.

Table 4. Distance sea line transect estimates of the parameters used to obtain an estimate of the number of *Tursiops truncatus* (bottlenose dolphins) in the area surveyed by boat around the Maltese Islands

Parameter	Point Estimate	Standard Error	%CV	95% Confid. Interval
f (0)	0.0036	0.0004	12.5	0.0028 - 0.0047
Effective search width (m) {1/ f (0)}	277.9	34.8	12.5	213.8 - 361.1
Encounter rat (schools/km) {n/L}	0.0114	0.0024	12.3	0.0072 - 0.0181
Density of schools (schools/km2)	0.0411	0.0102	24.7	0.0247 - 0.0684
Mean school size	6.1	1.4	23.9	3.6 - 10.2
Density of dolphins (dolphins/km2)	0.2500	0.0860	34.4	0.1264 - 0.4943
Number of dolphins	695	239	34	352 - 1375

Table 5. Distance aerial line transect estimates of the parameters used to obtain an estimate of the number of *Tursiops truncatus* (bottlenose dolphins) in the area surveyed by plane around the Maltese Islands.

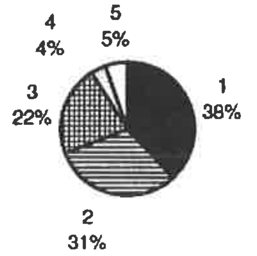
Parameter	**Point Estimate**	**Standard Error**	**%CV**	**95% Confid. Interval**
f (0)	0.0036	0.0004	12.5	0.0028 - 0.0047
Effective search width (m) {1/ f (0)}	277.9	34.8	12.5	213.8 - 361.1
Encounter rate (schools/km) {n/L}	0.0060	0.0017	27.7	0.0028 - 0.0128
Density of schools (schools/km2)	0.0216	0.0066	30.4	0.0104 - 0.0447
Mean school size	8.3	2.3	27.9	4.2- 16.2
Density of dolphins (dolphins/km2)	0.1789	0.0739	41.3	0.0753 - 0.4249
Number of dolphins	811	335	41.3	341 - 1926

Table 6. Combined distance line transect estimates of the parameters used to obtain an overall estimate of the number of *Tursiops truncatus* (bottlenose dolphins) in the area surveyed around the Maltese Islands

Parameter	**Estimate**	**%CV**	**95% Confid. Interval**
Group density (schools/km)	0.0290	21.3	0.0188-0.0449
Dolphin Density (dolphins/km2)	0.2059	28.7	0.1158-0.3662
Number of dolphins	1506	28.7	847-2678

Maltese Sea-Users - Cetacean Questionnaire Study Results

Fig. 1: Types of activities at sea undertaken by individuals in the sample (Maltese Islands)
(1=fishing; 2=sea-trips; 3=diving; 4=research; 5=others)



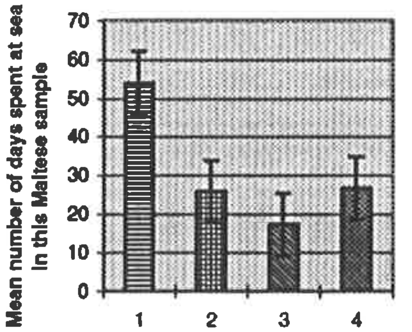


Fig. 2: Mean no. of days spent at sea per season
(1=summer; 2=autumn; 3=winter;

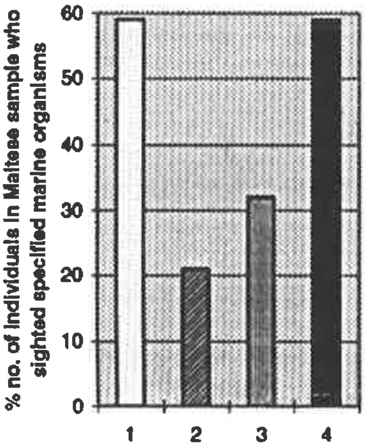


Fig. 3: Dolphin, whale, shark & sea-turtle sightings

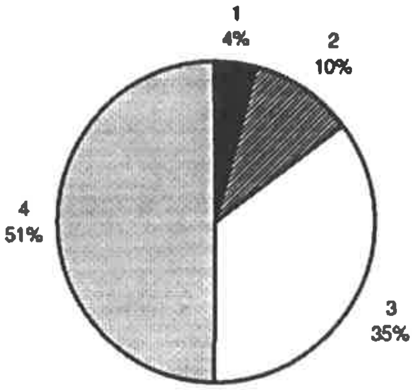


Fig. 4: Dolphin sighting reports by Maltese sample
1=in fishing nets; 2=close to fishing nets;
3=a distance away from the boat;
4=close to the boat

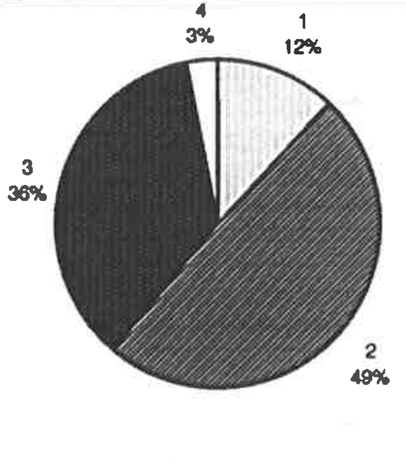


Fig. 5: Attitudes toward dolphins (Maltese sea-user sample)
1=dolphins are troublesome; 2=dolphins are a joy to see; 3=dolphins are important; 4=no interest in dolphins

STRUCTURE AND BEHAVIOUR OF A BLAINVILLE'S BEAKED WHALE (*MESOPLODON DENSIROSTRIS*) GROUP IN TENERIFE (CANARY ISLANDS)

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Between January 1995 and December 1996 we registered 38 sightings of the Blainville's beaked whale (*Mesoplodon densirostris*) in the south-western waters of Tenerife (Canary Islands). The study area is placed between "Caleta de Adeje" (28°06'N and 16°45'W) and "Punta de Teno" (28°20'N and 16°55'W), an area of about 180 square kilometres. These observations were a casual byproduct of an intensive monitoring programme of the residents bottlenose dolphins (*Tursiops truncatus*) and pilot whales (*Globicephala macrorhynchus*). We were studying the peculiar pigmentation patterns, behaviour and group structure of these species. The whales have a general yellowish ochre pigmentation partially correlated with sex and size. We also defined the breathing patterns and the cetaceans' reaction to the approaching whale-watching boats. Finally we defined the group structure based upon the existence of four different types combining number of whales, body size and sex.

MARINE MAMMALS OBSERVED AT THE ISLE OF MAYOTTE

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Situated in northern Mozambique Channel, Mayotte is the oldest comorian Archipelago's island, surrounded by one of the largest lagoons in the world, about 1.500 km2. Streams and depth (2.000 m at 10 nautics apart the reef) give an extraordinary faunistic exuberance. We think that about 38% of world marine Cetaceans may be observed in the surrounding seas of Mayotte. Since December 1994, 15 species have been observed, a doubt remaining about two or three species. Our investigation methods are direct observation from boat, and recently, photo-identification. Stranding is unknown, except once for sperm whale. *Tursiops truncatus* (resident in lagoon, and pelagic groups outside). *Stenella longirostris* (the most common : 4 or 5 groups about 200 to 300). *Stenella attenuata* (almost common as the precedent). *Lagenodelphis hosei* (first : January 1995 - P. Darmangeat). *Peponocephala electra (??)* (first : October 1996 - P. Darmangeat, R. Seitre). *Feresa attenuata.*(??) (first : April 1997 - M. VÈly, P. Darmangeat). N. b. : These two species are perhaps confounded, but surely, both have been observed. *Sousa chinensis* (first : December 1994 - P. Darmangeat). *Orcinus orca* (first : march 1995 - M. Genoulhac). *Grampus griseus. Pseudorca crassidens. Kogia sp. (simus ?)* (September 1995 - R. Setter). *Physeter catodon* (first : a 10 meters specimen stranded on November 1995 - J.-M. Maggiorani). *Megaptera novaeangliae* (a few regular population, from July to November ; about 6 to 8 females breeding inside the lagoon). *Balaenoptera acutorostrata* (first : November 1996 - filmed by J.-M. Maggiorani, and identified by Michel VÈly and Vic Cockcroft, April 1997). *Mesoplodon sp.* (first : September 1995 - R. Seitre - P. Darmangeat). These species may be *M. mirus, M. ginkgodens, or M. pacificus. Dugong dugon.* (first living animals : December 1996 - P. Darmangeat) Uncommon and probably in extinction.

CETACEAN MOVEMENTS THROUGH THE STRAIT OF GIBRALTAR

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Although it has been documented that the Strait of Gibraltar is an area with a relatively high density of at least four species - common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), bottlenose dolphin (*Tursiops truncatus*), and long-finned pilot whale (*Globicephala melas*), it is unknown whether this reflects favourable oceanographic conditions and/or movements between the Atlantic and the Mediterranean Sea. Movements through the Strait may relate to stochastic irregular exchange or regular migration. Both might give opportunity for a monitoring of Mediterranean cetacean stocks if large populations are involved, but regular migration would offer more appropriate conditions.

Cetaceans have been recorded in a standardised manner during a series of five transects (four in autumn, one in spring) carried out between 1986 and 1993. A total of 46,367 individuals (comprising all species) has been counted overall during 563 runs (625 hr of observation, 16,500 km trackline) across the Strait.

Studying cetacean movements through the Strait poses four main methodical problems:

(1) the high density often does not allow to distinguish between different schools;
(2) The two most abundant species are difficult to seperate in the field;
(3) Resident and migratory/nomadic populations might coexist;
(4) To estimate the scale of the movements, cetaceans must be recorded not only under favourable conditions but also in all sea-states.

By tackling these problems, it was possible to get a rough idea of the numbers migrating through the Strait, and their seasonal distributions within the periods covered by the transect series. There is some evidence of an autumn migration out of the Mediterranean for common dolphin, bottlenose dolphin, and long-finned pilot-whale. Comparing different transect series, there appears to be considerable variation in the timing and/or the magnitude of the movements. The movements of striped dolphin (the most oceanic species) are probably more stochastic than migratory. The seasonal course of migration may depend on habitat specialisations. In the Mediterranean Sea, there are marked differences in the seasonal patterns of primary productivity between neritic and oceanic waters.

THE STATUS OF THE GREY SEAL IN IRELAND: CULLS, CELTS AND CONSERVATION

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It has been widely suggested that Ireland's grey seal population has increased since it was last surveyed in 1980-1983. To test this hypothesis, we set out to investigate the year-round status of the grey seal population at the main breeding colonies of the Blasket Islands and Inishkea group in 1995 and 1996. Pup census data were used to estimate the total population sizes associated with these colonies. Ground counts were conducted through the subsequent moult and summer seasons for comparison with population estimates. Photo-identification was used to investigate site utilisation by individual females and to assess the feasibility of conducting population estimates. Photo-identification was used to investigate site utilisation by individual females, and to assess the feasibility of conducting population assessments in Ireland using this method.

Minimum population estimates of 546 and 530 were derived for the Blasket Islands and Inishkea group from pup census data. While total pup production figures suggested little change since 1983, changes in pupping site selection were observed at the Inishkea group. This may have resulted from sporadic change culls and other human disturbance between 1978-1983. Research during the moult also produced some interesting findings. Females began moulting during the closing stages of the breeding season. Maximum counts of 103 and 225 were present at the Blasket Islands and Inishkea Group respectively during this period, with up to 92% of females on the Blasket Islands, and 60% on the Inishkea group gathered at a single moult site.

Preferential selection of moult sites was also observed during the male moult and favoured sites were different to those chosen by females. Furthermore, there were commonly 1,000-1,500 male grey seal at the Inishkea group during the 1995 and 1996 moult periods. It is thought that this is an annual immigration event in this area. After the moult both colonies saw a rapid decline to relatively stable summer populations.

Photo-identification demonstrated a degree of female fidelity to pupping sites at both breeding colonies. At the Inishkea group, identified females were also observed at the same moult sites in 1995 and 1996. These studies, while relatively focused, highlight the importance of monitoring certain sites outside the breeding season for the evaluation of population dynamics, whether for management or conservation purposes.

CETACEANS SIGHTED IN THE CANARY ISLANDS DURING THE CAREMEX EXPEDITION (JANUARY-APRIL 1997)

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The Canary Islands are situated about 100 km off the north-west coast of Africa and constitute an interesting area to study pelagic populations of cetaceans, but the knowledge about the distribution of these species in the area is fragmentary due to the absence of observers. A census of cetaceans took place in this waters from January to April 1997 in the course of the expedition "CAREMEX", carried on by Aldebaran (Marine Research and Broadcast), in association with the Society for the Study of the cetaceans in the Canary Archipelago. The main objective of this study was to determine the occurrence and distribution of the cetaceans in this area. A total of 38 days of effort were completed, comprising a total of 627.3 nautical miles in good sighting conditions.

Most effort was restricted to the waters off the south-west coasts of Tenerife and La Gomera islands, well known areas where commercial whale watching take place. We obtained 85 sightings, and seven species of cetaceans were positively identified. The species sighted, in decreasing order, were the following: short-finned pilot whale (*G. macrorhynchus*) (n=26, 22.1%), bottlenose dolphin (*T. truncatus*) (n=18, 15.3%), Atlantic spotted dolphin (*S. frontalis*) (n=12, 10.2%), common dolphin (*D. delphis*) (n=6,5.1%), Risso's dolphin (*G. griseus*) (n=5, 4.2%), Rough-toothed dolphin (*S. bredanensis)* (n=3, 2.5%), Blainville's beaked whale (*M. densirostris*) (n=2, 1.7%), and unidentified beaked whales (n=11, 9.3%). Bottlenose dolphins and Risso's dolphin were found in closed association with the coast.

OBSERVATIONS ON CETACEANS IN NORTH-EASTERN SULAWESI, INDONESIA

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Between 6th July and 31st August 1995, a field study was conducted in the waters adjacent to the city of Manado, north-eastern Sulawesi, Indonesia. The goal was to study the abundance and distribution of cetaceans in these waters. Manado is situated on the north-eastern tip of Sulawesi at 1°29'N 124°50'E and faces the Sulawesi Sea (= Celebes Sea). Vessel surveys were conducted on ten days between 8th and 30th July 1995 in the waters of Manado Bay, the southern part of Bunaken Menado Tua Marine National Park and Lembeh Strait, Bitung. A total of 45 hr 17 min. was spent at sea, covering some 230 nm (430 km) of survey track, with an average of 4 hrs 31 min. per survey day. Nine cetacean species were recorded in 25 sightings on ten days of vessel surveys. The sighting of 7(*) species is confirmed by photographs and identification by cetacean specialists. Cetaceans observed included: rough-toothed dolphin, *Steno bredanensis* (1* sighting); bottlenose dolphin, *Tursiops* sp. (1); pantropical spotted dolphin, *Stenella attenuata* (1); spinner dolphin, *Stenella longirostris* (4*); Fraserís dolphin, *Lagenodelphis hosei* (1*); melon-headed whale, *Peponocephala electra* (1*); killer whale, *Orcinus orca* (1*); short-finned pilot whale, *Globicephala macrorhynchus* (2*); sperm whale, *Physeter macrocephalus* (9*); dwarf sperm whale, *Kogia simus* (3*); and *Kogia* sp. (1).

NEW CETACEAN OBSERVATIONS FOR THE AZORES

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During whale hunting times, cetacean observations in the Azores concerned exclusively the sperm whale species, and records were mostly found during the summer months. More recently, with the implementation of whale watching activities in the Azores. cetacean observations were initiated for a larger number of species, covering a longer period of time through the year.

In the last few years, a total of 25 species of whales and dolphins have been reported for the Azores. In this work, observations were made from land and from sea (around the Faial and Pico islands). Land-based and sea-based observations were made using a 15x80 binoculars and aboard a R.I.B, respectively.

A new species of balaenopterid was reported for the Azores, and another one confirmed. A Bryde's whale, (*Balaenoptera edeni*),was observed, for the first time, on the 9th July 1996 about 8.5 miles north of Faial. The animal was encountered feeding together with a group of 10-15 common dolphins. The water temperature was 24.5°C.

A blue whale, (*Balaenoptera musculus*), was photographed for the first time in the Azores, on the 4th Feb 1997, in the company of a smaller individual of the same species. They were probably feeding, and their swim speed was 6.5-7.0 knots. The water temperature was 16°C. Until now, five individuals of this species have been identified in the Azores. These observations were made only for a period of about two years.

The results obtained are not sufficient to draw conclusions regarding the periodicity of these occurrences. However, it was possible to register a new species to the region (*Balaenoptera edeni*), and to confirm the occurrence of another one (*Balaenoptera musculus*). Future studies, with more continuous observations, will provide further insight into the regularity of these sightings

MARINE MAMMALS OF THE AZORES

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This paper presents information on live sightings of cetaceans observed in the Azores over the last 10 years. "Song of the Whale", the International Fund for Animal Welfare's research yacht, has been studying the cetaceans in Azorean waters since 1987, typically operating between May and September, and making extended cruises of up to 8 days principally to find sperm whales.

In 1993, Whale Watch Azores began operations and has continued this research. The whale watching vessel however, would normally remain at sea for only one day at a time. Over this time, the two teams have logged almost 1,350 encounters with cetaceans other than sperm whales. Sightings of sperm whales which were typically the focus of these research cruises, are not noted here.

The most frequently sighted species (number of encounters in brackets) have been: spotted dolphin (417), common dolphin (297), bottlenose dolphin (231), Risso's dolphin (106), short-finned pilot whales (118) and striped dolphin (105). Less frequently observed species include: blue (2), fin (5), sei (7), and minke whales (1), humpback (1 whale over 2 weeks), killer whales (7), false killer whales (2), pygmy sperm whales (1) and rough-toothed dolphins (2). Beaked whales have also been seen on 35 occasions, including: True's, Sowerby's and Cuvier's. Bottlenose whales have also been infrequently observed (12).

Spotted dolphins seem to be summer visitors and have only been seen from July to the end of September. Most of the baleen whale sightings have been restricted to May and June. The exceptions are a single humpback observed feeding on small mackerel in August 1996, and a sei whale observed in August 1995. Bottlenose whales have only been sighted in July and August. Beaked whales have been most frequently seen in July and August also, but have been observed in all months (May-Sept.). Only the spotted dolphin and bottlenose whales show significant seasonal variation. Improved sighting effort through the winter, October-May, would provide better insights into the seasonal changes in abundance in this area.

ECOLOGY

CETACEANS IN NORTHEAST ATLANTIC WATERS: USING DIVERSE SIGHTINGS SOURCES TO MONITOR DISTRIBUTION AND RELATIVE ABUNDANCE

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INTRODUCTION Knowledge of cetaceans in northwest European waters (47°N - 62°N latitude, 8°E - 12°W longitude) is incomplete. Although there have been a variety of cetacean studies, there has been little co-ordination of research efforts within and between countries. This poster reports on work within the UK to merge a diverse array of cetacean distribution data sources. Merging of these data sources has provided an opportunity for a better understanding of cetacean distribution (geographical and seasonal) and relative abundance in the region.

There are two main sources of data. The Sea Watch Foundation (SWF), a conservation charity formed out of the Cetacean Group of the UK Mammal Society, has been collecting cetacean sightings since the early 1970's. Many sightings are reported by dedicated amateurs from land- and vessel-based observations, but SWF also runs its own surveys aboard dedicated vessels in various regions of UK, particularly in the Irish Sea and the Hebrides. The Joint Nature Conservation Committee (JNCC) operates the Seabirds and Cetaceans Team (originally the Seabirds At Sea team: SAST), which collects cetacean sightings from platforms of opportunity such as fisheries research and protection vessels, and most recently seismic vessels, as well as from its own surveys.

The main emphasis is on collecting effort-related data which allows estimates of relative abundance to be compared over variables of time and location. There are no attempts to calculate absolute abundances.

METHODS Combining diverse databases requires the use of a standardisation procedure and the application of corrections for factors affecting detectability, such as sea state and platform type. Distribution patterns were compared with a suite of environmental parameters (*e.g.* depth, temperature, salinity, distance from land) to identify species specific habitat preferences.

The normalisation of sightings data as a function of effort allows relative abundances to be calculated. However, there are differences in the way the various data sources present effort data. The map of Sea Watch effort (Fig. 1) shows overall area of effort-related coverage. The intensity of coverage varies with a greater degree of effort occurring in the Western Isles of Scotland and in the eastern Irish Sea, primarily due to Sea Watch's annual program of transect surveys in those regions. The JNCC effort data (Fig. 2) is primarily from vessel surveys and is represented in kilometres of survey tracklines. These are summed over a grid of 15 min. latitude and 30 min. longitude. This is similar to the way in which vessel-based effort is recorded for SWF. However, SWF also collects data from land-based sites. This effort is recorded as a function of the time spent watching (*e.g.* per hour or per 100 minutes). Approximately 40% of all Sea Watch sightings are land-based. The merging of this effort with that of JNCC will result in a more thorough coverage of the entire region.

RESULTS AND DISCUSSION Sea Watch received 40,466 sightings. Effort-related sightings comprised 62% of all sightings. The complete analyses of effort-related data are still underway, so some plots show sightings combining both effort-related and opportunistic sightings, to give a broad overview of each species' distribution.

Twenty-one species of cetaceans were recorded, with ten classified as common residents, three as seasonal visitors, and eight as rare visitors (Table 1).

The minke whale (*Balaenoptera acutorostrata*),was primarily found in protected waters of the Western Isles off west Scotland (Fig. 3), but were also reported though lerss frequently in the northern North Sea. Fig. 4 plots 1,611 sightings. Most sightings were received between May and October. In some areas of the Western Isles, minke whales can be regularly found on a daily basis, suggesting some degree of site fidelity.

Common dolphins (*Delphinus delphis*), were primarily found in offshore waters off south-west England in the approaches to the English Channel, off West Wales in the southern Irish Sea, and off west Scotland north to the Isle of Skye. Fig. 5 plots 1,597 sightings from all months; however, this species was most common during June to September. Their distribution was almost a mirror image of that of the white-beaked dolphin (below), with an area of overlap in the Minches off west Scotland

Atlantic white-sided dolphins (*Lagenorhynchus acutus*),are primarily an offshore species which only rarely comes into protected waters, especially when compared to the more nearshore habits of its close relative, the white-beaked dolphin. Only 210 sightings were received, mostly between July and September (Fig. 6). It was mostly seen north of 54° latitude. This is in contrast to the striped dolphin, which is also an offshore species, but only occurs off south-west Britain.

White-beaked dolphins (*Lagenorhynchus albirostris*), are primarily found in northern waters, especially in the North Sea and in the Minches west of Scotland. SWF received 1,403 sightings, primarily from vessels (Fig. 7). The effort-related plot of white-beaked dolphin sightings by JNCC (Fig. 2) shows a similar distribution. Sightings were received during all months, but mainly in May - October with a peak in August.

Harbour porpoise (*Phocoena phocoena*), is the most common species in the NE Atlantic. There were 20,787 sightings reported to SWF, representing 51% of all sightings received (Fig. 8). They were most abundant in the Western Isles and Shetland Islands, with rather few sightings off southern Britain. Sightings were received in all months of the year, but with marked peaks in late summer and autumn. The more detailed information will be used to identify critical habitat areas for harbour porpoise in UK waters.

CONCLUSIONS The merging of these data sets is still underway. The inclusion of data from line transect surveys of Small Cetacean Abundance in the North Sea (SCANS) will further expand the intensity of coverage. The diversity of data collection methods in these data sets will require careful consideration to reduce potential biases. Further analyses will also focus on the habitat preferences (or requirements) of the various species to understand the region's biodiversity.

The goal is to produce an "Atlas of Cetacean Distribution" which will help to identify important cetacean habitats. This will provide a major contribution to the process of designating special areas for conservation in the marine environment of the UK and hopefully other parts of the north-east Atlantic.

ACKNOWLEDGEMENTS This work could not have been completed without the help of the hundreds of people who have submitted observations. SWF data analysis was aided by funds from JNCC for Caroline Weir to input a large quantity of data onto computer, and a great many volunteers particularly Hajnalka Elekes, Alex Gaut, Ian Grant, Stephan Harding, Rachel Harding-Hill, Michael Morris, Rodrigo Perez, Joe Platt, Martin Rosen, and Glen Tyler. Special thanks go to Steve Hartley of West Wales Charter and Christopher Swann of Western Isles Sailing for sponsoring the SWF survey cruises for so many years.

Table 1 Cetacean species list (in order of sighting frequency)

RESIDENT	
Harbour porpoise	*Phocoena phocoena*
Minke whale	*Balaenoptera acutorostrata*
Common dolphin	*Delphinus delphis*
White-beaked dolphin	*Lagenorhynchus albirostris*
Atlantic white-sided dolphin	*Lagenorhynchus acutus*
Bottlenose dolphin	*Tursiops truncatus*
Risso's dolphin	*Grampus griseus*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
Fin whale	*Balaenoptera physalus*
SEASONAL	
Sperm whale	*Physeter macrocephalus*
Humpback whale	*Megaptera novaeangliae*
Northern bottlenose whale	*Hyperoodon ampullatus*
RARE	
Striped dolphin	*Stenella coeruleoalba*
Cuvier's beaked whale	*Ziphius cavirostris*
Beluga	*Delphinapterus leucas*
False killer whale	*Pseudorca crassidens*
Sowerby's beaked whale	*Mesoplodon bidens*
Sei whale	*Balaenoptera edeni*
Blue whale	*Balaenoptera musculus*
Northern right whale	*Eubalaena glacialis*

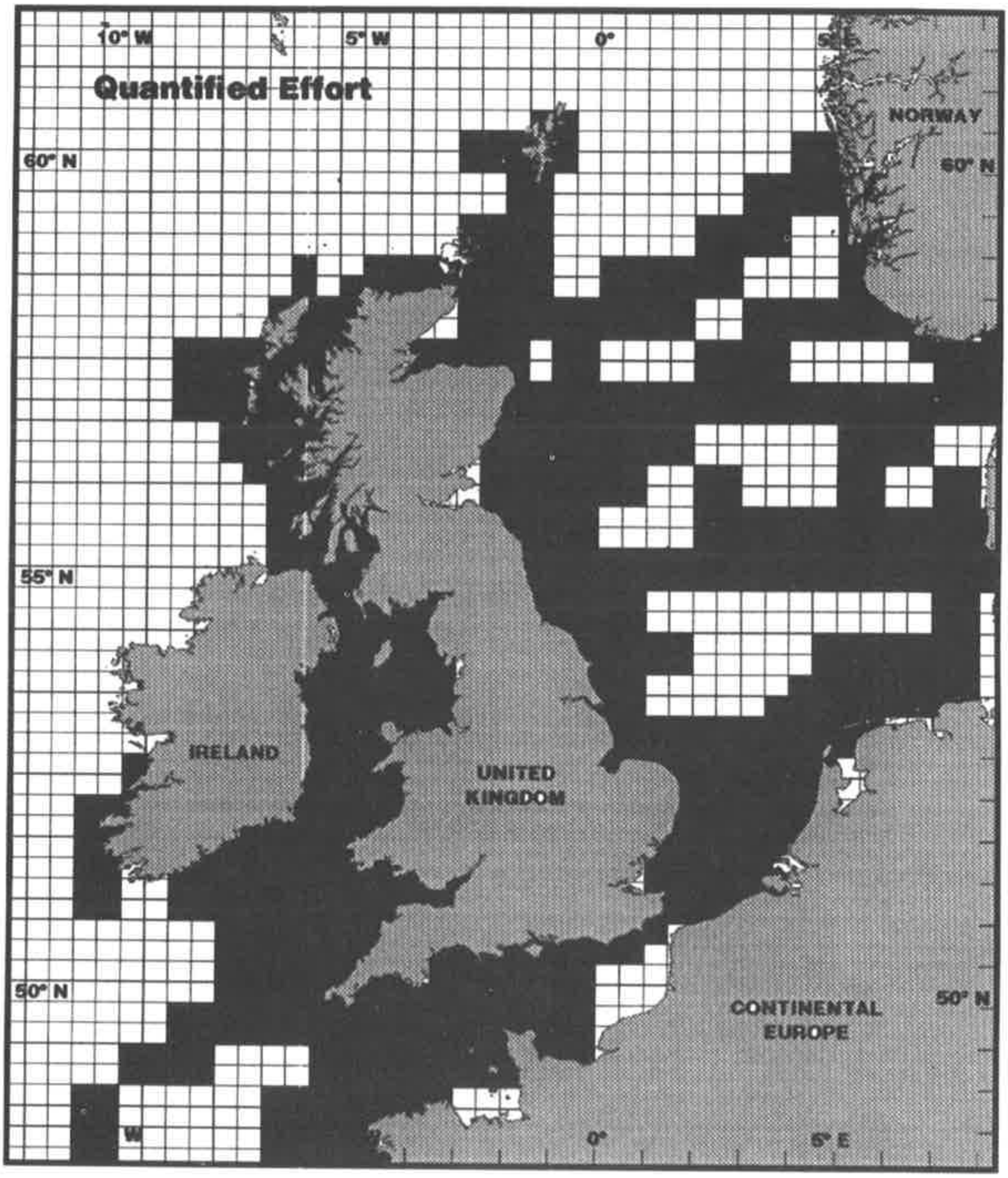

Fig 1. Coverage of Sea Watch effort

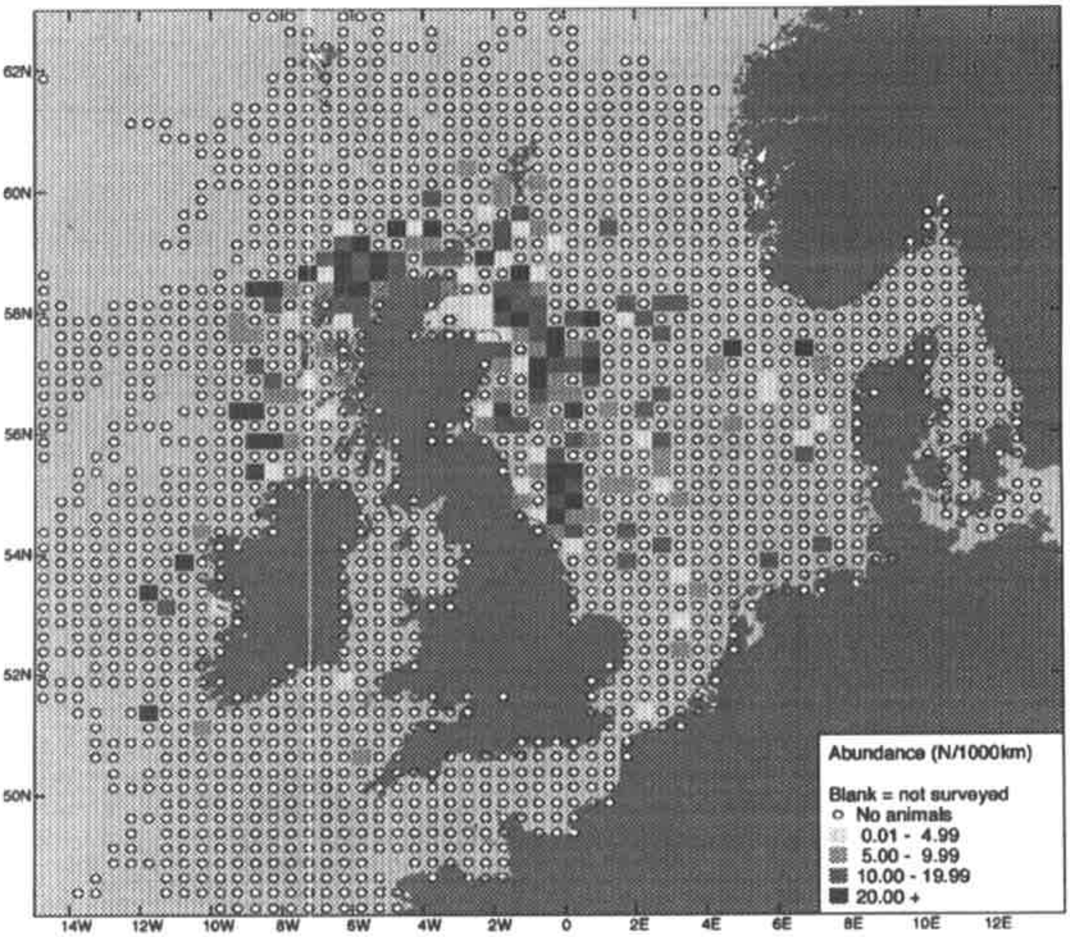

Fig. 2 JNCC Effort Database plot of white-beaked dolphin distribution

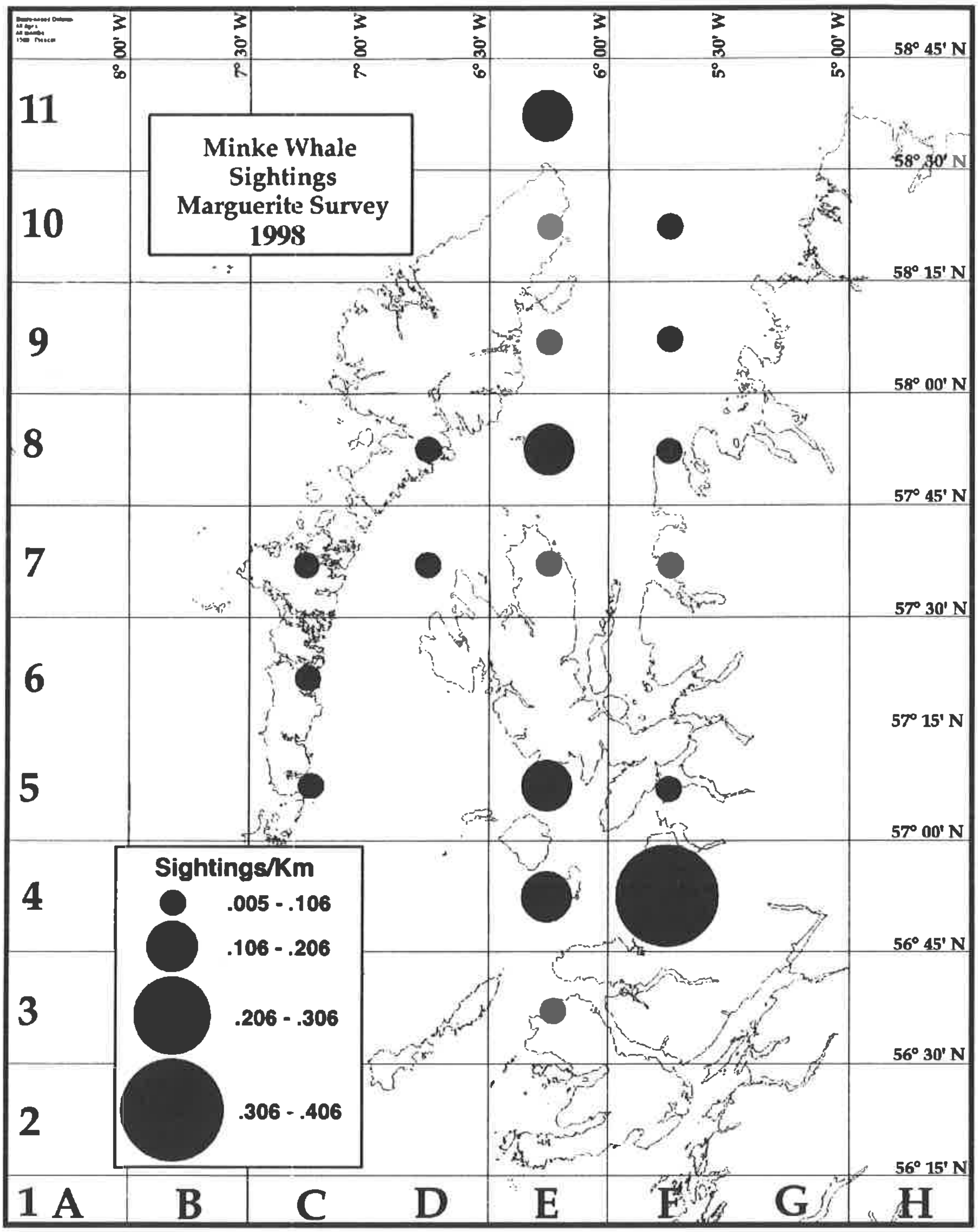

Fig. 3 Sea Watch effort-based plot of minke whales in the Hebrides, NW Scotland

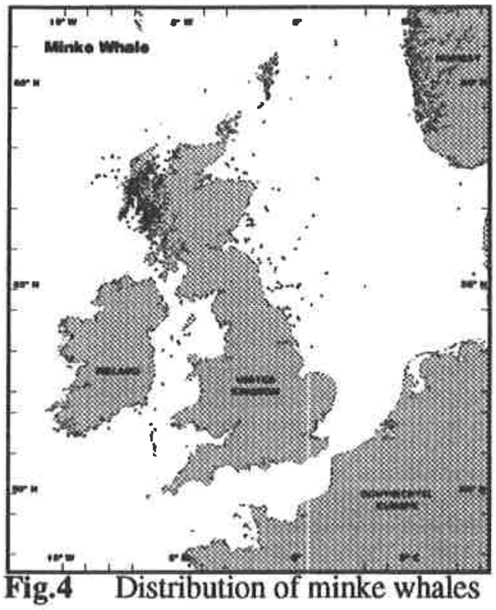

Fig.4 Distribution of minke whales

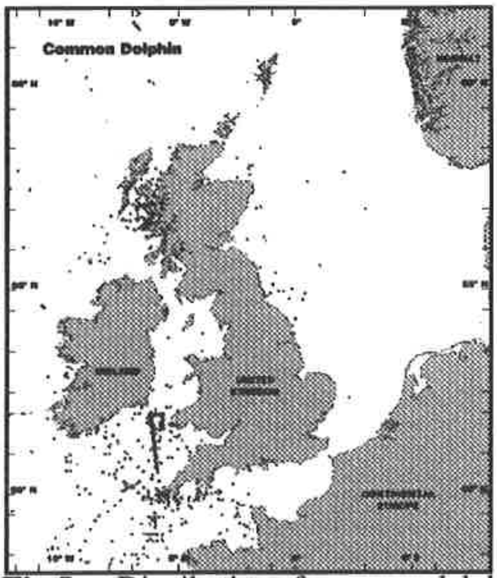

Fig.5 Distribution of common dolphin

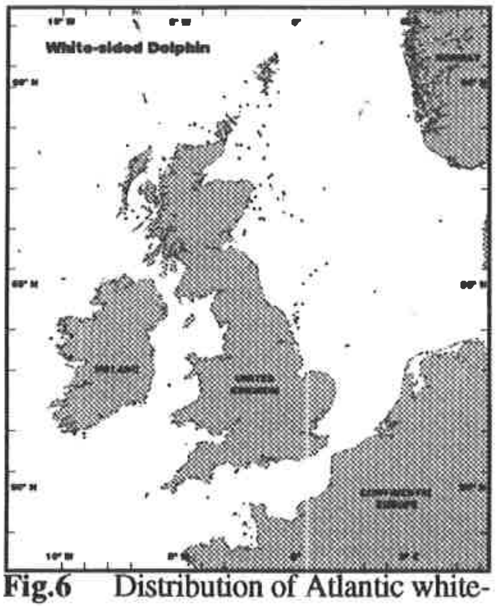

Fig.6 Distribution of Atlantic white-sided dolphin

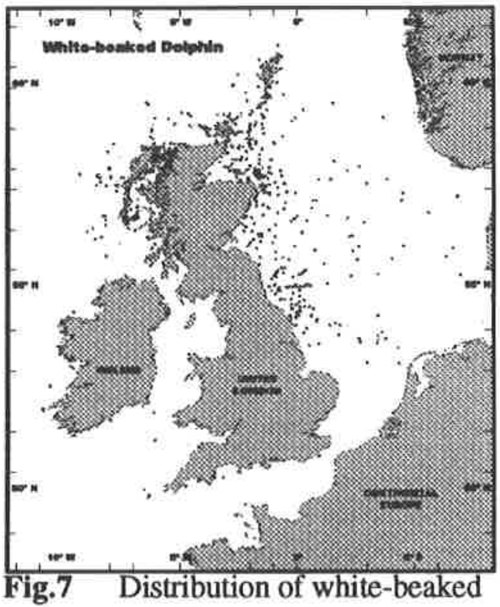

Fig.7 Distribution of white-beaked dolphin

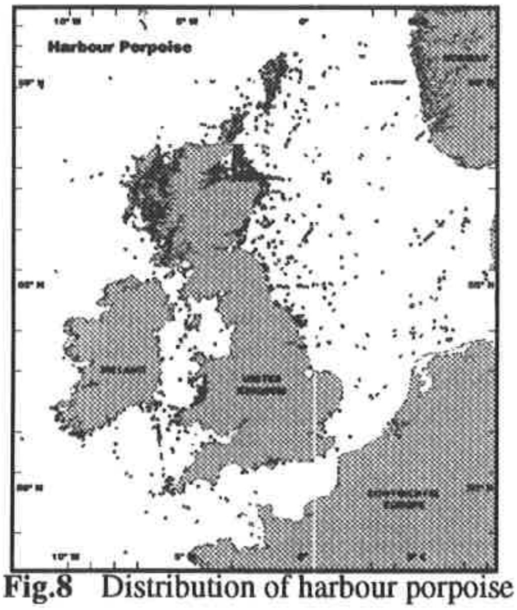

Fig.8 Distribution of harbour porpoise

FIRST REPORT OF A SHARKSUCKER (*ECHENEIS NAUCRATES*) ON A BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*), AND A RE-EVALUATION OF REMORA-CETACEAN ASSOCIATIONS

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The Family Echeneidae (= Echeneididae) (remoras) contains eight species, with all but one of these being worldwide in their distribution (Lachner, in Whitehead, 1986). Echeneid fishes attach to elasmobranchs, bony fishes, sea turtles, cetaceans, sirenians, ships, and other floating objects by means of a laminated adhesive disc on the dorsal surface of their head. Suspected benefits of echeneid fishes' association with these hosts include transportation, protection from predators, increased courtship/reproduction potential, enhanced gill ventilation, and expanded feeding opportunities (Strasburg, 1957, 1959, 1964; Cressy and Lachner, 1970; Alling, 1985).

A 259-cm male bottlenose dolphin (*Tursiops truncatus*) with three attached echeneids live-stranded in Galveston, Texas (29°16.4', 94°49.1') on 29th October 1995. Efforts to rescue the dolphin for subsequent rehabilitation dislodged all but one echeneid. This 119mm (standard length) specimen was collected and identified (Lachner in Whitehead, 1986) as a sharksucker (*Echeneis naucrates*) on the basis of the following characteristics: elongate body, its depth 7.8% of standard length; 23 disc lamellae; disc length 26.1% of standard length; 31 dorsal and 32 anal rays; caudal fin lanceolate with middle rays produced; white border on dorsal, anal and caudal fins; pectoral fin pointed; dark longitudinal band on anterior trunk; and lower jaw with fleshy flap.

Unlike the aforementioned dolphin stranding, whereby the sharksucker was retained and physically examined, most echeneid-cetacean associations described in the literature are based on visual or photographic observations of a remote, free-swimming host and its passenger(s) (Table 1). Several echeneids, such as *Remora brachyptera*, *Remora osteochir*, *Remorina albescens*, and *Remora australis*, are rather host-specific (Cressey and Lachner, 1970). These species are typically offshore, pelagic forms with a specialized morphology consisting of large discs, short stout bodies, and reduced fin size (when compared to inshore counterparts). More commonly reported echeneids are slender-bodied, inshore forms such as *Echeneis naucrates* which are least particular about their hosts.

Remora (= *Remilegia*) *australis* is an echeneid frequently collected from cetaceans, hence its common name "whalesucker" (e.g., Follet and Dempster, 1960; Rice and Caldwell, 1961). The whalesucker's preference for cetaceans may lead observers to assume that any remora spotted on a cetacean is this species. It is probable that other echeneids also associate with cetaceans. However, the difficulty in using remote observations/ photographs for species identification (most can only be identified as a specimen in hand) may limit documentation of other echeneid-cetacean associations."Remote" identifications mandate caution when classifying remoras found on cetaceans as the whalesucker.

The possibility that small, slender remoras as well as more stocky echeneids photographed on cetaceans may represent different life history stages of one species further complicates positive identification. The sharksucker-dolphin association described herein, as well as a photo-documented field observation of a mature sharksucker on a spinner dolphin(*Stenella longirostris*) in Brazil (L. Lodi, Projeto Golfinhos, *pers.*

comm.), suggests that at least two echeneid species utilise cetaceans as a host. The sharksucker has been reported (Cressey and Lachner, 1970) to 'loosely' associate with a wide variety of hosts (cetaceans not included). This account represents a new host record for the sharksucker.

REFERENCES

Alling, A. 1985. Remoras and blue whales: a commensal or mutual interaction? *Whalewatcher* (Journal of the Amer. Cet. Soc.), 19(1): 161-19.

Cressey, R.F. and Lachner, E.A. 1970. The parasitic copepod diet and life history of diskfishes (Echeneidae). *Copeia*, (1970): 310-318.

Follett, W.I. and Dempster, L.J. 1960. First records of the echeneidid fish *Remilegia australis* (Bennett) from California, with meristic data. *Proceed. CA Acad. Sci.*, 31: 169-184.

Radford, K.W. and Klawe, W.L. 1965. Biological observations on the whalesucker, *Remilegia australis* Echeneiformes: Echenediae. *Trans. San Diego Soc. Nat. Hist.*, 14: 65-72.

Rice, D.W. and Caldwell, D.K. 1961. Observations on the habits of the whalesucker *Remilegia australis*). *Norsk Hvalf-tid.*, 5: 181-189.

Strasburg, D.W. 1957. Notes on the respiration of small *Remora remora*. *Copeia*, (1957): 58-60.

Strasburg, D.W. 1959. Notes on the diet and correlating structures of some central Pacific echeneid fishes. *Copeia*, (1959): 244-248.

Strasburg, D.W. 1964. Further notes on the identification and biology of echeneid fishes. *Pacific Sci.*, 18: 51-57.

Whitehead, P.J.P. 1986. *Fishes of the north-eastern Atlantic and the Mediterranean*. Vol. 3. Food and Agriculture Organisation of the United Nations, Rome. [CD ROM].

TABLE 1. CETACEAN/ECHENEID ASSOCIATIONS

Cetacean/Location

***Eubalaena* sp**

?

Northern right whale (*Eubalaena glacialis*)

Maine
Long Island, New York

Bryde's whale (*Balaenoptera edeni*)

California
Sri Lanka
Gulf of California
New Zealand

Sei whale (*Balaenoptera borealis*)

central California

Blue whale (*Balaenoptera musculus*)

Vancouver Island
California
Gulf of California
Galapagos
Eastern Tropical Pacific (near Costa Rica dome)
Peru
northern/central Chile
Sri Lanka
Lembata Island, Indonesia

Fin whale (*Balaenoptera physalus*)

central California
Gulf of California
Long Island, NY

Bryde's whale (*Balaenoptera edeni*)

California
Gulf of California
Sri Lanka
New Zealand

Minke whale (*Balaenoptera acutorostrata*)

Unknown

Humpback whale (*Megaptera novaeangliae*)

Central California
Hawaii
Long Island, NY
Tonga
New Caledonia
Australia

Sperm whale (*Physeter macrocephalus*)

North Pacific
Gulf of Mexico
Galapagos
Peru
Sri Lanka
Durban, South Africa

Killer whale (*Orcinus orca*)

South Africa
Central North Pacific
Indonesia

Pilot whale sp.

Galapagos

Short-finned Pilot whale (*Globicephala macrorhyncus*)

Catalina Channel, Calif.

Rough-toothed dolphin (*Steno bredanensis*)

Hawaii

Pacific White-sided dolphin (*Lagenorhynchus obliquidens*)

California

Long-beaked common dolphin (*Delphinus capensis*)

Gulf of California

Common dolphin (*Delphinus delphis*)

Costa Rica
Galapagos
Sénégal (w.Africa)
south/east Africa
South Africa

Pantropical spotted dolphin (*Stenella attenuata*)

Eastern Tropical Pacific
Hawaii
Gulf of Mexico
Coiba Island, Panama

Bottlenose dolphin (*Tursiops truncatus*)

Texas
Eastern Tropical Pacific
Socorro, Mexico
Costa Rica
Puerto Rico
Izu Islands, southern Japan
Gulf of Mexico
Hawaii
Campeche Sound, Mexico
Coiba Island, Panama
Dominican Republic
Gulf Coast, Keys, and Atlantic Coast of Florida
Gulf of California
Belize
Galapagos
south/eastAfrica

Atlantic spotted dolphin (*Stenella frontalis*)

North Carolina
Gulf of Mexico
Bahamas
Belize
Mid-tropical Atlantic

Spinner dolphin (*Stenella longirostris*)

Venezuela
Hawaii
Gulf of Mexico
Brazil
Indonesia

Unidentified dolphin

Jamaica*
Southwest of Cape Verdes Islands

Unidentified whale

Peru

THE ACCURACY OF SATELLITE POSITIONING IN MARINE MAMMALS: AN EXPERIMENT WITH CAPTIVE GREY SEALS

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INTRODUCTION The Argos positioning and data collecting system is widely used in marine mammals studies for the investigation of long distance movements and activities at sea (e.g. McConnell *et al.*, 1992; Martin *et al.*, 1993). Because marine mammals spend most of their time underwater, the number of signals received and, therefore, the quality of the positioning are lower than in terrestrial or aerial applications. Consequently, the accuracy of location fixes is of greater concern in marine studies. Few experimental measurements, however, have so far been undertaken to assess this accuracy (Stewart *et al.*, 1989).

The aim of this study was to assess the difference between estimated and real positions of seals fitted with satellite tags and temporarily held in captivity. Additionally, possible relationships between signal quality and the activity of the seals were also investigated.

MATERIALS AND METHODS Four grey seals (*Halichoerus grypus*) from OcÈanopolis rescue centre, Brest, France, were fitted with Satellite Relay Data Loggers (SRDL) developed by the Sea Mammal Research Unit, Saint-Andrews, U.K, and kept in an outdoor tank for two to four weeks prior to their releasing at sea. Satellite fixes obtained during the experiment were compared with the real location of the tank, determined by using a differential GPS (4 metres accuracy). The difference was calculated in kilometres from latitudinal and longitudinal data (in WGS 84).

For each location calculated by Argos, a Location Class (LC) is assigned from a variety of technical criteria: number of signals received during the satellite pass, stability of the oscillator of the tags, distance from previous locationsÒ Standard LCs range from 1 to 3, the latter being the more accurate. Accuracies of 350, 500 and 1000 metres are respectively expected for locations of classes 3, 2 and 1 (Service Argos, 1996). In animal applications, because few locations can reach this high accuracy, LC 0, A and B are also used (LC: B for the more doubtful locations) but no expected error range is given.

As the tags were emitting, the activity of the seals was recorded during most satellite passes over the site. Four categories of activities were defined: Swimming (S), Resting (R), interaction with Human (H) and low Activity (A, defined as slowly moving – between swimming and resting). The tags, glued on the neck of the seals (Fedak *et al.*, 1983), were also carefully observed: their position relative to the water surface is important since a dry-wet sensor stops the emission when wet. Therefore, the position of the tag was also recorded at any time during satellite passes as follows: 0 while tag was fully submerged, 1 for intermediate position and 2 when fully emerged. At the end of the satellite passes, relative durations of each of the three positions of the tag were calculated.

RESULTS During the experiment, 778 satellite passes received at least one signal from the tags, and 507 of these allowed the calculation of a location (which requires two signals or more). The LC assigned to these locations were distributed as indicated in Table 1.

The 68 percentile error (one) for each LC measures the global dispersion of the positionings in this class (Table 2). Locations with LC 2 and 3 are the best and nearly have the same accuracy, ranging within less than one kilometre. LC 1 and A reaches 1.7 and 2.5 km, but LC 0 and B were by far the worst with errors of more than 10 kilometres. Fig. 1 shows the distribution of estimated locations of LC 1 compared to the real location of the tank.

The main activity of each seal was recorded during the satellite passes and, in 53 occasions, could be compared to the location class obtained from signals received at the same time by the satellite (Table 3). Because of the low number of location/observation pairs, no statistics were conducted on the results. Nethertheless, it seems that LC composition did not vary with activity.

The relative duration of the three possible positions of the emitting tags at the water surface were also compared to Location Classes subsequently calculated (Figure 2). No significant trend can be detected from the comparison of good or poor quality locations with the position of the tag.

DISCUSSION Errors in location estimates of LC 1 to 3 slightly exceeded expected values given by Service Argos, but remained comparable to most other estimates, even in terrestrial studies (see Keating *et al.*, 1991). Errors for LC 0, A and B were rarely if at all documented before in experiments carried out in real condition, and show some variability.

As expected, LC B gives the worst accuracy ; LC 0 also shows large errors in location estimation. By contrast, LC A seems to give quite accurate locations: this is due to the calculation method of LC. LC 0 to 3 are given to locations estimated from at least 4 uplinks per satellite pass, and LC A and B are automatically assigned when this number is lower. Nonetheless, a series of other tests are conducted on the uplinks, such as frequence stability: locations of LC 0 have failed in at least 2 of 4 of these tests. LC A is mostly assigned due to the lack of numerous uplinks but, in case of good quality tags, LC A can reach as high accuracies as for LC 1 (Service Argos, *pers. comm.*).

As shown on Fig. 1, geographical distribution of locations is more elliptical in shape than circular: the error in location is greater in longitude than in latitude. This difference is due to the more or less well-known position of the satellites which receive the signals from the transmitters. The satellites having a near-polar orbite, their position is well-known along their track (i.e in latitude), whereas their longitudinal position is less predictable and measurable (Service Argos, *pers. comm.*). Consequently, longitudinal location estimates are less accurate than latitudinal ones.

Concerning the influence of seal's activity on the quality of locations, no clear relationship has been observed. Similarly, we failed to detect any relationship between LC and the position of the tag relative to the water surface during the satellite passes. The occurrence patterns of the three positions defined were similar for all LC values, even though one could expect that the longer the tag is emerged, the more signals are received by the satellite and therefore the best the LC is.

This absence of relationship between biological parameters and location qualities is in accordance with Service Argos claims but in opposition to previous works (*e.g.* Stewart *et al.*, 1989). Our results can be explained by the few possible activities of the seals in their tank : long dives for instance, which is a major activity in free ranging grey seals at sea, does not occur in this situation and can bias the relationship with LC. Indeed, tracks of the same seals once released at sea have shown great differences between locations at sea (poor LC, almost only 0, A or B) and locations when around haulout sites (better LC, often from 1 to 3). Further experiments are therefore necessary to assess the possible relationship between location quality and activity of marine mammals at sea.

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REFERENCES

Fedak, M.A., Anderson, S.S. and Curry, M.G. 1983. Attachment of a radio tag to the fur of seals. *J. Zool.*, Lond., 200: 298-300.

Keating, K.A., Brewster, W.G. and Key, C.H. 1991. Satellite telemetry : performance of animal-tracking systems. *J. Wildl. Manage.*, 55: 160-171.

Martin, A.R., Smith, T.G. and Cox, O.P. 1993. Studying the behaviour and movements of high Arctic belugas with satellite telemetry. *Symp. Zool. Soc. Lond.*, 66: 195-210.

McConnell, B.J., Chambers, C., Nicholas, K.S. and Fedak, M.A. 1992. Satellite tracking of grey seals (*Halichoerus grypus*). *J. Zool.*, Lond., 226: 271-282.

Service Argos. 1996. *User's guide*. CLS ARGOS, Toulouse, France. 184pp.

Stewart, B.S., Leatherwood, S., Yochem, P.K. and Heide-Jorgensen, M.-P. 1989. Harbor seal tracking and telemetry by satellite. *Marine Mammal Science*, 5: 361-375.

Table 1. Total number of locations and corresponding Location Classes (LC)

LC	Number of location fixes	%
B	159	31.4
A	110	21.7
0	85	16.8
1	66	13.0
2	58	11.4
3	29	5.7
Total	507	100.0

Table 2. 68 percentile error for each LC value

68 percentile error	**LC**					
	B	**A**	**0**	**1**	**2**	**3**
this study (in metres)	15 000	2 500	10 000	1 750	650	660
Service ARGOS * (in metres)	~	~	~	1 000	500	350

* : given for terrestrial application. ARGOS, 1996
~: not documented

Table 3. Main activity of the seals during satellite passes and LC of corresponding localisations

LC	Number of observations for main activity:			
	S	R	H	A
B	13	7	1	2
A	6	1	0	2
0	5	0	0	1
1	4	0	1	0
2	4	1	0	0
3	4	1	0	0

With S: Swimming; R: Resting; H: Interaction with Human; A: Low Activity

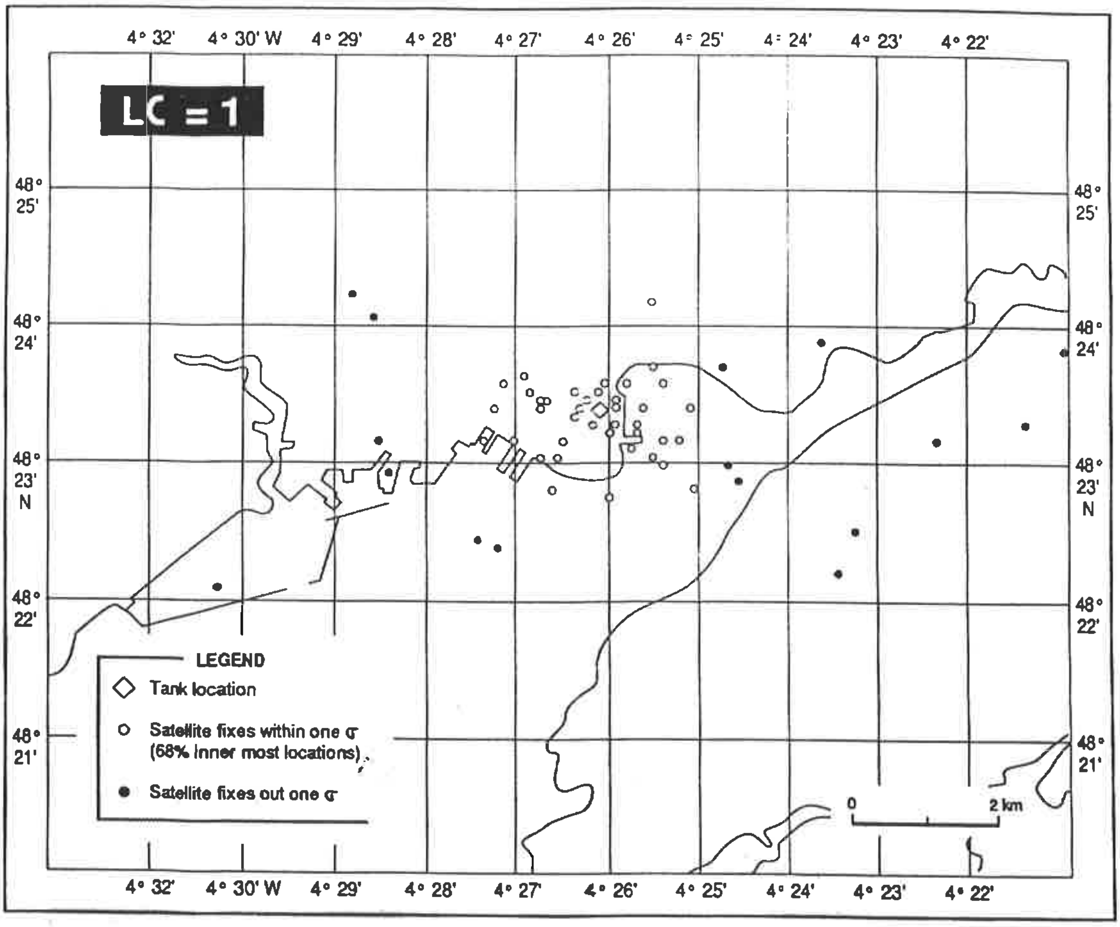

Figure 1. Distribution of estimated locations of LC 1

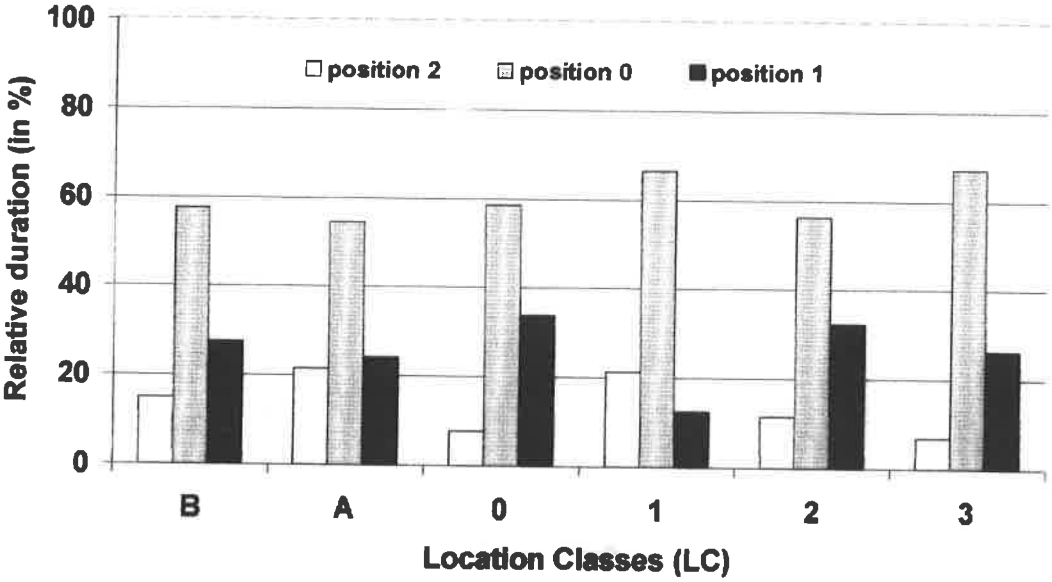

Figure 2. Comparison between LC and the position of the tags relative to the water surface while emitting

With position 0: fully submerged; position 1: intermediate; position 2: fully emerged

FIRST REPORT OF BLUE WHALES (*BALAENOPTERA MUSCULUS*) FREQUENTING THE CANARY ISLAND WATERS

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SURVEY AREA To date, twenty-five cetacean species are known to inhabit or visit the waters of the Canary Islands archipelago including physeterids, delphinids, several ziphiids and four species of the balaenopterid family: minke, bryde, sei and fin whale (Vidal Martin, *pers. comm.*). Seventeen cetacean species have been documented to use the waters southwest of La Gomera, as part of their habitat (Ritter, 1996; Ritter and Brederlau, unpubl. data).

La Gomera (17°15'W-17°21'W and 28°1'N-28°14'N) lies about 400 kilometres off the West African mainland (17°15'W-17°21'W and 28°1'N-28°14'N) in the Atlantic Ocean and belongs to the Western Canary Islands (see Fig.1). The islands are surrounded by waters which rapidly get deeper the farther away from the coast. Some authors consider the key oceanographic feature is the absence of a shelf (Martin *et al.*, 1992). In the western part of the archipelago, the sea-bottom drops steeply to about 4,000 metres into the Canaries basin (Rothe, 1986). In La Gomera's south-west, where our observations are made, a depth of 2,000 m. is already reached only a few kilometres away from the coast.

The climate is mainly determined by the islands' position in the north-eastern trade-wind. Water temperatures are approximately 22°C-24°C in summer and about 17°C-19°C in winter. This temperature is lower than might be expected from a subtropical region, mainly due to the cold lift off West Africa and the cooler Canaries Current (Montero and Arechavaleta, 1997).

METHOD Off La Gomera, small whale watching vessels operate from the Valle Gran Rey, situated in the south-west of the island. One of these boats - the *Viena*, a 9m. former fishing boat - since 1995 is being used as the platform for a long-term cetacean research project since 1995. This research is conducted by the Project *M.E.E.R. LA GOMERA*, (a NGO based in Germany), in co-operation with the Club de Mar, (a local whale watching operator).

Since September 1995, sighting data have been collected for every sighting made aboard the *Viena*. This is done during the regular whale watching trips, which usually takes place once or twice a day (10:00 and 17:00 hrs, according to tourist demand) and throughout the year. Data collected include determination of species, time, group size, distance to the coast, and duration of the sighting. These are complemented by field notes concerning the sighting described in this paper.

Photographic pictures were taken with a SLR camera equipped with 28-70mm/f3.5 and 80-200mm/f4.0 zoom lenses. Video footage was filmed with a HI 8 video camera.

RESULTS On 4th April 1997, at 11:20 hrs, a sighting of blue whale (*Balaenoptera musculus*) was made. Three whales were encountered approximately 1 nm off the south coast of La Gomera (Pta. Iguala). We believe this to be the first report of blue whales frequenting waters off the Canary Island waters. Beaufort Sea State was 2-3 with low (<1 m) swell. The water depth at the place of first sighting was 100-150 m. The whales were first approximately about 500 m away from each other. Only towards the end of the encounter could the number of whales be determined accurately when they remained close to eachother (50-200 m). Two of the whales were estimated to be 25 m long, the third animal being considerably smaller (approx. 20 m). The species identity was ascertained by the animals' size, the bluish colour, and the mottled pigmentation pattern on the flanks which is unique to blue whales.

The whales were followed by the *Viena*, and after a while, two more whale watching boats (of about the same size as the *Viena*) joined the encounter. The sighting lasted 2 hrs and 5 mins. The whales travelled in the same direction (northwest) the entire time at a speed of c. 3 knots, and were followed by the boats. Only towards the end of the sighting died they accelerate to 4-5 knots. The dive cycles - as long these could be established with the observation platform remaining with a single whale - were regular with dive times ranging from 30 secs up to 32 mins. The whales remained close to the water surface, and thus were visible even when submerged. When they came to the surface to breathe, they did this almost exclusively beside or in front of the boats.

The distance to the boats varied from 10 to 100 m., some close approaches to the boats were observed. The general behaviour was inconspicuous; no fluke-up dives or any spectacular behaviours were observed. Sometimes a whale diving close to the boat turned on its side, presumably to have a look at the whale watchers. No fluke-up dives or any spectacular behaviours were observed. The distance to the boats varied from 10 to 100 m.; some close approaches to the boats were observed. Once, an animal dived right below the *Viena* at a depth of c. 10 m for 2-3 mins.

Photographs (colour slides, ISO 100) were taken throughout the encounter and also a total of 1h 15 min of Hi 8 video footage were filmed by a guest on the whale watching trip.

DISCUSSION Blue whales inhabit all oceans and are said to have a typical "balaenopterid life cycle": they remain in their tropical mating and calving grounds during winter, and migrate to the arctic and antarctic feeding grounds in summer. However, there is evidence for non-migrating animals and resident populations in the eastern tropical Pacific (Reilly and Thayer, 1990). Very little is known about the North Atlantic stock. Neither migrating routes nor feeding and mating areas have been determined (Lockyer, 1990). On the other hand, there are indications of two separate stocks, one in the western and the other in the eastern Atlantic (Klinowska, 1991). Concerning the eastern Atlantic, there have been sightings off West Africa at the level of Cape Blanco, with the southernmost record for the eastern North Atlantic being from the Cape Verde Islands (Ingebrigsten, 1929). Estimates of the population size of the North Atlantic Ocean range from around 100 animals to more than 500 (Yochem and Leatherwood, 1985).

The sizes of the animals observed off La Gomera suggest two adults and one younger, almost sexually mature. The group size was similar to numbers given in literature: blue whales mostly swim alone or in groups of 2 or 3 animals (Yochem and Leatherwood, 1985).

Western Atlantic blue whales apparently start migrating northwards as early as March/April (Sears *et al.*, 1990). Eastern Atlantic blue whales are said to migrate from the area of the Cape Verde Archipelago to Spitsbergen and the Barents Sea (Klinowska, 1991; Yochem and Leatherwood, 1985). Given the date of our sighting and the observed direction of travel, we may conclude that these blue whales were on their way to the Arctic. Also, the speed of the whales during our sighting corresponds to the migrating speed of blue whales (5 to 33 km/hour - Yochem and Leatherwood, 1985). Nevertheless, these whales may have stayed in the area for a longer period, possibly responding to special oceanographic conditions such as water temperature, salinity, and the like. The latter could also have been the reason for them frequenting the Canaries archipelago.

Increased observer coverage over the last years has increased the probability of sightings of "new" species in the Canaries, which is especially true for La Gomera.

The long duration of the encounter and the constant close distance to the whale-watching boats leads us to the conclusion that it was the whales which stayed with the boats and not vice versa.

The use of whale-watching vessels as a platform of opportunity is demonstrated here as very important in the collection of data on a regular basis. The co-operative partnership of tour operator and researchers alike at La Gomera is an important example of the reciprocal benefits to whale-watching tourism and scientific research. Such a collaboration is generally viewed as a necessary feature of whale-watching activities (Hoyt 1994; IFAW, Tethys & Europe Conservation, 1995). Moreover, the alliance of scientists and operators enables the direct realisation of conclusions from experiences gained in cetacean encounters. The (human) conduct towards the animals can thus be adjusted directly to the animals' natural occurring behaviour, a procedure which is vital for whale watching areas in development (Forestell 1995; Smith and Hoyt 1996, in prep.). If we consider the fact that there is an additional link to the public work done by the *Project M.E.E.R. La Gomera*, the precautionary approach, being the basis of the whale watching activities off the coast of La Gomera, can be regarded as a special kind of mutualism.

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REFERENCES

Forestell, P. 1995. Ensuring Scientific Proposals for Rules are Practicable. Workshop on the Scientific Aspects of Whale Watching, Montecastello di Vibio, Italy. 30th March - 4th April 1995: Working Paper MWW 95/46. 10pp.

Hoyt, E. 1994: *Whale Watching and the Community: The way Forward.* Whale and Dolphin Conservation Society, Bath, UK. 29pp.

IFAW, Tethys and Europe Conservation 1995. *Report of the Workshop on the Scientific Aspects of Whale Watching.* Montecastello di Vibio, Italy. 30th March - 4th April 1995. 45pp.

Ingebrigsten, A. 1929. Whales caught in the North Atlantic and other seas. *Rapp. Cons. Explor. Mer, Rapp. Proc.-Verb Reun.*, 56: 1-26.

Klinowska, M. 1991. Blue Whale *Balaenoptera musculus* (Linnaeus 1758). Pp. 401-410. In *Dolphins, Porpoises and Whales of the World.* The IUCN Red Data Book. IUCN, Gland, Switzerland. 429pp.

Lockyer, C. 1990. Blue Whale, *Balaenoptera musculus.* Pp. 68-70 In *Whales and Dolphins.* (Ed. A.R. Martin). Salamander Books, London. 191pp.

Martin, V., Montero, R., Heimlich-Boran, J. and Heimlich-Boran, S. 1992. Preliminary Observations of the Cetacean Fauna of the Canary Islands. Pp. 61-63. In: *European Research on Cetaceans - 6.* (Ed. P.G.H. Evans) Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb 1992. European Cetacean Society, Cambridge, UK. 254pp.

Montero, R. and Arechavaleta, M. 1997. Distribution patterns: relationships between depths, sea surface temperature, and habitat use of short-finned pilot whales south-west of Tenerife. Pp. 193-198. In *European Research on Cetaceans - 10.* (Ed. P.G.H. Evans) Proc. 10th Ann. Conf. ECS, Lisbon, Portugal, 11-13 March 1996. European Cetacean Society, Kiel, Germany. 334pp.

Reilly, S.B. and Thayer, V.G. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. *Mar. Mammal Sci.*, 6(4): 265-277.

Ritter, F. 1996. *Abundance, Distribution and Behaviour of Cetaceans off La Gomera (Canary Islands) and their Interaction with Whale-watching Boats and Swimmers.* Diploma Thesis to the University of Bremen, Faculty of Biology. 114pp.

Rothe, P. 1986. *Sammlung Geologischer Fuehrer, 81: Kanarische Inseln.* Gebrueder Borntraeger, Berlin. 289pp.

Sears, R., Williamson, J.M., Wenzel, F., Bérubé, M., Gendron, D. and Jones, P. 1990. Photographic iIdentification of the Blue Whale (*Balaenoptera musculus*) in the Gulf of St. Lawrence, Canada. *Rep. int. Whal. Commn* (Special issue 12): 335-342.

Smith, A. and Hoyt, E. 1996. *A Review of International Regulations for Small Cetacean Watching and Swimming.* Whale and Dolphin Conservation Society, Bath, UK.

Yochem, P.K. and Leatherwood, S. 1985. Blue Whale *Balaenoptera musculus* (Linnaeus, 1758). Pp. 193-240. In *Handbook of Marine Mammals. Volume 3. The Sirenians and Baleen Whales* (Eds. S.H. Ridgeway and R. Harrison). Academic Press, London. 362pp.

THE DISTRIBUTION OF THE MEDITERRANEAN MONK SEAL (*MONACHUS MONACHUS*) IN GREECE

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This study is an attempt to determine the distribution of the Mediterranean monk seal, (*Monachus monachus*), in Greece, using information related to monk seal sightings from throughout the country. The information collected includes: the date and site of observation, the description of the animal, its behaviour, and other relevant details. This study is part of a Rescue and Information Network, established in 1990, which consists of a network of more than 1,000 contacts in coastal Greece and with which there is continuous communication through questionnaires received by mail from relevant authorities (port police, fishery and veterinary services, fishery co-operatives, coastal municipalities) and from local inhabitants, interviews of observers contacted during expeditions to coastal areas, in order to sensitise the local population and collect information about the past and present status of the monk seal (163 different locations visited).

During the study period (1990-96), 711 reports of alive seal observations (49 were related to newly born pups, 566 to adult or juvenile animals and in 99 cases the stage of the animal could not be determined) and 92 reports of dead seals were collected or received. The distribution of the seal sightings indicate that the Mediterranean monk seal still remains widely distributed in Greece. This is further supported by the fact that dead monk seal strandings were also found to be distributed throughout the country's coastline. The high frequency of dead seal strandings found in specific areas (N. Sporades and Ionian islands), is considered to be due to the presence of research teams monitoring the status of the species and the larger size of the local monk seal populations. Furthermore, the sightings of newborn pups in a number of different areas, and the consistency of such observations through the project period, provide evidence that several breeding populations are found within the species distribution.

The high frequency of seal sightings in conjunction with evidence of breeding in several areas of the country, suggest that there may be a number of important subpopulations, which should be considered in the strategy for the protection of the species on a national scale.

GROWTH, AGE AT SEXUAL MATURITY AND CONDITION IN BEARDED SEALS (*ERIGNATHUS BARBATUS*) FROM SVALBARD, NORWAY

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The aim of this study was to describe growth, determine age at sexual maturity and investigate the condition of bearded seals from the Svalbard area. Morphometric data, jaws, and sex organs were collected from 110 animals. Age was determined by reading cementum layers in hard longitudinal sections of canine teeth.

Females were defined as sexually mature based on findings of mature follicles or corpora lutea/albicantia. Sexual maturity in males were determined based on size of testes and bacula.

Von Bertalanffy growth curves were applied on both standard length and body mass data, and asymptotic values for males were 231.1 ±11.4 cm and 271.0 ±26.8 kg, and for females 233.1 ±7.5 cm and 276.9 ±48.2 kg, respectively.

Maximum recorded lengths and masses were 254 cm and 313 kg in males and 242 cm and 358 kg in females.

Females were found to be sexually mature at 200 cm (90% of asymptotic value), corresponding to an age of 5 years. All males older than 6 years were sexually mature.

A significant decrease was found in condition in adult females from May to July, and a significant increase when comparing July and August data (based on a condition index CI = [standard length/axillary girth] 100). A similar trend was found for adult males, but these differences were not significant. This difference between the sexes, can be explained by the high energetic costs in connection with lactation in females.

CAUSES OF DEATH IN THE MEDITERRANEAN MONK SEAL (*MONACHUS MONACHUS*) IN GREECE

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The decline of the Mediterranean monk seal (*Monachus monachus)* has to a large extent been attributed to the deliberate killing of animals. This has been mainly based on occasional reports of dead monk seal strandings. In order to evaluate the relative importance of deliberate killing, we examined the causes of death of this species in Greece, for the period from 1973 until 1996.

The reports of dead animals were collected through a network of more than 1,000 contacts throughout Greece, as part of a Rescue and Information Network, and through monitoring of the monk seal population of the Northern Sporades Islands. When possible, depending on how recent the report was and on the state of decomposition of the animal, full autopsies were conducted and samples were taken for laboratory analyses to assist in the identification of the cause of death.

Even though identification of the cause of death may not always be reliable without an autopsy, for comparative reasons we present results from 27 cases where autopsies were conducted, as well as from 65 cases where the cause of death was determined based only on the information provided by the reporters.

Considering the results from the autopsies performed, in the adult and juvenile stages, deliberate killing was found to be the most frequent cause of death (43%), while natural deaths (25%) and accidental captures in fishing gear (13%) were also recorded. By contrast, in the cases involving newly born animals natural causes of death constitute the most important mortality factor, accounting for 92% of the deaths of animals of this stage. The results obtained from the cases where autopsies were not conducted, provide evidence that deliberate killing is the most frequent cause of death in animals of all stages.

The high frequency of deliberate killing found and the fact that this phenomenon still occurs in most areas of the species distribution makes this factor critical in the design of effective conservation measures. A further argument for the establishment of additional protected areas is the reduction of deliberate killing in the National Marine Park of Alonnissos, Northern Sporades, Greece, over the last decade.

A PHOTO-IDENTIFICATION STUDY OF RISSO'S DOLPHINS IN THE OUTER HEBRIDES, NORTHWEST SCOTLAND

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During surveys by the Sea Watch Foundation of coastal waters west of Scotland over the summers of 1992-97, Risso's dolphins (*Grampus griseus)* were seen annually around the Eye Peninsula, Isle of Lewis. A photo-identification study was initiated in August - September 1995 and repeated during May - October 1996. Regular surveys were conducted from Kebock Head (58°02'N 60°21'W) to Tolsta Head (58°21'N, 60° 09'W) seaward to the 100 m depth contour (a total area of 175 km^2). Total boat effort amounted to 358 hrs, of which 115 hrs (32%) were recorded with Risso's dolphins. Approximately 3,000 photographs of dorsal fins and bodies have been taken for photo-identification, using a variety of natural markings.

At least 142 individuals have been identified to date (results from summer 1997 to be incorporated) with at least 52 individuals (37%) re-sighted between 1995 and 1996. Group sizes ranged from 3 to 50, with a modal group size of 8-12. Although groups were typically of mixed ages and sex, on three occasions groups comprising exclusively subadults/juveniles were encountered and on one occasion a group of eight females each with a calf was observed. Individuals identified together in 1995 were re-sighted in the same groups the subsequent year, suggesting that longer term affiliations may exist along with more fluid group structures.

Particular localities were favoured by Risso's dolphins although these could vary seasonally. Between May and July the species was generally seen offshore in deeper waters and in large groups. In August and September animals were regularly in coastal bays or nearshore, foraging solitarily or in small groups. This change in behaviour may be for social reasons or relate to prey availability. A dead Risso's dolphin washed up locally in May contained quantities of lesser octopus (*Eledone cirrhosa*) beaks in its stomach. Local creel fishermen reported octopus as abundant throughout the coastal area of Lewis especially around the Eye Peninsula, with apparent peaks in June and August - October. Studies are currently underway to investigate whether spatio-temporal variation in dolphin distribution correlates with variations in potential prey abundance.

SEASONAL ABUNDANCE, DISTRIBUTION AND HABITAT USE OF OFFSHORE BOTTLENOSE DOLPHINS AT ISLA DEL COCO, COSTA RICA

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Little is known about the occurrence and habitat use of offshore bottlenose dolphins (*Tursiops truncatus*) in Eastern Tropical Pacific oceanic islands. The objectives of this study were to determine the distribution, relative abundance, and habitat use patterns of bottlenose dolphins in waters surrounding Isla del Coco, Costa Rica. Isla del Coco is a small (23 km in circumference) island centered at 05° 32'N, 87° 04'W and located 500 km southwest of the Pacific coast of Costa Rica. From February 1993 to August 1993 and November 1993 to July 1994, non-random surveys were conducted from a small inflatable boat. Environmental parameters (e.g. water temperature, salinity, wind, Beaufort, turbidity) were recorded regularly, as well as after every dolphin sightings. Spatial distribution and associated environmental and oceanographic parameters were analysed by dividing the 206 km^2 study area into 1x1 km grids.

A total of 296 surveys (6218 km on-effort) were conducted with 589 dolphin sightings. Dolphins were observed throughout the study area and during all seasons. Sighting rates were highest ([0.15-0.23 sght/km]) between April and August, and lowest ([0.02-0.05 sght/km]) from December through March. Dolphin sightings tended to be concentrated in the northwestern part of the study area, and to a lesser extent in the northern and western region, where deep waters closely approached shore.

In general, dolphins were seen within 1 km of shore (mean = 0.97 km) and in relatively shallow waters (mean = 120 m). High sighting rates nearshore and low sighting rates during northwesterly wind periods suggested a utilisation of protected waters. The mean water depth corresponds with the presence of epipelagic fishes which are the main prey of offshore bottlenose dolphins. Further studies are needed to confirm the seasonal trends in abundance and to assess seasonal availability and distribution of epipelagic fishes in the area.

THE QUANTITY ESTIMATION OF RUSSIAN ARCTIC BELUGA ACCORDING TO THE PECULIARITY OF THEIR POPULATION STRUCTURE

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Beluga is an excellent species as an indicator of ecosystem condition. Monitoring of this species seems to be very important because of the intensive industrial development of the shelf regions. Large dimensions, white coloration, and population structure make the beluga a most convenient monitoring subject.

With respect to the populations of belugas in the Russian Arctic, it is considered that 10-20,000 live in the White Sea and Barents Sea; almost the same number in the Kara Sea; and very few in the Laptev Sea. They are rare in Vostochmo-Siberian Sea; there are not many near the Chukotsk; and the population in Anadir Bay is estimated at up to 10-20,000. The nearest population of beluga to these lives only in thousands of kilometres in the Sea of Okhotsk: in the northern part - Gijiginsko-Penjinskaya, 10-20,000; and in the southern part - Shantarskaya and Amurskaya populations, 10-20,000. All these quantitative estimates have been carefully determined.

Only in recent years have we conducted special investigations and determined the true abundance of the beluga population in the southern part of the White Sea - 800-1,000 animals (Bel'kovich, 1995, 1996). During this work we studied five reproductive aggregations of beluga composed of females and young animals of different age, and of 10-14% of adult males (Bel'kovich, 1996, 1997). This part of the population is resident. The second part of this population consist of adult males (90%), and migrates, foraging great distances away (in the Barents Sea, and maybe the Kara Sea). We consider the two parts of the population almost equal. We suggest that one can use the seasonal stability of the breeding aggregations as a great opportunity for quantitative estimates of the first part of the population, and to arrive at an estimate of about one half of the whole population.

VARIATION IN THE DEGREE OF SEXUAL DIMORPHISM BETWEEN GREY SEALS (*HALICHOERUS GRYPUS*) IN THE BALTIC SEA AND THE BRITISH ISLES

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The degree of sexual dimorphism varies extensively between different species of phocid seals. This variation follows a general pattern with a high degree of dimorphism in polygynous species breeding on land and slight dimorphism or monomorphism in less polygynous or monogamous species breeding on ice. In order to test whether the same pattern exists within a species inhabiting various habitat types, we investigated the cranial morphometry of grey seals (*Halichoerus grypus*) from the Baltic Sea and the British Isles. While grey seals around the British Isles generally form terrestrial breeding colonies, the majority of the Baltic grey seals breed on pack ice in the northern part of the Baltic.

We measured six cranial variables on a total of 145 grey seal craniums, 97 from the Baltic Sea (51 females and 46 males) and 48 from the British Isles (25 females and 23 males), and the data was analysed using multivariate statistical methods. General size accounted for 81.71% of the total variation. Among Baltic seals, this was the only aspect for which males and females differed significantly.

In contrast, males and females in the UK also differed with respect to skull shape, with relatively larger orbital openings and more elongated maxillary region in males than in females. In a Discriminant Function Analysis, greater separation was obtained between males and females in the UK sample than in the Baltic sample, indicating a higher degree of sexual dimorphism in the UK sample (Mahalanobis multivariate distances: 10.93 and 4.64 respectively). When the general size factor was excluded UK males and females were still highly separated, while separation was almost absent in the Baltic sample (Mahalanobis distances: 1.274 and 0.128 respectively). Therefore, size alone does not account for all dimorphism in the UK sample.

Our results indicate that grey seals in the Baltic lack the extreme sexual dimorphism which is otherwise characteristic to this species. This may be the result of stronger selection for large size and secondary sexual characteristics in males in the Eastern Atlantic, in combination with a greater relative reproductive advantage to large females in the harsh climate of the Baltic pack-ice.

COMPARATIVE POPULATION DYNAMICS OF STELLER SEA LIONS AND NORTHERN FUR SEALS ON COMMANDER IS., RUSSIA

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Northern fur seals (NFS) and Steller sea lions (SSL) have similar areas of distribution and sometimes breed on the same rookeries. Both also have a wide variety of feeding species. However the abundance of both NFS and SSL is reliant on the stocks of herring and pollock, key species in the ecosystem of the Bering Sea.

Both seals and sea lions were abundant in 1950 but numbers have declined over the last few decades, though not all populations at the same rate. Between 1950 and 1990, NFS colonies on Pribilof Is. (USA) declined twice, and those on Robben Is. (Russia) three times. The NFS population on Commander Is. however, increased in 1960, and was more or less stable during 1970-1990. During 1960, NFS created two new reproductive rookeries there and several small rookeries on Kuril Is. In 1970, NFS were found in California and late in 1980 a rookery was found on Bogoslov Is., Alaska.

Analysis of observation on tagged animals has shown an important redistribution of NFS from Pribilof Is. creating rookeries on Commander Is. A similar emigration of SSL to Commander Is. was observed between 1960 and 1970. In 1969, SSL began reproduce on the south of Medny Is.

There is not much information from other areas for that period but we guess the process of the redistribution was the same for NFS and SSL during 1960-70 when SSL numbers started to decline also. Food resources could be the primary reason for the emigration of NFS and SSL from their native area. Fishery activity is a general factor influencing fish and shellfish stocks. Fisheries are developing faster in the eastern Bering Sea, the US coast of the Pacific Ocean, and in the south of the far eastern Russian seas than in the western Bering Sea.

Marine mammals represent the high trophic level of the oceanic ecosystem, showing the accumulative effects of environmental factors and are therefore good indicators of variations in the ecosystem.

DIET OF ATLANTIC WHITE-SIDED DOLPHINS SOUTHWEST OF IRELAND

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The diet of Atlantic white-sided dolphin (*Lagenorhynchus acutus*) in the Northeast Atlantic is poorly known. Here, we provide stomach content data for 50 specimens, caught accidentally in the fishery for horse mackerel and mackerel at the shelf-edge Southwest of Ireland. In addition data are presented on the diet of seven common dolphins (*Delphinus delphis*) and two bottlenose dolphins (*Tursiops truncatus*). The dolphins were caught between 1992 and 1995, in the period January - April, except for one white-sided dolphin which was sampled in September 1994.

In stomachs of white-sided dolphins a total of 4,029 prey items were found, of which 1,118 items originated from the specimen caught in September. From January to April, the most important prey groups of white-sided dolphins, expressed as percentage of the total weight and proportion of the total number of prey respectively, are: mackerel (67% and 12%), Gadidae (13% and 49%), other fish (7% and 27%) and Cephalopods (13% and 12%). Cephalopods consisted of at least 12 mainly meso-pelagic species. The most important fish species in numbers were the gadid silvery pout (*Gadiculus argenteus*, 44%) and the myctophid *Notoscopelus kroeyerii* (13.5%), both meso-pelagic species. In the single specimen from September, the most important prey-groups were Cephalopods (52%; almost exclusively Ommastrephidae) and Gadidae (45% of weight and 76% of number; mainly silvery pout and blue whiting *Micromesistius poutassou*). Horse mackerel was completely absent in the stomach of white-sided dolphins, while the species was found in the stomachs of common dolphin and bottlenose dolphin.

The occurrence of both meso-pelagic species and mackerel in the stomachs do suggest that white-sided dolphins combine a more oceanic distribution with excursions in the outershelf area, where they may associate with schools of mackerel and where they possibly also scavenge on discards.

STATUS AND CONSERVATION OF THE MONK SEAL POPULATION IN THE NATIONAL MARINE PARK OF ALONNISSOS, N. SPORADES, GREECE

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The existence of one of the largest breeding Mediterranean monk seal,(*Monachus monachus*), populations in the Nortrhern Sporades island complex in Greece, provides a unique opportunity for studying in the field this endangered species. In 1990, a long-term project was initiated with aim to study and monitor the status of the local monk seal population.

Fieldwork is being conducted by direct visits to the 35 seal shelters of the study area, during which the presence of animals is recorded. In parallel, programmed photographic cameras have been installed within specific shelters. Direct observations and photographs taken of animals encountered are used in the identification of individuals.

From 1990 until 1996, surveys to the species shelters have been conducted 1,950 times, during which 480 times, individual animals were encountered. Through recent analysis of the data, at least 32 individual adult or juvenile animals have been identified. Patterns of the animals' daily and seasonal use of shelters, as well as, movements within the area have been recorded. Furthermore, 42 different new born pups, of equal sex ratio, have been identified. Births are distributed between July and December with a peak in October. Moulting period was observed to start at the earliest at the age of 30-40 days and to last at least 15 days. During the first two months of development, pups spend considerable time with their mothers. They were observed to enter the sea in the first week of life, even in the absence of their mothers, and to change shelters and travel distances of several hundred meters even at an early age.

These results were taken under consideration in the design and subsequent modifications of a zone system with varying degrees of conservation measures, originally established in the area in 1992. The conservation measures involve mainly restrictions in fishery and tourism activities providing complete protection in the main reproduction habitats of the species. The existing measures are actively enforced through a guarding system. The data collected on the human activities within the park area, provide evidence of a decline in illegal activities during the project period.

MATERNAL ATTENDANCE AND PUP GROWTH RATE IN SUBANTARCTIC FUR SEALS (*ARCTOCEPAHLUS TROPICALIS*) ON AMSTERDAM ISLAND

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In SubAntarctic Fur Seals the pup rearing period lasts ten months. In temperate latitudes such as on Amsterdam Island, fur seal maternal strategies are predicted to be intermediate between tropical strategies where females undertake short foraging trip and subpolar strategies where long foraging trips are preceded by long attendance bouts. To test this hypothesis, mass change and pup growth rates calculated from birth to the age of maximum pup mass (230 days) were monitored in 78 mother-pup pairs. Pups were weighed daily and mothers were weighed before and after several consecutive foraging trips. In addition, diving effort was monitored in 14 females, for one foraging trip, with Time Depth Recorders through the whole study.

Foraging trip durations were among the longest described in Otariidae 10.2±4.5 d (x±S.D., n=297) in summer, 14.0±5.5 d. (n=279) in fall, and 21.5±6.9 d. (n=50) in winter. Attendance bouts were also long (3.7±1.6 d., n=671), and they did not vary in duration throughout the year. Pup growth rate did not vary with pup sex, but larger mothers which made shorter foraging trips had pups which grew faster. In summer, the absolute and daily mass gains of pups depended on maternal characteristics (body size, body mass and maternal attendance behaviour), but were limited by the pup mass -i.e. the quantity of milk the pup is able to ingest in relation to its size.

In fthe autumn, despite longer foraging trips, mothers were able to feed their pup at the same rate as in summer because i) mass gain of the pup was no longer limited by its size and ii) absolute maternal mass gain at sea increased. However, despite increased diving effort in winter, females were unable to maintain the daily mass gain of their pup. The maternal strategy of Subantarctic Fur Seals breeding on Amsterdam Island was not intermediate between a tropical and a subpolar strategy with respect to the hypothesised latitudinal gradient in maternal attendance. This can be explained by the absence of coastal upwelling at Amsterdam Island where females have to travel further at sea to reach the more productive waters of the subtropical front.

MIGRATIONS OF ADULT RINGED SEALS BASED ON SATELLITE TELEMETRY

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Ringed seals (*Phoca hispida*) associate closely with fast-ice, in which they breed and nurse their young. Adult ringed seals are territorial in the breeding season, and there are indications that they show site fidelity to the same areas of the land-fast fjord ice in successive breeding seasons. Virtually nothing is known about their movements outside the breeding period.

We believe that adult ringed seals in the fjords of Spitsbergen conduct prolonged feeding excursions either to the offshore banks or to the drifting pack-ice, and that they show site fidelity upon return to the fjords. We tested this hypothesis using satellite telemetry.

In the beginning of July 1996, eight post-moulting adult ringed seals (6 females; 2 males) were equipped with satellite transmitters. Seven of these were tagged in St. Johnsfjorden, Spitsbergen (78°30'N 13°E) and the eighth in Van Mijenfjorden. The latter did not function well and ceased transmitting after 8 days. It is therefore not included in the analysed data. The seven other transmitters lasted from 103-325 days (mean 191 days). The seals displayed a varying pattern of dispersion. Two spent most of their time at inshore fishing banks, three went to offshore banks and two swam 400 km north to the drifting pack ice (82°N 13°E). All of the seals returned to Spitsbergen. All tags that transmitted long enough showed that the seals returned to the tagging area. The animal with the longest stay outside its breeding fjord left the tagging area on 8 July and returned on 30 December.

This study has shown that adult ringed seals undertake varying patterns of post-moulting excursions and that there are strong indications that they show site fidelity when returning from these.

THE BIOLOGY OF HARBOUR PORPOISES FROM WEST GREENLAND

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During August and September 1995, harbour porpoises (*Phocoena phocoena*) were sampled from the catches in three locations off West Greenland (Paamiut (23), Maniitsoq (52) and Nuuk (28)). Measurements of body length, girths, blubber thickness, body and organ weights were taken and teeth for age determination, stomach content for diet analysis, blubber for lipid analysis and gonads were collected for this study. The data and samples were analysed for biological parameters and ecological status, and comparisons with similar data for porpoises from the eastern North Atlantic and North Sea, where genetic studies have shown differences in population, and with western Atlantic Canadian animals.

The modal age class in both sexes was the first year, with a longevity of 12 yr in females and 17 yr in males. This is more similar to eastern Canada where there is a history of bycatches, but lower than the 24 yr reported for British Isles. Females ovulated from age 3-4 yr at a length of about 135 cm; testes weights >200 g indicated maturation in males from age 2 yr upwards at a length >125 cm. Several small embryos were found, consistent with a mating season in late summer. Application of the Gompertz growth model indicated a maximum length of 154 cm in females and 141 cm in males with a corresponding weight of 57 kg and 52 kg respectively. These length values and those at maturation are consistently smaller than those reported for North Sea porpoises and from elsewhere.

Stomach content analysis for 92 animals indicated regional differences, although capelin (*Mallotus villosus*) was predominant in all samples, as reported off north Norway, but different to the predominantly benthic species off Denmark. The presence of fish, squid and crustaceans indicated opportunistic feeding if presented. Indicators of body condition showed that the pregnant females were fattest, as reported from Canada and British Isles. Animals were significantly heavier and fatter for length than the Canadian and North Sea animals. The blubber lipid content was generally 92-95% wet weight of tissue, a higher level than for British animals (83-87%).

While indicators of body condition may reflect seasonal biases and local ecology, and also origins of the animals (strandings or take), certain biological parameters do indicate differences between West Greenland and eastern North Atlantic populations in concert with the genetic findings.

DIVING BEHAVIOUR IN NEWLY-WEANED SOUTHERN ELEPHANT SEALS DURING THEIR FIRST TRIP TO SEA

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The ability to successfully forage during their first trip to sea is fundamental to the ultimate survival of newly weaned elephant seals. However, there is considerable variation in the weight and fat content of the seals at weaning, which results in some individuals having larger energy and oxygen stores than others. This study was designed to study the development of diving behaviour in newly-weaned elephant seals during their first foraging trip, and to quantify the influence of body size on that behaviour.

The diving behaviour of 21 newly-weaned seals was studied using satellite linked time depth recorders. Seals were captured at Macquarie Island in December 1995 and 1996, approximately four weeks after weaning. Two groups of seals were specifically targeted; a heavy group from the top quartile of weaning weights (n=6) and a light group from the lower quartile (n=15).

Most of the seals made dives in excess of 100 m and 5 min prior to finally departing. However, for the first 60-80 d all of the seals exhibited behaviour quite distinct from the patterns reported for older conspecifics, making relatively shallow (100±39 m) and short (5.7±1.23 min) dives. During this time the seals spent on average 74.3±12.6 % of each day diving, and the depth of the dives did not follow any diurnal pattern. For all seals, the diving behaviour changed abruptly, coincident with their beginning to return to land. During this time the behaviour was more like that of adults, with the seals making deeper (159±9 m) and longer dives (9.01±1.69 min) than previously, with a strong diurnal pattern in depth. There is no obvious explanation for this change in behaviour, although it's abrupt nature suggests that it is unlikely to be due to physiological changes in the seals.

The size of the seals at weaning was an important influence on diving behaviour. Heavy weaners made significantly deeper (130±40 m) and longer dives (7.36±0.55 min) than light weaners (88±32 m and 5.04±0.64 min respectively). This indicates that the smaller seals are constrained to some extent by their physiological capabilities, perhaps requiring them to adopt different foraging strategies.

FEEDING HABITS OF BEARDED SEALS (*ERIGNATHUS BARBATUS*) FROM THE SVALBARD AREA, NORWAY

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The objective of the present study was to assess feeding habits of bearded seals from Svalbard. Stomachs and/or intestine content was collected from 47 individuals. Prey were identified from whole specimens or hard parts as otoliths, exoskeleton fragments, cephalopod beaks, polychaete jaws, operculae and shell remains.

The most dominant fish species were polar cod (*Boreogadus saida*), found in 33% of the stomachs, followed by *Cottidae* spp. (36%), *Hippoglossoides platessoides* (27%) and *Lumpenus medius* (18%). The most dominant crustaceans were *Hyas coarctatus* (55%), *Sabinea septemcarinatus* (48%), *Sclerocrangon boreas* (45%) and *Lebbeus polaris* (18%). Six species of molluscs were found and the whelk *Buccinum* spp. was the most common and found in 12 % of the stomachs, while the 5 other species occurred in 3-6 % of the stomachs only. Cephalopods, polychaetes, amphipods and echiuroide worms occurred in small amounts in some of the samples.

This study shows that the bearded seals were feeding from both benthic and pelagic food sources. Cod (*Gadus morhua*) was found in 5 stomachs, but only small specimens were taken (<17 cm), and the commercially exploited shrimp (*Pandalus borealis*) was found in one stomach only. A potential conflict with respect to bearded seal diet and commercial fisheries in the Svalbard area therefore seems unlikely.

BEHAVIOUR AND HABITAT USE OF RESIDENT BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) IN THE ENTRANCE TO THE SHANNON ESTUARY, IRELAND

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Surveys of bottlenose dolphins in the river Shannon show that the mouth of the estuary is a particularly important habitat area, with significantly more dolphin sightings than in other areas of the river ($p<0.05$). One hypothesis is that areas of strong current in the entrance to rivers are important foraging habitats for bottlenose dolphins. Data were collected using scan samples ($n=341$) during standardised shore watches ($n=41$) from Kilcredaun Head (52° 34.8'N, 09° 42.4'W). Watches were made between June 1996 and May 1997 during which data were collected on the abundance and movements of bottlenose dolphins in an 11.5 km^2 area of the estuary. The estuary is used by dolphins throughout the year with peak abundance occurring during the summer months. The Kilcredaun area of the river is a constricted channel with steep benthic topography leading to tidal currents which can exceed 8km/h.

Behavioural data were collected during standardised scan samples of the survey area ($n=341$). Dolphin schools were observed travelling in 65% of scans, foraging in 26% and resting in 3%. When observed travelling, dolphin schools were seen moving parallel to the shore in 84% of scans. Most frequently, the direction of travel was against the tide; this was very highly significant during the flood tide ($p<0.001$).

Understanding habitat use is important when planning the management and conservation of resident bottlenose dolphin populations. The results show a low incidence of resting behaviour, and a high incidence of the energy expensive activity of swimming against the tide. It is proposed that the dolphins are making specific use of the Kilcredaun area of the river for activities such as foraging, rather than simply travelling through the area. Swimming against the tide may be associated with foraging and thus may support the hypothesis that recording behaviour as travelling during scan samples may result in an underestimation of foraging activity.

DISTRIBUTION OF CETACEANS IN THE SOUTHERN INDIAN OCEAN

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More than 60,000 km of transects through the Southern Indian Ocean, in a zone covering from subtropical to subAntarctic waters, enabled us to make a census of cetacean species. Their distribution and abundance between 1978 and 1988 are established here in relation to the limits of the Indian Ocean Sanctuary. Maps show the distributions of the 23 species observed. These distributions and their abundance appear to be related to the surface distribution of salinity and temperature. In the light of correlations, other various features of the biological and physical environment vary in the same way as the first two do: a low-salinity water is also colder and occurs in conditions of low-temperature and barometric pressure. This situation in conjunction with a shallow ocean depth gave the closest fit to the observations. These conditions tended to stay constant throughout the 10-year observation period, except in 1984-85 when all species showed the highest abundance. At the same time, hydrographic and environmental patterns were revealed to change greatly from other years. Future transects will be conducted in the next years so as to be able to compare the situations before and after the decision on whale protection.

HERRING AS A KEY SPECIES IN NORTHEAST ATLANTIC MINKE WHALE (*BALAENOPTERA ACUTOROSTRATA*) DIETS

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Substantial changes have occurred in Norwegian waters during the last decades, where the most conspicuous were related to the rise and fall of stocks of the two major fish species, the Norwegian spring spawning herring (*Clupea harengus*) and the Barents Sea capelin (*Mallotus villosus*). Thanks to extensive annual studies since 1992, recent effect of these ecological changes upon the diet and food consumption of one of the most important top predators, the minke whale (*Balaenoptera acutorostrata*), can be analysed. This paper, however, emphasises the interaction between herring and Northeast Atlantic minke whales.

The spring spawning herring is a commercially very important fish species in the Northeast Atlantic. The distribution and migration of Norwegian spring spawning herring has changed the last decades. Before the major collapse of the stock in the late 1960s, the stock was distributed in the Norwegian Sea during most of the year. However, after the collapse its distribution became more coastal and the stock began to winter in different Norwegian fjords. The spawning take place along the Norwegian coast, and the larvae are transported into the Barents Sea, mainly the southern parts, where they spend the first two to four years of life. Good recruitment gives strong cohorts and a large number of young, immature herring, in the southern parts of the Barents Sea.

The predation of Northeast Atlantic minke whales upon spring spawning herring is probably very high. In the period 1992-95, the Northeast Atlantic minke whale appeared to have consumed 633,000 tons of spring spawning herring per year. This corresponds to about 70% of the herring fisheries in the Northeast Atlantic in 1995. The major part of this herring (97%) was immature fish, mainly belonging to the strong 1991 and 1992 year classes. The abundance and dietary importance of herring appears to be well correlated. An example of this was when the major part of the 1992 year class migrated out of the Barents Sea in 1995. This was followed by a subsequent reduction in the dietary importance of herring (in the spring) by 50% as compared with the year before. The consequences the minke whales impact on the immature herring may have for the future recruitment of herring is difficult to say.

MIGRATORY PATTERN AND DIVE BEHAVIOUR OF BARENTS SEA HARP SEALS

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The Barents Sea population of harp seals (*Phoca groenlandica*) counts in the order of 600,000 animals, and represents an important component of the Northeast Atlantic marine ecosystem. The current study was undertaken to determine for the first time the seasonal migratory pattern, feeding areas and potential prey of adult Barents Sea harp seals by use of satellite tracking. In early May 1996, just after moulting in the White Sea, ten harp seals were equipped with head-mounted 0.5 W satellite-linked dive recorders (Wildlife Computers, Redmond, WA).

The longest individual track obtained was 309 days, while average life-time of the tags was 237±35 (SD) days, excluding two transmitters that were lost after less than 10 days. After release at 68.4°N and 42.6°E the seals immediately moved out of the White Sea and migrated northwest into the shallow Barents Sea (max depths 300-400 m), before they dispersed along the southern extension of the polar pack ice from 5°W to 87°E in July and August, in periods reaching as far north as 82°N. While the seals spent much of the time in close association with the pack ice, frequent foraging trips were made into open water of the Barents Sea.

In late autumn and early winter, when pack ice was distributed further south, the seals gradually moved south as well. Data on more than 134,000 dives showed that there are both seasonal and regional changes in dive activity and depths. In the period May-August 50-70% of dives were shallower than 50 m, while in September - October, 30-40% of dives were within this range. Still, a rather large fraction of dives were deeper than 100 m (15-51%) and 200 m (6-28%), indicating that both pelagic and benthic prey are important food for harp seals. It is concluded that Barents Sea harp seals within one yearly cycle are distributed over vast areas, covering parts of the Norwegian Sea and Kara Sea and all of the Barents Sea, and that the distribution and dive depths overlap with ecologically important and commercially interesting fish species like herring, capelin and cod.

MIGRATION PATTERNS OF FIN WHALES, BALAENOPTERA PHYSALUS: SHAKY OLD PARADIGMS AND LOCAL ANOMALIES

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Pelagic habits during both feeding and breeding cause fin whales to be among the least known of all mysticetes, as far as their migration patterns are concerned. According to common knowledge, fin whales migrate seasonally between localised, high-latitude summer feeding grounds and widely dispersed, warm-temperate and tropical winter breeding grounds. However, acoustic data collected in the North Atlantic from deep-ocean hydrophone arrays provide some differences with the traditional paradigm based on whaling records and visual surveys. Although a southward migratory flow during fall and a northward flow in spring are discernible in the acoustic data on either side of the Northern Atlantic, during winter whales are heard throughout the entire basin. Furthermore, acoustic activity is consistently intense in high latitudes (*e.g.*, Norwegian Sea) from September through April when animals are traditionally thought to be in lower latitudes.

Fin whales in the Mediterranean, which are considered a separate, resident population on the basis of genetic data, concentrate during summer in few highly productive localities to feed, whereas their winter distribution remains unknown. However, there are reports of high acoustic activity during the winter months. We suggest that during their winter breeding season Mediterranean fin whales may disperse over a wide range encompassing most of the basin, possibly maintaining social contact throughout the entire area by means of high-intensity, low-frequency vocalisations. However, unlike the oceans, the peculiar Mediterranean environment may provide whales opportunities for extending their breeding activities in summer, and their feeding activities in winter. It is thus not unlikely that fin whales in the Mediterranean have adapted to a more permissive environment by modifying their ecology, behaviour and reproductive physiology.

Clearly, more information is necessary on population and reproductive ecology, bioacoustics, feeding habits, and energetics of fin whales to fully understand the mechanisms shaping their complex distribution patterns, and to account for the many observed deviations from the "norm". We suggest that studies of the behavioural ecology of the year-round accessible, yet possibly aberrant Mediterranean fin whales may provide useful insight on such mechanisms, and on the ways in which the animals have adapted to varying and diverse environmental conditions.

ANTIPREDATOR BEHAVIOUR OF HERRING SCHOOLS DURING KILLER WHALE ATTACK IN NORTHERN NORWAY

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Antipredator strategies of Norwegian spring spawning herring (*Clupea harengus* L.) during repeated attack from killer whales (*Orcinus orca* L.) were studied in November 1993 in the herring's main overwintering area in Tysfjord, northern Norway. Predator-prey interactions were mapped using a high frequency multibeam sonar. This is one of the first field studies to apply sonar in studying behavioural relations between marine mammals and fish. The schools' repertoire of predator avoidance strategies included Tight ball, Bend, Dive, Split, Join, Hourglass, Vacuole, Herd and Fountain. Antipredator behaviour was dependent on size, relative density and shape of schools, in addition to the number and co-ordination of predatory killer whales. Functional explanations for the observed behavioural responses during killer whale attack are given.

NOTES ON ECOLOGY OF THE MEDITERRANEAN KRILL, A MIRROR OF THE BEHAVIOUR OF MEDITERRANEAN FIN WHALES

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The western part of the Ligurian Sea (Western Mediterranean) is known to be an area of abundance of the Euphausiid shrimp (*Meganyctiphanes norvegica*) and of summering of fin whales; the feeding of the whale on this krill was repeatedly verified by analysis of faecal residues. Autoecological characteristics of the Mediterranean krill are significantly different from those of the North Atlantic (the same is probably true for the harvesting strategies of its consumers): *M. norvegica* lives in a temperate tropical range of temperatures (12.8-25°C), reaches very deep waters (500-900m during the day) and spawns in winter. Its horizontal distribution is scarcely known and a progress in this direction would be useful to a better understanding of the behaviour of fin whales, at least in terms of their seasonal displacements. In the period 1990 - 1994, by several R/V surveys, a large scale sampling of *M. norvegica* was performed in the Ligurian-ProvenÁal basin. Seasonal patterns of relative abundance in terms of volumes in IKMT hauls were ascertained along four transect, which covered an area of about 8000 square nautical miles. The size structure of the catches was recorded in single stations in different seasons. An important biological borderline for *M. norvegica* was identified in the 43°N: north of this line, the adult share of population prevails and therefore the most relevant biomasses can be found at sea. Inside this area during distinct surveys patches of Euphausiids could be associated with hydrological fronts and densities of large pelagic animals, including fin whales and bluefin tuna could be related to those of the krill. It is concluded that the area in which the whales can found a rich pasture is rather limited (about 4,500 square nautical miles) and can therefore induce particular concentrations of the consumers. Hence caution is suggested in evaluation of total animals per various areas (*i.e.* the Western Mediterranean, the Ligurian-ProvenÁal basin, etc.); in the same time the need of protection for the pelagic resources of this area, at their different food levels, becomes stronger.

UNEXPECTED PREVALENCE OF COMMON DOLPHINS OVER SYMPATRIC BOTTLENOSE DOLPHINS IN EASTERN IONIAN SEA INSHORE WATERS

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Two sympatric communities of common dolphins (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncatus*) were studied from 1993 to 1996 in the coastal waters adjacent to the Greek island of Kalamos. Ad libitum surveys were conducted from June to October in an area of approximately 500 km^2, totalling 183 days spent at sea.

Although the common dolphin has reportedly declined in several portions of their former Mediterranean range during recent times, common dolphins in the study area were encountered twice as frequently as bottlenose dolphins. Both species were consistently observed in the same inshore waters, but mixed groups were rare. We spent 74% of the total observation time (327 h) with common dolphins, 24% with bottlenose dolphins, and 2% with groups including both species. A total of 100 common dolphins and 25 bottlenose dolphins were photoidentified by means of long-term natural marks on their dorsal fins. Most individuals of both species were consistently resighted across the study period, and showed a high level of site fidelity during the summer.

Photo-identification data analysis also indicate that the common dolphin community was larger than the small and rather discrete bottlenose dolphin community. Common dolphin groups averaged 10.2 individuals, with a mode of 5, while bottlenose dolphin groups were significantly smaller (mean 6.4, mode 3).

According to the current scenario on the status of the common dolphin in the Mediterranean Sea, the predominance of this species over the opportunistic and wide-spread bottlenose dolphin is surprising. Therefore, the study site provides remarkable opportunities to conduct comparative research that may shed light on the causes that determined the decline of the common dolphin in other Mediterranean areas, where other cetacean species are still regularly found.

CHARACTERISTIC OF FIRST FEEDING TRIP OF NORTHERN FUR SEAL FEMALES ON THE BERING ISLAND, KAMCHATKA, RUSSIA

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The northern fur seal population on Commander Is. in 1950-90 increased or was stable while on Pribilof Is. (USA) and Robben Is. (Russia), it declined. The study of foraging ecology and feeding behaviour is important to understand differences in population terends of northern fur seals. Foraging behaviour during the first trip to sea after parturition was investigated for 15 known aged females of northern fur seals on Bering island in 1995. Females spend on shore after parturition an average of 5.87 days (SD=1.77). Time onshore of females correlated with their age ($p<0.05$) and pup sex ($p<0.001$). Most females have left shore for a trip to sea at night and were back during day or night. The feeding trip duration of females was 5.23 days (SD=1.68).

There was a negative correlation between feeding trip duration and mother's mass ($r = -0.47$; $p<0.05$) for both sexes offspring and mother's age ($r = -0.45$; $p<0.05$) for female pups only. Daily mass loss during period from parturition to end of first trip to sea were 0.31 kg for mothers of female pups and 0.51 ($p=0.005$) for mothers of male pups.

In contrast to northern fur seal females on Pribilof Is., females on the Bering Is. have a shallow diving pattern. They are diving at night only and have a maximum depth dive of 153 m. The average depth of dives for all females was 11.3 m. During feeding trips, females have 7-8 diving series with 143 dives into each series. Females spend 23% of time for feeding diving, 45.8% of time for resting, and 31.2% of time for swimming and other behaviours during feeding trip.

We found a negative correlation between female age and time of rest after dives at sea ($r = -0.47$; $p<0.05$) and a positive correlation between "bottom time" and female age ($r = 0.62$; $p<0.05$), and "bottom time" female mass ($r = 0.49$; $p<0.05$). Most females are feeding in the pelagic waters of the Bering Sea approximately 200-300 miles to the north of the Commander Islands.

STUDIES OF RINGED SEALS (*PHOCA HISPIDA*) FEEDING HABITS IN THE BARENTS SEA AND POSSIBLE NICHE OVERLAP WITH HARP SEALS (*PHOCA GROENLANDICA*)

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Feeding ecology studies of Barents Sea ringed seals (*Phoca hispida*) and harp seals (*Phoca groenlandica*) were carried out in the North-eastern Barents Sea in October 1995. A simultaneous acoustic survey, aimed to estimate the abundance of potential prey items, was conducted concurrently with the sealing activities. A total of 18 and 27 harp and ringed seals, respectively, were included in the feeding study.

Of the 18 harp seals sampled, food was mainly found in the intestines. A minimum of five prey categories were identified, with polar cod (*Boreogadus saida*) and the amphipod *Themisto libellula* being the most frequent. Some T. libellula was found in stomachs, whereas polar cod dominated in the intestines. In terms of calculated fresh prey biomass polar cod contributed 62% to the intestinal contents, *T. libelulla* 20% and snailfish 11% (Liperidae).

None of the 27 ringed seal stomachs/intestines sampled were empty. Nine identified prey species occurred in stomachs and two in the intestines. Dominant prey items in stomachs were polar cod and *T. libellula*. Polar cod was also the most abundant prey item in the intestines. In terms of calculated fresh biomass, *T. libellula* contributed with 81% of the intestinal contents, when polar cod was the only other identified prey item. Applying the same index to stomach remains, it appeared that polar cod contributed with 87 % of the biomass.

Pianka's measure of niche overlap (O_{jk}) was used to quantify a prospective niche overlap between the two seal species. Calculated biomass values were the basis for calculations. Niche overlap was observed between the ringed, and harp seals, in that the two seal species exploit 90% of the same resources. A significant niche overlap between the two seal species in the examined area is therefor suggested.

EPIDERMAL LESIONS ON BOTTLENOSE DOLPHINS: A PRODUCT OF POLLUTION OR THE NATURAL ENVIRONMENT?

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It is now known that anthropogenic pollutants can reduce immune function in marine mammals and, by increasing susceptibility to disease, may affect population viability. However, little is known about how human impacts interact with endemic disease in wild populations and thus what overall effect they have. To compound this problem, the natural environmental factors influencing disease are little understood in themselves.

In this comparative study, a range of bottlenose dolphin populations were selected representing a spectrum of natural and human-impacted variables and the levels of epidermal disease examined. Ten populations were selected from European, Austral-Asian and North American waters. From each, a sample of photo-identification pictures was chosen and the presence and severity of epidermal lesions determined from digitised pictures.

Epidermal lesions were common in all populations with prevalences ranging between 68 and 98%. Of the different types observed, some were universal, whilst others were restricted to only neighbouring populations. Multivariate analyses were used to compare these levels against natural variables (water temperature, salinity, UV exposure) and pollution (organochlorine, heavy metal burdens and sewage exposure). The strongest relationships with disease were found amongst the natural variables, demanding a better understanding of these before anthropogenic impacts can be fully interpreted

SITE FIDELITY, SEASONAL RESIDENCE AND SEX RATIO OF FIN WHALES (*BALAENOPTERA PHYSALUS*) IN THE LIGURIAN SEA FEEDING GROUNDS

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Presence and site fidelity of fin whales (*Balaenoptera physalus*) in the Ligurian Sea, the principal feeding ground for this species in the Mediterranean, were studied using photo-identification techniques during dedicated cruises on eight consecutive summers (1990-1997). A total of 328 individuals were identified, 62 of which were resighted at least once during the study period. Re-sighting rate was established at 18.9%; 45 resightings occurred on different years and 24 within the same season. Individuals were resighted up to 4 times on different years, while within-season resightings ranged from 1 to 3. The rate of discovery was steadily increasing throughout the study, thus confirming previous line-transect data indicating that this whale population is still much greater than the photo-identified sample. Resighting data point to the existence of a persistent site-fidelity by whales to this feeding ground. The seasonal residence of re-sighted whales varied from 1 to 90 days indicating that at least some whales spend the entire summer in the Ligurian Sea to feed on the abundant euphausiid *Meganyctiphanes norvegica.*

Genetic analyses of remotely collected skin biopsies allowed gender determination of 100 whales, 51 of which were female, 49 male; sex ratio did not significantly differ from 1:1 ($P<0.01$). Group size varied from 1 to 7 (mean=1.94, S.E.=0.071, mode=1). When both individuals in pairs could be sexed (14 cases), neither gender was predominant, while significative difference existed in the occurrence of male-female pairs versus couples of the same gender ($P<0.05$). This argues against sexual segregation of fin whales on the Ligurian Sea feeding grounds.

BEHAVIOUR

FIN WHALE REACTIONS TO RESEARCH VESSELS, ASSESSED BY THE USE OF LASER RANGE-FINDING BINOCULARS AND RESPIRATION MONITORING

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INTRODUCTION The fin whale (*Balaenoptera physalus*) is the only species of Mysticete to be regularly sighted in the Mediterranean Sea (Notarbartolo di Sciara and Demma, 1994). During the summer, the Corso-Ligurian Basin represents the main feeding ground of the Mediterranean fin whale population, due to the presence of large swarms of Meganyctiphanes norvaegica, their principal prey item (Relini *et al.*, 1992). The Corso-Ligurian Basin is exposed to high levels of boat traffic year-round. However, traffic peaks in the summer, when a large number of tourist boats concentrate in the area. Despite its slow expansion, the whale-watching industry represents a potential source of disturbance for fin whales.

In order to introduce guidelines that may limit the harassment of the whales, baseline information on their behaviour and on the potential effects of disturbance from vessels is needed.

This study proposes a new tool for describing cetacean behaviour and investigates the impacts of boat disturbance on Mediterranean fin whales in terms of horizontal swimming speed, course and diving behaviour (*e.g.*, various respiration parameters).

MATERIALS AND METHODS The study was conducted in the Ligurian Sea, between June and September 1995 and 1996, over an area bounded by the co-ordinates 44°00'N-42°20'N and 07°40'E-09°20'E. Observations were made from the deck of the 19.8 m ketch motorsailer Gemini Lab. A total of 135 days were spent in the field.

The experimental protocol consisted of two phases:

i) Control (Low Disturbance): a 60-min period when the main vessel manoeuvred at minimum speed and kept a distance of several hundred metres from the whale.

ii) Experimental (High Disturbance): a 60-min period (max.) during which a 4.20 m inflatable boat (25 HP outboard engine) approached the whale to enable photo-identification and biopsy sampling.

Surfacing intervals for individual whales were timed to the nearest second throughout both phases of the experiment. Simultaneously, the range and bearing to the whales were measured using Leica Vector 1500 DAES 7x42 Class 1 laser range-finding binoculars. This information was automatically downloaded to a portable computer with concurrent GPS boat position.

Purpose written software combined the information from the GPS and the laser range-finding binocular to calculate the co-ordinates of the whale, using trigonometric functions (Fig. 1).

The accuracy of the technique was previously assessed by tracking a zodiac, equipped with a GPS for independent position determination, from a fixed point ashore (Biassoni, 1996).

To avoid potential ambiguities caused by contiguous surfacings of indistinguishable whales, only complete dive-surfacing cycle data from single-whale sightings were considered.

A dive was defined as any interval between successive blows lasting 26 or more seconds. This cut-off time was determined by employing the log-survivorship analysis (Fagen and Young, 1978). Other respiratory parameters considered included: (1) blow interval (any interval shorter than 26 seconds); (2) surface time (??blow intervals); (3) cycle length (dive time +surface time); (4) N of blows per surfacing; blow rate (??N of blows per surfacing/??cycle length x3600), and (5) percentage of time spent at surface (?? surface time/? cycle length x100).

Horizontal swimming speed (m/s) and milling index (linear distance/travelled distance, between the first and last blow of each phase) (Tyack, 1982) were also calculated. Differences between experimental and control phases were statistically tested using Wilcoxon's signed-rank test.

RESULTS A total of 14 individual fin whales were successfully tracked, mean experimental duration was 2h 24 min (SD=0.45). Results for the control and experimental phases of this study are summarised in Table 1.

The "experimental" phase of this study was characterised by significant increases in horizontal swimming speed ($p<0.05$) and milling index ($p<0.05$), and by significant decreases in surface time ($p<0.01$), No. of blows per surfacing ($p<0.01$), blow rate ($p<0.05$), and percentage of time at the surface ($p<0.01$). No significant differences were found between the two phases for dive time, cycle length and blow interval.

CONCLUSIONS The new method presented here enabled to describe fin whale behaviour and to quantify their reactions to approaching vessels.

The results are in accordance with the few similar studies conducted on this and other cetacean species: disturbed whales seem to increase their speed and spend less time at the surface in response to approaching vessels (Baker *et al.*, 1982; Richardson *et al.*, 1986; Kruse, 1991; Gordon *et al.*, 1992; Stone, 1992; Weinrich *et al.*, 1992; Sadove and Kopelman, 1995; Michaud and Giard, 1997).

Mediterranean fin whales showed significant responses to the presence of boats. The increase in swimming speed and in the linearity of their course (milling index), characterising the "experimental" phase of the experiment, suggests that the animals interrupted routine behaviours to move away from the disturbance source.

The concurrent decrease in the percentage of time spent at the surface may represent a strategy adopted by fin whales to reduce energy expenditure during their flight, as it is known that underwater swimming is more energy efficient (Kooyman, 1973; Sumich, 1981).

These results suggest that disturbance from vessels could have potential long-term consequences for the Mediterranean fin whale population. The Corso-Ligurian Basin is the principal feeding ground for this species in the Mediterranean Sea (Relini *et al.*, 1992) and any displacement of individuals from this area could be detrimental to the entire population.

The reduction of the time spent at the surface is another cause of concern. Fin whales control ventilation by modifying the dive/surface ratio: reducing the time spent at the surface would reduce oxygen reservoirs and could lead to shorter dives, because cetaceans tend to avoid anaerobic metabolism (Kooyman *et al.*, 1981; Kanwisher and Ridgway, 1983; Dolphin, 1987; Fish, 1992).

The Mediterranean population appears to feed mainly in the water column, as animals from this population have never been seen feeding at the surface, and any reduction in the dive time duration could affect their feeding success and may have repercussion on energy budgets and reproductive success.

In order to investigate any long-term effects of this disturbance we recommend that monitoring should be continued.

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REFERENCES

Baker, C.S. and Herman, L.H. 1982. *The impact of vessel traffic on the behavior of humpback whales in Southeast Alaska.* Unpubl. Rep. to NMFS Natl. Mar. Mammal Lab., Contract 81-ABC-00114, Seattle, 39pp.

Biassoni, N. 1996. *Modificazioni comportamentali indotte dalla presenza di imbarcazioni nella Balenottera comune,* Balaenoptera physalus *(Linnaeus, 1758), nel Mar Mediterraneo.* Degree thesis, Universit‡ degli Studi di Milano (Italy), Facolt‡ di Scienze biologiche. 81pp.

Dolphin, W.F. 1987. Dive behavior and estimated energy expenditure of foraging humpback whales in Southeast Alaska. *Can. J. Zool.*, 65: 354-362.

Fagen, R.M. and Young, D.Y. 1978. Temporal patterns of behaviour: durations, intervals, latencies and sequences. Pp. 79-114. In *Quantitative Ethology.* (Ed. F.W. Colgan). Wiley-Interscience, New York.

Fish, F.E. 1992. Acquatic locomotion. Pp. 34-63. In: *Mammalian energetics: interdisciplinary views of metabolism and reproduction.* (Eds. T. Thomasi and T. Horton). Comstock Publ. Assoc., Ithaca. 276pp.

Gordon, J., Leaper, R., Hartley, F. G. and Chappell, O. 1992. *Effects of whale-watching vessels on the surface and underwater acoustic behaviour of Sperm whales off Kaikoura, New Zealand.* Dept. of Cons., Science and Research series No. 52. Wellington, New Zealand.

Kanwisher, J.W. and Ridgway, S.H. 1983. The physiological ecology of whales and porpoises. *Sci. Amer.*, 248 (6): 110-120.

Kooyman, G.L. 1973. Respiratory adaptations of diving mammals. *Am. Zool.*, 13: 457- 468.

Kooyman, G.L., Castellini, M.A. and Davies, R.W. 1981. Physiology of diving in marine mammals. *Ann. Rev. Physiol.*, 43: 343- 356.

Kopelman, A.H. and Sadove, S.S. 1995. Ventilatory rate differences between surface-feeding and non-surface-feeding Fin whales (*Balaenoptera physalus*) in the waters off eastern Long Island, New York, U.S.A., 1981-1987. *Mar. Mamm. Sci.*, 11(2): 200-208.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. Pp 149-59. In *Dolphin societies. Discoveries and puzzles* (Eds. Pryor, K. and K. S. Norris). University of California Press, Berkeley, CA.

Michaud, R. and Giard, J., 1997. VHF tracking of fin whales provide scientific ground for the management of whale watching in the St. Lawrence estuary. WMMS, Monaco, January 1997, Abstract Volume. p.91.

Notarbartolo di Sciara, G. and Demma, M. 1994. *Guida dei mammiferi marini del Mediterraneo.* Franco Muzio Editore, Padova. 262pp.

Relini, G., Orsi Relini, L., Cima, C. , Fasciana, C., Fiorentino, F., Palandri, G., Relini, M., Tartaglia, M.P., Torchia, G. and Zamboni, A. 1992. Macroplankton, *Meganyctiphanes norvegica* and *Balaenoptera physalus* along some transects in the Ligurian Sea Pp. 134-137. In *European Research on Cetaceans - 6.* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb 1992. European Cetacean Society, Cambridge, UK. 254pp.

Richardson, W.J., Davies, R.A., Evans, C.R., Ljungblad, D.K., and Norton, P. 1986. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. *Arctic*, 40(2): 93-104.

Stone, G.S.,. Katona, S.K., Mainwaring, A., Allen, J.M. and Corbett, H.D. 1992. Respiration and surfacing rates of Fin Whales (*Balaenoptera physalus*) observed from a lighthouse tower. *Rep. Int. Whal. Commn*. 42:

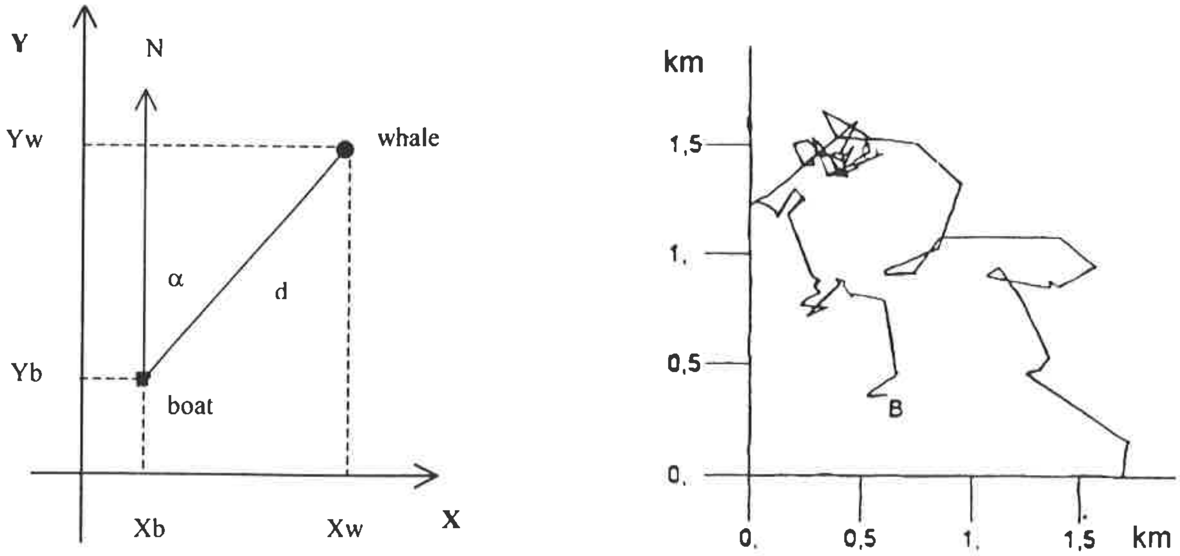
Sumich, J.L. 1982. Swimming velocity, breathing patterns, and estimated costs of locomotion in migrating gray whales, *Eschrichtius robustus. Can. J. Zool.*, 61: 647-652.

Tyack, P. L. 1982. *Humpback whales respond to the sound of their neighbours.* Ph.D. Dissertation, The Rockfeller University. 204pp.

Weinrich, M.T., Lambertsen, R.H., Belt, C.R., Schilling, M. R., Iken, H.J. and Syriala, S.E. 1992. Behavioural reactions of humpback whales (*Megaptera novaeangliae*) to biopsy procedures. *Fish Bull.*, 90: 588-598.

Table 1 Summary of the results. Sd=1 standard deviation

Parameters	Control ($\bar{X}$±sd)	Experimental ($\bar{X}$±sd)	Wilcoxon signed-rank test (n=14)
swimming speed (m/s)	1.13 ± 0.38	1.38 ± 0.41	P<0.05
milling index	0.50 ± 0.23	0.64 ± 0.26	p<0.05
dive time (s)	238.38 ± 146.62	207.78 ± 89.20	p>0.05
blow interval (s)	17.22 ± 1.53	17.51 ± 1.63	p>0.05
surface time (s)	84.47 ± 41.30	52.76 ± 17.28	p<0.01
N of blows per surfacing	5.42 ± 2.68	3.54 ± 1.15	p<0.01
blow rate (blows/h)	66.28 ± 22.74	55.12 ± 18.66	p<0.05
cycle length (s)	313.51 ± 173.10	250.35 ± 93.18	p>0.05
% time at the surface	23.98	18.31	p<0.01



$$X_{whale} = X_{boat} + d * \sin(\alpha * \pi/180)$$

$$Y_{whale} = Y_{boat} + d * \cos(\alpha * \pi/180)$$

Fig.1. Trigonometric functions used to calculate the whale position (N=magnetic north) and a whale track example (B = beginning of the experiment)

EARLY SOCIAL DEVELOPMENT IN BOTTLENOSE DOLPHIN CALVES WITH SPECIAL REFERENCE TO THE ROLE OF ADULT MALES

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INTRODUCTION The social organisation of bottlenose dolphins (*Tursiops truncatus*) is based on complex, dynamic relationships between the members of each community (Irvine *et al.*, 1981). The most cohesive association is the mother-infant bond, which exceeds the period of nutritional dependency of the offspring by far (Smolker *et al.*, 1993, Wells *et al.*, 1987). The prolonged contact between mother and calf is considered to support learning processes important to the survival within a social group.

According to observations both from captivity and the wild, parental investment is exclusively supplied by dolphin mothers. Within the envelope of the social community, assistance to the mother may be given during and shortly after the birth or during foraging activity. The assisting animals were, whenever identifiable in the wild, found to be females ('aunts'), whereas in captive situations both sexes and even various species were observed with very young bottlenose dolphin calves (e.g. Essapian, 1963). Attention by adult males then often resulted in aggression towards the calves. In the wild males are generally assigned protective functions for the group rather than specific responsibilities in rearing the calves (*e.g.* Leatherwood, 1977).

Considerable progress in the understanding of the behavioural development in captive mother-infant pairs has been made due to breeding successes in various institutions all over the world (e.g. Chirighin, 1987; Eastcott and Dickinson, 1987). Nevertheless, there has been a lack of opportunities to closely observe the rearing of calves in richly structured captive environments, both socially and physically, and in wild populations. Therefore, influences of other individuals but the mother, especially of adult males, might have been underestimated or left unnoticed.

The semi-free housing conditions in the Dolphin Reef Eilat, Israel, allow the observation of bottlenose dolphin calves born into a colony of mixed sex and age classes (Todt and Hultsch, 1996). Presented here are data collected over a period of three years to document the social relationships of calves to their mothers, and to the other individuals of the group throughout their first three months of life (Bojanowski, 1995).

MATERIAL AND METHODS **Study site**: The Dolphin Reef Eilat is situated in the Gulf of Aqaba, Israel. Its open sea enclosure encompasses a surface area of about 10,000 square metres with a maximum depth of approximately 15 metres. It includes typical marine habitats of subtropical and tropical regions inhabited by a variety of characteristic benthic and pelagic organisms.

Subject animals: At the onset of scientific observations in June 1994, the dolphin colony consisted of six individuals, five wild-born adults (sex ratio 2.3) held in the semi-free enclosure since 1990, and a two-year old female born in the facility. Included in the study are data on three calves, two males born in June 1994 and one female born in June 1995.

Data sampling: Data sampling covered the first three months after the births of two male calves in June 1994 and a female calf born in June 1995. Quantitative data were taken in 30-second intervals, while additionally documenting specific behavioural patterns and interactions upon occurrence (Todt and Hultsch, 1996). Observation hours excluded feeding times (four times daily, each approx. 15 min), and hours varied daily to cover the whole daylight period. A total of 141 observation hours were analysed for the present study. Data sampling was conducted from an observation platform overlooking the dolphin area (approx. 10 metres above sea level).

Analyses of the data presented here focused on behaviours, which are identifiable from the surface, with emphasis on distance and degree of synchronisation to assess association patterns. A calf was reported as being 'with' the respective individual if 1) both animals move and breathe synchronously within a distance of less than one body length (2.5 metres) or 2) both animals engage in the same activity or interaction (e.g. chasing, pushing, stroking) while being within a distance of less then one body length. Two general categories of mother and calf separations were distinguished: A) solitary separation: the calf leaves or is left by the mother without joining or being joined by another individual; B) social separation: the calf joins or is joined by another individual while separated from the mother. It is important to know that none of the observed separations between the mother-calf pairs involved physical barriers of any kind, but were defined by spatial distance between individuals only.

Although not formally independent, all sightings were treated as independent events for statistical analyses, mainly because individuals may disappear from sight in between sightings, so that no information was available on exact duration of associations, or separations of mothers and infants respectively. Data sampling continued through to the present (July 1998), enabling the coverage of another three calves born to the same three females included in the data presented here. Since the two male calves born in June 1994 were the first born to their respective mothers, these data will be used *e.g.* to assess the importance of prior experience of the females in rearing calves.

RESULTS & CONCLUSIONS Calves associated with other individuals but their mothers from their first week of life (see Fig. 1). For all three observed calves, both frequency and duration of separations from their mothers increased significantly in correlation to age (Spearman's rank correlation coefficient 0.69-0.97). Close associations with individuals other than their mothers varied mainly in identity of individuals occurring as associates and the frequency of their occurrence over time. Adult females were dominant associates of all three calves throughout the first two months, averaging a share of 50.9-73.7% in weeks where social separations occurred. The most striking difference concerns adult males, which were close associates of all three calves in their third month of life, but occurred as early as in week four with one particular male calf (see Fig. 2). For both male calves, the same adult male was the only individual they associated with more often than expected in case of random distribution of all possible individuals as associates Chi^2 test for 'goodness of fit', $p<0.001$).

Besides indicating individual differences from calf to calf (and in the behaviour of the mothers, see above), data suggest other individuals of the social group including adult males to play roles in rearing dolphin calves. As discussed for numerous primate species with extensive adult male - infant interactions (see review by Whitten 1987), there is the potential for the utilisation of young dolphin calves as social tools by individuals of different sex, age and social status. The term social tool is referring to possible reasons for the use of infants, for gaining access to desired resources (e.g. females), as "passports" or "agonistic buffers", or for protection (as discussed for primates by Strum, 1984). Comparisons with results from wild populations only will unequivocally show if the association patterns observed under spacious but nevertheless captive conditions reflect the social organisation of wild bottlenose dolphin, or are artifacts of the housing conditions.

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REFERENCES

Bojanowski, E. 1995. *Zur frühen Entwicklung des Mutter-Kalb-Verhaltens beim Großen Tümmler* (Tursiops truncatus) *in einer unter halbfreien Bedingungen lebenden Kolonie*. Diplom Thesis, Free University of Berlin, 79 pages.

Chirighin, L. 1987. Mother-Calf Spatial Relationships and Calf Development in the Captive Bottlenose Dolphin (*Tursiops truncatus*). *Aquatic Mammals*, 13(1): 5-15.

Eastcott, A. and Dickinson, T. 1987. Underwater Observations of the Suckling and Social Behaviour of a New-born Bottlenosed Dolphin (*Tursiops truncatus*). *Aquatic Mammals*, 13(2): 51-56.

Essapian, F.S. 1963. Observations on Abnormalities of Parturition in Captive Bottlenose Dolphins, *Tursiops truncatus*, and Concurrent Behavior of Other Porpoises. *Journal of Mammalogy*, 44: 404-414.

Irvine, A.B., Scott, M.D., Wells, R.S. and Kaufmann, J.H. 1981. Movement and activities of the Atlantic bottlenose dolphin near Sarasota, *Fishery Bulletin*, 79(4): 671-688.

Leatherwood, S. 1977. Mother-infant interactions of bottlenose dolphins in captivity and at sea. Pp. 143-167. In *Breeding dolphins: Present status, suggestions for the future*. (Eds. S.H. Ridgway & K. Bernischke). Final report to U.S. Marine Mammal Commission, Report No. MMC - 76/07.

Smolker, R.A., Mann, J. and Smuts, B.B. 1993. Use of signature whistles during separations and reunions by wild bottlenose dolphin mothers and infants. *Behav. Ecol. Sociobiol.*, 33: 393-402.

Strum, S.C. 1984. Why males use infants. Pp. 146-185. In: *Primate Paternalism* (Ed. D.M. Taub). Van Nostrand Reinhold, NewYork.

Todt, D. and Hultsch, H. 1996. Projects and perspectives of a research programme established at the Dolphin Reef Eilat, Israel. Pp. 287- 290. In: *European Research on Dolphins* - 9. Proc. 9th Ann. Conf. ECS, Lugano, 9.-11. February 1995 (Eds. P.G.H. Evans & H. Nice), European Cetecean Society, Kiel, Germany. 302pp.

Wells, R.S., Scott, M.D. and Irvine, A.B. 1987. The social structure of free-ranging bottlenose dolphins. Pp. 247-305. In *Current mammalogy*, vol. 1. (Ed. H. Genoways). Plenum, New York. 519pp.

Whitten, P.L. 1987. Infants and adult males. Pp. 343-357. In: *Primate Societies* (Eds. B.B. Smuts, D.L. Cheney, R.M. Seyfarth, R.W. Wrangham & T.T. Struhsacker). Chicago University Press, Chicago.

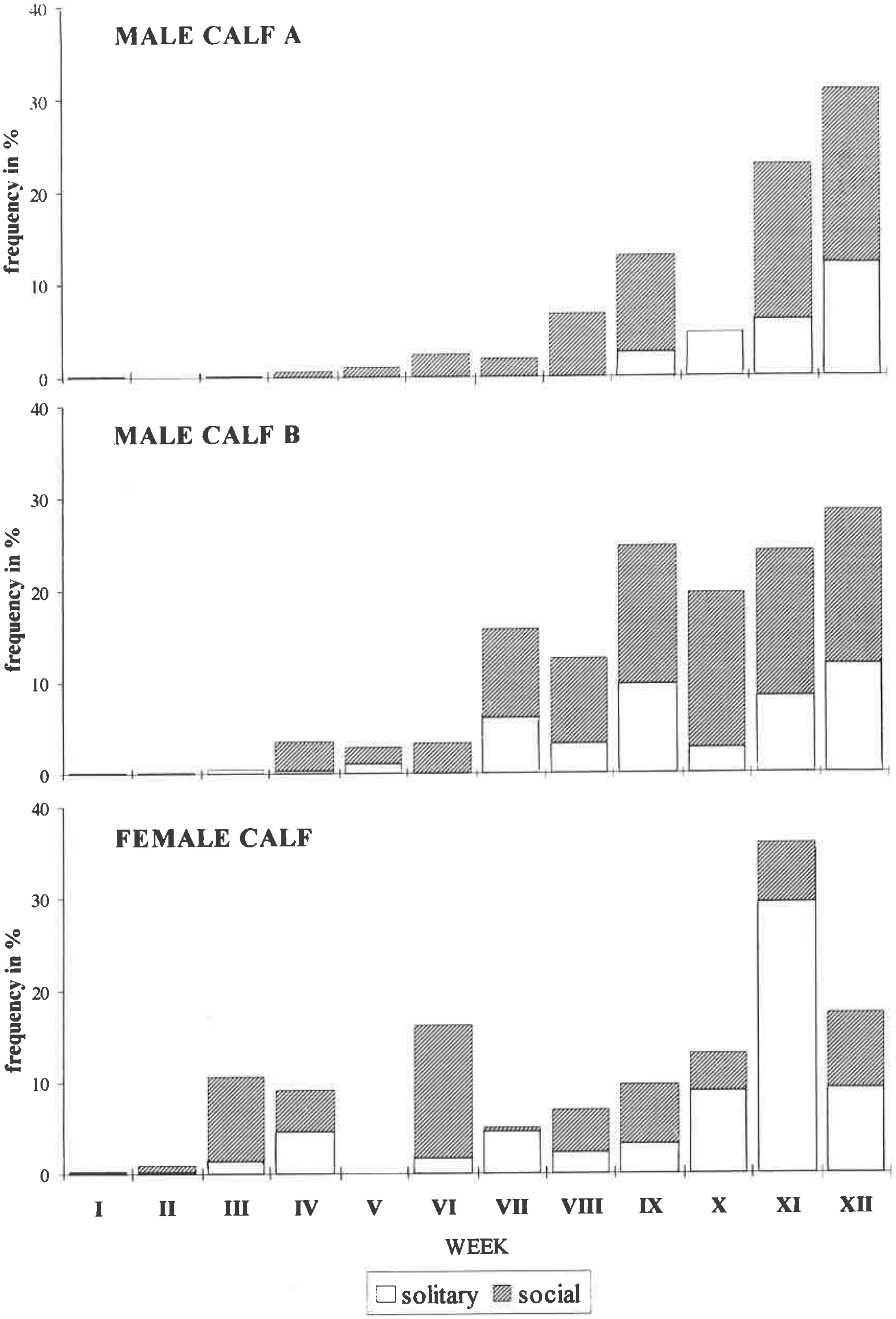

Fig. 1: Separated sightings of mothers and calves throughout the first twelve weeks of live, divided in two categories: A) solitary separations, B) social separations (for further details see text).

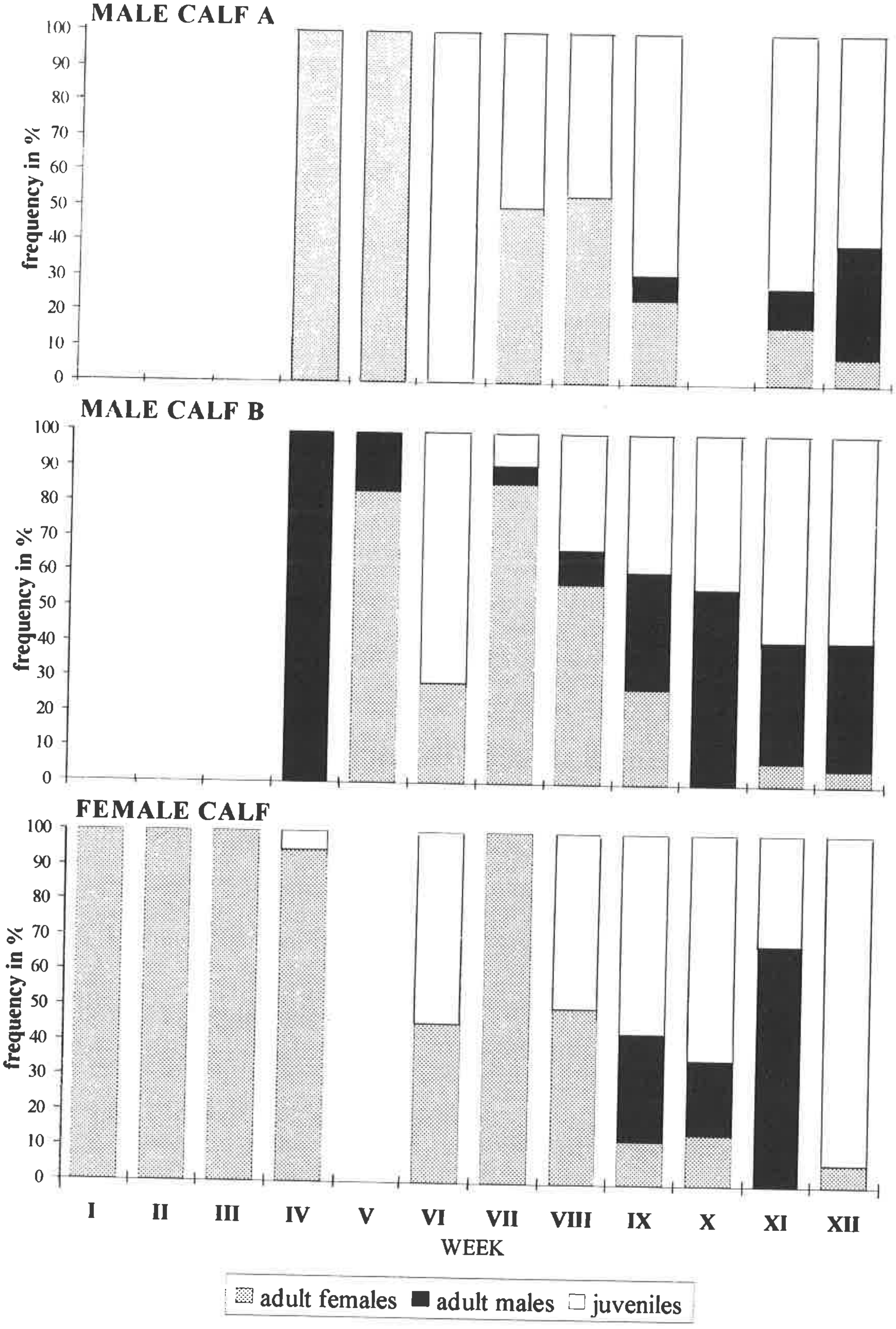

Fig. 2: Share of the different age and sex classes in the overall amount of sightings of calves with other individuals but their respective mothers throughout their first twelve weeks of life.

IS THE ALBORAN SEA A REGION OF SPECIAL IMPORTANCE FOR LONG-FINNED PILOT WHALES (*GLOBICEPHALA MELAS*) IN THE MEDITERRANEAN?

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The long-finned pilot whale (*Globicephala melas*) is a common species throughout the Western Mediterranean basin (Di Natale, 1986; Gannier, 1995). However, little is known about their population status and distribution, size, home range, etc. The Alboran sea is a region of extraordinary oceanographic conditions due to the influence of Atlantic waters, considered both as a transition chamber between Atlantic and Mediterranean, and as the oceanographic motor of the western Mediterranean basin (Rodriguez, 1982). The clashing of water masses in the region is responsible for the formation of important regions of productivity (Rubín *et al.*, 1992; Packard *et al.*, 1985). A comparative study has been carried out with data of this species in other regions of the Mediterranean, in order to establish the relative importance of the Alboran region for this species.

METHODOLOGY Sighting cruises have been carried out on board the 18 m sailing boat "Toftevaag" during the months of April, June, July, August, September and November 1992 to 1997, covering the south-eastern coast of Spain from Cabo de Palos - 37°38'N 0°33'W to Almerimar 36°20'N 2°55'W (Fig. 1). Navigation, oceanographic and meteorological data are recorded during surveys. Data recorded for all sightings include species, number of individuals, group structure, behaviour, etc. Since 1995, most of the data collected during surveys are directly logged from a GPS to a personal computer, using IFAW's LOGGER program. Whenever possible, individuals are photographed for photo-ID purposes. Since 1997, a towed array hydrophone has been used to detect and record cetacean sounds. For the analysis of distribution, the whole research region is divided into four major areas (I=north, II=centre, III=south and IV=southwest) which in turn are subdivided in 10*8 nautical miles (18.6 x 14,9 km) quadrats. In addition, six depth ranges are considered: 0-200, 200-500, 500-1,000, 1000-1500, 1,500-2,000 and >2,000 metres depth. Sea state is also taken into account for the analysis, being divided into five categories using Douglas sea state scale: 1, 1S, 2, 2S and 3 (S=swell) (approximate equivalence to Beaufort scale: 1 Douglas - Beaufort 0-2, Douglas 2 - Beaufort 3, Douglas 3 - Beaufort 4-5). Sighting effort stops with sea states over 3 Douglas. Surface and underwater video are used for analysing behaviour patterns and social structure in conjunction with acoustic recordings and ad-libitum notes.

RESULTS AND DISCUSSION Encounter rates. Survey cruises have covered 10531.6 nautical miles (19,589 km). A total of 109 sightings of long-finned pilot whales were made. The encounter rate calculated for this species was 1.035 sightings per 100 nm sailed in the research region. Under sea state 1 or 1S, the encounter rate was 1.339 sightings per 100 nm, with sea state 2 or 2S, the encounter rate went down to 0,638, and under sea state 3, it was only 0.204 (Fig. 2). These different results show the important effect of sea state on detectability of long-finned pilot whales, as they are usually seen resting or swimming slowly, and not breaching or splashing. An increase of sightings has been recorded in the last two years, and specially in 1996, with an encounter rate of 2.039 for 1996 (39 sightings) and 1.393 for 1997 (24 sightings). In comparison, rates of 0.577 for 1992, 0.782 for 1993, 0.855 for 1994 and 0.471 for 1995 were obtained (Fig. 3). Pilot whale observations totalled 159 hours.

The encounter rate obtained in this area (1,035) is much higher than those obtained for other areas in the Mediterranean, ranging from 0.0 to 0.178 (Souquet and Charriere, 1991; Fabbri and Lauriano, 1992; Pulcini *et al.*, 1993; Gannier *et al.*, 1994; Politi *et* *al.*,1994; Gannier, 1995; Barberis *et al.*, 1995; Barberis *et al.*, 1996). At the same time, the data obtained from strandings show a greater percentage in the Alboran Sea (Table 1), and the percentage of sightings of long-finned pilot whale in the Alboran Sea related to other cetaceans is much higher than in the rest of the Mediterranean basin (Table 2).

Distribution per depth. Most of the sightings were made in areas between 500 and 1200 m depth (83.33% of the sightings) with a peak in the area between 900 and 1,000 meters depth (20.37%) (Fig. 4). This contrasts with data provided by other authors which locate pilot whales in the Mediterranean in more than 2,000 m. depth (Giordano and Tringali, 1992; Gannier and Gannier, 1989). Some of the groups were tracked for several miles, and in most of the cases they seemed to follow a depth contour, especially between 600 and 1,200 m. depth.. These results apparently agree with the reported teutophagous feeding habits (Evans, 1987; Gannier, 1995; Relini and Garibaldi, 1992) on meso- and epi-pelagic cephalopods living mainly between 500 and 1,500 m depth (Guerra, 1992).

Group size and special behaviours observed in big groups. The average group size of the groups encountered was 41.4 (N=114, SD=58.402, range: 1 [big lone male) - 350). The peak frequency of group size range was 6-20 individuals (49 groups = 45%) (Fig. 5). These groups probably correspond to single pods as described by Heimlich-Boran (1993). The second most encountered group size range was between 21 and 60 individuals (34 groups = 31.2%). In these cases, the groups were usually split up in several subgroups of 8 to 15 individuals (maybe single pods) at distances of tens or hundreds of meters from each other, but mixing and splitting again several times. When this occured, usually the group structure seemed to stay the same before and after every mix and split (from visual observations). Calves were observed in 83.5% of the groups (100% of the groups every year, except in 1996 when 36,8% of the groups did not have calves), and many of them being new-borns, especially in June and beginning of July.

There are also several interesting encounters of big concentrations of pilot whales: 12 sightings of 100 or more individuals (11%) and 6 sightings of 200 or more animals (5.5%), including 2 sightings of more than 300 individuals. In three of these sightings (the two of more than 300 individuals and one of the more than 200), some outstanding behaviour was observed. At first sighting, several groups came from different directions to gather. When some of these groups or pods were intercepted before they joined the larger grouping, the animals showed very excited behaviour and much curiosity towards the ship and dinghy (more than usual with a lot of rubbing against the bow and spinning in vertical position by the hull of ship and dinghy), as well as towards the researcher filming underwater (in some cases "too much" interest was showed towards the diver). When all the animals were together in a big group, they stayed stationary. The ship then stopped its engine and stayed close by to observe and film activities.

Extensive surface behaviour was observed, including many jumps (even with the whole body out of water several meters high), tail slaps, spyhops, flipper slaps, breachings, erections, etc. Additionally, two big males were observed exhibiting very excited and violent movements around and against each other perhaps playing or fighting. In one of these groups, the whole group was observed simultaneously porpoising very fast in one direction for some seconds, and suddenly all changing direction 180° and porpoising again before stopping and staying in the same position. Most of these behaviours have been filmed. Underwater filming also shows very interesting behaviours. Big males were seen turning vertically very rapidly (spinning), each one surrounded by several other individuals. During the spinning, they would "bite" the surrounding individuals with the mouth wide open. On two occasions in different sightings, the diver cameraman was integrated into these "spinning groups", receiving "bites" which were aborted by the males at a few centimetres from the camera. Filming thereafter was carried out from the zodiac due to the insistence of pilot whales to integrate the diver in their groups. Much penile activity and several copulations were observed during these sightings, even at the bow of the ship.

Similar mating behaviour to that repeatedly observed in the Alboran Sea region has only once been reported for pilot whales in other parts of the Mediterranean, in the Ligurian Sea, where cetacean research effort has been historically more intense (Di Natale, 1986). These observations of free ranging long-finned pilot whales support the idea put forward by genetic research on captured animals of reproduction occurring between members of different pods (Amos *et al.*, 1993; Heimlich-Boran, 1993).

CONCLUSIONS The results obtained from the encounter rates and comparison with those obtained from other areas of the Mediterranean, as well as the observation of big concentrations of long-finned pilot whales in the area and the photographic "recapture" of many individuals throughout these first years of research seem to indicate that the Alboran Sea is an important area for this species in the Mediterranean.

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REFERENCES

Amos, B., Bloch, D., Desportes, G., Majerus, T., Bancroft, D., Barret, J.A. and Dover, G.A. 1993. A review of molecular evidence relating to social organisation and breeding system in the long-finned pilot whale. *Rep. Int. Whal. Commn* (Special Issue 14): 209-217.

Androukaki, E. and Tounta, E, 1994. A study of the distribution and pathology of cetaceans in Greece. Pp. 203-206. In *European Research on Cetaceans- 8* (Ed. P.G.H. Evans). Proc. 8th Ann. Conf. ECS, Montpellier, France, 2-5 March 1994. European Cetacean Society, Lugano, Switzerland. 288pp.

Barberis, S., Bonaccorsi, R., Chiarlone, F., Chiesa, O., Davico, A., Davico, L., Massajoli, M. and Trucchi, R. 1995. A preliminary study presenting data collected during a WWF research campaign in the Ligurian Sea (summer 1994). Pp. 108-109. In: *European Research on Cetaceans - 9.* Proc. 9th Ann. Conf. ECS. Lugano, Switzerland, 9-11 February, 1995 (Ed. P.G.H. Evans) European Cetacean Society, Kiel, Germany. 302pp.

Barberis, S., Chiarlone, F., Davico, A., Davico, L., Massajoli, M., Trucchi, R. and Varaldo, S. 1996. Monitoring of cetaceans in the Ligurian Sea: summer 1995. Pp. 122-124. In: *European Research on Cetaceans - 10.* (Ed. P.G.H. Evans). Proc. 10th Ann. Conf. ECS, Lisbon, Portugal, 11-13 March, 1996. European Cetacean Society, Kiel, Germany. 334pp.

Berrow, S.D. and Rogan, E. 1994. Ireland - A sanctuary for whales and dolphins: the implications of Irelands' Sanctuary Declaration.. Pp. 12-13. In: *European Research on Cetaceans - 8* (Ed. P.G.H. Evans). Proc. 8th Ann. Conf. ECS, Montpellier, France, 2-5 March, 1994. European Cetacean Society, Lugano, Switzerland. 288pp.

Boutiba, Z. 1989. *Repartition et frequence des Èchouagés des cétacés sur le littoral ouest algerien.* Séminaire national sur les Sciences et Technologies de la Mer. Alger, February.

Casinos, A. and Filella, S. 1977. Les cétacés de la Mediterranée espagnole: Ètat actuel de nos connaisances. *Rapp. Comm. Int. Mer. Medit.*, 24: 5.

Casinos, A. and Vericad, J.R. 1976. The Cetaceans of the Spanish coasts: a Survey. *Mammalia*, 40(2):1-29.

Castells, A. and Mayo, M., 1991. *Cetáceos de las costas españolas y portugesas.* Quercus. Madrid.

Di Natale, A. 1986. *New information about the pilot whale,* Globicephala melaena *Traill, in the Central Mediterranean Sea.* XVIII Congress and Plenary Assembly of the C.I.E.S.M., Cannes, December 2-11.

Duguy, R. 1978. Les mammifères marins de la Mediterranée occidentale. *Bulletin de la Société Zoologique de France*, 114(3).

Evans, P.G.H. 1987. *The Natural History of whales and dolphins*. Christopher Helm, London. 343pp.

Fabbri, F. and Lauriano, G. 1992. Greenpeace report on two years of research in the Ligurian Sea. Pp. 146-151. In: *European Research on Cetaceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb, 1987. European Cetacean Society, Cambridge, UK. 254pp.

Franco, I. and Mas, J. 1994. Distribution and evaluation of cetaceans in the Alboran Sea. P. 103. In: *European Research on Cetaceans - 8*. Proc. 8th Ann. Conf. ECS. Montpellier, France, 2-5 March, 1994. (Ed. P.G.H. Evans) European Cetacean Society, Lugano, Switzerland. 288pp.

Gannier, A. and Gannier, O. 1989. Some sightings of cetaceans in the western Mediterranean Sea. Pp. 62-64. In: *European Research on Cetaceans - 3* (Eds. P.G.H. Evans & C. Smeenk). Proc. 3rd Ann. Conf. ECS, La Rochelle, France, 24-26 Feb, 1989. European Cetacean Society, Leiden, The Netherlands. 132pp.

Gannier, A. 1995. *Résultats des campagnes et Exploitation: Les cétacés de Méditerranée nord-occidental: estimation de leur abondance et mise en relation de la variation saisonnière de leur distribution avec l'Ècologie du milieu*. PhD Thesis, Univ. of Montpellier, France.

Gannier, A., Beaubrun, P. and Di-Meglio, N. 1994. Cetacean occurrence in the Gulf of Lion and surroundings. Pp. 87-91. In: *European Research on Cetaceans - 8*. (Ed. P.G.H. Evans). Proc. 8th Ann. Conf. ECS, Montpellier, France, 2-5 March, 1994. European Cetacean Society, Lugano, Switzerland. 288pp.

Giordano, A. and Tringali, M., 1992. Presence and individual recognition of Globicephala melas in the Liguro ProvenÁal Basin. European Research on Cetaceans - 6. Proc. VI Ann. Conf. ECS. San Remo, Italy, 20-22 February, 1992. (Ed. P.G.H. Evans). European Cetacean Society.

Guerra, A. 1992. *Mollusca. Cephalopoda*. Fauna Iberica. CSIC. Vol. 1.

Grau, E., Aguilar, A. and Filella, S. 1980. Cetaceans stranded, captured or sighted in the Spanish coasts during 1976-1979. *Bull. Inst. Cat. Hist. Nat.*, 45 (Sec. Zool., 3).

Grau, E., Filella, S., Raga, J.A. and Raduán, A. 1985. Cetáceos varados en las costas del mediterráneo ibérico, durante los años 1980-1981. Misc. Zool., 10.

Heimlich-Boran, J.R, 1993. *Review of the life history and behaviour of pilot whales* (Globicephala *sp.). Social organisation of the short-finned pilot whale,* Globicephala macrorhyncus, *with special reference to the comparative social ecology of delphinids*. DPhil. Thesis, Cambridge, UK.

Marini, L. Consiglio, C., Maria, A. Sanna, A. and Valentini, T. 1992. Cetacean sighting campaign in the Central Tyrrhenian sea: Results of the Second year of activity. Pp. 66-68. In: *European Research on Cetaceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb, 1992. European Cetacean Society, Cambridge, UK. 254pp.

Packard, T.T., Minas, H.J., Coste, B., Martínez, R., Bonin, M.C., Gostan, J., Garfield, P., Christensen, J., Dortch, Q., Minas, M., Copin-Montequt, G., Copin-Montequt, C. and Roca, P. 1985. Formation of the Alboran Oxygen Minimum Zone.

Politi, E., Airoldi, S. and Nortarbartolo di Sciara, G. 1994. A preliminary study of the ecology of cetaceans in the waters adjacent to Greek Ionian Islands. Pp. 111-115. In: *European Research on Cetaceans - 8* (Ed. P.G.H. Evans). Proc. 8th Ann. Conf. ECS, Montpellier, France, 2-5 March, 1994. European Cetacean Society, Lugano, Switzerland. 288pp.

Pulcini, M., Angradi, A.M. and Sanna, A. 1993. Distribution and frequency of cetaceans in the Ligurian-Provençal basin and in the North Thyrrenian Sea (Mediterranean Sea). Pp. 144-147. In: *European Research on Cetaceans - 7* (Ed. P.G.H. Evans). Proc. 7th Ann. Conf. ECS, Inverness, Scotland, 18-21 Feb, 1993. European Cetacean Society, Cambridge, UK. 306pp.

Raga, J.A., Raduán, M.A. and Blanco, C. 1985. Contribución al estudio de la distribución de cetáceos en el Mediterráneo y Atlántico ibérico. *Misc. Zool.*, 9

Relini, L.O. and Garibaldi, F. 1992. Feeding of the pilot whale, Globicephala melas, in the Ligurian sea. A preliminary note. Pp. 138-145. In: *European Research on Cetaceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb, 1992. European Cetacean Society, Cambridge, UK. 254pp.

Rey, J.C. and Cendero, O. 1979. Les cétacés vus en mer et echoués sur les côtes espagnoles en 1977 et 1978. *Conseil International pour l'Exploitation de la Mer*. C.M. 1979 / N: 2.

Rey, J.C. and Cendero, O. 1981. Nouvelles informations sur les cétacés et pinnipèdes vus et Échoués sur les côtes espagnoles en 1980, et trouvailles en 1981. *Conseil International pour l'Exploitation de la Mer*. C.M. 1981 / N: 3.

Rey, J.C. and Cendero, O. 1982. Les mamifères marins trouvés sur les côtes espagnoles en 1981. *Conseil International pour l'Exploitation de la Mer*. C.M. 1982 / N: 6.

Rey, J.C. and Rey, J.M. 1979. Cetáceos varados en la costa surmediterránea española -mar de Alborán-durante los años 1975, 1976 y 1977. R. Soc. Española Hist. Nat. (Biol), 77.

Rodriguez, J. 1982. *Oceanografía del mar Mediterráneo*. Ed. Pirámide.

Rubín, J.P., Gil, J., Ruiz, J., Cortés, M.D., Jiménez-Gómez, F., Parada, M. and Rodriguez, J. 1992. La distribución ictioplanctónica y su relación con par·metros físicos, químicos y biológicos en el sector norte del Mar de Alboran, en julio de 1991 (Resultados de la Campaña "Ictio. Alboran 0791"). Instituto Español de Oceanografía. Informe Técnico No. 139, Madrid. 49pp.

Souquet, M. and Charreire, F. 1990. *Operation Cetacés 1990*. Unpubl. Report, Greenpeace France, Paris.

Souquet, M. and Charreire, F., 1991. *Operation cetacés 1991*. Unpubl. Report, Greenpeace France, Paris.

Area	%	Source
Alboran Sea	*18,8-33*	*Rey and Cendero, 1979; Rey and Rey, 1979; Rey and Cendero, 1981; Rey and Cendero, 1982; Castells and Mayo, 1991*
Algeria	3,10-5,5	Boutiba, 1989; Franco and Mas, 1994
NW Mediterranean (coast of Spain)	2,8-10,6	Duguy, (); Casinos and Filella, 1977; Grau et al., 1980; Grau et al., 1985; Castells and Mayo, 1991
Greece	0,8	Androukaki and Tounta, 1994

Table 1. Percentage of strandings of long-finned pilot whales (related to total strandings of all cetacean species) in different areas of the Mediterranean Sea.

Area	%	Source
Alboran Sea	*22,2-47,4*	*Casinos and Vericad, 1976; Raga et al., 1985; Castells and Mayo, 1991*
Algeria	3,6	Franco and Mas, 1994
Thyrrenic Sea	0,9	Marini et al, 1992
NW Mediterranean	0,5	Souquet and Charreire, 1990; Souquet and Charreire, 1991; Fabbri and Lauriano, 1992; Pulcini et al., 1993; Gannier et al., 1994; Gannier, 1995; Barberis et al., 1995; Barberis et al., 1996

Table 2. Percentage of sightings of long-finned pilot whales (related to total strandings of all cetacean species) in different areas of the Mediterranean Sea.

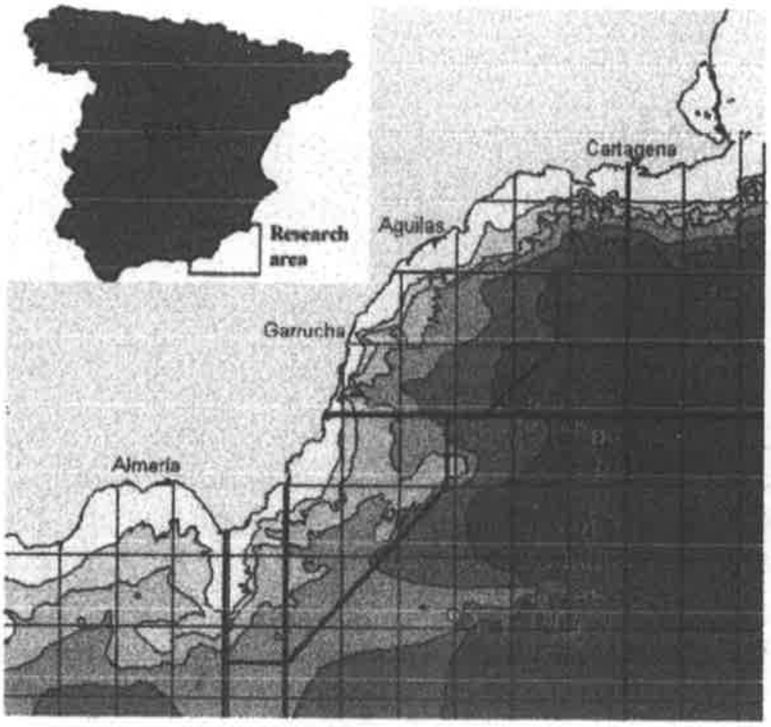

Figure 1. Research area

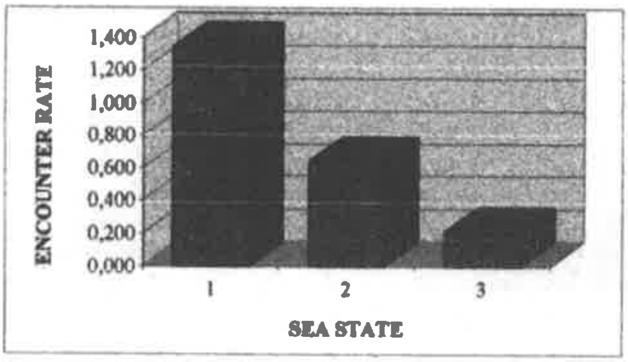

Figure 2. Encounter rates (sightings per 100 nautical miles surveyed) for pilot whales in the research area for different sea states.

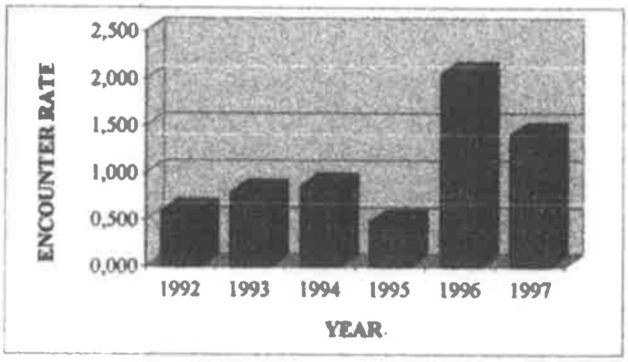

Figure 3. Encounter rates (sightings per 100 nautical miles surveyed) for pilot whales in the research area since 1992 to 1997.

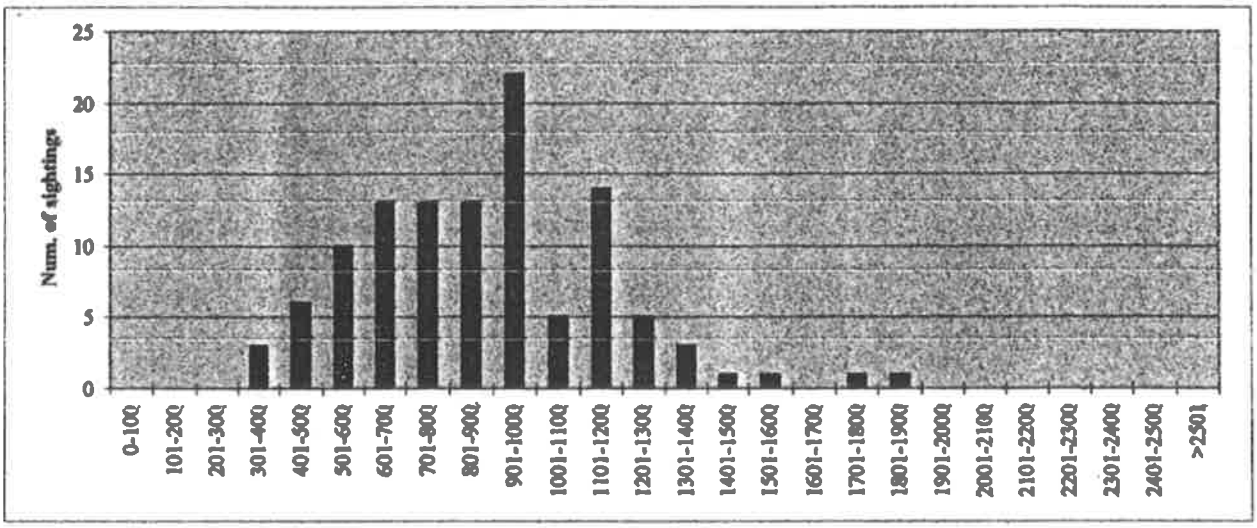

Figure 4. Frequency distribution of depth at encounters of pilot whales in the research area (1992-1997)

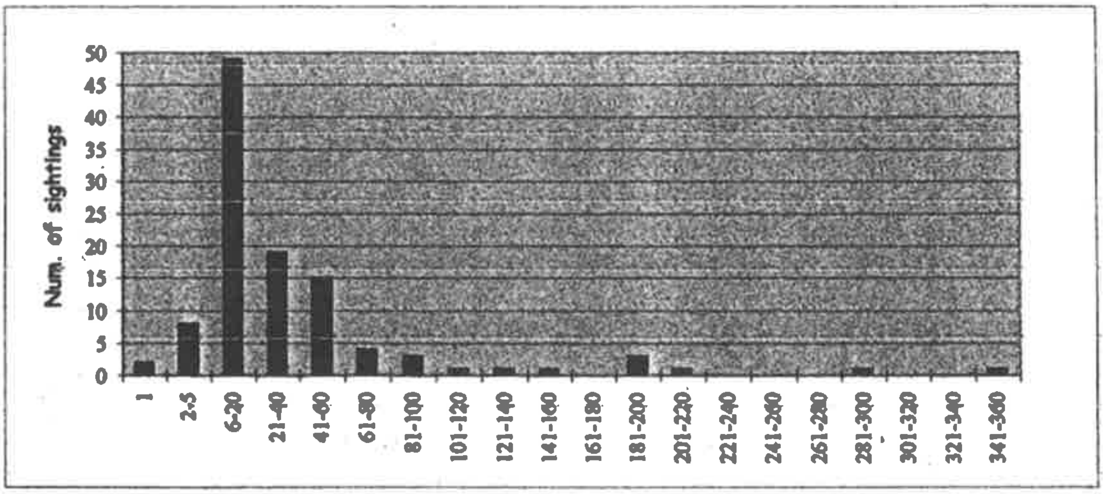

Figure 5. Frequency distribution of group sizes of pilot whales encountered in the research area (1992-1997)

INDIVIDUAL VARIATION IN GREY SEAL MATERNAL BEHAVIOUR IN A LOCAL BREEDING ENVIRONMENT.
WHAT ARE THE CONSEQUENCES FOR PUPS?

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INTRODUCTION Grey seal (*Halichoerus grypus*) female reproductive success is based on milk (energy) transfer from maternal stores to the pup. The efficiency of this transfer depends on physiological, environmental and **behavioural factors**.

The behaviour of lactating grey seal females and pups varies with:
- the breeding biotope (Anderson and Fedak, 1985; Kovacs, 1987; Haller *et al.*, 1996),
- the local breeding area (Anderson and Harwood, 1985; Twiss *et al.*, 1997),
- the pup sex and age (Anderson and Fedak, 1985; Kovacs and Lavigne, 1986; Kovacs, 1987; Bowen *et al.*, 1992),
- the pupping time (Boness *et al.*, 1995).

However, individual variation in maternal behaviour **within a defined social and topographical environment** has not been documented. In this study, we test the hypothesis of behavioural homogeneity in grey seal mothers facing similar ecological conditions.

METHODS Identified mother-pup pairs were observed using instantaneous scan sampling (Altmann, 1974; Martin and Bateson, 1993) in 1994, 1995 and 1996 breeding seasons for a total of 670 h divided between two study areas of the Isle of May, Scotland.

Behaviour of females was described by six mutually exclusive categories: (1) low activity = resting and low active non-social behaviours; (2) alert = head up, neck stretched, looking around; (3) aggressive interactions = non-sexual aggressive encounters; (4) interactions with pup = feeding, flippering, nosing or playing with pup; (5) locomotion = change of location; and (6) sexual interactions = attempted and successful copulations.

Behaviour of pups was described by three mutually exclusive categories: (1) resting, = immobile, considered as conserving energy; (2) active = not immobile and not feeding, considered as energy output; (3) suckling = pup mouth in contact with female nipple, considered as energy input.

Each day, mothers were characterised by their pup distance from pools and visit(s) to the water, both influenced by the chosen pupping place. We defined this variable as the **adopted maternal pattern**. The amount of variation in mothers' activity budget that can be explained by this maternal choice and the consequences of these patterns on pup behaviour, were measured using log-linear models developed with GLIM 4 (Glim, 1993; Lindsey, 1995) while controlling for pup age, pupping date, study area, mother age, disturbance, year and observer.

RESULTS AND DISCUSSION In local breeding areas, the adopted maternal patterns could be classified into five types:

1: pup far (>25m) from any pool, its mother remained close by for the whole day;
2: pup far (>25m) from an access pool but close to a puddle visited by its mother at least once on that day;
3: pup close (within tidal range, so regularly immersed) to an access pool which its mother visited at least once on that day;
4: pup close (above the highest tide level) to an access pool which its mother visited at least once on that day;
5: pup far (>25m) from an access pool which its mother visited at least once on that day;
Or Not defined: no pup position defined yet (pregnant females).

Log-linear models showed that a high proportion of the variability in mothers' activity and pup attendance can be associated to the adopted maternal pattern (Table 1). As long-living mammals, grey seals may display choice or habituation to very local site characteristics (see pupping site fidelity in Pomeroy *et al.*, 1994) leading to a behavioural individuality within apparently homogeneous environments. Furthermore, the pup activity budget was strongly influenced by this maternal choice (Table 2): patterns associated to a low pup energy input (low proportion of time feeding) were also caracterised by a low output (low proportion of time active) or a high proportion of time resting except for patterns 3 and 4 apparently more costly for pups: **these pups were less fed, more active and more often in the water**.

In conclusion, we have shown that an important variation may occur in the maternal behaviour of grey seals even when controlling for major factors known to have a significant effect like pup age, pupping date and study area. Important consequences for pup energy balance may be expected (Fig. 1). Within a defined range of energetic costs to mothers in the same environment, the finite energy resources available were used differently which was likely to contribute to some of the individual variation in reproductive success.

ACKNOWLEDGEMENTS Thanks to C. Bradshaw and E. Whittingham who assisted in collecting the activity budget data. This study was supported by Belgian fellowships from F.R.I.A. and F.N.R.S. to A. Caudron during a PhD thesis in collaboration with the Polar Ecology Lab., VUB, Belgium. Merci aux membres de l'Institut de Zoologie, ULg, pour leur aide technique lors de la réalisation de ce poster.

REFERENCES

Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour*, 49: 227-267.

Anderson, S.S. and Fedak, M.A. 1985. Grey seal males: energetic and behavioural links between size and sexual success. *Anim. Behav.*, 33: 829-838.

Anderson, S.S. and Harwood, J. 1985. Time budgets and topography: how energy reserves and terrain determine the breeding behaviour of grey seals. *Anim. Behav.*, 33: 1343-1348.

Boness, D.J., Bowen, W.D. and Iverson, S.J. 1995. Does male harassment of females contribute to reproductive synchrony in the grey seal by affecting maternal performance? *Behav. Ecol. Sociobiol.*, 36: 1-10.

Bowen, W.D., Stobo, W.T. and Smith, S.J. 1992. Mass changes of grey seal *Halichoerus grypus* pups on Sable Island: differential maternal investment reconsidered. *J. Zool.*, Lond., 227: 607-622.

GLIM, 1993. *The Glim system Release 4.* (Eds. B. Francis, M. Green, and C. Payne) Oxford University Press, Oxford. 821pp.

Haller, M.A., Kovacs, K.M. and Hammill, M.O. 1996. Maternal behaviour and energy investment by grey seals (*Halichoerus grypus*) breeding on land-fast ice. *Can. J. Zool.*, 74: 1531-1541.

Kovacs, K.M. 1987. Maternal behaviour and early behavioural ontogeny of grey seals (*Halichoerus grypus*) on the Isle of May, U.K. *J. Zool.*, Lond., 213: 697-715.

Kovacs, K.M. and Lavigne, D.M. 1986. Growth of grey seal (*Halichoerus grypus*) neonates: differential maternal investment in the sexes. *Can. J. Zool.*, 64: 1937-1943.

Lindsey, J.K. 1995. *Introductory statistics: A modelling approach.* Oxford University Press, Oxford. 214pp.

Martin, P. and Bateson, P. 1993. *Measuring behaviour. An introductory guide.* 2nd Ed., Cambridge Univ. Press, Cambridge. 222pp.

Pomeroy, P.P., Anderson, S.S., Twiss, S.D. and McConnell, B.J. 1994. Dispersion and site fidelity of breeding female grey seals on North Rona, Scotland. *J. Zool.*, Lond., 233: 429-447.

Twiss, S.D., Caudron, A.K., Pomeroy, P.P., Thomas, C.J. and Mills, J.P. 1997. Fine scale topographical influences on the breeding behaviour of female grey seals.(Submitted).

Table 1. Major variables influencing the behaviour of the lactating grey seal females under study. A log-linear model was developed that includes the effects of ten potential explanatory variables; the significance of the effect of each variable is measured by the decrease in deviance due to this variable when the effects of all the other studied variables are controlled. Within variables, the nature of the effect (sign and size) for each category is measured by the estimate of the log odds ratio compared to the reference category (with an estimate = 0).

Maternal Pattern		Low Activity	Alert	Agg. Interact.	Interact. Pup	Locomotion	Sex. Interact.
Deviance = 363	Not defined	0	0	0	0	0	0
25 df, P < 0,001	Type 1	0,39	0,9	-0,98	0,48	-0,37	-0,42
n = 763 ind-days	Type 2	0,39	0,9	-0,48	0,29	0,08	-1,17
	Type 3	0,09	0,89	-0,79	0,11	0,18	-0,48
	Type 4	0,01	0,87	-0,78	-0,002	0,36	-0,46
	Type 5	-0,001	0,78	-0,83	-0,02	0,61	-0,54
Pup Age							
Deviance = 337	Pregnant Fem.	0	0	0	0	0	0
15 df, P < 0,001	0 to 2 days	-2,01	-1,57	0,14	6,99	-2,24	-1,3
n = 758 ind-days	3 to 14 days	-2,96	-2,4	-0,93	6,36	-3,35	3,27
	15 to 21 days	-3,34	-2,68	-1,17	6,42	-3,74	4,51
Pupping Date*							
Deviance = 194	Early	0	0	0	0	0	0
10 df, P < 0,001	Mid	-0,23	-0,29	-0,28	-0,37	-0,09	1,26
n = 758 ind-days	Late	-0,34	-0,08	-0,28	-0,71	-0,22	1,63
Study Area							
Deviance = 132	West Rona	0	0	0	0	0	0
5 df, P < 0,001	Tarbet	-0,24	-0,07	-0,18	-0,17	0,38	0,28
n = 778 ind-days							

*before 25% of births (early), between 25% and 75% of births (mid), or after 75% of births in study area (late)

Table 2. Major variables influencing the behaviour of the grey seal pups under study.

Maternal Pattern		Resting	Activity	Feeding
Deviance = 172	Type 1	0	0	0
8 df, P < 0,001	Type 2	0,18	0,04	-0,22
n = 543 ind-days	Type 3	-0,04	0,26	-0,22
	Type 4	0,06	0,14	-0,2
	Type 5	0,08	0,03	-0,11
Pup Age				
Deviance = 118	0 to 2 days	0	0	0
4 df, P < 0,001	3 to 14 days	-0,1	-0,29	0,38
	15 to 21 days	-0,2	-0,5	0,7
Pupping Date				
Deviance = 100	Early	0	0	0
4 df, P < 0,001	Mid	0,08	-0,05	-0,03
	Late	0,3	0,03	-0,33

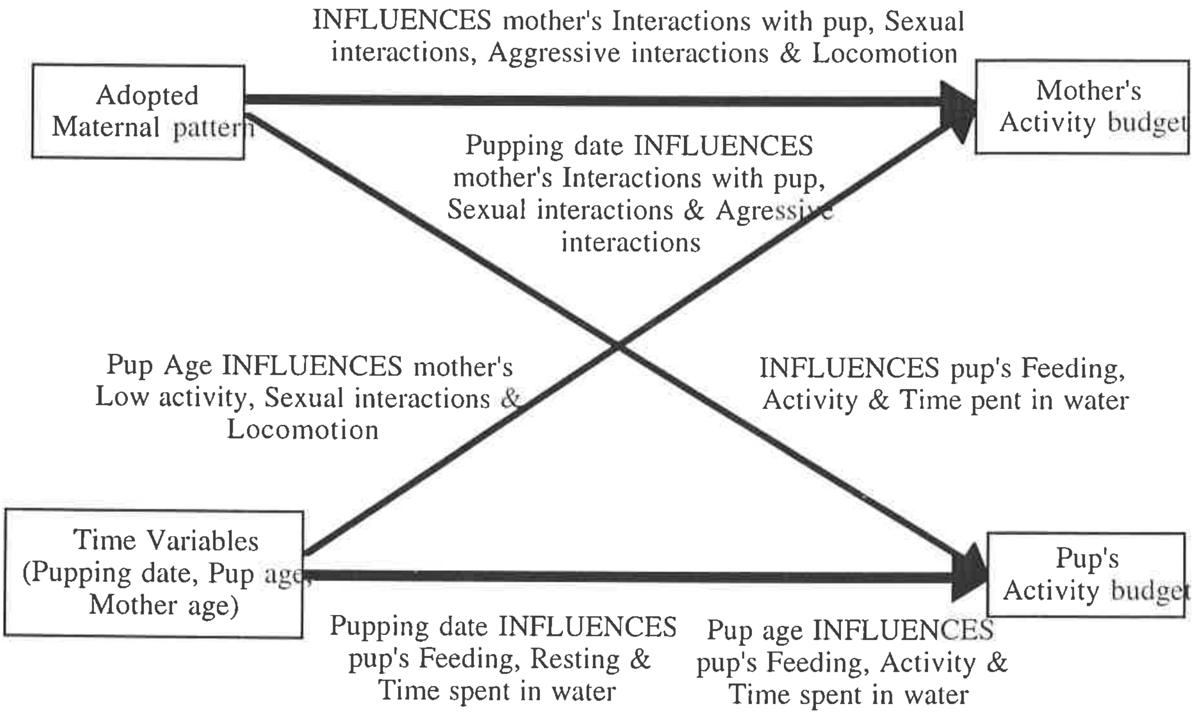

Figure 1. Significant effects on grey seal mother and pup activity budgets as suggested by log-linear models.

ESTIMATING THE ABUNDANCE OF AMAZON RIVER DOLPHINS (*INIA GEOFFRENSIS*) IN THE CUYABENO RESERVE, ECUADOR

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ABSTRACT Since May 1996, studies about the population size and structure of the Amazon River Dolphin (*Inia geoffrensis*) were carried out in two black water rivers, the Cuyabeno in the South and the Lagartococha in the north of the Cuyabeno Reserve, situated in the northern part of Amazonian Ecuador. The two rivers are connected to the Aguarico, the main stream of the Reserve, and lie 100 km apart from eachother. Both rivers rise in inundated forests and have black tannin-rich water, whereas the Aguarico has its source in the Andes and carries nutrient-rich white water.

The population density was estimated using a modified strip-transect method. A 22.57 km strip in the Cuyabeno upstream from the estuary was covered twice a day (n = 36). Comparing the number of animals sighted on there and back transects a failing quota of 29% was calculated with the help of survey efficiency by Caughley and Goddal. According to this method, the population density in the Cuyabeno is 0.23 boto/km river and in the Lagartococha 0.47 boto/km river.

The home range of the boto was examined using photo-identification. Up to now, a total of 21 animals can be identified. Fourteen animals were seen only in the Cuyabeno, four in the Lagartococha, and three in both the Cuyabeno and the Lagartococha Rivers with a maximum distance of 208 km from each sighting position. Hence an exchange of *Inia* within the two rivers does exist.

Additional data are needed from both rivers to more accurately assess the exchange of individual animals or groups within the two rivers and the reason for the difference in the population density in the both rivers.

METHODS The Cuyabeno was studied from the mouth up to the Lagunas Grandes, a system of five lagoons 87 km upstream and the Lagartococha from the mouth with the Aguarico River to Piuricocha 47 km upstream. The width of both rivers has an average of 30 m and depth varies with rainfall. Observations were made from a 10 m dugout canoe with a 25 hp out-board motor, travelling at a speed of 10 to 15 km/h. Two observers in a canoe surveyed the river from the front and back. Animals were classified into three classes estimating their size. Up to 1 m as calves, from 1 m to 2 m as intermediate and animals larger than 2 m, as adults.

Abundance and population density was studied using the strip transect method (Caughley 1977) in a modified way. The width of the track line is given by the width of the river (20 - 30m). To calculate missed botos on the track line, 36 return transects from the Bocana Cuyabeno to Aguas Negras were made during the same day within a period of 4 to 5 hours. By this means, the possibility that animals would have left the sector surveyed is very low. To control this method, the true abundance of repeated censuses made at two levels of survey efficiency, according to Caughley and Goddard (1972), was calculated using return transects at the two survey levels.

From both methods, return transects, and the survey efficiency method of Caughley and Goddal (1972), the average percentage of missed animals was calculated, and included in the calculation for both abundance and population density. ID pictures of dorsal fins were also taken and analysed for natural markings such as scars, nicks, deformations and pigmentations (Trujillo, 1994).

RESULTS. According to the survey efficiency, the abundance in the section from Bocana Cuyabeno to Aguas Negras is 4.44 botos. The average of all animals sighted on 36 strip transects from the Bocana Cuyabeno to Aguas Negras is 135 botos/36 transects = 3.75 animals.

To control strip transects to Aguas Negras themselves, and in regard of the different size classes, the percentage of missed animals was compared. The comparison of return ransects showed that 28% of the sightings (sightings of individuals or groups), 20% of all animals, 64% of adults, 25% of intermediates, and 19% of calves were missed. The total average of all, missed sightings and animals, is 31.2%. (Table 1).

The mean percentage of all sightings and animals overseen [(sightings 28% + an 20% + 64% + i 25% + c 19%+ transect efficiency 15%) / 6 = 29%], leads to a maximum under-estimate of 29%. In the future, population density and abundance will be calculated including the 29% failure, in order to estimate the maximum abundance and population density. The 29% of animals missed on transects will be named *inialoss*.

The population density is higher on transects to Aguas Negras (CAN) than on the long transects from the Bocana Cuyabeno to the Lagunas Grandes (C). On transects to Aguas Negras, an average of 3.16 animals were sighted yielding a density of 0.23 boto/km river on the 22.57 km transect. While population density on the 87.9-km river to the Lagunas Grandes is only 0.06 boto/km river, density in the Lagartococha River is still higher with 0.33 boto/km river. The entire river length is considered when calculating the maximum abundance in the Cuyabeno and Lagartococha. In the case of the Cuyabeno River, it is a total of 20.44 botos within a river length of 111 km. In the Lagartococha River ,the maximum abundance is estimated to be 28.31 botos on 85.8 km river (Table 2).

Since May 1996, a total of 21 botos were identified according to natural markings on the dorsal fin. Three of the animals identified have been seen in both the Cuyabeno and the Lagartococha River, travelling a maximum distance of about 208 km. In the Cuyabeno itself 14 animals could be identified, and four in the Lagartococha. (Table 3).

DISCUSSION On transects to survey boto populations, a certain amount of animals are overlooked, as dolphins spend most of their time underwater. As the strip transect method assumes that all animals on the trackline are seen (Caughley 1977), it needs to be modified for dolphin surveys. At sea, to estimate whale and dolphin populations by line transects, animals missed are determined using the g(0)-factor (Buckland *et. al.*, 1993). To estimate the g(0)-factor, independent platforms are required (Hammond *et. al.*, 1995), which was impossible to realise with the equipment used for the present study. The population density estimated with the *inialoss*-factor with 0.33 boto/km river in the Lagartococha, and 0.23 in the Cuyabeno river fit well with the results of Best and Da Silva (1993), where population density of boto in Brazil ranges from 0.08 to 0.33 *Inia*/km river. According to these observations, the population density in both rivers is fairly high. Still, abundance is quite low and that may be due to the relatively short length of the rivers considered as home range. Comparing transects and photo ID work, the modified strip transect method seems to be more accurate than the unmodified one. Abundance of 20.44 boto in the Cuyabeno river is more likely in regard of the 14 individuals identified since ID pictures of boto are hard to obtain. With the unmodified strip transect method, the estimate of 17.76 animals would be very close to the 14 animals identified. Nevertheles, abundance estimates in both rivers are likely to be under-estimates, since waste parts of the study area are lagoons with inundated forests, where dolphins can easily hide behind bushes and trees, making it fairly hard to spot and track boto. Therefore, surveys were concentrated on rivers only.

Since abundance is much higher in the Lagartococha River, it seems to be a more suitable habitat for *Inia* than the Cuyabeno River. Since during the dry season, the Cuyabeno River runs dry in its upper parts, the Lagartococha represents a safer habitat for botos which will not get trapped in places that run dry. Boat traffic is also higher in the Cuyabeno than in the Lagartococha River. Henningsen *et al.* (1995) could only find a small difference in behaviour towards motor boats while studying boto in Peru, but there might be an effect on the distribution of this species.

According to the photo-ID results, it seems that animals migrate within the two rivers since three animals were seen in both of them. Those animals were all intermediate sized - that is juveniles and young adults. These first results lead us to the suspicion that these animals might be solitary male juveniles searching for mating groups as has been observed in the case of bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, USA (Shane and Wells, 1986). Analysis of available ID pictures from 1996 and 1997 is going on as well as a continuous photo-ID work. Mark-recapture results will help to control abundance estimates obtained from transects, and give more accurate methods to estimate abundance and population density.

ACKNOWLEDGEMENTS The study presented was realised with the help of various people. I am especially thankful to Eugenio Ortiz, Gonzalo Meza, Susanne Thaler, and Rafael Aguinda who helped in the field. Meike Scheidat helped with the data work. INEFAN and the staff from the Cuyabeno Reserve gave host and transport. Prof. L. Albuja and Prof. R. Barriga from the Escuela Politecnica Nacional in Quito gave helpful comments. The Project was financed by Yaqu Pacha, and with a grant from the DAAD (German academic exchange program).

REFERENCES

Best, R. C. and da Silva, V.M.F. 1993. *Inia geoffrensis. Mammalian Species* No. 426, pp.1-8. American Society of Mammologists.

Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. *Distance sampling. Estimating abundance of biological populations.* Chapman and Hall.

Caughley, G. 1977. *Analysis of Vertebrate Populations.* Wiley & Sons.

Caughley, G. and Goddard, J. 1972. Improving the estimates from inaccurate census. *J. Wildl. Mgmt.*, 36: 135-140.

Hammond, P.S., Benke, B., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jørgensen, M.P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F. and Øien, N. 1995. *Distribution and abundance of the harbour porpoise and other small cetaceans in the North Sea and adjacent waters.* Final Report. LIFE 92-2/UK/027.

Shane, S. H. and R. S. Wells. 1986. Ecology, behaviour and Social organisation of the bottlenose dolphin: a review. Marine Mammal Science 2(1):34 -36 (January 1986).

Trujillo, F. 1994. The use of photo-identification to study the Amazon River Dolphin (*Inia geoffrensis*) in the Colombian Amazon. *Marine Mammal Science*, 10(3): 348-353, July 1994.

Table 1: Comparison of there and back transects

Transects to Aguas Negras	Total number on there transects (18 transects)	Total number on back transects (18 transects)	Total of all sightings or animals from both transects	Total of missed sightings or animals comparing both transects	% of missed sightings or animals
Sightings	26	27	53	15	28
Animals	66	69	135	27	20
Adults	4	7	11	7	64
Intermediate animals	33	34	67	17	25
Calves	29	28	57	11	19

Table 2. Population density and size including the inialoss

Transect	Number of animals sighted	Population density in Inia per km river	Population density* in Inia per km river	abundance
CAN	3.16	0.16	0.23	5.16
C	3.7	0.04	0.06	5.27
Cuyabeno max.			0.23	20.,44
LLU	5.11	0.24	0.33	6.86
LLO	6,5	0,23	0,32	8,75
Lagarto max.			0,33	28,31

Legend *CAN*: Transects from Bocana Cuyabeno to Aguas Negras; C: Transects from Bocana Cuyabeno to Lagunas Grandes; *LLU*: Transects from Bocana Lagartococha to Delfinecocha, *LLO*: Transects from Delfinecocha to Piuricocha; *Cuyabeno max* : highest density* on 111km (section between Bocana and Puente Cuyabeno where the occurrence of Inia is confirmed with incidental sightings); density*: density in consideration of the likelihood of the sighting; population size = density* multiplied with the length of the river section; *Lagarto max:* highest density* on 85.8 *km* (section between Bocana Lagartococha up to Quebrada Sur where the occurrence of Inia is confirmed with incidental sightings).

Table 3: Sightings of identified Inia in the Cuyabeno and in the Lagartococha river and the maximum distance travelled.

Age class	Identified in	number of animals identified	maximum distance travelled (in km)
i	both Cuyabeno and Lagartococha	3	208
a	Cuyabeno	2	88
i	Cuyabeno	10	80
c	Cuyabeno	2	0
i	Lagartococha	3	0

Legend: a: adults, i: intermediate sized animals, c: calves

ANALYSIS OF RESPIRATION PATTERNS OF BOTTLENOSE DOLPHINS OBSERVED IN THE KVARNERIC (NORTHERN ADRIATIC SEA, CROATIA)

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SUMMARY In this study we verified the possibility of a behavioural analysis on bottlenose dolphins (*Tursiops truncatus*) through the observation of respiration patterns. We analysed the eco-ethological aspects of respiration events in order to detect a relationship between energy expenditure and foraging activities.

Respiration frequencies of focal animals following bottom trawlers were used as a control: conditions such as bottom depth and trawler speed were relatively costant and measurable compared to the other observed activities.

MATERIALS AND METHODS Surveys were conducted from an inflatable boat in the waters of the Kvarneric (Northern Adriatic Sea) (Fig. 1), from August 1991 to October 1996. Each surfacing of the focal individual as well as its behaviour were recorded vocally on a constantly running tape-recorder. The dolphin's position was determined by GPS at regular intervals. The dive intervals were successively timed, approximating the surfacing to the nearest second.

Behavioural states - "Diving" (D), "Dive-Travelling" (DT), "Following a Fishing Boat" (FFB), modified from Bearzi) were defined combining only two objectives parameters:

- focal animal directionality (yes or no);

- presence/absence of a working trawler

RESULTS A total of 7,928 dive intervals were recorded during 56 hours of respiration sampling on 33 individuals. The mean duration of dives was 25 s (SD=48.2, SE=0.5, range=2-415, mode=7).

The most common respiration patterns were "type A" and "type B" (Fig. 2).

For each behavioural state, the "type A" pattern was quantified using five respiration parameters - "Short dive" and "Long dive" duration, number of ventilation, duration of "Short dives sequence" and "Ventilation rate" (Tables 1-3, Figs 3-5).

Ventilation rates were found to differ significantly (Kruskal-Wallis test: df=2, N=397, H=6.89, $p<0.05$), increasing from "Following a Fishing Boat" to "Diving".

During the *FFB* state a low correlation was found between the duration of Long dive and the Number of ventilations (r=0.3; N=120). The bottom depth showed a weak relationship with both number of ventilations (r=0.11; N=120) and duration of Short dives' sequence. No correlations were found between Long dive times, bottom depth and duration of Short dives' sequence.

During the DT a high correlation was found only between the previous Long dive and the number of ventilations (r=0.5; N=165). When bottlenose dolphins were "Diving" a strong correlation between the duration of previous Long dive and the number of ventilation was found (r=0.6; N=112). A strong correlation was also found between the duration of Short dives' sequence and the duration of Long dive (r=0.5; N=112).

DISCUSSION Respiration pattern type A appeared to be related to foraging activities, while the type B seemed to reflect periods of swim-transit or exploratory-swim. To understand the ecological aspect of respiration patterns, the number of ventilations was considered as an indication for the re-establishment of the normal level of O_2 and CO_2 in the tissues; whereas the time spent at surface as a factor related to the ADL (aerobic dive limit).

The result of respiration patterns' analysis within each behavioural category can be summarised as follow:

1. During the *FFB* state, dolphins seemed to perform a Long dive of a given duration that ensures they do not exceed their physiological threshold. They did not show any "recovery" behaviour. The bottom depth did not seem to influence the duration of Long dive. These results matched strongly with the scenario suggested by Williams and colleagues (1993) for the aerobic dives in bottlenose dolphins.

2. During the *DT*, it seemed that the dolphins did not perform Long dives over their ADL. The mean duration of Long dives was about 34% shorter than during the *FFB*. However, they did seem to consume more oxygen than during the *FFB*.

3. During the category *D* the Long dive seemed to exert a clear influence both on the number of ventilations and on the duration of Short dives' sequence. Compared to the previous behavioural states, this could indicate a higher energetic cost of these activities and possibly be the result of anaerobic Long dive. Such hypotheses are consistent with the values of ventilation rates of each behaviour.

CONCLUSIONS In terms of energetic costs, the foraging strategies during the category "Diving" were the most expensive, while the less energy consuming were found during the "Following a fishing boat" category.

During the *FFB* bottlenose dolphins forage near fishing nets and can take advantage of easily accessible prey. In this circumstance, they could stay below their physiological threshold by investing the energy and time saved from searching for unpredictable prey in prolonged dives near a predictable food source.

When bottlenose dolphins are "Dive-Travelling" they could forage at the bottom (*e.g.* on buried fish) or in the water column on fish schools. They are probably able to dive within their ADL, balancing the expenses of swim-transit, ascent/descent speed, pursuit speed and duration of Long dive. Nevertheless, this activity seemed to be energetically more expensive, due to the unpredictablility of the prey distribution. Lastly, the behavioural state "Diving" is noticeably the most expensive. This could be due to largely unpredictable prey occurrence and behaviour.

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REFERENCES

Bearzi, G. 1994 . Behavioural states: terminology and definitions. Pages 9-12. In: Proceedings of the workshop: *Methods for the study of bottlenose dolphins in the wild*. 8th Ann. Conf. ECS, Montpellier, 3 March 1994. European Cetacean Society, Cambridge, UK.

Williams, T.M., Friedl, W.A., Haun, J.E., and Chun, N.K. 1993. Balancing power speed in bottlenose dolphins (*Tursiops truncatus*). *Symp. zool. Soc. Lond.*, 66: 383-394.

TABLE 1. DESCRIPTIVE STATISTIC OF RESPIRATION PARAMETERS (*FFB*)

	Mean	*SD*	*SE*	*N*	*Range*	*Mode*
Short dive (s)	8.5	3.7	0.1	1,640	2-25	6
Long dive (s)	203.1	82.1	6.5	158	26-364	248
Short dive sequence duration (s)	82	47.2	4.2	125	6-268	54
Number of ventilations	11.1	4.6	0.4	125	2-23	10
Ventilation rate	2.3	0.7	0.05	125	0.5-4.3	2.6

TABLE 2. DESCRIPTIVE STATISTIC OF RESPIRATION PARAMETERS (*DT*)

	Mean	*SD*	*SE*	*N*	*Range*	*Mode*
Short dive (s)	10.5	4.6	0.1	1,552	2-28	8
Long dive (s)	136.2	72.2	4.7	234	29-384	200
Short dive sequence duration (s)	69.3	38.4	2.9	171	7-208	60
Number of ventilations	7.6	3.9	0.3	171	2-21	7
Ventilation rate	2.4	0.7	0.05	171	0.5-4.7	-

TABLE 3. DESCRIPTIVE STATISTIC OF RESPIRATION PARAMETERS (*D*)

	Mean	*SD*	*SE*	*N*	*Range*	*Mode*
Short dive (s)	8.8	3.2	0.1	1,537	2-22	7
Long dive (s)	173.4	86.7	6.6	170	23-415	234
Short dive sequence duration (s)	74.4	36.6	3.3	125	7-201	81
Number of ventilations	10.3	4.9	0.4	125	2-25	12
Ventilation rate	2.5	0.9	0.07	125	0.5-5.7	-

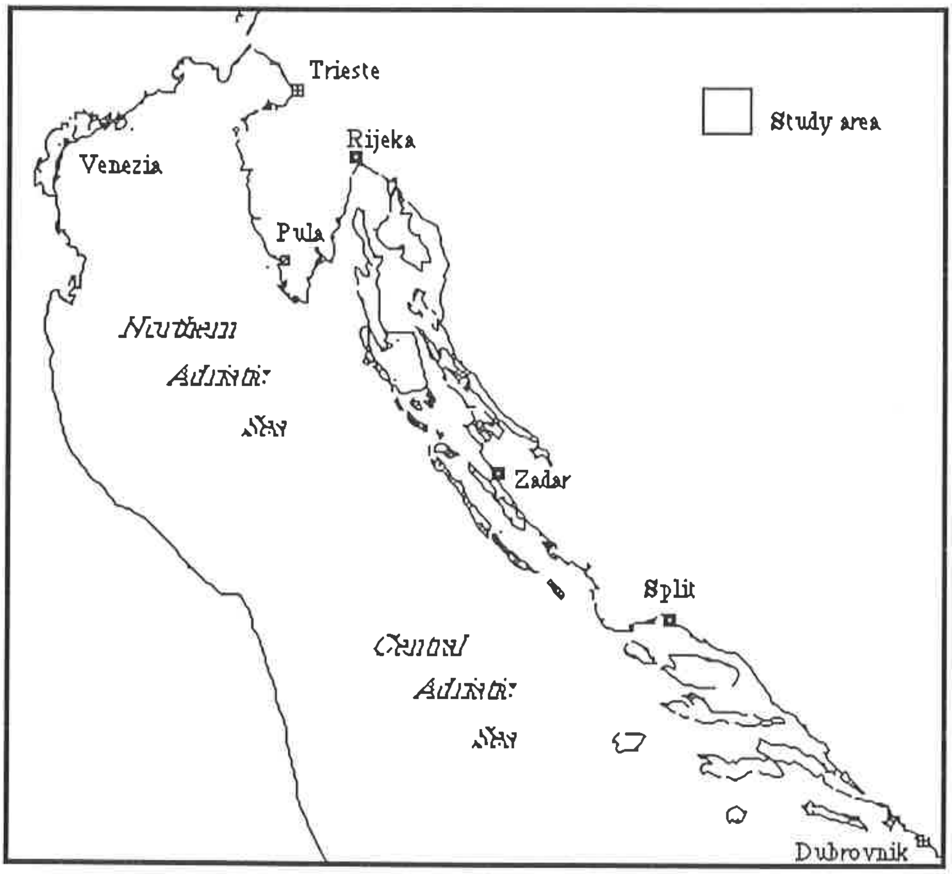

Fig. 1. Study area

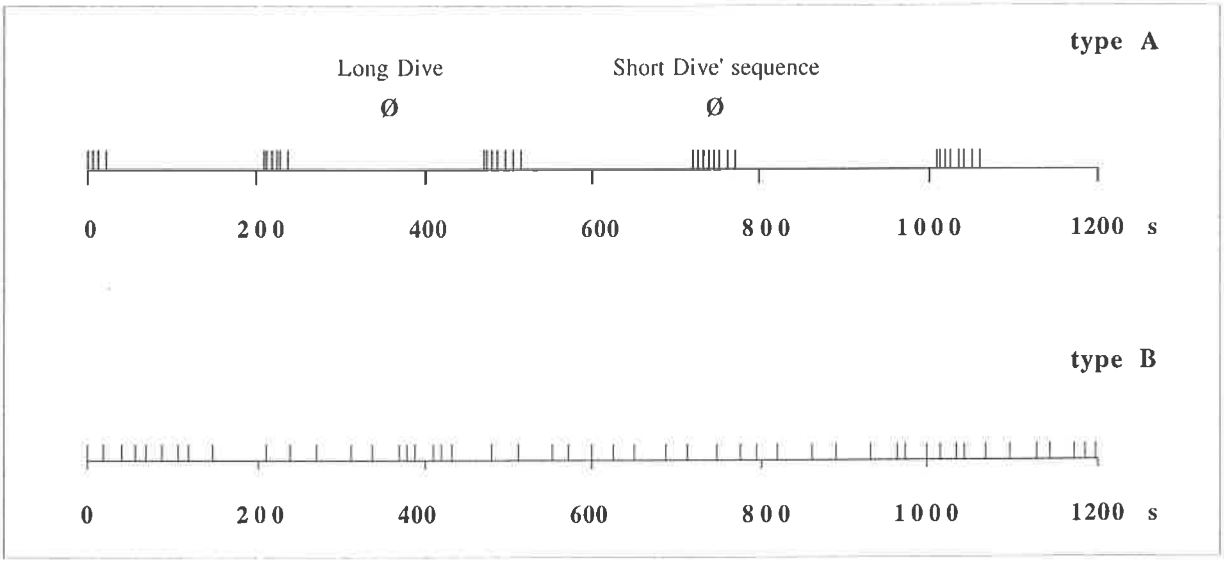

Fig. 2. “Bar-code” of respiration patterns on temporal scale (s): “type A” and “type B”

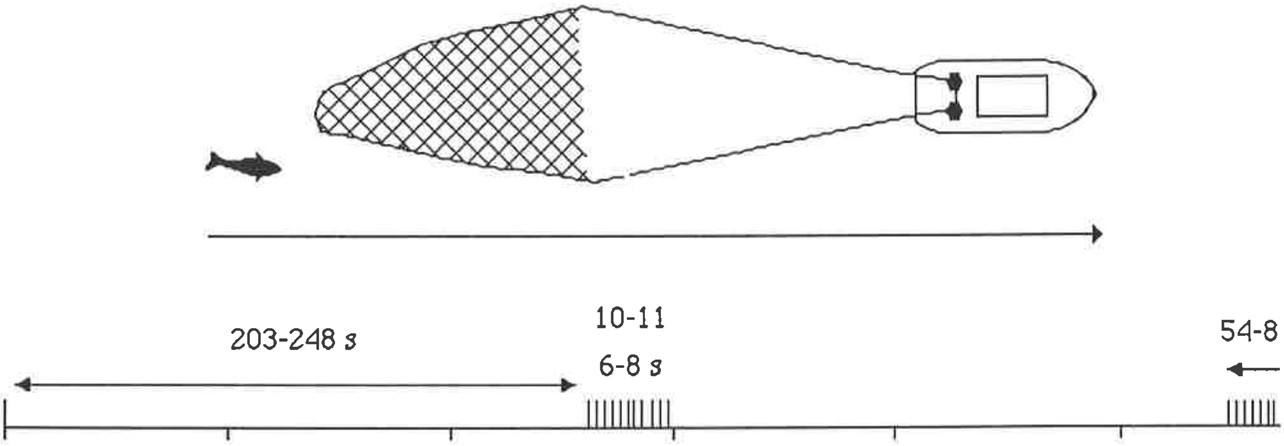

Fig. 3. Mean respiration pattern “type A” during the “Following a Fishing Boat”

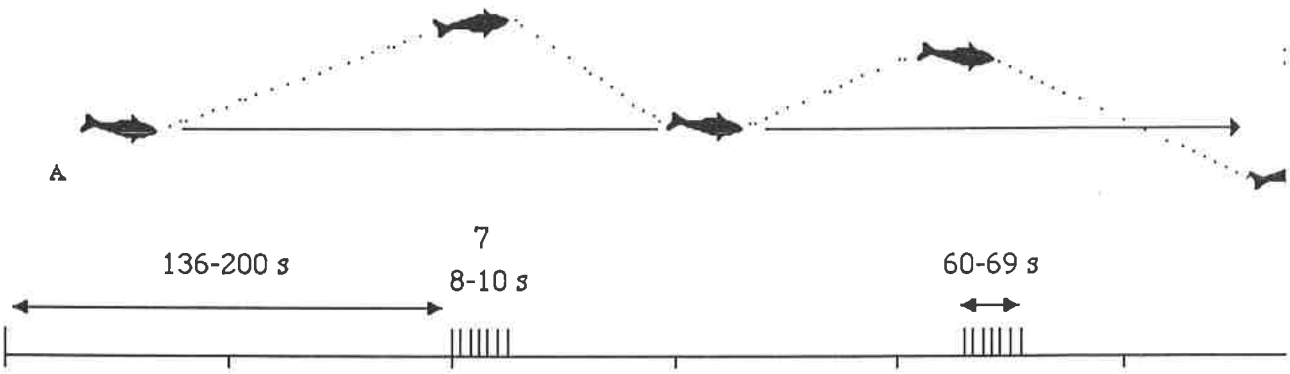

Fig. 4. Mean respiration pattern “type A” during the “Dive-Travelling”

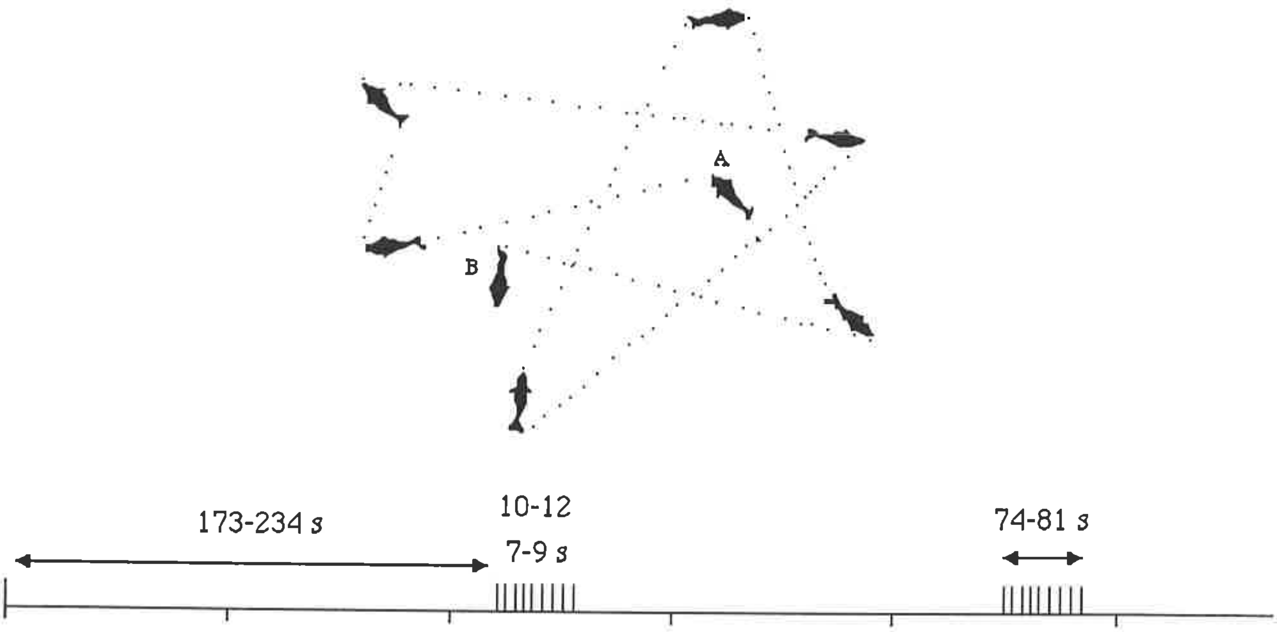

Fig. 5. Mean respiration pattern “type A” during the “Diving”

LOCOMOTOR BEHAVIOUR AND RESPIRATORY PATTERN IN MEDITERRANEAN FIN WHALES (*BALAENOPTERA PHYSALUS*) TRACKED IN THEIR SUMMER FEEDING GROUND

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In the Mediterranean ecosystem, fin whale is an important species whose abundance in western basin was estimated in the order of 2,000 - 8,500 individuals (Forcada *et al.*, 1993). Moreover, recent evidence (Bérubé *et al.*, 1995) based on genetic analysis strongly supports the idea that the Mediterranean fin whale is reproductively segregated from Atlantic populations and, hence, as an endemic breed of a relatively restricted area, particularly susceptible to interference with the intense human activity of Mediterranean Sea. Thus, an understanding of the biological behaviours and their physiological basis is of considerable importance in this species. Unfortunately, in the summering ground of the Ligurian Sea, fin whales feed in deep water, and visual detection of their activity is difficult. The aim of this study was to combine a new method for short-term tracking with respiratory monitoring. This would permit us to shed some light on physiological principles underlying locomotor behaviours. On the basis of such information, an estimate of the energy requirement can be presented.

MATERIALS AND METHODS During the summer period (range: June-September) of three consecutive years (1995-97), 21 lonely adult fin whales were tracked from a 15' motorsail boat at 40-400 m distance in the Ligurian Sea (44°00' to 42°20' N and 07°40' to 09°20' E). The animals were included in the study when sighted alone and no other whale was sighted throughout the period of the measurements. To exclude measurement on re-encountered animals, at the end of the study, all the whales were identified with a photographic method (Zanardelli *et al.*, 1992). The tracking technique was based on the simultaneous determination of vessel position with a Global Positioning System (GPS), and relative distance and azimuth of sighted animals with a Laser Range Finder system (LRF). The respiratory pattern was also simultaneously determined by recording the timing of the respiratory activity. Accuracy of LRF system was previously assessed by tracking from ashore the course of an inflatable boat on which a GPS system independently recorded changes of position at 20 sec. intervals. Figure 1 compares two samples of the tracks obtained with the two methods. Over a test period of 1250 sec., the LFR/GPS ratio for the total course length measured was 0.960 while it was 0.963 for the average speed. All of the values are given as means ± SD. The Least Square method for computation of regressions was employed, while statistical comparison among means were performed using Student's unpaired-samples *t* test. A *P* value <0.05 was considered statistically significant.

RESULTS AND DISCUSSION On average, each whale was tracked over a route of 4674 m ± 1813 (SD) during a period of 3697 sec. ± 1040 (SD). The overall respiratory pattern determined on 477 respiratory cycles of 283 sec. ± 137 (SD) of duration (Tcycle) in all animals consisted with a period near the surface (Tsurf, 58 sec. ± 34 SD), during which 4.6 blows ± 2.3 (SD) were taken, and a prolonged dive (Tdive, 226 sec. ± 117 SD). The swimming pattern of tracked whales was analysed by means of a Milling Index (MI) calculated as: (net distance between the initial and final point of tracking)/(total distance travelled during tracking period). Figure 2 shows the course of two whales with extreme MI values. Duration of tracking, distance travelled and average velocity are also indicated in the figure.

On the basis of the calculated MI, the swimming patterns appeared distributed in a bimodal fashion, as shown in Fig. 3, which can be the expression of different animal behaviour referable to: a) a quasi-linear travel pattern (TRAV) and, b) a convoluted feeding pattern within a relatively restricted area (FEED), with a discriminating MI threshold value of 0.5. The two groups so obtained significantly differed in swimming velocity as referred to the surface (v), surfacing ratio (sr = Tsurf/Tcycle), blow rate (br = number of breaths/Tcycle), Tsurf and number of respiratory periods per surfacing (P/surf), as can be seen in Table 1.

In TRAV whales, a significant correlation was found between v (m/s) and br (blows/min), as shown in Fig. 4, reflecting the velocity dependent increase in metabolic demand, as previously reported in other cetacean species (Sumich, 1983; Williams *et al.*, 1992). The lack of such a correlation in FEED whales suggests that velocity relative to the surface does not represent the true metabolic scope, since a considerable amount of energy is required also for vertical displacement.

A linear positive correlation (Fig. 5) was found between the average number of blow intervals during the surfacing (P/surf) and the duration of the surfacing itself (Tsurf). The slope of the curve represents the average instantaneous frequency of breathing (in s) during the surfacing phase, which results to be constant and corresponds to an average interval of 15.8 sec. between consecutive blows. So, independent from the locomotor pattern, a unique control of breathing acts to increase blow rate by a relative increase in Tsurf.

Since cetacean tidal volume, differently from terrestrial mammals, is considered rather constant, representing a relevant amount of total lung volume (Olsen *et al.*, 1969), blow rate is a close indicator of pulmonary ventilation: it thus appears that the ventilatory control can be achieved in fin whales throughout a regulation of the fraction of time spent near the surface for respiratory purposes. In accordance with values reported for minke whales (Blix and Folkow, 1994), FEED whales require a more elevated ventilation which is achieved either by a higher surfacing ratio and longer periods near water surface.

By cetacean allometry, a 40,000 kg fin whale is expected to breathe with a tidal volume of about 1,000 l; assuming an O_2 extraction of 50% (as commonly observed in exercising mammals) and a conversion factor of 20.1 kJ per l O_2, it results that swimming in the range of 1.5 - 2.5 m/s with the observed blow rate entails a cost of transport of about 0.05 J/(Nm) and requires an energy intake of 80 - 100 kJ/(kg day); these are figures which compare nicely with data determined in other baleen whales (Blix and Folkow, 1994; Sumich, 1983). Such an energetic budget can be achieved with about 1,200 kg of *Meganyctiphanes norvegica*, the prevalent food of fin whale in Mediterranean Sea. Due to the paucity of information about density distribution of this krill in the Ligurian Sea, it is not possible to evaluate the impact of the real cost of foraging in fin whales.

CONCLUSIONS The present technique combining the study of locomotor and respiratory activity enabled the detection of two distinct behaviours in free ranging fin whales referable to travel and feeding, respectively. The former behaviour is characterised by a quasi-linear displacement over a relatively extended territory, higher velocity referred to water surface, and lower blow rate, while the latter entails a convoluted course in a restricted territory, a lower velocity probably due to a vertical displacement, and a higher blow rate.

Independently from the specific behaviour, a general model for the control of breathing is devised in fin whale: since the interval between consecutive breaths of the surfacing phase is invariant, blow rate and ventilation appear to be regulated through the duration of surfacing and its ratio with dive within each cycle.

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REFERENCES

Bérubé, M., Palsboll, P., Larsen, F., Sears, R., Notarbartolo di Sciara, G., Aguilar, A., Sigurjonson, J., Urban Ramirez, J. and Dentato, D. 1995. Genetic structure of the Northern Atlantic fin whale, *Balaenoptera physalus*: analysis of mitochondrial DNA. *11th Biennial Conference on the Biology of Marine Mammals*, Orlando, U.S.A.

Blix, A.S. and Folkow, L.P. 1994. Daily energy expenditure in free living minke whales. *Acta Physiologica Scandinavica* 153: 61-66.

Forcada, J., Aguilar, A., Hammond, P., Pastor, X. and Aguilar, R. 1993. Distribution and abundance of fin whales in the western Mediterranean during the summer. Pp. 128-130. In: *European Research on Cetaceans - 7* (Ed. P.G.H. Evans). Proc. 7th Ann. Conf. ECS, Inverness, Scotland, 18-21 Feb, 1993. European Cetacean Society, Cambridge, UK. 306pp.

Olsen, C.R., Hale, F.C. and Elsner, R. 1969. Mechanics of ventilation in the pilot whale. *Respiration Physiology* 7: 137-149.

Sumich, J.L. 1983. Swimming velocities, breathing patterns, and estimated cost of locomotion in migrating gray whales, *Eschrichtius robustus*. *Canadian Journal of Zoology*, 61: 647-652.

Williams, T.M., Friedl, W.A., Fong, M.L., Yamada, R.M., Sedivy, P. and Haun, J.E. 1992. Travel at low cost by swimming and wave-riding bottlenose dolphins. *Nature*, Lond., 355: 821-823.

Zanardelli, M., Notarbartolo di Sciara, G. and Jahoda, M. 1992. Photo-identification and behavioural observations of fin whales summering in the Ligurian Sea. Pp. 86-89. In: *European Research on Cetaceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy. European Cetacean Society, Cambridge, UK. 254pp.

Table 1. Comparison of fin whales with different swimming patterns

		TRAV (N = 10)	FEED (N = 11)	*P**
MI	(-)	0.77 ± 0.11	0.30 ± 0.13	< 0.0001
v	(m/s)	1.55 ± 0.54	1.18 ± 0.51	< 0.05
br	(blows/min)	0.90 ± 0.30	1.17 ± 0.34	< 0.05
sr	(%)	17.7 ± 7.10	24.9 ± 8.90	< 0.05
Tsurf	(s)	45.0 ± 21.5	72.7 ± 40.8	< 0.05
P/surf	(n)	3.79 ± 1.70	5.53 ± 2.50	< 0.05

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* assessed with Student's unpaired-samples *t* test.

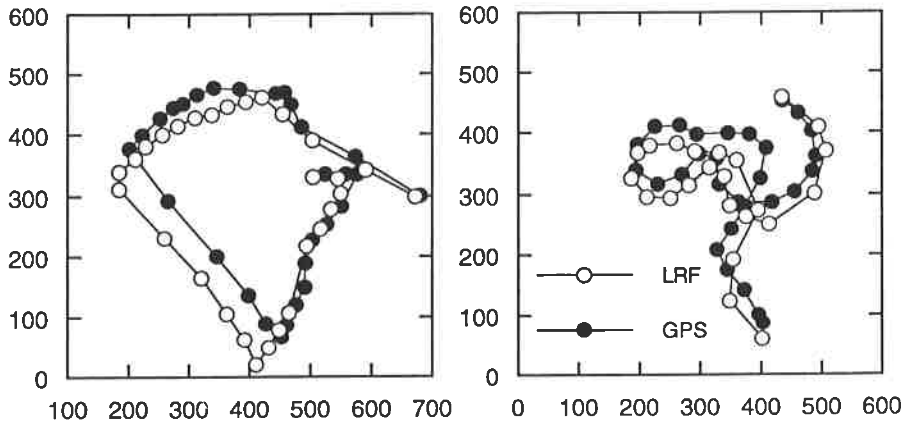

Figure 1 - Track of an inflatable boat (in metric coordinates) over two periods of about 500 s during random linear and curvilinear courses at different speed determined with two independent methods: by means of a GPS mounted on board the boat (closed circles) and by means of LRF system (open circles) operated from a stationary observer on shore at coordinates 0,0. GPS data were taken at 20 s intervals.

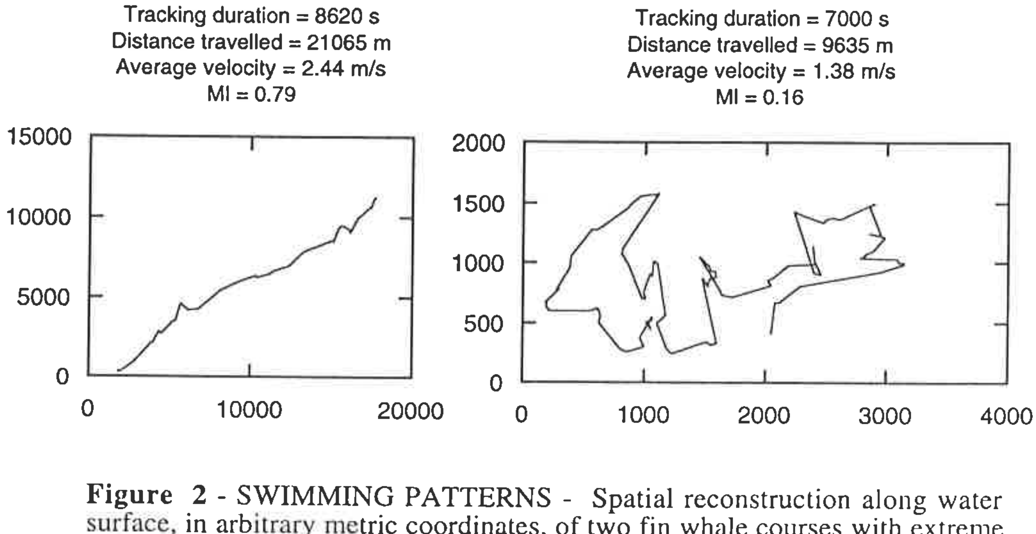

Figure 2 - SWIMMING PATTERNS - Spatial reconstruction along water surface, in arbitrary metric coordinates, of two fin whale courses with extreme values of Milling Index (MI).

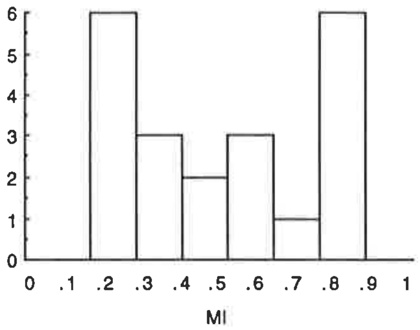

Figure 3 - DISTRIBUTION OF LOCOMOTOR PATTERNS - Frequency distribution of Milling Index (MI) relative to the tracks of 21 fin whales.

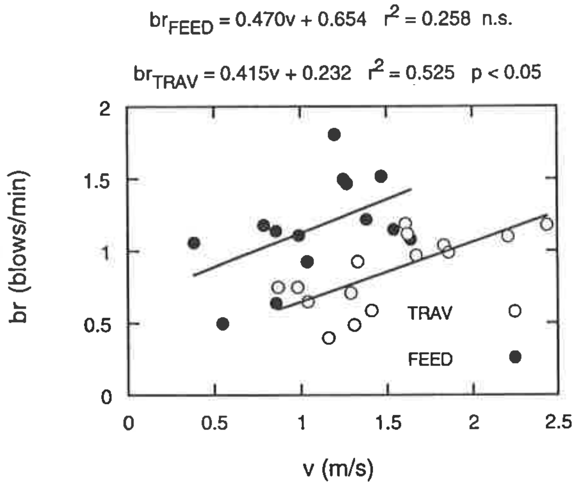

Figure 4 - RESPIRATORY RESPONSE TO LOCOMOTION - Relationship between blow rate and swimming velocity in fin whales with different locomotor pattern. A significant correlation was found in TRAV whales (open circles) but not in FEED animals (closed circles).

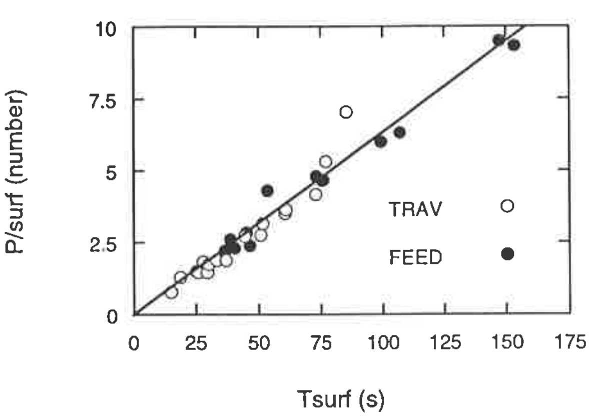

Figure 5 - REGULATION OF BREATHING - A strict correlation was found between the number of breath intervals during the surfacing (P/surf) and the duration of surfacing (Tsurf).

PATCHY HOME RANGE IN COASTAL BOTTLENOSE DOLPHINS

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INTRODUCTION A group of coastal bottlenose dolphins (*Tursiops truncatus*) uses mainly small areas within its home range, dependent on activity. This patchy utilisation, which varies over the year, may be related to environmental parameters, which themselves show striking patchiness in small preferential sites. Such a study was conducted at Sein Island, Brittany, France, between 1994 and 1997, where 17 bottlenose dolphins remained very close to the inhabited island all year round, within an annual home range averaging 5.5 km^2 (Liret and Ridoux, 1998).

METHODS Data concerning the group of bottlenose dolphins and the environmental parameters around Sein Island were recorded throughout the daylight hours during summer (from July to September) between 1994 and 1997.

The bottlenose dolphins Field sessions were performed during July and September from July 1994 to July 1996. Dolphin activity and location were noted every five minutes by instantaneous sampling (Altmann, 1974). Three categories of activity were recorded: travelling, resting and foraging (Shane, 1990), and locations were included in a 200 m cell-sized grid of the study area. The result was a quantitative map of summer space utilisation by the group.

The environmental parameters The direction of the tidal current was recorded within the study area during each field session between 1994 and 1997. On the sea bed, the percentage of each substrate, including seaweed, was determined in several local zones of the study area during August and September 1997 by viewing through a glass window placed on the surface. The abundance of fishes was estimated in different sites within the study area, each one corresponding to a particular sea-bottom (Harmelin-Vivien et al., 1985). Fishes were counted and identified by diving along 20 m long and 4 m wide transect (80 m^2) replicated 5 times (400 m^2) during each summer field session from 1994 to 1996. The fish species encountered were wrasse (*Labrus bergylta*), pollack (*Pollachius pollachius*), mullet (*Liza aurata*), bass (*Dicentrarchus labrax*) and sand-eel (*Hyperoplus lanceolatus*). Maps of substrate type and fish density were made for each sampled site.

RESULTS In summer, the bottlenose dolphins of Sein Island preferentially used three restricted sites within their home range, totaling 68% of the observations and whose surfaces averaged 0.5 km^2. The other 32% mainly corresponded to travelling between the preferential sites. Such a patchy utilisation was closely linked to group activity. During the summer daylight hours, resting occured more often, and foraging less often, in the entrance of the harbour (*Nerroth*) than in the two shallow western areas (Ar bouffe and Ar fot). Activities of dolphin group in these 3 sites were statistically different (Chi *Ar bouffe/Ar fot* = 5.99, (Chi^2 *Ar bouffe/Nerroth* = 86.71, (Chi^2 *Ar fot/Nerroth* = 82.84, df = 2, $P<0.05$).

Environmental parameters within these preferential sites also showed a patchwork pattern, but at a smaller scale. The north-eastern zone, corresponding to the entrance of the harbour, called Nerroth, was characterised by low tidal currents and a sea bed made up of seaweed except in the navigational channel (Fig. 2).

Corresponding fish density was low, and thus could explain why bottlenose dolphins did not spend much time foraging there. Foraging might have occurred within the small plots of the site corresponding to highest fish abundance, but the sampling scale for dolphins, which is 200 m, could not show such precise use. Nevertheless, why dolphins rest during the summer in the zone of highest shipping traffic in their home range remains a mystery. The two western sites, *Ar Bouffe* and *Ar Fot*, had strong tidal currents oriented north-southwardly, as shown in Fig. 2. During summer, the *Ar bouffe* sea bed was characterised by the presence of maerl (*Lithothamnium calcareum*), except around rocks where the percentage of seaweed increased, whereas the sea bed of Ar fot was essentially composed of seaweed (*Laminaria*) (Fig. 2). Such habitats within the two areas resulted in a high density of fish, which corresponded to a high percentage of foraging activity by dolphins. As suggested in the Nerroth site, the group might only use very small patches within these two areas according to the direction of tidal currents, the nature of the sea bed, and corresponding fish density.

CONCLUSION Such spatial distribution of activity related to the environmental parametres indicates that bottlenose dolphins optimise their patchy habitat in terms of foraging. Preferential use by bottlenose dolphins of areas with strong currents has also been observed in the Moray Firth (Wilson *et al.*, 1997). Dolphin groups were mainly observed in summer and their presence corresponded to the increase in food availability. During summer, dolphin group of Sein island takes advantage of a high abundance of food in the western part of their range and, thus, spend less time foraging and more time resting in the entrance of the harbour during daylight hours. The present method applied to investigate dolphin space utilisation is among the most accurate available (200 m cell size), allowing the use of very small preferential sites (0.5 km^2) to be highlighted. However, submarine habitat at these sites showed even more fine scale heterogeneities. Only the use of an even more accurate positioning of dolphin groups and of continuous sampling could allow us to map their spatial utilisation clearly enough to be able to relate it to their patchy environment.

ACKNOWLEDGEMENTS Many thanks to P. Carn, P. Creton, C. Guinet and J.M. Ménégaz for their help in the field and in the laboratory.

REFERENCES

Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour*, 49: 227-267.

Harmelin-Vivien, M.L., Harmelin, J.G., Chauvet, C., Duval, C., Galzin, R., Lejeune, P., Barnabé, G., Blanc, F., Chevalier, R., Duclerc, J. and Lasserre, G. 1985. Evaluation visuelle des peuplements et populations de poissons: méthodes et problèmes. *Rev. Ecol.*, 40: 467-539.

Liret, C. and Ridoux, V. 1998. Spatio-temporal variation in habitat use and activity patterns of coastal bottlenose dolphins. *J. Zool.*, Lond. (submitted).

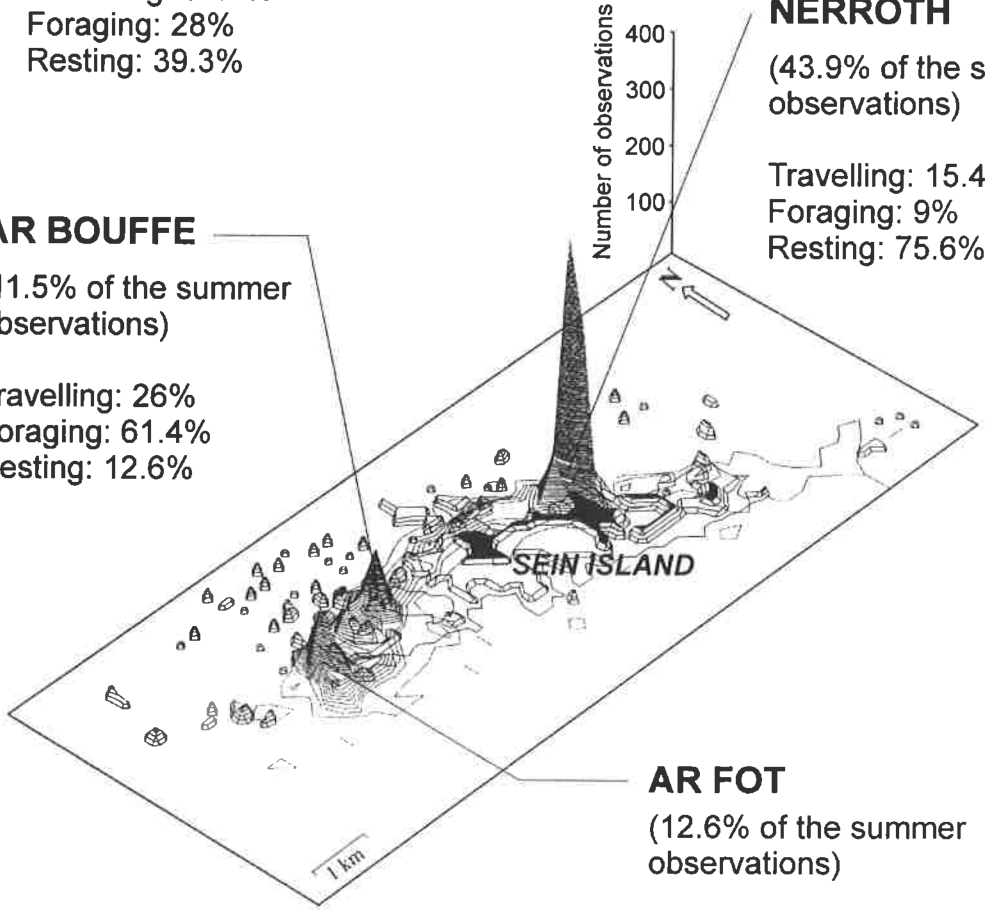
Shane, S.H. 1990. Behavior and ecology of the bottlenose dolphin at Sanibel Island. Pp. 2458-265. In *The Bottlenose Dolphin*. (Eds. S. Leatherwood and R.R. Reeves). Academic Press, San Diego. 653pp.

Wilson, B., Thompson, P.M. and Hammond, P.S. 1997. Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *J. Appl. Ecol.*, 34: 1365-1374.

July 1994/95/96 and September 1994/95

(1946 observations)

Travelling: 32.7%
Foraging: 28%
Resting: 39.3%



NERROTH

(43.9% of the summer observations)

Travelling: 15.4%
Foraging: 9%
Resting: 75.6%

AR BOUFFE

(11.5% of the summer observations)

Travelling: 26%
Foraging: 61.4%
Resting: 12.6%

AR FOT

(12.6% of the summer observations)

Travelling: 9.8%
Foraging: 71%
Resting: 19.2%

Fig. 1 – Space used by bottlenose dolphins around Sein island during summer.

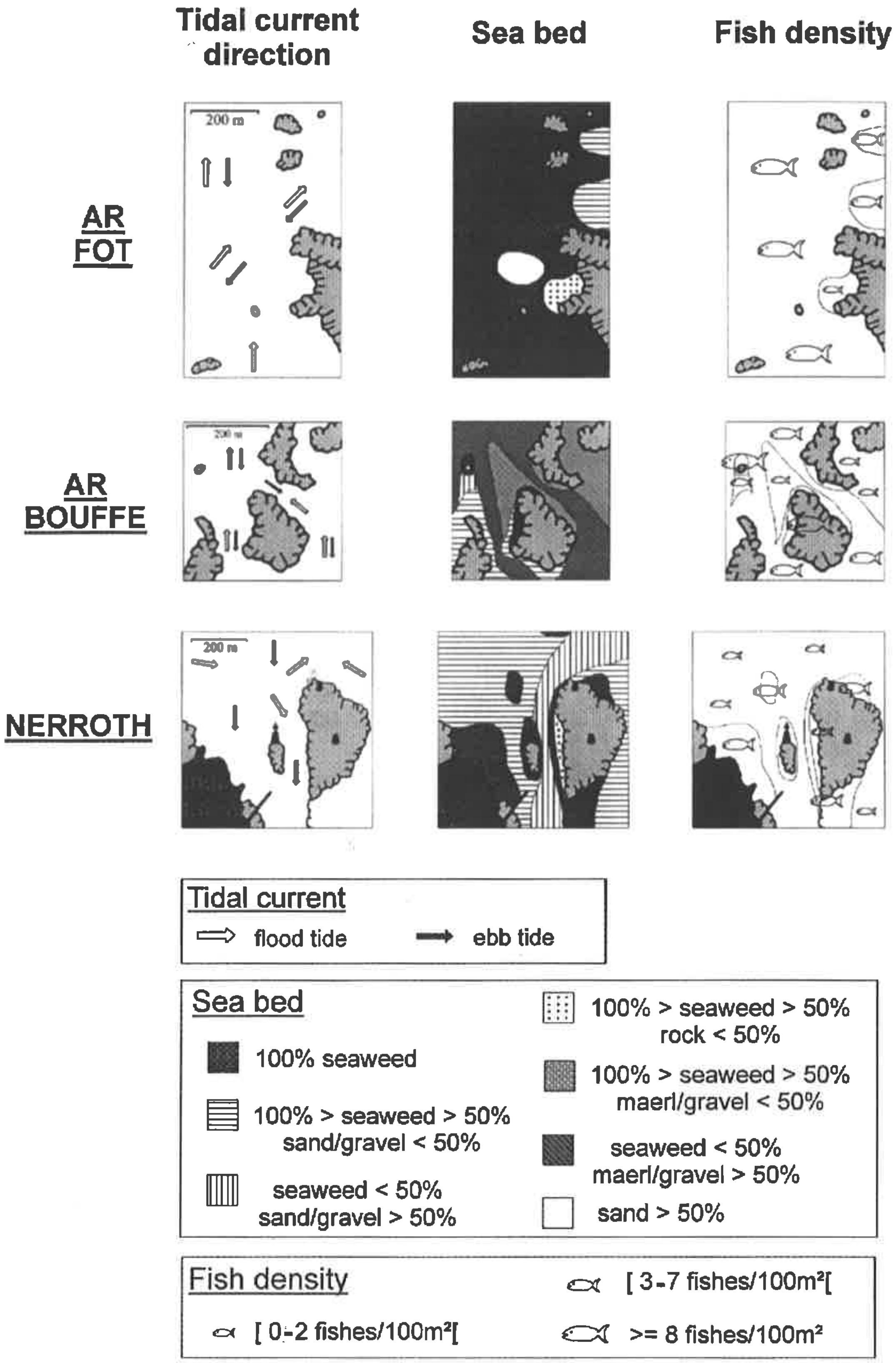


Fig. 2 - Environmental parametres (direction of the tidal current, sea bed and fish density) recorded during summer in the *Ar fot*, *Ar bouffe* and *Nerroth* sites.

TURSIOPS TRUNCATUS POPULATION AT LAMPEDUSA ISLAND (ITALY): PRELIMINARY RESULTS

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INTRODUCTION The most comprehensive studies of free-ranging dolphins have focused on accessible coastal populations; several, have examined the social system, ranges, behavior, and other aspects of the life history of bottlenose dolphin (*Tursiops truncatus*) (Würsig, 1984; Scott *et al.*, 1990; Wells, 1991; Bearzi *et al.*, 1997). Some specific surveys on this species have been undertaken in the Mediterranean Sea; however, the dolphins' occurrence along Lampedusa Island coasts (Pelagie's Archipelago, Sicily) had been still uninvestigated.

In the last few years, the presence of an inshore population of bottlenose dolphin along the coasts of Lampedusa Island was first noted and reported by local fishermen. Due to their coastal nature, bottlenose dolphins have frequent contact with human activities, and many interactions with fishery operations have been described in this area (Mazzola *et al.*, 1996). *Tursiops truncatus* commonly interact with fisheries around the world (reviews in Shane *et al.*, 1986; Fertl and Leatherwood, 1998). However, a limited number of these studies has elaborated on the nature of the association, and few attempts to quantify the effects of this relationship on feeding ecology, sociality, inter-specific interactions, or movements were reported.

The primary goal of this study was to collect systematic data on the habitat-use patterns of bottlenose dolphins along Lampedusa Island in order to provide a better understanding of their local ecology and behaviour. In addition, the purpose of these observations was also to examine animal association and/or feeding during trawling fishing activities and related behaviours.

MATERIALS AND METHODS Dedicated research surveys during July through September 1996 and 1997 were conducted. Sightings of bottlenose dolphins were recorded by a 4.5 inflatable powered outboard, and few observations were made from two land-bases sites. Photographic surveys allowed recognisable dolphins to be reidentified later, in order to define the home range and number of dolphins in the study area (Fig. 1). All the pictures were taken with a 35mm camera using a 35-80 mm, 70-210 mm and 60-300 mm lenses.

Because groups were typically small, it was possible to record the visible behaviours of all individuals simultaneously every three minutes using a check-list (instantaneous sampling, Altmann, 1974) and in an *ad libitum* manner (Altmann, 1974) using a tape-voice recorder. Data recorded included date, time, location, direction of travel, distance between and orientation of individuals, relative speed of travel, group size and composition (numbers of adults, juveniles and calves), dive duration, and occurrence of discrete behaviours. Sea conditions, other environmental factors and the number and the type of the nearby vessels were also noted. When dolphin group was observed in association with trawls, the boat's operational state was recorded.

RESULTS A total of approximately 200 km2 of water was covered during the two years study, and 576 hours in the field searching for dolphins were spent. Animals were sighted with higher frequency near two zones - named Albero Sole (N) and Punta Sottile (S-E) - at an average of 50 m in depth and 2.7 km offshore. Bottlenose dolphins were reported within the area on 109 occasions (n=41 in 1996 and n=68 in 1997), with the recording of 332 specimens (n=125 in 1996 and n=207 in 1997) (see Table 1).

Group size ranged from 1 to 12 individuals in 1996 (mean 3.048; s.d. 2.213; mode 2), and from 1 to 13 in 1997 (mean 3.044; s.d. 2.262; mode 1). A total number of 51 recognisable individuals were catalogued by the photo-identification method (n=27 in 1996 and n=24 in 1997), and 12 were sighted more than one time.

Total age class composition of the groups was: 267 adults, 43 juveniles and 18 calves and newborns.

Approximately 47 hours of behavioural observations were recorded during these encounters, with a total number of 928 records of instantaneous sampling every three minutes. All major activity patterns and specific events were noticed, in order to identify the main behavioural traits such as socialising, milling, resting, travelling and mixed behaviours (defined according to Shane, 1990) (see Fig. 2).

Bottlenose dolphins were occasionally seen feeding on schooling fish near the surface, showing well defined group formations (i.e. circle, carousel, kettle; see Bel'kovich, 1991), lunge at high speed, large irregular splashes, and frequent respiration. Usually, the water depth did not allow to determine if the animals were certainly engaged in foraging operations. In this case, feeding groups were identified by tail-stock or fluke-up modality prior to dive (Shane, 1990), less frequent surfacing, dives longer than those observed in the surface feeding pattern and/or clustered short dives followed by a long one, and distribution in a limited area. Moreover, other two feeding-related categories - defined as SEARCHING (Bel'kovich, 1991) and TRAWLING - were scored. While the first one indicated the looking for prey activity, in which the dolphins scattered through a specific water area moving in varying directions, showing irregular dives and no established group geometry, the second one involved dolphins following trawlers and feeding on their by-catch. This last point was carefully checked and four different behavioural patterns were measured in order to focus the influence of the fishing operations on cetacean feeding behaviour: TRW1=following the trawls at a distance of 100-200 m (53%); TRW2=feeding on the by-catch, close to the boat, at a distance of 5-10 m (16%); TRW3=waiting for the by-catch withdraw and trash fish (23%); TRW4=feeding of trash fish discarded at the end of a trawl (8%) (Fig. 3).

A close association between animals and trawling boats was observed with a total frequency of 57 times (52.3%).

Finally, three sightings of *Stenella coeruleoalba*, and one of *Delphinus delphis* associated with *Tursiops truncatus*, were performed in the study area.

DISCUSSION Bottlenose dolphin is cosmopolitan species and exhibits a series of forms which differ behaviourally and morphologically (Ballance, 1992). Results of this study - pertaining only to the inshore coastal form - showed that Lampedusa's waters were particularly interesting for the cetological fauna occurrence (Pulcini *et al.*, 1997). In fact, a certain degree of fidelity was noticed through the photoidentification results. The peculiar distribution of the sightings, not related to a particularly focused effort in these areas, suggested a probable relationship with environmental factors: while the dolphins' presence to the North, at Albero Sole, seemed to be not associated with any particular features, their appearance at Punta Sottile (S-E) was specifically related to trawls and shallow waters. Other authors have already reported that dolphins follow fishing boats, adapting their behaviour at taking advantage of human activity (Norris and Prescott, 1961; Leatherwood, 1975; Würsig, 1986; Corkeron *et al.*, 1990; Shane *et al.*, 1986; Shane, 1990; Bearzi and Notarbartolo di Sciara, 1997; Fertl and Leatherwood, 1998). Bottlenose dolphin is often described as a species displaying a large degree of behavioural plasticity, best exemplified by a wide variety of feeding behaviours adapted to particular habitats. As a consequence, the presence of trawling boats seemed to influence the dolphins' foraging strategy in the study area because the animals followed a trawling vessel probably feeding on organisms stirred-up by the trawl, on fish which passed through the mesh, or may be picking out fish entangled in the net's mesh.

Opportunistic feeding in association with fisheries is perhaps best exemplified by feeding on culled and discarded trash fish. However, the effect of this method of feeding on aspects of the dolphin's behavioural ecology has not been investigated, although normal searching and feeding activities resulted to be inverse proportionally to the "trawling behaviour". In addition, the observation of some mother-calf pairs associated to trawling boats suggested that bottlenose dolphins could have learned the advantages of following and feeding in conjunction with trawls. In this respect, it has been speculated that the calves may learn this foraging behaviour by observation and participation (Shane *et al.*, 1986).

Although these observations are preliminary, the recorded data suggest more detailed long-term studies on this bottlenose dolphin population should be needed. Data gathered using standardised methods could provide quantitative results for this specific population which could also be used for detailed comparative purposes.

ACKNOWLEDGEMENTS We are grateful to the many individuals involved in the collection of these data: Stefano Cerioni for his constant help, Marco Melodia for providing additional photographic material, Alvise Zannetti for his precious field assistance, and the local fishery community. Special thanks to the Italian Coast Guard for providing help and host in the CP 244 and CP 279. We also thank "CTS - Dipartimento per l'Ambiente" for the logistic support. We are also very grateful to Raffaella Tizzi for her kindness in the poster realisation. Finally, we would like to thank the two anonymous referees for useful comments to improve the manuscript.

REFERENCES

Altmann, J. 1974. Observational study of behavior: Sampling methods. *Behaviour*, 49: 227-267.

Ballance L. T. 1992. Habitat use patterns and ranges of the bottlenose dolphin in the Gulf of California, Mexico. *Mar. Mamm. Sci.*, 8(3): 262-274.

Bearzi, G. and Notarbartolo di Sciara, G. 1997. Bottlenose dolphins following bottom trawlers in the Kvarneric (Northern Adriatic Sea). Pp. 202-204. In *European Research on Cetaceans - 11*. Proc. 11th Ann. Conf. ECS, Stralsund, 10-12 March, 1997. (Eds. P.G.H. Evans, E.C.M. Parsons and S.L. Clark). European Cetacean Society, Cambridge, England. 324pp.

Bearzi, G., Notarbartolo di Sciara, G. and Politi, E. 1997. Social ecology of bottlenose dolphins in Kvarneric (northern Adriatic Sea). *Mar. Mamm. Sci.*, 13(4): 650-668.

Bel'kovich, V.M., Agafonov, A.V., Yefremenkova, O.V., Kozarovitsky, L.B. and Kharitonov, S.P. 1991. Dolphin herd structure. Pp. 17-78. In *Dolphin societies*. (Eds. K.W. Pryor and K.S. Norris). University of California Press. 397pp.

Corkeron, P.J., Bryden, M.M. and Hedstrom, K.E. 1990. Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia. Pp. 329-336. In *The Bottlenose Dolphin*. (Eds. S. Leatherwood & R.R. Reeves), Academic Press, San Diego. 653pp.

Fertl, D. C. 1994. *Occurrence, movements, and behaviour of bottlenose dolphins* (Tursiops truncatus) *in association with the shrimp fishery in Galveston Bay, Texas.* M.Sc. Thesis, Texas A&M University, College Station, Galveston, TX. 116pp.

Fertl, D. and Leatherwood, S. 1998. Cetaceans interactions with trawls: a preliminary review. *J. Nortwest. Atl. Fish Sci.*, 22: 219-248.

Leatherwood S. 1975. Some observations of feeding behavior of bottlenose dolphins (*Tursiops truncatus*) in the northen Gulf of Mexico and *Tursiops* (cf *T. gilli*) off southern California. *Mar. Fish. Rev.*, 37(9): 10-16.

Mazzola, S., Guerrini, A., Bonanno, A., Patti, B. and Giusto, G. B. 1996. Preliminary study on census data about the interaction between dolphins and fishing activity in the Sicilian fisheries. Pp. 256-259. In

European Research on. Cetaceans - 10. Proc. 10th Ann. Conf. ECS, Lisbon, 11-13 March, 1996 (Ed. P.G.H. Evans). European Cetacean Society, Cambridge, England. 334pp.

Norris, K.S. and Prestcott, J.H. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. *Univ. Calf. Publ. Zool.* 63(4): 291-402.

Pulcini, M., Pace, D.S., Triossi, F. and Cerioni, S. 1997. Preliminary results on the occurrence of bottlenose dolphin *Tursiops truncatus* along Lampedusa island coasts. Pp. 256-259. In *European Research on Cetaceans -11*. Proc. 11th Ann. Conf. ECS, Stralsund, 10-12 March, 1997 (Eds. P.G.H. Evans, E.C.M. Parsons and S.L. Clark). European Cetacean Society, Cambridge, England. 324pp.

Scott, M.D., Wells, R.S. and Irvine, A.B. 1990. A long-term study of bottlenose dolphins on the west coast of Florida. Pp. 235-244. In *The Bottlenose Dolphin* (Eds. S. Leatherwood and R.R. Reeves). Academic Press, San Diego. 653pp.

Shane, S.H. 1990. Behavior and ecology of the bottlenose dolphin at Sanibel Island, Florida. Pp. 245-265. In *The Bottlenose Dolphin*, (Eds. S. Leatherwood and R.R. Reeves), Academic Press, San Diego. 653pp.

Wells, R.S. 1991. The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pp. 199-225. In *Dolphin Societies: Discoveries and Puzzles* (Eds. K.S. Norris and K. Pryor). Berkeley: University of California Press.

Würsig, B. 1984. Aspects of the natural history of bottlenose and dusky dolphins. *Nat. Geograph. Res. Rep.* ,1975: 759-769.

Würsig, B. 1986. Delphinid foraging strategies. Pp. 347-359. In *Dolphin Cognition and Behavior: a comparative approach* (Eds. R.J. Schusterman, J.A. Thomas and F.G. Wood), Lawrence Erlbaum Associates, Hillsdale and London. 379pp.

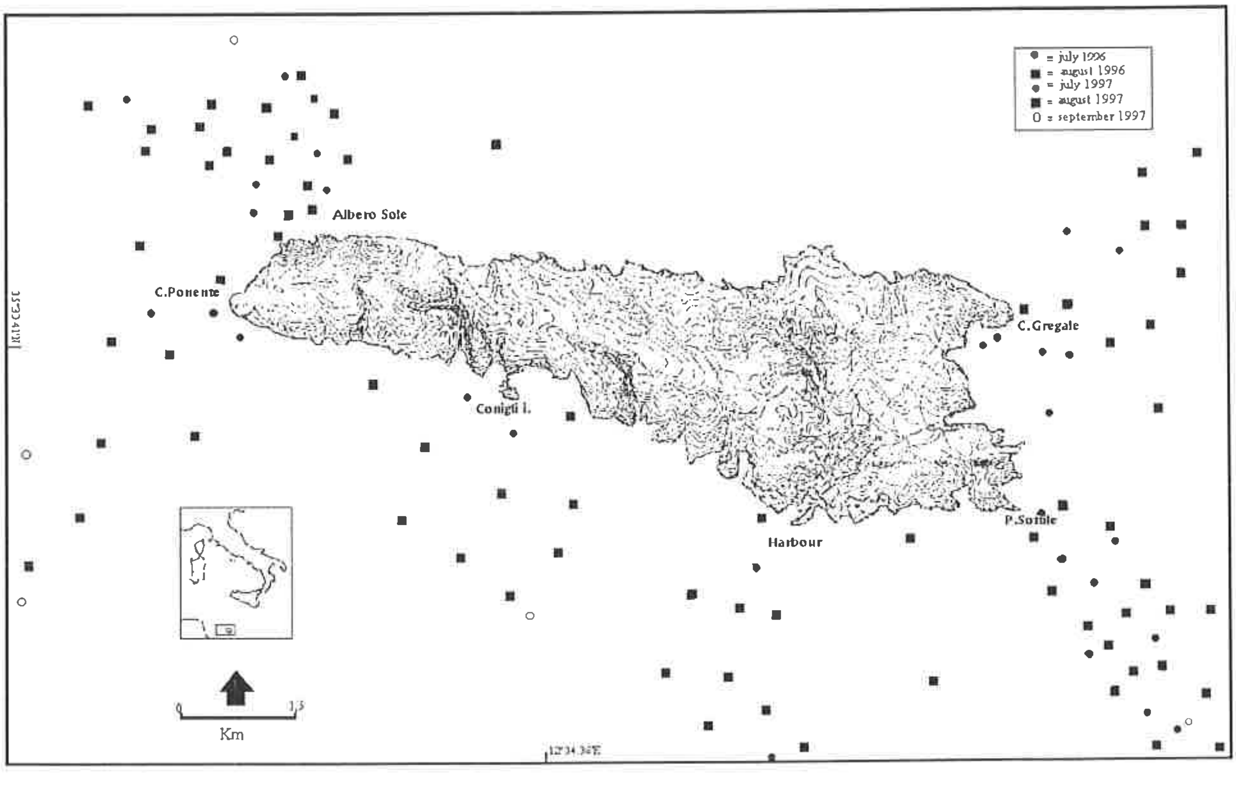

Figure 1

	Sightings	Individuals sighted	Sea sightings	Land sightings	Sightings with trawlers' presence
1996	41	127	31	10	30
1997	68	201	54	14	27
Tot.	109	328	85	24	57

Table 1.

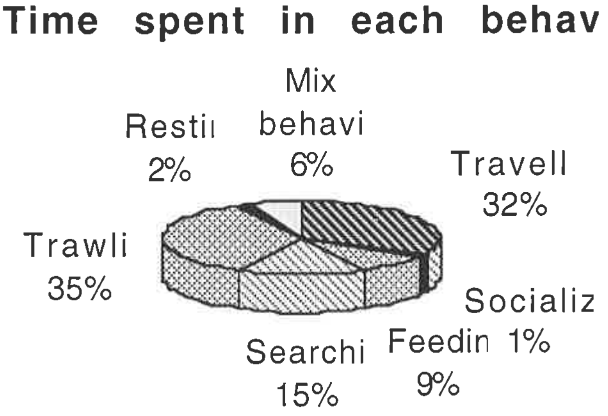

Figure 2

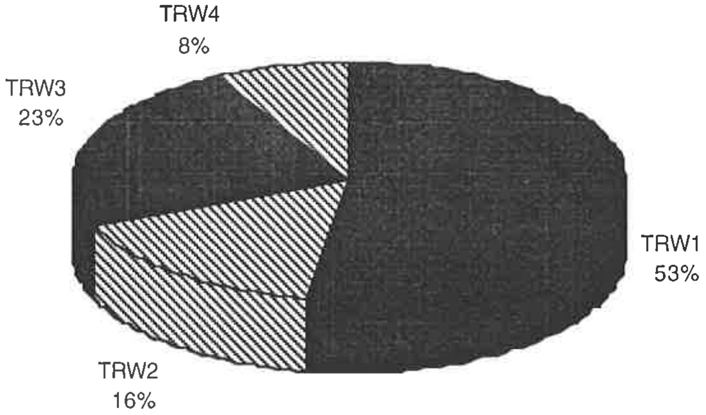

Figure 3

BEHAVIOUR AND ECOLOGY OF *DELPHINUS DELPHIS* AROUND THE IONIAN ISLAND OF GREECE

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INTRODUCTION. The common dolphin (*Delphinus delphis*) is widely distributed in continental shelf regions throughout the world, especially in warm-temperate and subtropical latitudes; occasionally it strays into shallow inshore waters (Evans, 1975; Gaskin, 1991, 1992).

The semi-enclosed relatively mild and sheltered waters of the Mediterranean sea provide suitable conditions for a number of cetaceans. In this respect, the western Mediterranean is much better known than the eastern portion. Although the range and distribution of the eastern Mediterranean cetaceans has not yet been investigated, few details on the geographical distribution of *Delphinus delphis* are reported (Focarda *et al.* 1990; Cebrian & Papaconstantinou, 1992; Politi *et al.*, 1992; Pulcini *et al.*, 1995; Frantzis, 1996).

The aim of this study was to collect systematic data to provide a better understanding of the ecology and behavior of *Delphinus delphis* in the Ionian Islands of Greece (eastern Mediterranean sea). In these particular inshore waters, the common dolphin - known as a behaviourally flexible species - resulted more consistently than the bottlenose dolphin (present in the same area), suggesting peculiar characteristics of the local populations. In addition, an advanced knowledge of this community could provide significant information to understand the disappearance of the species during the last decades in several portions of Mediterranean Sea (Evans, 1987).

MATERIALS AND METHODS Dedicated cruises were conducted from 1993 to 1996 along the islands from June to September, covering a total area of approximately 1,200 km^2 of water.

The observations were made from a 16-m vessel, and information about dolphins' distribution, composition and activity were collected. Data concerning size, formation and type of the school, breathing rates, leaps, dives, speed, root followed, and types of occasional events was scored. At every sighting, detailed measures about behavior were recorded using *instantaneous sampling* (Altmann, 1974) of focal-group activity every 3 minutes. Sea conditions, other environmental factors and the number and the type of the nearby vessels were also noted.

Every behaviour and associated event were catalogued in a specific ethogram for this population, and a general analysis on their frequency and duration was performed. Photographic surveys allowed recognisable dolphins to be identified later, in order to define the home range and the number of dolphins in the study area.

RESULTS Survey effort (number of miles/days) was comparable among the four years, and 224 days were spent in the field searching for dolphins. Common dolphins were reported within the study area on 63 occasions, with the recording of 864 specimens. The distribution of animals was patchy, and sightings were recorded at an average of 102 m in depth and 1.7 km offshore (Fig. 1).

A total number of 64 recognisable individuals were identified by photo-ID, but the photographic data collected were not sufficient for reliable estimates of the population size. Eighteen (28%) animals were sighted only once. The remaining 46 showed a variety of patterns of occurrence. Many dolphins (42%) were re-sighted one or two times; fourteen (22%) were observed four to seven times; five animals (8%) were seen eight times or more (up to 16 separate occasions for one individual).

Mean group size was 14, ranging from 1 to 45. Despite the occasional occurrence of groups composed of over 30 dolphins (6%), most groups (83%) included less than 20 individuals. Total age class composition of the groups, on the basis of body length, was: 564 adults, 176 juveniles and 124 calves and newborns.

Approximately 154 hrs of behavioral observations were registered during all the encounters, with a total number of 3,080 records of instantaneous sampling every 3 mins. All major activity patterns (94.5% of the total behavioural budget) were observed and their relative frequency was measured: feed (24%), mill (17%), travel (15%), socialise (9%), sexual behaviour (7%), rest (4%), defined according to Shane (1990) and search (24%) (Bel'kovich, 1991). In this respect, the animals showed a different group geometry which varied depending on their activity and calves presence (Table 1).

Common dolphins typically surfaced in four distinctly different ways prior to diving, as reported by Shane (1990) for *Tursiops truncatus*: while "regular dive"(blowhole, back and dorsal fin out of the water) was recorded with higher frequency during mill and search activities (26%, 25% respectively), "racing dive" (more speed swim; more share of the back out of the water) was the dominant dive type for all activities (56%); while dolphins travelled and fed, they primarily performed "tail-stock dive" (arched back, body out of the water, with flukes plunged; 25%, 21% respectively) and "flukes-up dive" (flukes out of the water during the dive, all the body out of the water; 24%, 23 % respectively).

DISCUSSION AND CONCLUSIONS A relative high number of resightings, a long period of time between the first sight and the last resight, and a short time interval between adjacent sightings may be important facts indicating a high degree of fidelity (Ballance, 1990) in the study area at least in the studied months. The high presence of common dolphin along the continental slope is reported by Selzer and Payne (1988) and Gaskin (1991). As a consequence, its distribution can be geographically explained, correlated with environmental factors such as bottom topography, and understood in terms of prey abundance (Hui, 1979; Young and Cockcroft, 1994).

Dolphins were infrequently sighted alone. Many authors (Shane *et al.*,1986; Wells *et al.*, 1980) describes that group size generally varies significantly according to activity and depends on habitat. The results presented above seems to confirm these statements, suggesting important local differences. In fact, travel/feeding groups were always larger than the social/mating ones, even if the mean group size was generally smaller than in other parts of the Mediterranean sea (Politi *et al.*, 1994). In addition, their structure seemed to be rather fluid since individuals sighted in one group in the morning may be found within another group in the afternoon or the next day. Furthermore, although water depth in the area is generally shallow, dolphins appeared to concentrate specific activities in correspondence with particular depth ranges (-50/-100 m). Travelling and socialising activities were generally seen to increase as depth raised and most searching and feeding behaviours occurred in shallow waters. As observed by Wells *et al.* (1980), group size tends generally to increase with water depth, possibly showing mechanisms for co-operative foraging and protection.

As shown (Table 1), group geometry was not random but had also functional significance depending on the dolphins' activity. When traveling, common dolphin usually formed front groups, allowing individuals to be in close contact. In most cases, feeding groups showed either circle and horizontal formations, suggesting that cooperative feeding was the norm in the study area. On the other hand, in some specific cases of cooperative feeding, the observed group tended to disperse in subgroups over some hundred meters. Resting and socialising groups preferred close formations as horizontal or tight, sometimes showing particular geometry possibly related to calves presence and courtshipping activities.

Common dolphins typically surfaced in four distinctly ways prior to diving. The type of dive recorded in this study was generally related to the animals' specific behaviour pattern (see results), although these data were not similar to those reported by Shane (1990) for bottlenose dolphin. We could hypothesise that such a difference is due to the species own characteristics in group size, searching and feeding strategies, and the capability of moving nimbly.

Many authors (Hui, 1979; Young & Cockcroft, 1994; Evans, 1975) have already demonstrated additional relationships between environmental factors and dolphin distribution, habitat use and behavior. To apply these models to the studied population, this obviously required some experimental verifications. The ongoing analysis of behavioral sequences and its temporal variations appears to be a promising step forward to a better understanding of the species' dynamic relationships with its environment, since these specific aspects have not been adequately studied to date. Moreover, in order to evaluate the population stability, analysis on school fluctuation and intra/inter-specific associations are our parallel fields of investigation, although more information is needed and additional studies of residence patterns of common dolphin in different habitat types would be useful.

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REFERENCES

Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour*, 49: 227-267.

Bel'kovich, V.M., Agafonov, A.V., Yefremenkova, O.V., Kozarovitsky L.B. and Kharitonov S.P. 1991. Dolphin herd structure. Pp. 17-78. In *Dolphin Societies*. (Eds. K. Pryor and K.S. Norris). University of California Press.

Ballance, L.T. 1990. Residence patterns, group organization and and surfacing associations of bottlenose dolphins in Kino Bay, Gulf of California, Mexico. Pp. 267-284 In *The Bottlenose Dolphin* (Eds. S.Leatherwood and R.R.Reeves). Academic Press, New York.

Cebrian, D. and Papaconstantinou, C. 1992. Distribution of Cetaceans in Greece. 1990-1992. *Rapp. Comm. Int. Mer Médit.* 33: 287-288.

Evans, W.E. 1975. *Distribution, differentiation of populations and other aspects of the natural history of* Delphinus delphis *Linnaeus in the northeastern Pacific*. Ph.D dissertation. University of California. Los Angeles.164 pp.

Evans P.G.H. 1987. *The Natural History of Whales and Dolphins*. Academic Press. 343pp.

Focarda, J., Aguilar, A. Evans, P.G.H., and Perrin, W.F. 1990. Distribution of common and striped dolphins in the temperate waters of the Eastern North Atlantic. Pp. 64-66. In: *European Research on Cet.aceans - 4* (Eds. P.G.H. Evans, A. Aguilar and C. Smeenk). Proc. 4th Ann. Conf. ECS, Palma de Mallorca, Spain, 2-4 March 1990. European Cetacean Society, Leiden, The Netherlands. 140pp.

Frantzis A. 1996. Cetaceans and cetology in the hellenic seas. Pp. 114-118. In: *European Research on Cet.aceans - 10* (Ed. P.G.H. Evans). Proc. 10th Ann. Conf. ECS, Lisbon, Portugal, 11-13 March 1996. European Cetacean Society, Kiel, Germany. 334pp.

Gaskin D.E., 1992. Status of the Common Dolphin, *Delphinus delphis*, in Canada. *Can. Field Nat.*, 106(1): 55-63.

Hui, C.A. 1979. Undersea topography and distribution of dolphins of the genus *Delphinus* in the southern California Bight. *J. Mammal.* 60: 521-527.

Hui, C.A. 1985. Undersea topography and the comparative distributions of two pelagic dolphins. *Fish. Bull.* 83: 472-475.

Pilleri, G. and Knuckey. 1967. Behaviour Patterns of some Delphinidae observed in the Western Mediterranean. *Cer. An. Istit. Univ. of Bern. Waldau Bern.* Switzerland. 72pp.

Politi, E., Bearzi, M., Notarbartolo di Sciara, G., Cussino, E., and Gnone, G. 1992. Distribution and frequency of cetaceans in the water adjacent to the Greek Ionian Islands. Pp. 75-78. In: *European Research on Cet.aceans - 6* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, Italy, 20-22 Feb 1995. European Cetacean Society, Cambridge, UK. 254pp.

Politi, E., Airoldi, S. and Notarbartolo di Sciara, G. 1994. A preliminary study of the ecology of cetaceans in the water adjacent to Greek Ionian Island. Pp. 111-115. In: *European Research on Cet.aceans - 8* (Ed. P.G.H. Evans). Proc. 8th Ann. Conf. ECS, Montpellier, France, 2-5 March 1995. European Cetacean Society, Lugano, Switzerland. 288pp.

Pulcini, M., Mecozzi, M., Lamberti, C., and Bergamasco, C. 1995. Application of multivariate statistical techniques on a community of *D. delphis* in the Ionian Islands of Greece. Pp. 147-150. In: *European Research on Cet.aceans - 9* (Eds. P.G.H. Evans & H. Nice). Proc. 9th Ann. Conf. ECS, Lugano, Switzerland, 9-11 Feb 1995. European Cetacean Society, Kiel, Germany. 302pp.

Selzer, L.A. and Payne, P.M. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphin (*Delphinus delphis*) vs. environmental features of the continental shelf of the Northeastern United States. *Mar. Mamm. Sci.*, 4: 141-153.

Shane, S.H., Wells, R.S. and Würsig, B. 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. *Mar. Mamm. Sci.*, 2: 34-63.

Shane, S.H. 1990. Behavior and ecology of the bottlenose dolphin at Sanibel Island, Florida. In *The Bottlenose dolphin* (Eds. S. Leatherwood and R.R. Reeves), Academic Press, New York.

Wells, R.S., Irvine, A.B. and Scott, M.D. 1980. The social ecology of inshore odontocetes. Pp. 263-318. In: *Cetacean Behavior* (Ed. L.M. Herman). Wiley Interscience, New York.

Wursig, B. and Wursig, M. 1980. Behavior and ecology of dusky porpoises, *Lagenorhynchus obscurus*, in the South Atlantic. *Fish. Bull.*, U.S. 77: 871-90.

Young, D.D. and Cockcroft, V.G. 1994. Diet of common dolphins (*Delphinus delphis*) off the south-east of southern Africa: opportunism of specialisation?. *J. Zool.*, Lond. 234: 41-53.

Table 1. Activity Patterns of Common Dolphins in Greece

Formations (%)	TRAVEL	FEED	SEARCH	SOCIALISE	SEXUAL BEHAV.	MILL	REST
horizontal	12	19	13	17	5	15	25
team	6	9	7	0	0	13	0
echelon	3	1	1	0	0	10	1
front	23	18	15	3	0	12	0
doublefront	4	1	3	0	0	1	0
line	10	2	3	1	1	1	0
tight	1	2	1	4	0	1	4
circle	4	14	3	2	2	1	2

Formations (%)	TRAVEL	FEED	SEARCH	SOCIALIZE	SEXUAL BEH.	MILL	REST
horizontal	**12**	19	13	17	5	15	25
team	**6**	9	7	0	0	13	0
echelon	**3**	1	1	0	0	10	1
front	**23**	18	15	3	0	12	0
doublefront	**4**	1	3	0	0	1	0
line	**10**	2	3	1	1	1	0
tight	1	2	1	4	0	1	4
circle	**4**	14	3	2	2	1	2

Table 1

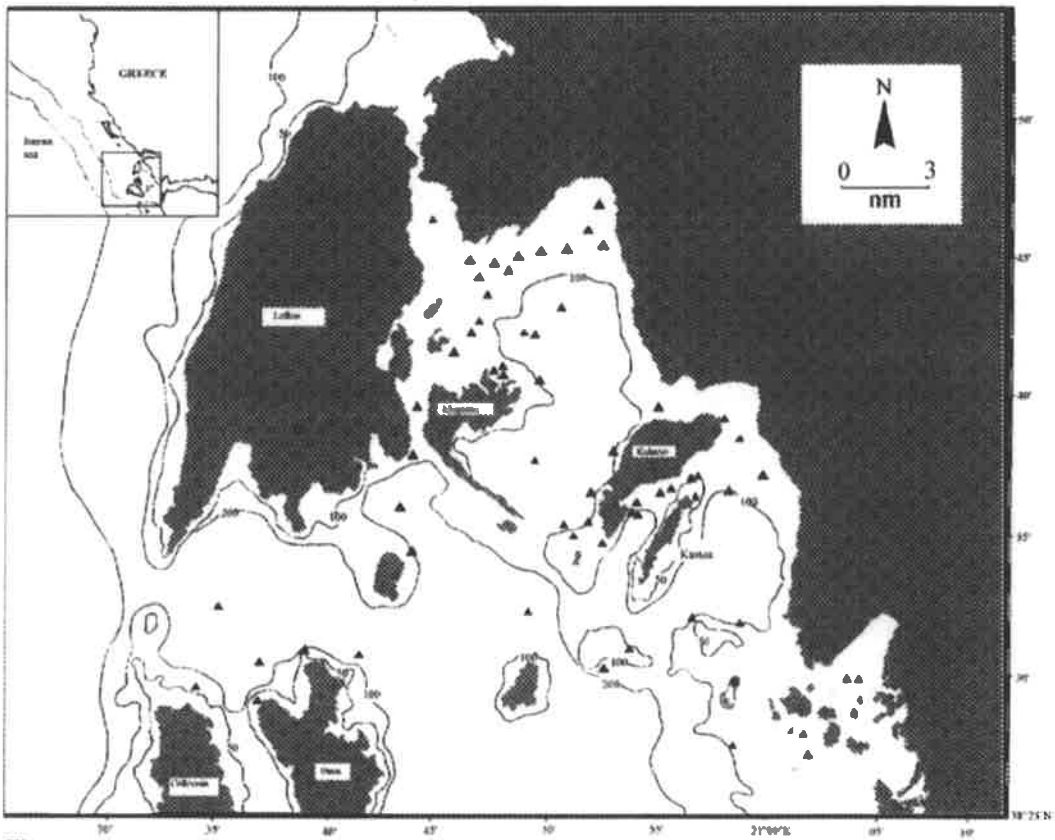

Figure 1

A COMPARATIVE STUDY ON THE DISTRIBUTION AND BEHAVIOUR OF THE COMMON DOLPHIN (*DELPHINUS DELPHIS*) AND THE STRIPED DOLPHIN (*STENELLA COERULEOALBA*) ALONG THE SOUTH-EASTERN COAST OF SPAIN.

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The short-beaked common dolphin (*Delphinus delphis*) in the western Mediterranean basin is at present only occasionally observed north of latitude 38°00'N (Fabri and Laureano 1992; Notarbartolo di Sciara *et al*,1993; Pulcini *et al*, 1993; Gannier 1995). This species is thought to have suffered a decline in population in favour of the striped dolphin (*Stenella coeruleoalba*) (Pelegrí 1980, Viale 1980, Evans 1987, Laurent 1991, Aguilar 1991, Viale 1993, Notarbartolo di Sciara 1993, Gannier 1995). Since 1992, a research programme has been conducted in the Alboran region in order to establish the possible causes and magnitude of the common dolphin decline in the western Mediterranean Sea, focusing on the distribution, feeding habits, and behaviour of these two species. The lack of previous research on this issue and the general lack of information on both species in the Mediterranean Sea (specially the common dolphin) are seen as a major obstacle to the conservation of cetaceans in this region.

METHODS Shipboard surveys have been conducted during the months of April, June, July, August, September and November 1992 to 1997 covering the area from Cabo de Palos (37°38'N 0°33'W) to Almerimar (36°20'N 2°55'W) (Fig. 1). Transects were sailed as perpendicular as possible to the coastline at an average speed of six knots, keeping a constant lookout for cetaceans alternating non assisted vision and using 7x50 mm handheld binoculars from two height levels (3 m. and 14 m. height of eye above sea level). Navigation, oceanographic and meteorological data were recorded during surveys. Throughout the surveys, data are also recorded on species encountered, number of individuals, group structure and behaviour. Since 1995, most of the data collected during sailing was directly imported from the GPS to a personal computer loaded with the IFAW's LOGGER program. Whenever possible, individuals are photographed for photo-ID purposes. Since 1997, a towed array hydrophone supplied by IFAW has been used as well to detect and record cetacean's sounds. For the analysis of distribution, the whole research region has been divided into four major areas (I=north, II=centre, III=south and IV=southwest) which in turn are subdivided in 10*10 nautical mile quadrats (18.6 x 14,9 km) (Fig. 1). In addition, six depth ranges are considered: 0-200, 200-500, 500-1,000, 1,000-1,500, 1,500-2,000 and >2,000 metres depth. Sea state is also taken into account for the analysis, being divided into five categories using Douglas sea state scale: 1, 1S, 2, 2S and 3 (S=swell) (approximate equivalence to Beaufort scale: 1 Douglas - Beaufort 0-2, Douglas 2 - Beaufort 3, Douglas 3 - Beaufort 4-5). Sighting effort stopped with sea states over 3 Douglas.

RESULTS.

Encounter rates. To obtain a relative index of abundance, the encounter rate was calculated by dividing the number of groups encountered in each of the divisions mentioned above (areas, quadrats or depth ranges), by the nautical miles sailed on effort in the division. This was then multiplied by 100 in order to avoid unnecessary decimals. Survey cruises have covered 10,531.6 nm (19,589 km). Of these, 6,123.5 nm were sailed under sea state 1 and 1S, 3,916.5 nm were sailed under sea state 2 or 2S, and 491.3 nm were sailed under sea state 3. 176.7 hours have been spent on common dolphin observation (233 sightings, 25% of all sightings), and 127 hours on striped dolphin observation (314 sightings, 33,7%). Fig. 2, shows the encounter rates for both species over all sea states. Common dolphins show a clear gradient for the encounter rates, being higher as the latitude decreases (area I is the more northern area, and IV is the more southern area). A similar result is apparent within each sea state condition. This gradient clearly shows the importance of the Alboran Sea for the common dolphin, which becomes rarer northwards.

For the striped dolphin, the situation is different. There is no latitudinal gradient, but two trends are evident. Firstly, in the southern areas (III and specially IV), the encounter rates for common dolphins are higher than those for striped dolphins. Secondly, the encounter rate for striped dolphin in area II is generally higher than in the other areas, except for the two last years in which area I have the greatest rate. Both trends are evident under all sea states surveyed. These results again show how the Alboran area seems to be more important for the common dolphin than for the striped dolphin.

Distribution per depth. A significant difference ($p>0.05$) has been found for both species in terms of distribution by depth range: X=619.5 SD=490.206 for common dolphin (n=182) and X=938 SD=471.837 for striped dolphin (n=256). In Fig. 3, the difference between both species can be clearly observed: the striped dolphin has a growing gradient of encounter rate as the depth increases, whilst the common dolphin has no gradient and is encountered more often in shallower waters than the striped dolphin. Fig. 4 shows how both species can be found in every depth range, but the common dolphin has a higher frequency from the coast to 300 m., while the striped dolphin has its higher frequencies between 500 and 1200 m.

Distribution per months. Striped dolphin exhibited strong seasonality (Fig. 5). Every year, starting in September, when the first westerly storms alter the oceanographic conditions of the region, striped dolphin encounters increased.

Group size. More schools of striped dolphins were seen; however, more individual common dolphins were counted: 15,826 (41.5%) common dolphins and 14,265 (37.4%) striped dolphins. A significant difference ($p>0.05$) was found for the average group size of both species, for common dolphins X=67,8, median=40, mode=60 (SD=82,885, n=237, range 1-500) and for striped dolphins X=45,4, median=30, mode=20 (SD=51.388, n=319, range 1-350) (Fig. 6). For both species, the observation of new-born calves is very frequent during the summer months. Common dolphin groups observed in the more northern regions tend to be smaller than groups in Alboran, where the average group size is 84.9. Striped dolphins appear generally more dispersed than common dolphins, seldom gathering in large groups, and with no differences being observed between areas. The common dolphin shows also a much bigger group size in shallower waters, where they have been observed feeding, than in deeper waters. No difference in group size has been observed for striped dolphins.

Behaviour. Common dolphins show greater curiosity and interest towards ships than striped dolphins. Confidence towards the research ship and researchers in water has increased over the years, with increasing approaching behaviour, especially by resident groups of dolphins. This has allowed us to increase the efficiency of video filming as a method of analysing behaviour patterns. In relation to the research ship, striped dolphins appeared mainly indifferent or evasive (63.33% of encounters, n=201), approaching the ship only on 36.67% of the encounters (n=102), while common dolphin groups show more curiosity and tolerance to our presence, approaching the ship on 67.82% of encounters (n=149). Common dolphins showed indifference or evasiveness towards research ship only on 32.18% of encounters (n=76).

Feeding. Feeding is often observed in the common dolphin groups, especially in the region of Almería. Prey species have been identified with the help of underwater filming of foraging. Foraging almost always occurred in big relatively compact groups when feeding on small pelagic fish. Several non-commercial species of fish concentrate along the coast of regions III and IV where upwellings created by the Alboran gyres set off primary production (Rubín *et al*, 1992; Packard *et al*, 1985).

Feeding was also observed in the track of bottom trawlers while fishing on the shelf and shelf edge, a foraging strategy more commonly observed throughout the Mediterranean for the bottlenose dolphin (Fortuna *et al.*, 1996; Bearzi and Notarbartolo di Sciara, 1997). When this kind of foraging was observed, groups were generally smaller. Striped dolphins are more seldom observed feeding in the coastal regions, and then only when seasonal abundance of flying fish or small red tuna come into the region. These observations correspond with the gathering of individuals into bigger groups and their entrance into shallower depth ranges. Stomach contents of striped dolphins in the Mediterranean seem to indicate a preference for cephalopods, which could explain the lack of foraging observations for this species (Blanco *et al.*, 1995).

DISCUSSION Although more research is needed, especially for other seasons of the year, the results of these six years show a significant difference in distribution, behaviour and feeding habits between the two species. However, there are no clear signs of direct competition between the two species.

- The common dolphin is more abundant as the latitude decreases, being more common in the south of the research region than the striped dolphin. Group size in the southern areas also increases significantly.
- Striped dolphins were found to be predominantly pelagic whereas common dolphins were more often observed close to the coast on the continental shelf.
- The striped dolphin groups observed during the summer months appeared to be mainly small groups of young animals, or even nurseries, and very dispersed groups of adults; whereas from September to May groups were observed to have a bigger proportion of large adults. This seasonal change in group structure was not observed in the common dolphin.
- Common dolphin groups in the region of Alboran are bigger than striped dolphin groups.
- The attitude of common dolphin groups towards the research ship and to divers filming was radically different from striped dolphins, with much more playing and approaching behaviour.

These first six years of research in this region have allowed us to follow several groups of common dolphin in the Alboran sea, a region of important productivity (Rubín *et al*, 1992; Packard *et al*, 1985), and abundance of several species of non commercial small pelagic fish (Rodriguez, 1982). The size of groups and the amount of calves observed yearly seem to be a positive indicator for this species in the Mediterranean. However, this situation could quickly change if appropriate steps are not taken to avoid future threats, mainly the over-exploitation of fish stocks and commercialisation of common dolphin prey species. Alnitak will be concentrating effort in future years on the monitoring of these groups to assess any possible environmental or human pressures that might threaten the remaining common dolphins in the western Mediterranean.

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REFERENCES

Aguilar, A. 1991. Calving and early mortality in the western Mediterranean striped dolphin, *Stenella coeruleoalba*. *Can. J. Zool.*, 69 (5): 1408-1412.

Bearzi, G. and Notarbartolo di Sciara, G. 1997. Bottlenose dolphins following bottom trawlers in the Kvarneric (Northern Adriatic Sea). Pp. 202-204. In: *European Research on Cetaceans - 11.* (Eds. P.G.H. Evans, E.C.M. Parsons & S.L. Clark). Proc. 11th Ann. Conf. ECS, Stralsund, Germany, 10-12 March 1997. European Cetacean Society, Kiel, Germany. 314pp.

Blanco, C., Aznar, J. and Raga, J.A. 1995. Cephalopods in the diet of the striped dolphin *Stenella coeruleoalba* from the western Mediterranean during an epizootic in 1990. *J. Zool.* Lond., 237: 151-158.

Evans, P.G.H. 1987. *The Natural History of Whales and Dolphins.* Christopher Helm Mammal Series. London. 343pp.

Fabri, F. and Lauriano, G. 1992. Greenpeace report on two year research in the Ligurian sea. Pp. 69-74. In: *European Research on Cetaceans - 6.* (Ed. P.G.H. Evans). Proc. 6th Ann. Conf. ECS, San Remo, 20-22 Feb 1992. European Cetacean Society, Cambridge, England. 254pp.

Fortuna, C.M., Bearzi, G. and Delfino, G. 1996. Surfacing pattern of bottlenosed dolphins following bottom trawler in the kvarneric (Northern Adriatic sea). P. 244. In: *European Research on Cetaceans-10.* Proc. 10th Ann. Conf. ECS, Lisbon, Portugal, 11-13 March 1996. European Cetacean Society, Kiel, Germany. 334pp.

Gannier, A. 1995. *Les cétacés de Méditerranée nord-occidentale: estimation de leur abondance et mise en relation de la variation saisonnière de leur distribution avec l'ecologie du milieu.* Master Thesis. Ecole Pratique des Hautes Etudes. Montpellier, France

Laurent, L. 1991. Observations cétologiques en Méditerranée occidentale. *Vie Milieu*, 41(4): 263-269.

Notarbartolo di Sciara, G. 1993. Cetacei del Mediterraneo. *Contributi del Centro Linceo Interdisciplinare "Beniamino Segre"* N. 86. XIX Seminario sulla Evoluzione Biologica e i grandi problemi della biologia: 39-52

Notarbartolo di Sciara, G., Venturino, M.C., Zanardelli, M., Bearzi, G., Borsani, F.J., and Cavalloni, B 1993. Cetaceans in the central Mediterranean Sea: Distribution and sighting frequencies. *Boll. Zool.*, 60: 131-38

Packard, T.T., Minas, H.J., Coste, B., Martínez, R., Bonin, M.C., Gostan, J., Garfield, P., Christensen, J., Dortch, Q., Minas, M., Copin-Montequt, G., Copin-Montequt, C. and Roca, P. 1985. *Formation of the Alboran Oxygen Minimum Zone.*

Pelegrí, J., 1980. Recull de la Comisó de Cetologia de la Institució Catalana d'História Natural. II: anys 1974 i 1975. *Bull. Inst. Cat. Hist. Nat.*, 45 (Sec. Zool., 3): 155-165.

Pulcini, M. Angradi, A.M. and Sanna, A. 1993. Distribution and frequency of cetaceans in the Ligurian-Provençal basin and in the north Tyrrhenian Sea (Mediterranean sea). Pp.144-147. In: *European Research on Cetaceans - 7.* (Ed. P.G.H. Evans). Proc. 7th Ann. Conf. ECS, Inverness, Scotland. 18-21 Feb 1993. European Cetacean Society, Cambridge, UK. 306pp.

Rodriguez, J. 1982. *Oceanografia del mar Mediterr·neo.* Ed. Pirámide.

RubÌn, J.P., Gil, J., Ruiz, J., Cortés, M.D., Jiménez-Gómez, F., Parada, M. and Rodriguez, J., 1992. *La distribución ictioplanctónica y su relación con parámetros físicos, químicos y biológicos en el sector norte del Mar de Alboran, en julio de 1991 (Resultados de la Campaña "Ictio. Alboran 0791").* Instituto EspaÒol de Oceanografía. Informe Técnico No. 139, Madrid.49pp.

Viale, D. 1980. Les modifications du peuplement de cétacés de Méditerranée occidentale. *Journées Étud. Systém. Et Biogéogr. Médit.* Cagliari, C.I.E.S.M.

Viale, D. 1993. Cetaceans as indicators of a progressive degradation of Mediterranean water quality. *Pr. Malaysia:* 183-198.

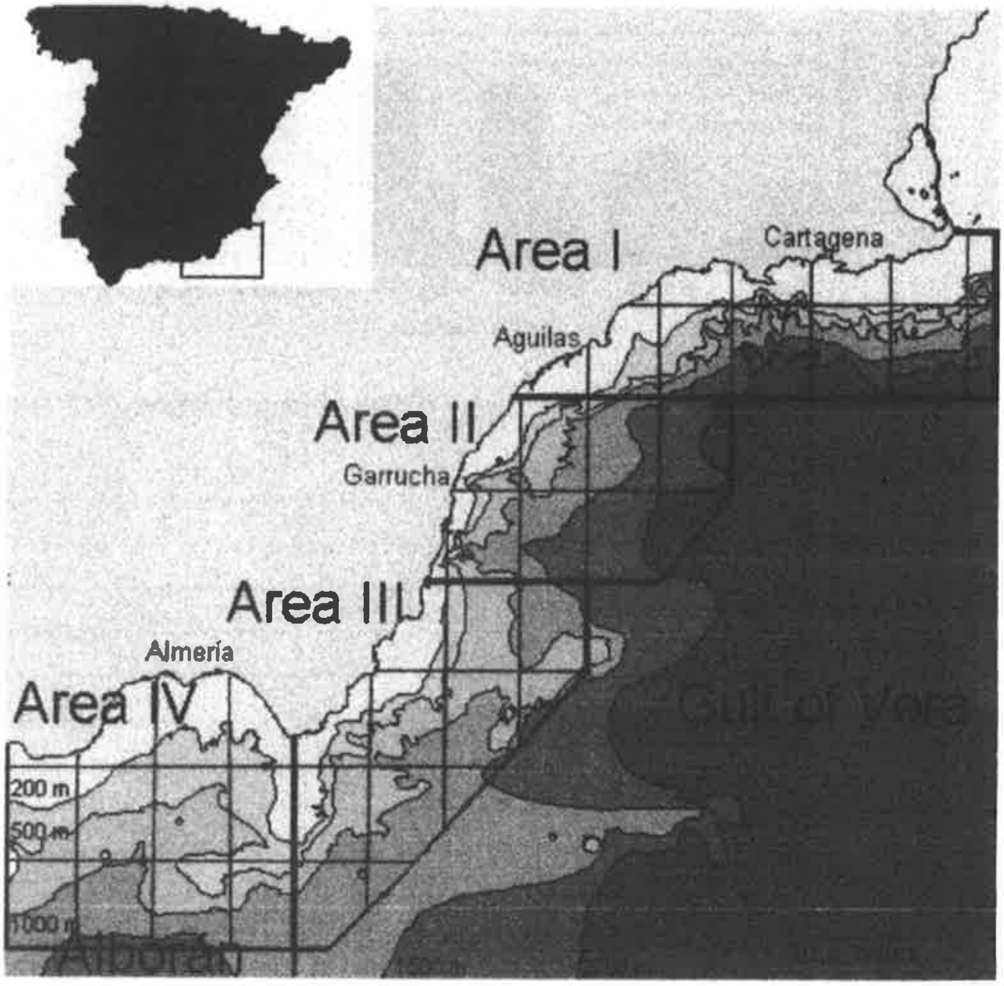

Figure 1. Research area

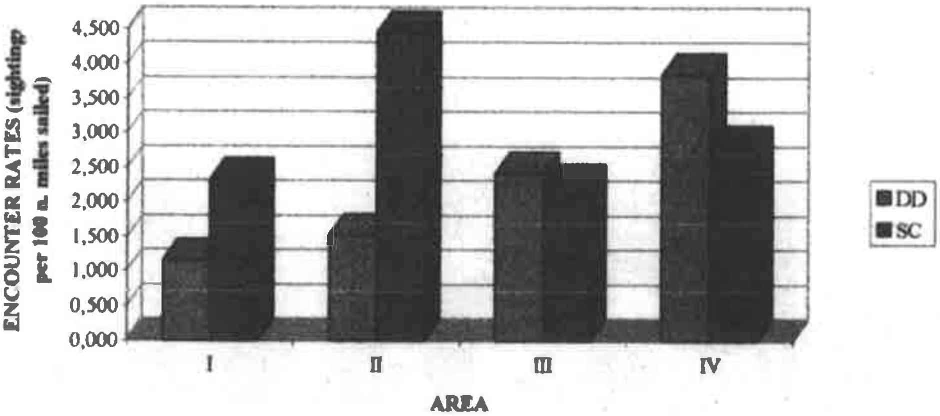

Figure 2. Encounter rates per area for common dolphins (DD) and striped dolphins (SC) (1992-97)

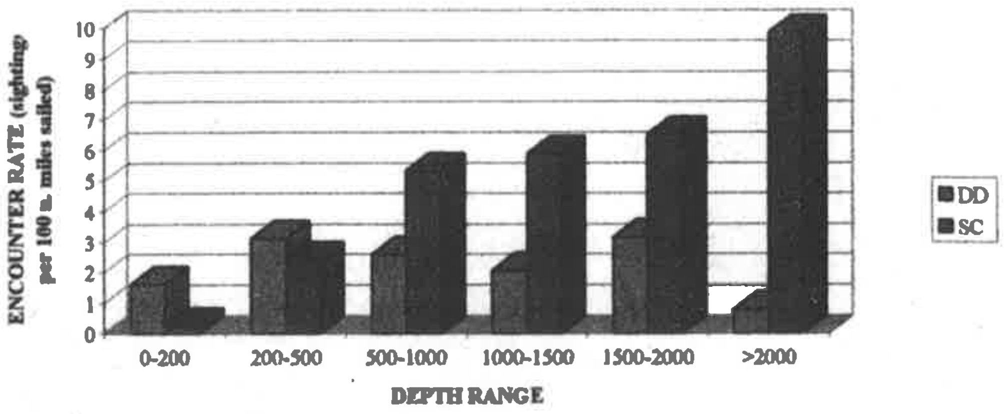

Figure 3. Encounter rate per depth for common (DD) and striped dolphin (SC) (1992-97)

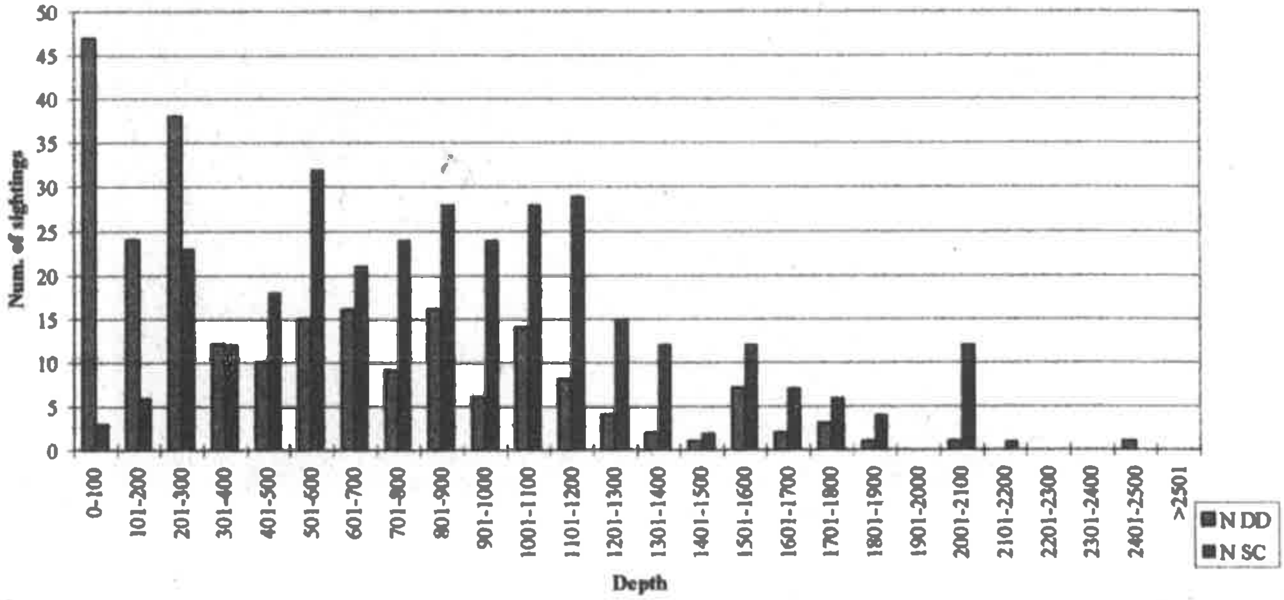

Figure 4. Frequency of sightings per depth for common (DD) and striped dolphins (SC) (1992-97), being the survey effort equal for both species

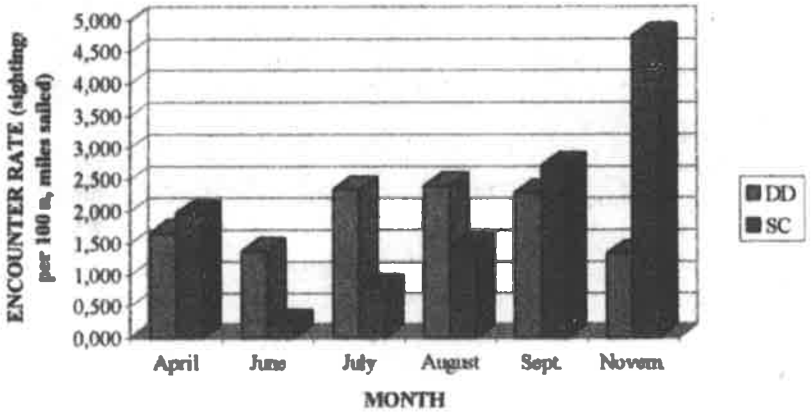

Figure 5. Encounter rates per month for common and striped dolphins (1992-97)

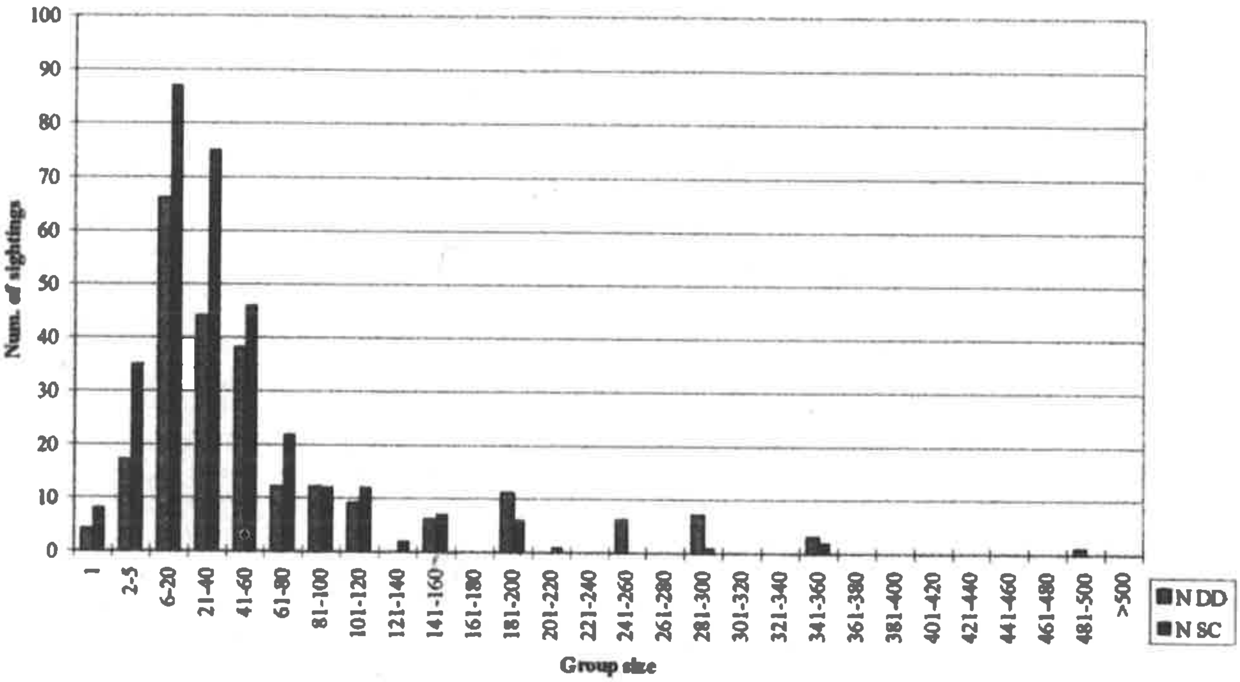

Figure 6. Frequency of group size for common (DD) and striped dolphins (SC) (1992-97)

ALLOPARENTAL CARE IN *TURSIOPS TRUNCATUS*: A CASE REPORT

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INTRODUCTION In the majority of mammal species, mothers provide virtually all of the care for their young alone, even more rarely non-parental animals provide care (Riedman, 1982). Recently, many researchers have become interested in the interactions between newborns and individuals other than mothers (Mann and Smuts, 1998). Among captive bottlenose dolphins (*Tursiops truncatus*) the mother is often assisted by another female during parturition and neonatal care (Caldwell and Caldwell, 1964, 1966; Tavolga, 1966), and such behaviour which benefits the young is defined alloparental. Conflicting opinions have been expressed about the adaptive significance of such interaction and several functions have been proposed. The babysitting function, referred to remaining with the young during the absence of the mother, seems to benefit the mother by releasing her for more efficient foraging, which may represent one instance of apparent "altruism" that has evolutionary significance in terms of kin selection theory (Riedman, 1982). On the other hand, some authors have regarded the interactions as selfish behaviour on the part of the allomother, *e.g.* "learning to mother" to develop maternal skill by the allomother (Lancaster, 1971).

Quantitative observations on the mother's and allomother's responses in such interactions in relation to the infant in the natural environment tend to be very difficult, especially in sea environments. Captive colonies could provide a basis for this approach. The aim of this study is to investigate the development of an alloparental relationship occurred in bottlenose dolphins in captivity conditions. The birth of a calf at Rimini's Aquarium provided the opportunity for studies of mother-calf and aunt-calf interactions observing detailed behaviour sequences.

METHODS **Animals and environment.** Subjects of the study were one newborn female bottlenose dolphin named **Luna**, its own mother **Alfa**, and an unrelated female (defined as "aunt") **Beta**. Luna was born in the pool on May 12, 1995 (see Table 1 for details on dolphins housed at Rimini's Aquarium).

Observations has been carried out at the Rimini's Aquarium, whose open-air pool (20x20 m; capacity of 1400 m^3; surface of 314 m^2; maximum height of 5.5 m) is equipped with four underwater windows (80x80 cm).

Hygienic conditions were controlled by means of a close-circuit water system, and a chemical conditioning process monitored the intake of sodium hypoclorite-based disinfectants (range 0.2-0.8 ppm). The water was weekly checked for the presence of bacteria (*Colibacilluses* <20 colonies/100 ml), pH was kept between 7.6 and 7.8 and water temperature oscillated, according to the season, between 13° and 27°C.

Data collection and Analysis. Mother-calf pair and the aunt were constantly observed from birth to 52 weeks of age (*i.e.* from May 1995 to May 1996) in order to monitor maternal and allomaternal relationships in controlled conditions.

"Focal animal sampling" (Altmann, 1974) observational sessions lasting 30 minutes were carried out for the calf according to a decreasing temporal scheduling (from week 1 to week 26: 4 sessions/2 times a week; from week 27 to week 52: 4 sessions/1 time a week).

Sessions were randomly distributed in four time periods lasting three hours (from 08:00 am to 08:00 pm) and counterbalanced in order to equate, as much as possible, the representation of the different days (within each week) and of the different times of day (within each day).

A list of behavioural categories was first set up and then used for the systematic observations. Two main groups were selected from the catalogue and analysed for this specific study: locomotory behaviour and interactions. While the first one included 10 behavioural patterns of relatively long duration (Table 2), the second one was characterized by five short time behaviours mainly related to touches (Table 3).

The following parameters were scored for the calf, by means of a video camera and a specific computer program for behavioural studies (Observer 3.0; Noldus, 1997):

a) hourly mean duration of locomotory behaviours (mainly **swimming**) with the mother, or the aunt, or both, or alone;
b) hourly mean frequency of interactions (mainly **contacts**) with the mother or the aunt; the indication of the calf's active/passive situation and the part of the body involved in the contact were also measured. In this respect, **active state** indicates a condition in which the calf clearly approaches the mother or the aunt to begin interacting (*i.e.* given contacts), and **passive state** is referred to a situation in which the calf is clearly approached by the mother or the aunt to undergo the interaction (*i.e.* received contacts).

Mean duration and frequencies were analysed by Student's *t*-test for correlated measures.

RESULTS A total number of 312 sessions, corresponding to 156 hrs of observation, was recorded. A typical formation with the calf kept in a central position between mother's and aunt's sides was observed immediately after birth, and this close association in locomotory behaviour was maintained particularly over the next four months ($p<0.05$) (see Fig. 1). Moreover, the aunt seemed to show a babysitting function - remaining with the young during the absence of the mother - particularly during the first month, while this close proximity was maintained at lower level over the following months. Finally, the calf association in swimming with its mother only showed a non-monotonic trend, with two maximum values reached at the fifth and tenth month, while a constant increasing in time spent in locomotory behaviour alone was seen. Significant changes in the time spent in each association were observed comparing the first six months of the calf's life with the next months of the studied period (see Figs. 2a and 2b).

Contact behaviours were the most frequent interaction seen (78%). In fact, the calf showed an higher frequency of given (**active state**) and received (**passive state**) contacts with the aunt during the first month ($p<0.05$), reaching very low levels after the second one until the end of the studied year (see Figs. 3a and 3b). Both given and received contacts with the mother increased after the first month until the fourth, declined over the following four months, and rose again during the last three ($p<0.05$). Behavioural patterns including yielded touches through pectoral fins and received contacts on the trunk were the most frequent calf's interactions seen during all the studied period [see Tables 4 (active state) and 5 (passive state) for details on hourly mean frequency of calf's contacts involving different body portions with the mother and the aunt].

DISCUSSION The role of the unrelated female as an aunt was clear from the first stage of calf's life. In fact, Beta's babysitting function in swimming and providing assistance with the infant was particularly evident during the mother's deppartures. The care of another's young by the inexperienced female and the apparent benefit of such behaviour, points to allomothering as a prerequisite for successfully raising its own future offspring due to the fact that first time mothers are initially inept at handling calves, but gradually gain competence in maternal skills with maturity and experience (Hrdy, 1976). One important point of this "learning to mother" argument is the existence of a disparity in maternal competence between primiparous and multiparous mothers which may be lessened by aunting experiences prior to motherhood. In general, interactions between infants and individuals other than mother undoubtedly represent a complex phenomenon and the hypothesis concerning the function and the evolution of infant handling are even more numerous the terms to which this phenomenon has been referred (see Table 1 in Mastripieri, 1994).

The Beta's care-giving "training" activity seemed to be particularly relevant during the first month of the calf's life, as also documented by the high frequency of aunt-infant contact behaviours. Touch signals can be varied in many ways to increase their information content, including how produced, where touched, and the intensity of contact (Herman and Tavolga, 1980). Extensive contact with pectorals, flukes or trunk during affiliative relationships is common among dolphins, giving evidence of strong social bonding between the mother-calf and aunt-calf pairs, which may be in part developed and maintained through touch. In addition, the apparent variation in the occurrence of mother's and aunt's cares, suggests that individual differences may play a role in the quality of "sitting" but this is a difficult topic on which to gather information. Nevertheless, distinctive features of mother-calf and aunt-calf interactions were observed and different spatial location in their occurrence were recorded. In fact, the young animal maintained a position at the aunt's side never showing some typical mother-calf actions (*e.g.* swim beneath the mother, bump the mammary area with the top of the head, attempt to suckle), suggesting the development of a specific differential recognition made by the calf.

The aunt female gave birth to its first own calf on June 1997. A parallel study is proceeding in order to verify if the benefits of altruistic behaviours (Hamilton, 1963; Trivers, 1971; Connor and Norris, 1982), such as alloparental care and babysitting, may have been instrumental in the evolution of sociality in female bottlenose dolphins in a situation where it has the opportunity to receive a future increase of fitness via reciprocity. Preliminary data seems to confirm the Hrdy (1976) hypothesis of babysitting as a way to gain experience ("learning to mother") for the primiparous animal (Beta) since the older and experienced female (Alfa) did not show an evident babysitting function. This captivity observation suggests a possible environmental influence in the occurrence and development of allomaternal behaviour since in the wild the aunt role is often played by experienced females (Norris and Pryor, 1991).

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REFERENCES

Altmann, J. 1974. Observational study of behavior: Sampling methods. *Behaviour*, 49: 227-67.

Axelrod, R. and Hamilton, W.D. 1981. The evolution of social cooperation. *Science*, 211: 1390-96.

Caldwell, D.K. and Caldwell, M.C. 1964. Experimental studies on factors involved in care-giving behaviour in three species of the cetacean family Delphinidae. *Bulletin of the Southern California Academy of Sciences*, 63: 1-19.

Caldwell, D.K. and Caldwell, M.C. 1966. Epimeletic (care-giving) behavior in Cetacea. Pp. 755-789. In *Whales, Dolphins and Porpoises* (Ed. K.S. Norris) Univ.of California Press. Berkeley.

Connor, R.C. and Norris, K.S. 1982. Are dolphins reciprocal altruists? *American Naturalist* 119: 358-374.

Gould, L. 1992. Alloparental Care in Free-Ranging *Lemur catta* at Berenty Reserve, Madagascar. *Folia Primatologica*, 58: 72-83.

Hamilton, W.D. 1963. The evolution of altruistic behavior. *American Naturalist*, 97: 354-356.

Hrdy, S.B. 1976. Care and exploitation of nonhuman primate infants by conspecifics other than the mother. Pp. 101-158. In: *Advanced in the study of behavior* (Eds. J.S. Rosenblatt, R.A. Hinde, E. Shaw and C. Bier). Academic Press, New York, Vol 6.

Herman, L.M. and Tavolga, W.N. 1980. The communication systems of Cetaceans. Pp. 148-209. In *Cetacean Behavior: Mechanisms and Functions* (Ed. L.M. Herman, ed.), J. Wiley and Sons, New York.

Herzing D.L. 1995. An ethogram of underwater behaviours of the Atlantic Spotted Dolphins (*Stenella frontalis*). Behavioral Ethogram Workshop, 9th European Cetacean Society Annual Conference, Lugano February 9-11.

Mann J. and Smuts B.B. 1998. Natal attraction: allomaternal care and mother-infant separations in wild bottlenose dolphins. *Anim. Behav.*, 55: 1097-1113.

Mastripieri D. 1994. Social structure, infant handling and mothering styles in group-living old world monkeys. *Int. J. Primatol.*, 15(4): 531-553.

Maynard Smith, J. 1964. Group Selection and Kin-Selection. *Nature*, Lond., 14: 1145-1147.

Nelson D.L. and Lien J. 1994. Behaviour patterns of two captive Atlantic white-sided dolphins, *Lagenorhynchus acutus*. *Aquatic Mammals* (20)1: 1-10.

Norris, K.S. and Pryor, K. 1991. Some Throughts on Grandmothers. Pp. 287-289. In *Dolphin societies: Discoveries and Puzzles* (Eds. K.S. Norris & K. Pryor). University of California Press, Berkeley.

Norris, K.S., Würsig, B., and Wells, R. S. 1994. Aerial Behavior. Pp. 103-121. In: *The Hawaiian Spinner Dolphin*. (Eds. K.S. Norris, B. Würsig, R.S. Wells, and M. Würsig), Univ. of California Press, Berkeley and Los Angeles.

Quiatt, B. 1979. Aunts and Mothers: adaptative implications of allomaternal behavior of nonhuman primates. *American Anthropologist* 81: 310-319.

Renjun, L., Gewalt, W., Neurohr, B. and Winkler, A. 1994. Comparative studies on the behaviour of *Inia geoffrensis* and *Lipotes vexillifer* in artificial environments. *Aquatic Mammals* 20(1): 39-45.

Riedman, M.L. 1982. The evolution of Alloparental Care and Adoption in mammals and birds. *The Quarterly Review of Behavior*, 57(4): 405-435.

Sobel, N., Supin, A. and Myslobodsky, Ya. 1994. Rotational swimming tendencies in the dolphin (*Tursiops truncatus*). *Behavioural Brain Research*, 65: 41-45.

Stanford, C. B. 1992. Costs and benefits of allomathering in wild capped langurs (*Presbytis pileata*). *Behavioral Ecology Sociobiology*, 30: 29-34.

Tavolga, M.C. 1966. Behavior of bottlenose dolphins (*Tursiops truncatus*): social interaction in a captive colony. Pp. 718-730. In: *Whales, Dolphins and Porpoises* (Ed. K.S. Norris) Univ.of California Press., Berkeley.

Trivers, R.L. 1971. The evolution of reciprocal altruism. *The Quarterly Rewiev of Biology*, 46: 35-57.

Whitehead, H. 1996. Baby-sitting , dive sinchronicity and indication of alloparental care in Sperm Whale. *Behavioural Ecology and Sociobiology*, 38(4): 237-244.

Table 1. Information on dolphins housed at Gimini's Aquarium

Name	Sex	Age/Birth Date	Provenience	Residence in captivity (years)
Speedy	m	25 years (adult)	Adriatic Sea	17
Alfa	f	16 years (adult)	Gulf of Mexico	9
Beta	f	14 years (adult)	Gulf of Mexico	9
Sole	m	05/03/1993 (juvenile)	Rimini's Aquarium	captive-born (Alfa x Speedy)
Luna	f	05/12/1995 (infant)	Rimini's Aquarium	captive-born (Alfa x Speedy)

TAB. 2. LOCOMOTORY/RESTING BEHAVIOURS

CATEGORY	CODE	TYPE	DESCRIPTION	REFERENCE
swim normal posture	SNR	state	The usual mode of swimming or normal swimming posture	Renjun L., Gewalt W., Neurohr B. & Winkler A. (1994), Aq. Mamm. 20(1), 39-45
swim b-up	SBU	state	Dolphin is swimming inverted	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
swim left side/ swim right side	SLS-SRS	state	The dolphin swam on its side	Nelson D. L. & Lien J. (1994), Aq. Mamm. (20)1, 1-10
swim random	SRD	state	Random swimming	Sobel N., Supin A. Ya. & Myslobodsky (1994), Behav. Brain Res. 65, 41-45
exploratory behaviour	EXP	state	Scanning horizontal/perpendicular to the bottom	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
bottom rub	BTR	state	Dolphin is rubbing side/ventral, back area on bottom	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
bottom lying	BTL	state	Dolphin is lying on bottom, motionless	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
vertical stand	VST	state	Dolphin hangs vertically, head towards bottom/surface	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
rest	RST	state	The animals floated at the surface of the water without any body movements, the blowhole only was exposed to the air, the breathing frequency was reduced and the small eyes appeared to be closed	Renjun L., Gewalt W., Neurohr B. & Winkler A. (1994), Aq. Mamm. 20(1), 39-45
fluke out	FKO	state	Dolphin may literally surface vertically tail-first, thrusting the tail stock and flukes into the air before subsiding again. Dolphins may emerge to the level of the umbilicus and hold still or wriggle the tail in the air for up to 8 sec	Norris K. S., Wursig B. & Wells R. S. (1994), in The Hawaiian Spinner Dolphin. Univ. of California Press, Berkeley and Los Angeles, pp.103-121

TAB. 3. INTERACTIONS

CATEGORY	CODE	TYPE	DESCRIPTION	REFERENCE
bonding	BND	state	One dolphin swims pec to body with another	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
push	PUS	state	One dolphin pushes another with rostrum	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
rubbing	RUB	event	One dolphin is rubbing ventral area, flank, head or pectoral fin of another dolphin with pectoral fin	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.
contact	CNT	event	Any behaviour which involved physical contact between two animals; a "bout" of interaction began when one dolphin touched the other and continued until they moved greater than one body length apart	Nelson D. L. & Lien J. (1994), Aq. Mamm. (20)1, 1-10
chase	CHS	state	One dolphin, or group of dolphins chasing each other in fast, medium, or slow chase	Herzing D. L. (1995), 9th European Cetacean Society annual Conference, Lugano February 9-11.

TAB. 4. Hourly mean frequency of calf's given (active state) contact behaviours related to the mother and the aunt body portions

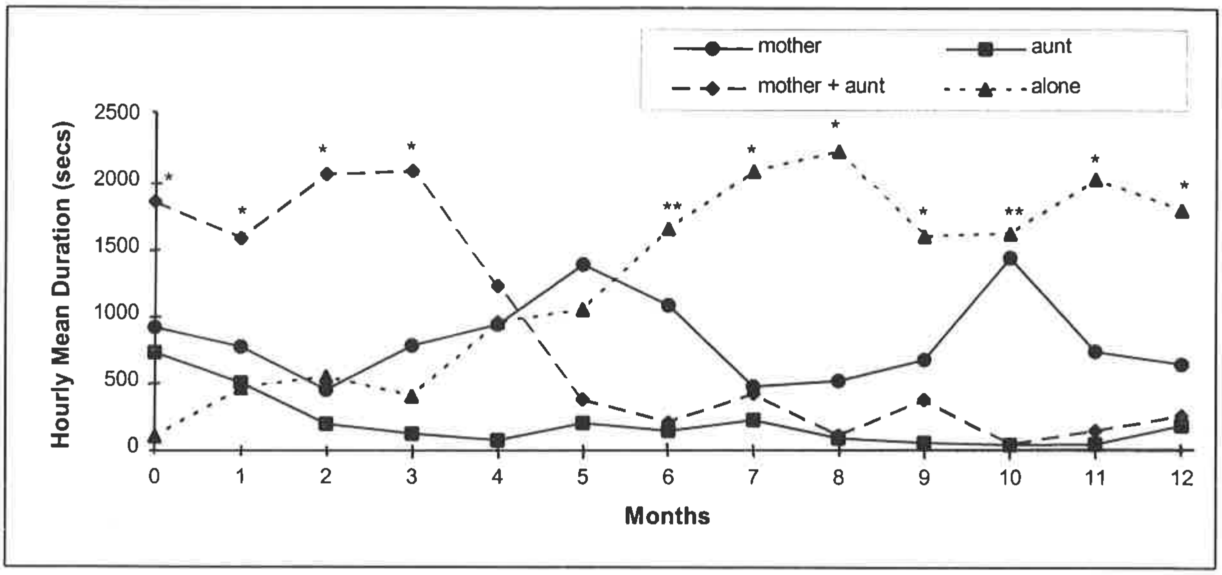
MONTHS	HEAD		BACK		SIDE		BELLY		PECT FINS		DORS FINS		TAIL	
	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT
0	0,87	1,48	0,78	0,26	0,26	1,74	0,00	0,17	1,74	5,91*	0,00	0,00	0,17	0,26
1	2,73	1,53	2,60	0,13	0,73	1,13	0,47	0,13	3,60	7,07*	0,80	0,07	1,33	0,20
2	2,36	1,07	2,29	0,43	1,07	0,93	0,50	0,21	4,93	5,36	0,71	0,00	0,36	0,07
3	4,71*	0,21	5,21*	0,07	1,29	0,14	0,64	0,00	6,36*	1,71	2,00*	0,00	0,21	0,07
4	3,79*	0,29	4,64*	0,21	1,21	0,14	0,79	0,00	4,29*	1,64	0,93	0,00	0,93	0,00
5	2,43	0,07	1,71	0,07	0,93	0,21	0,43	0,07	4,79*	1,50	0,71	0,00	0,07	0,07
6	3,30*	0,40	0,90	0,10	0,90	0,10	0,70	0,20	3,30*	0,20	0,30	0,00	0,20	0,00
7	0,67	0,33	2,00*	0,00	1,17	0,33	0,00	0,17	1,83	1,00	0,17	0,00	0,50	0,17
8	0,71	0,14	0,86	0,14	0,43	0,43	0,00	0,00	0,71	0,71	0,14	0,00	0,00	0,00
9	2,43*	0,00	1,14	0,00	0,57	0,14	0,29	0,00	2,14	0,43	0,29	0,00	0,00	0,00
10	2,00	0,17	2,83*	0,00	1,00	0,00	0,17	0,00	2,00*	0,00	0,17	0,00	0,33	0,00
11	1,83	0,33	0,83	0,00	1,17	0,17	0,33	0,00	2,70	1,00	0,50	0,00	0,67	0,00
12	1,20	0,67	2,53	0,40	1,87	0,53	1,60	0,00	2,27	2,00	0,00	0,00	1,07	1,07

* $p<0.05$

TAB. 5. Hourly mean frequency of calf's received (passive state) contact behaviours related to the mother and aunt body portions.

MONTHS	HEAD		BACK		SIDE		BELLY		PECT FINS		DORS FINS		TAIL	
	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT	MOTHER	AUNT
0	0,26	0,96	0,52	1,30	0,87	4,87	0,96	4,35*	0,00	0,87	0,00	0,00	0,26	1,65
1	1,80	1,20	0,80	1,27	2,07	1,13	1,73	1,00	0,33	1,13	0,27	0,27	0,80	0,73
2	0,64	0,71	0,43	0,57	1,07	1,36	0,50	0,43	0,29	0,29	0,00	0,07	0,21	0,36
3	1,29	0,14	0,29	0,14	2,00	0,64	0,93	0,57	0,93	0,14	0,07	0,00	0,50	0,50
4	1,36	0,07	1,29	0,00	2,71	0,71	2,14*	0,29	0,64	0,14	0,21	0,07	1,21	0,00
5	0,93	0,00	0,57	0,00	2,00*	0,07	1,14	0,00	0,43	0,00	0,21	0,07	0,29	0,00
6	0,30	0,10	0,70	0,00	0,80	0,00	0,40	0,00	0,20	0,00	0,20	0,00	0,20	0,00
7	0,33	0,17	0,17	0,17	0,33	0,67	0,50	0,00	0,17	0,17	0,17	0,00	0,67	0,17
8	0,14	0,57	0,14	0,14	0,29	0,43	0,29	0,00	0,14	0,00	0,00	0,00	0,00	1,00
9	0,14	0,00	0,43	0,00	0,14	0,14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10	0,33	0,00	0,50	0,00	1,50	0,00	0,50	0,00	0,00	0,17	0,00	0,00	0,67	0,00
11	1,67	0,17	0,83	0,17	1,33	0,00	2,00	0,17	0,00	0,00	0,00	0,00	1,00	0,17
12	0,53	0,00	0,40	0,00	1,47	0,40	1,07	0,00	0,13	0,00	0,00	0,00	0,27	0,00

* $p<0.05$



* p<0.05 vs "mother", "aunt" and "alone"
** p<0.05 vs "mother+aunt" and "aunt"

FIG. 1. Hourly mean duration of calf's association with the mother, the aunt, both or alone during locomotory behaviours.

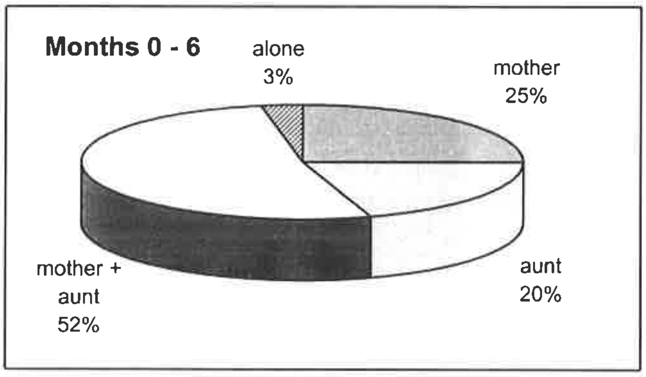


FIG. 2a. Time spent by the calf in locomotory behaviours in association with the mother, the aunt, both or alone (months 0 - 6).

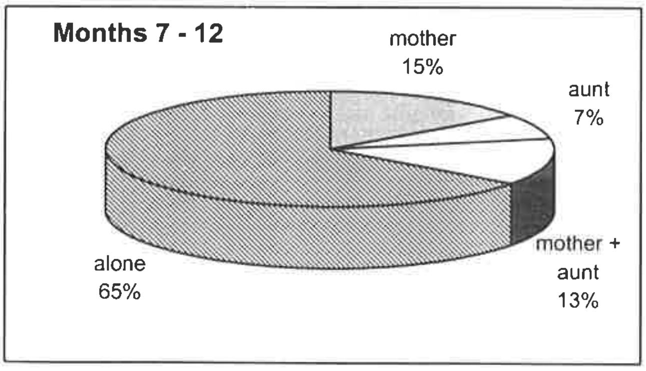
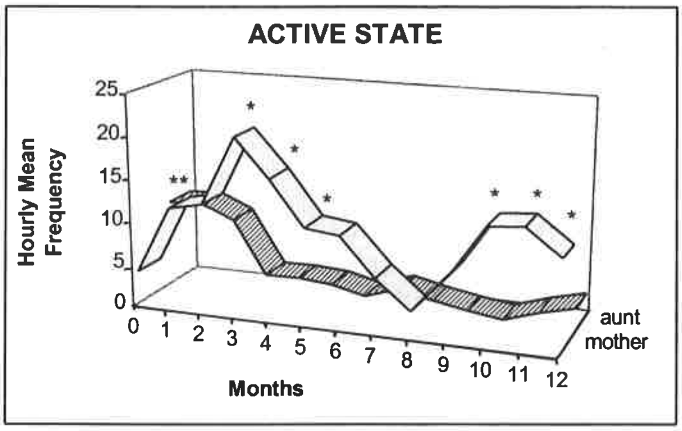
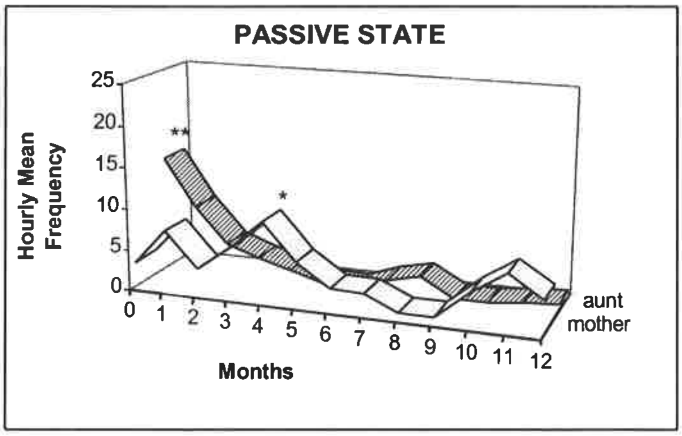


FIG. 2b. Time spent by the calf in locomotory behaviours in association with the mother, the aunt, both or alone (months 7 - 12).



* p<0.05 "mother" vs "aunt"
** p<0.05 "aunt" vs "mother"

FIG. 3a. Hourly mean frequency of calf's contact behaviours (**active state**) with the mother and the aunt.



* p<0.05 "mother" vs "aunt"
** p<0.05 "aunt" vs "mother"

FIG. 3b. Hourly mean frequency of calf's contact behaviours (**passive state**) with the mother and the aunt.

FINE SCALE TOPOGRAPHIC INFLUENCES ON ENVIRONMENTAL POTENTIAL FOR POLYGAMY (EPP) IN GREY SEALS

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INTRODUCTION Emlen and Oring (1977) proposed that certain environmental factors determine the degree to which mates can be monopolised and thus define the environmental potential for polygamy (EPP). The primary environmental factor identified was the spatio-temporal dispersion of resources or receptive females. Where females are uniformly distributed in space, there is little opportunity for monopolisation of mates (low EPP); where females are aggregated, EPP is greater. The degree of synchrony of oestrus forms the temporal component to EPP. Moderate synchrony enhances EPP, whilst both extreme synchrony (individual males are unable to mate with females simultaneously) and extreme asynchrony (males are less likely to maintain positions amongst breeding females for extensive periods) depress EPP.

Female grey seals (*Halichoerus grypus*) gather annually at remote, usually offshore islands to give birth to a single pup and, after weaning the pup, to mate. Within colonies, grey seals exhibit moderate synchrony of oestrus, having discrete breeding seasons of approximately two months duration, with each female present for approximately 19 days, the period from parturition to weaning. Male grey seals have sufficient energy reserves to maintain positions on the colony for the entire breeding season and compete aggressively for access to oestrus females. Thus, the size, density and temporal coherence of female groups on breeding colonies will be the primary determinant of EPP in this species.

As the spatio-temporal dispersion of resources and/or females may differ between populations, Emlen & Oring (1977) anticipated "considerable lability" in mating systems, with intra-specific variation in EPP and consequently the intensity of sexual selection and the degree of polygyny. Grey seals breed on a wide variety of substrates (Stirling 1975), which may differentially constrain or promote spatial aggregation. Here we test fine scale topographic influences on breeding female spatio-temporal dispersion at two topographically differing Scottish colonies; North Rona (59O06'N, 05O50'W) and the Isle of May (56O11'N, 02O33'W). We use high resolution images from aerial photography within a GIS to provide accurate quantification of breeding female dispersion patterns and thus estimate the relative EPP at these sites and make predictions concerning the expected differences in degree of polygyny.

MATERIALS AND METHODS Large format colour aerial photographs of our two study colonies (Hiby *et al.* 1988), taken on four dates during the 1994 breeding season at the Isle of may and five dates at North Rona, were scanned as high resolution images. Images were registered and rectified to real world co-ordinates within a GIS (ARC-INFO Version 7.0.3: ESRI, 380 New York Street, Redlands, Ca., USA) using sub-meter accurate ground control points derived in the field with Carrier Phase Differential GPS. Rectified images had pixel sizes equivalent to approximately 5cm x 5cm on the ground. Locations and sex-age class of all seals were digitised from these images. Overlapping images, used as stereo-pairs, provided sub-meter accurate Digital Elevation Models (DEMs) of the sites with measures of elevation and slope in 2m grid cells (Mills *et al.* 1997). Observations suggest that access to water may be an important determinant of pupping site selection. Therefore, we used GIS cost-surface functions to generate indices for each grid cell within the DEMs indicating the relative cost of moving from that location to the nearest pool or access point to the sea (as digitised from the images). Indices were based on least-cost routes incorporating modifiers for the surface features traversed or topographical barriers circumnavigated. GRID based functions of the GIS were used to compare topographical parameters between colonies and, within colonies, between areas containing breeding seals and areas where seals were absent.

Breeding female dispersion patterns through the breeding season were compared between colonies using the spatial tools of the GIS. Frequency distributions of the numbers of females in 10 m quadrats were compared against random and negative binomial distributions to examine the degree of spatial aggregation. In addition, for each coverage of breeding females, individuals were classified according to their nearest male. These arbitrary groupings were designed to assess female group size based solely on proximity to males. Frequency distributions of group sizes for each colony and date were compared.

Pupping curves from both study colonies (derived from direct observations of pup numbers during 1994) were used to calculate the number of new pups born on each date through the breeding season. These were converted to estimates of the number of females in oestrus per day by displacing the resulting curve by 19 days to the right on the abscissa. This provided an estimate of changes in the temporal availability of receptive females.

RESULTS We examined the standard deviation in slope values observed in neighbouring grid cells for each cell in our DEMs. This process was repeated at grid cell resolutions ranging from 10 to 50m and revealed that local variation in slope at North Rona remained relatively constant irrespective of the spatial scale at which it was measured. This indicates that the terrain at North Rona is relatively even. By contrast the Isle of May is more broken and rugged, showing significantly greater variation in slope (Mann-Whitney U tests, significant at $p < 0.001$) at all grid cell resolutions.

Female location was dictated by topography (see also Pomeroy *et al.* 1994). Compared to unoccupied areas, sites containing breeding seals were at significantly lower elevations, on shallower slopes and had relatively easy access to either the sea (Mann-Whitney U: Isle of May; $z = -3.9$, $n = 26039$, $p < 0.001$, North Rona; $z = -5.6$, $n = 27,450$, $p < 0.0001$) or pools of water (Isle of May; $z = -10.7$, $n = 27,536$, $p < 0.001$, North Rona; $z = -20.9$, $n = 27,450$, $p < 0.0001$).

Female dispersion patterns at both sites were random at the onset of the season, but became aggregated around the peak pupping date (variance >> mean, significant differences from Poisson distribution, $1/k$ values ranging from 4.2 to 9.0 at the Isle of May and 3.9 to 6.2 at North Rona) with maximum aggregation occurring mid-season, between peak pupping and peak oestrous dates (Fig. 1). Female aggregation was significantly greater at the most topographically rugged site (Isle of May) than at the less rugged colony (North Rona). This difference was maintained throughout the breeding season (Fig. 1) (ANOVA with Scheffe's Multiple range test for nearest neighbour distances for females: $F8,2355 = 35.69$, $p < 0.0001$).

Operational sex-ratios, as observed from the coverages were more skewed at the Isle of May than at North Rona (Table 1). Female groupings based on proximity to individual males at these sites also showed significant differences between colonies with larger groups at the Isle of May than at North Rona until the end of the breeding season (Table 1) (ANOVA with Scheffe's Multiple range test for female group size: $F8,250 = 12.43$, $p < 0.0001$).

There were notable differences between the two colonies in the temporal availability of receptive females (Fig. 2). The Isle of May had a single sharp peak of high availability of oestrus females. By contrast the period of high availability of oestrus females at North Rona is more extended with a secondary peak of availability in the latter half of the season.

DISCUSSION Broad scale topographic influences on pinniped dispersion patterns within and between breeding colonies have long been acknowledged (Bartholomew 1970, Stirling 1975, Boness 1991, Le Boeuf 1991), however few studies have provided accurate quantitative measures of dispersion patterns (*e.g.* Baldi *et al.* 1996) and most rely on qualitative comparisons of topography. Our use of high resolution aerial photography within a GIS has allowed the accurate mapping of dispersion patterns and topography.

Breeding females at the Isle of May were spatially more aggregated than those at North Rona throughout the breeding season. This was largely as a consequence of the differing topographies. The more rugged, broken terrain at the Isle of May lead to tighter groups of females, whilst the relatively open grassy lawns of North Rona allowed females to be more dispersed. Viewed simply from the perspective of spatial aggregation, these result indicate a greater EPP at the Isle of May than at North Rona. This interpretation is supported by the observed differences in sex ratios and female groupings based on proximity to males. Greater clustering of females promotes male exclusion by resident males and leads to more skewed sex ratios (Bartholomew 1970). If EPP predicts the actual degree of polygyny these results suggest more extreme polygyny at topographically rugged sites than at less rugged sites. However, preliminary results from extensive molecular studies (unpubl. data. W. Amos & J. Worthington-Wilmer, Cambridge Univ.) show no significant differences in the degree of polygyny between these two colonies. Therefore, male reproductive success may not reflect variation in group size as determined by topography. This suggests that either (i) EPP is not being capitalised upon by males, perhaps due to factors such as inter-annual mate fidelity (Amos *et al.* 1995), or (ii) the relationship between the relative timing of maximal spatial aggregation and of temporal availability acts to moderate EPP at both sites (i.e. comparing spatial aggregations without regard to the temporal aspect may give misleading indications of the relative EPP). At the Isle of May, where females are more spatially aggregated (therefore relatively high EPP in spatial terms), the temporal spread of high availability of females is relatively short, giving individual males relatively less time during which to capitalise upon the high 'spatial' EPP (thus, reducing EPP overall). Conversely, at North Rona, females are spatially more dispersed (lower 'spatial' EPP) but with a longer temporal spread of high availability of oestrus females (higher 'temporal' EPP). Thus, although the spatio-temporal dispersion patterns do differ between these colonies, such intra-specific plasticity in behaviour may result in similar levels of EPP and, consequently, degrees of polygyny.

ACKNOWLEDGEMENTS The work presented here forms part of a study funded by a UK NERC Fellowship. Special thanks to Paddy Pomeroy of SMRU for our long and fruitful collaboration and to Callan Duck, Dave Thompson and Phil Lovell of SMRU for access to the aerial photographs. Thanks also to Bill Amos and Jessica Worthington-Wilmer for providing preliminary results. Funding for SDT's attendance and presentation at The WMMSC 1998 was provided by the Royal Society.

REFERENCES

Amos, B., Twiss, S. D., Pomeroy, P. and Anderson, S. 1995. Evidence for mate fidelity in the gray seal. *Science*, 268: 1897-1899.

Baldi, R., Campagna, C., Pedraza, S. and Le Boeuf, B.J. 1996. Social effects of space availability on the breeding behaviour of elephant seals in Patagonia. *Anim. Behav.*, 51: 717-724.

Bartholomew, G.A. 1970. A model for the evolution of pinniped polygyny. *Evolution*, 24: 546-559.

Boness, D.J. 1991. Determinants of mating systems in the Otariidae (Pinnipedia). Ch. 1 in *Behaviour of Pinnipeds.* (Ed. Deane Renouf). Chapman and Hall, London. 1st Edition. Pp 1-44.

Emlen, S.T. and Oring, L.W. 1977. Ecology, sexual selection, and the evolution of mating systems. *Science*, 197: 215-223.

Hiby, A.R., Thompson, D. and Ward, A.J. 1988. Census of grey seals by aerial photographs. *Photogrammetric Record,* 12(71): 589-594.

Le Boeuf, B.J. 1991. Pinniped mating systems on land, ice and in the water: Emphasis on the Phocidae. Ch. 2 in *Behaviour of Pinnipeds.* (Ed. Deane Renouf) Chapman and Hall, London. 1st Edition. Pp 45-65.

Mills, J.P., Newton, I. and Twiss, S.D. 1997. Photogrammetry from archived digital imagery for seal monitoring. *Photogrammetric Record,* 15 (89): 715-724.

Pomeroy, P.P., Anderson, S.S., Twiss, S.D. and McConnell, B.J. 1994. Dispersion and site fidelity of breeding female grey seals (*Halichoerus grypus*) on North Rona, Scotland. *J. Zool.* Lond., 233, 429-447.

Stirling, I. 1975. Factors affecting the evolution of social behaviour in the Pinnipedia. *Rapp. P.-v. Reun. Cons. int. Explor. Mer,* 169: 205-212.

Table 1. Seasonal changes in mean natural log transformed female group size + 1 (based on proximity to males - see text) at the Isle of May and North Rona in 1994. Sex ratios are expressed as males:females. Date is expressed as number of days relative to peak pupping date.

Site	Date	Mean	Standard error	No. of groups	Sex ratio
Isle of May	-2	2.15	0.21	8	1:10.29
	9	3.15	0.17	18	1:29.50
	26	2.41	0.14	36	1:14.83
	37	1.07	0.12	47	1:3.88
North Rona	-2	0.62	0.13	15	1:1.30
	9	1.37	0.14	40	1:4.96
	22	1.81	0.14	37	1:7.49
	32	1.87	0.11	42	1:7.07
	48	1.71	0.20	16	1:6.17

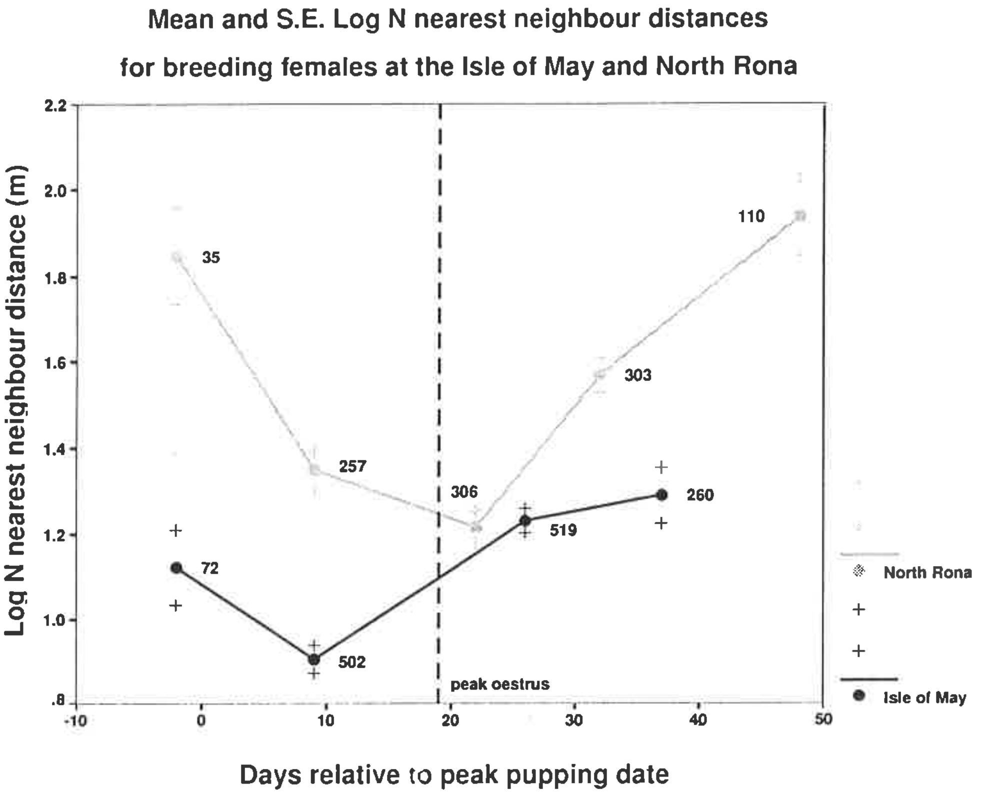

Fig. 1. Plot of seasonal changes in mean natural log transformed nearest neighbour distances for breeding females at the Isle of May and North Rona in 1994. Crosses indicate standard errors. Note: date is expressed in days relative to peak pupping date.

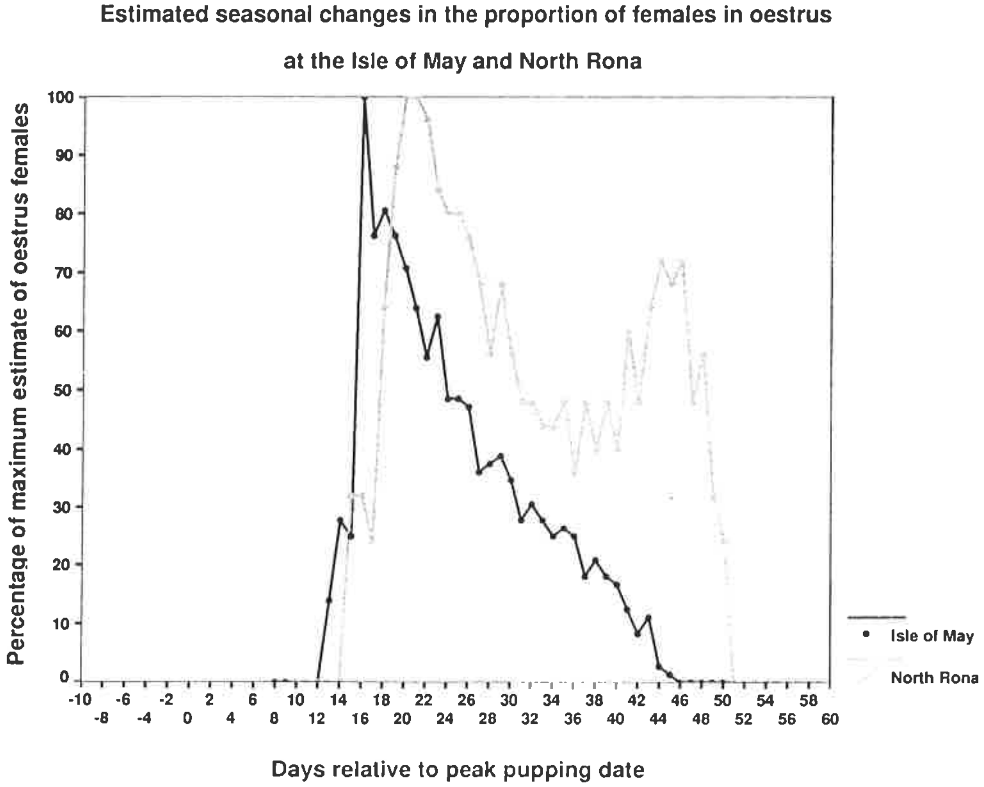

Fig. 2. Seasonal changes in the estimated number of females in oestrous per day for the Isle of May and North Rona 1994. Date is expressed as number of days relative to peak pupping date.

ANALYSIS OF SIGHTINGS, PHOTO-IDENTIFICATION AND ACOUSTIC DATA FROM A SMALL GROUP OF BOTTLENOSE DOLPHINS IN CENTRAL SOUTHERN ENGLAND: MOVING TOWARDS AN INTEGRATED APPROACH

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INTRODUCTION In 1988, a systematic cetacean survey was initiated to record the presence and absence of cetaceans off the coast of Dorset in southern England (Harland *et al.*, 1996). A dedicated team of local volunteers carried out the observations. The dolphin watch, as it became known, was prompted by regular sightings of a small number of bottlenose dolphins (*Tursiops truncatus*) in the area of Durlston Country Park (Fig 1). As the project developed, so the sightings data became supplemented with other studies, co-ordinated by the Coastwatch project based at the Country Park. There are three main parts to the study: Sightings, Photo-Identification and Acoustics. This paper examines all three arms, and the respective results for the first time.

SIGHTINGS STUDY The sightings study has been conducted by trained volunteers who have given up their time to keep watch from the cliff top at Durlston Country Park (Browning and Williams 1998). A core watch of 30 hrs per week has been maintained since 1988, yielding data that reveal trends in the presence and absence of the study animals (Williams *et al.*, 1997). Sightings records from casual observers are also recorded, and prior to 1995 these were unfortunately not distinguished from those of trained volunteers. Although this factor limits the extent to which data from the early years of the study can sensibly be analysed, rudimentary analysis shows that the sightings rate of the study animals has increased over the study period (Fig. 2) and that there is a marked seasonality associated with it (Fig. 3).

The sudden increase in the total number of sightings days between 1993 and 1994 (Fig. 2) cannot be explained fully, but it occurred at a time when a project officer dedicated to marine issues was appointed and this may have resulted in an increase in observer support and motivation (Browning and Williams 1997). However, this apparent change in the number of encounter days may reflect the effort of the project to obtain public sightings through education and the deployment of the seabed mounted hydrophone (Harland *et al.*, 1996) rather than a genuine increase in occurrence rate of the dolphin group.

Fig. 4 shows the proportion of yearly sightings falling in the four peak months (April, May, October and November). The proportion has remained stable at around 50% from 1991 to 1996, revealing that the increase in sightings over the study period is attributable to a year-round increase in sightings, rather than an exaggeration of the seasonal peaks. Sightings data have also been analysed to examine the mean group size observed, and this has helped us to understand the dynamics within the group. Taking the 1996 core watching hours as a study, and adjusting the data to account for effort, gives an index of relative abundance with the peak at 1.76 sightings 1,000/mins of effort and the minimum at 0. Evans reported in 1992 that the encounter rate was 0.7 sightings per 1,000 mins of effort. The group size (Fig. 5), taking account of all the sightings for the year 1996, varies between 1 and 5, with a mean of 3.0.

PHOTO ID Since 1995, a boat-based photo-ID study has been undertaken, during the seasonal peaks in dolphin activity. The purpose of this study is to identify those individuals that are seen in the study area. Once identified, the photo-ID study can be used to establish population parameters, monitor recurrence of individuals and the association of individuals within a group (Scott *et al.*, 1990; Wells 1991; Hammond *et al.*, 1990). This study has shown that five individuals are regularly seen and these individuals are considered to be the core group. All five were photographed during the first year of the study and have been photographed subsequently. Those identified individuals have been designated names. They are Alpha, Bravo, Charlie, Delta, and Echo (Fig. 6). During the study, the five individuals have occurred each year with some individuals' recurrence rate being greater than others (Table 1). All the individuals have been seen together on one occasion. The animals that recur most often are Alpha and Bravo recurring respectively on 78% and 92.8% of identifiable encounters. The association is calculated using $x/(x+Y_a+Y_b)$, where x=number of sightings of animal a and b together and Y_a is the number of times animal 'a' has been seen without animal 'b', and Y_b is the number of sightings of animal 'b' without animal 'a' being present. The association between individuals Alpha and Bravo is strong at 0.86 (Table 2). This demonstrates some fidelity between these two individuals within the study area. Dolphin Charlie recurs third most frequently with a recurrence rate of 71.4% and an association with Alpha of 0.61, and with Bravo of 0.77. Animal Echo has been seen in 50% of photo-ID encounters and has been seen to be both solitary and to associate with other animals. Delta has the lowest recurrence of the group rate at just 28% of encounters and has never been positively identified in a group size of less than 3. The animals that were seen to associate least during this period were Delta and Echo with an association of 0.1. On only one occasion has another group been photo-identified within the study area, and none of the regular study animals were present. The animal's presence semed to be part of a generally easterly movement of a population from Cornwall (Williams *et al.*, 1997).

ACOUSTIC MONITORING The acoustic programme at Durlston began in 1993 with the deployment of a seabed-mounted hydrophone (Harland *et al.*, 1996). It was intended to monitor the acoustic activity of the dolphins and to complement the visual watch with an acoustic monitoring capability. Following some testing, a 20 mm ball hydrophone was chosen with a bandwidth to 150 kHz. A pre-amplifier with a gain of 52 dB was constructed and encapsulated in a UPVC water pipe using polyurethane. The hydrophone and pre-amplifier were mounted on a tripod and deployed within Durlston Bay (Fig. 1). The signals are processed at the shore station and recorded on DAT. Since 1993, a total of 21 hours of recordings have been made on which there are acoustic data from cetaceans. There has never been a concerted effort to record the exact position of the study group and correlate this with the acoustic data. However, during the 1999 field season, a new approach fully integrating acoustic, photo-ID, and surface observations will commence using a portable hydrophone, video and stills cameras from a moving platform.

The study animals are the only animals seen within the study area with any regularity. It has therefore been assumed that the vocalisations recorded have been of the core group. Gross analysis of these data has permitted only broad categorisation of the vocalisations at this time. The categories are whistles, clicks and buzzes or burst pulse sounds. This lack of detailed analysis reflects our inability to directly correlate sound and behaviour in these animals and is a recognition that the acoustic data represent a preliminary study that has allowed us to look broadly at the vocalisations of the study group.

Whistles have only been recorded on three occasions, and were between 3 kHz and 10 kHz with a maximum duration of 0.7 secs. The clicks and pulsed sounds are broad band in nature and show highly variable characteristics. Clicks are the most frequently recorded sound with 55.5% of the analysed data recording clicks, 43% burst pulsed sounds and to date just 1.5% whistles.

DISCUSSION The English Channel is known to have low cetacean density (Hammond *et al.*, 1995). The area off Durlston Country Park has been the centre of a project utilising three different methods of gaining data on a group of five dolphins. The project has been developing in a way that is moving towards the convergence of the three approaches into a fully integrated study. For the past ten years, the study has utilised scientists and non-scientists in a collaborative venture (Browning and Williams, 1998.). To date, we have established that there is a group of five resident or semi-resident animals. These are seen to associate together and have not been observed associating with any other animals. The infrequent use of whistles in the recorded repertoire is an interesting feature, and a programme is being developed to investigate this aspect of the groupís behaviour. The research programme is about to begin studying the surfacing and acoustic behaviour simultaneously in order to give an insight into the relationships within the group. The predominance of click trains and buzzes suggests that in the vicinity of the hydrophone the animals tend to be foraging or otherwise acoustically investigating their surroundings or each other.

Developing the programme to include all sightings, photo-ID and acoustics studies has given us the opportunity to study the animals' temporal use of the area, their acoustic use, and the way they associate together. The programme is now actively developing new methods to allow closer scrutiny of these five animals to establish the sexual composition of the group and the behavioural dynamics. In addition, it is important for us to ask where they go when they are not in the study area and whether there are any significant threats to their survival.

REFERENCES

Browning, L.J. and Williams, A.D. 1998. The effective utilisation of scientists and non-scientists in an integrated study of free-ranging bottlenose dolphins (*Tursiops truncatus*) at Durlston Country Park, Dorset, UK. Pp.286-288. In *European Research on Cetaceans - 11*. (Eds. P.G.H. Evans, E.C.D. Parsons & S.L. Clark). Proc. 11th Ann. Conf. ECS, Stralsund, Germany. European Cetacean Society, Kiel, Germany. 314pp.

Evans, P.G.H. 1992. *Status Review of Cetaceans in British and Irish waters*. Unpubl. Report to UK Dept. of Environment. Sea Watch Foundation, Oxford. 100pp.

Ginsberg, J.R. and Young, T.P. 1992. Measuring associations between individuals or groups in behavioural studies. *Animal Behaviour*, 44: 377-379.

Hammond, P.S., Benke, H., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jørgensen, M.P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F. and Øien, N. 1995. *Distribution and Abundance of the Harbour Porpoise and other small cetaceans in the North Sea and Adjacent Waters*. European Commission LIFE Programme.

Hammond, P.S., Mizroch, S.A. and Donovan, G.P. (editors) *Individual recognition of cetaceans: use of photo-identification and other techniques to estimate population parameters*. (1990). *Rep. intern. Whal. Commn*. (special issue 12). 1-440pp.

Harland, E., Turnbull, M., Williams, R. and Copley, V. 1996. The Durlston Cetacean Monitoring Project. Pp. 89-91. In *European Research on Cetaceans - 9*. (Eds. P.G.H. Evans and H. Nice). Proc. 9th Ann. Conf. ECS, Lugano, Switzerland, 9-11 Feb 1995. European Cetacean Society, Kiel, Germany. 302pp.

Harland, E., Plowman, R. and Turnbull, M. 1996. Deployment of a sea-bed mounted hydrophone for cetacean monitoring. Pp. 69-71. In *European Research on Cetaceans - 9*. (Eds. P.G.H. Evans and H. Nice). Proc. 9th Ann. Conf. ECS, Lugano, Switzerland, 9-11 Feb 1995. European Cetacean Society, Kiel, Germany. 302pp.

Scott, M.D., Wells, R.S. and Irvine, B. 1990. A long term study of bottlenose dolphins on the west coast of Florida. Pp. 235-244. In *The bottlenose dolphin* (Eds. S. Leatherwood and R. Reeves). Academic Press, New York.

Wells R.S. 1991. The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pp 199-225. In *Dolphin Societies* (Eds. K. Pryor and K.S. Norris) University of California Press.

Williams A.D., Williams, R., Heimlich-Boran, J.R., Evans, P.G.H., Tregenza, N.J.C., Ridoux, V., Liret, C., and Savage, S. 1997. A preliminary report on an investigation into bottlenose dolphins (*Tursiops truncatus*) of the English Channel: A collaborative approach. Pp. 217-220. In *European Research on Cetaceans - 10.* (Ed. PGH Evans). Proc. 10th Ann. Conf. ECS, Lisbon, Portugal, 11-13 March 1996. European Cetacean Society, Kiel, Germany. 334pp.

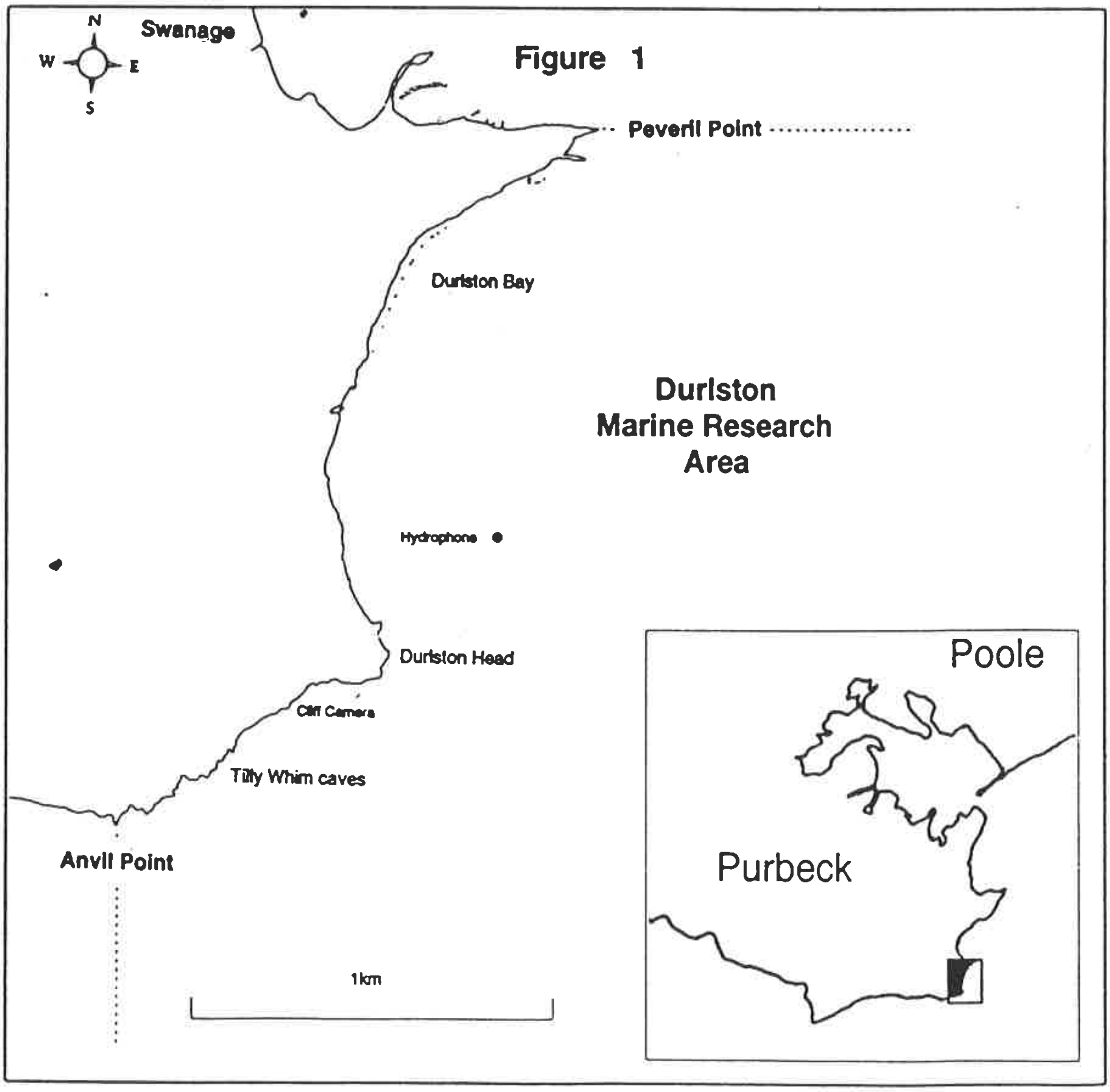
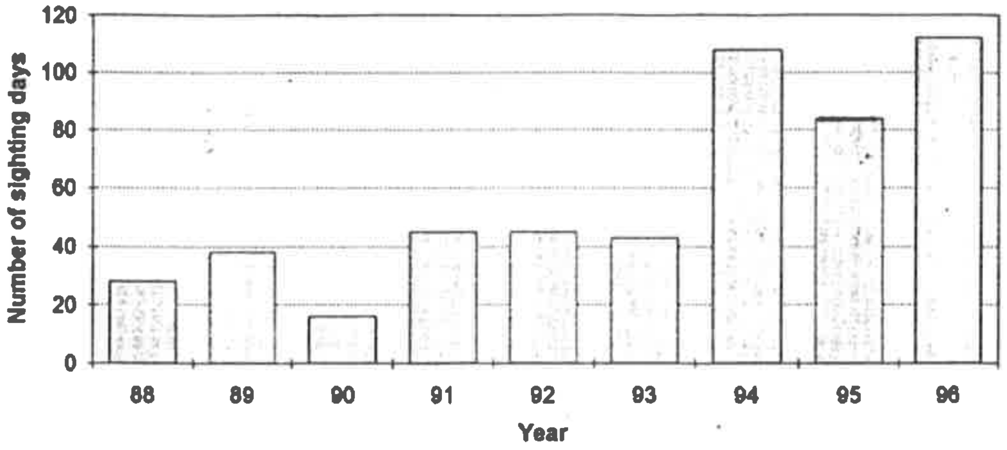


Figure 1

Figure 2



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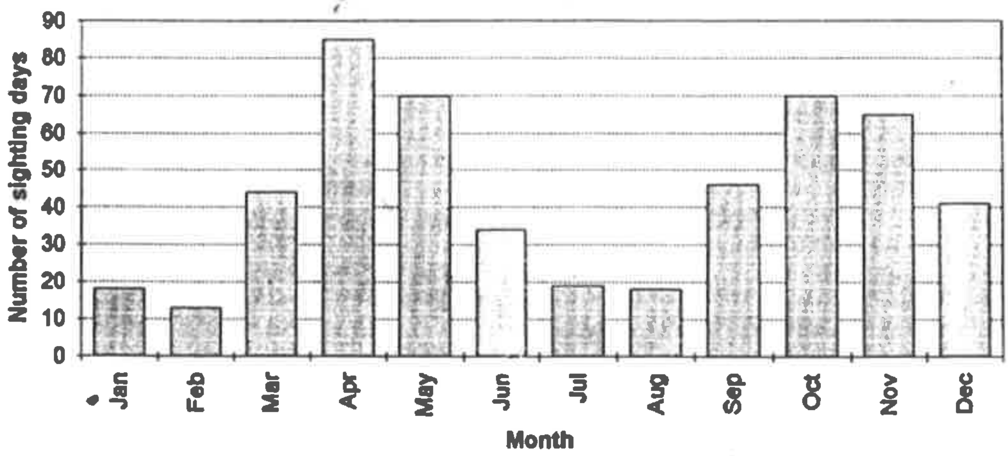

Figure 4

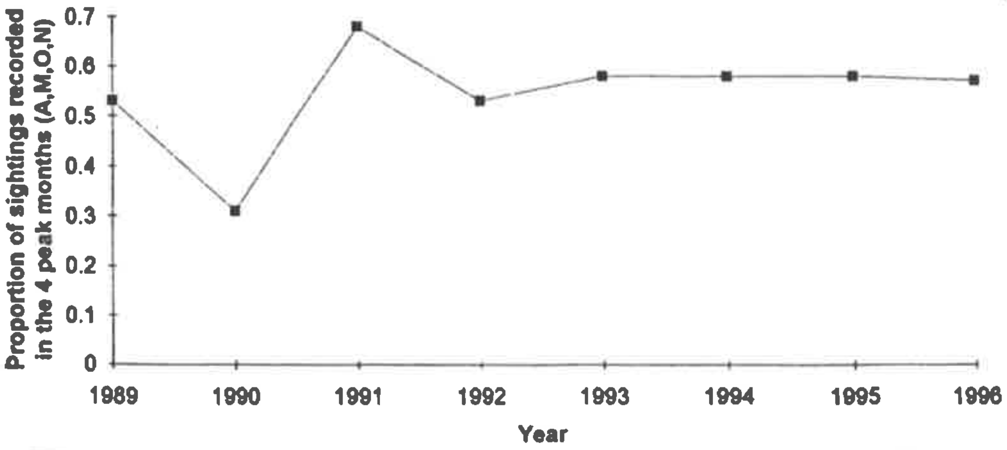

Figure 5

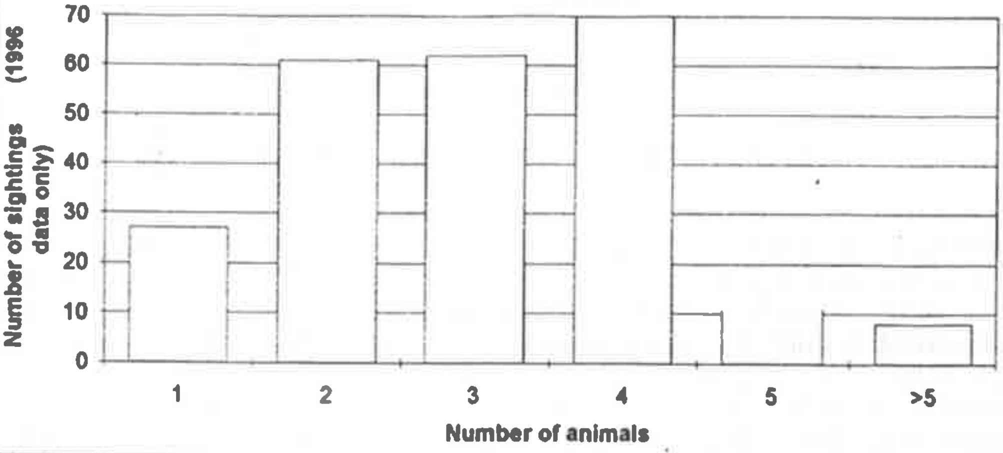

Figure 6

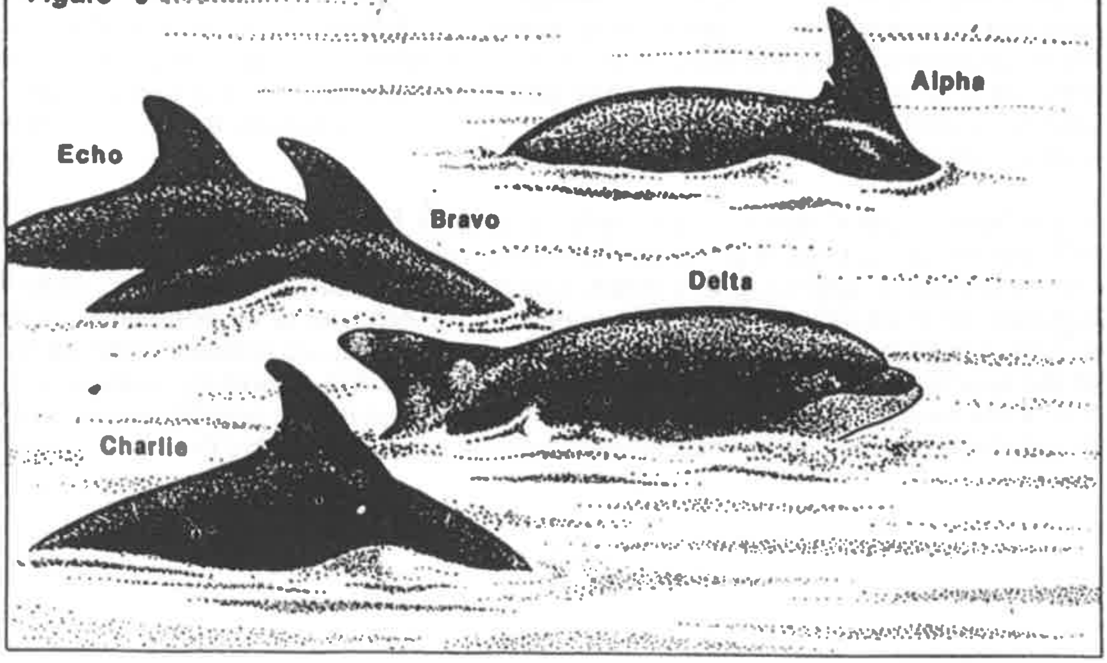

	Photo ID log number													
Animal	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Nick (Alpha)	x	x	x			x		x	x	x	x	x	x	x
Bob (Bravo)	x	x	x	x		x	x	x	x	x	x	x	x	x
Lumpy (Charlie)	x	x	x	x		x	x			x	x		x	x
Spot (Delta)	x		x	x			x							
Echo (Echo)		x	x		x	x				x	x	x		

APPARENT LACK OF SEASONAL PATTERNS IN THE BEHAVIOUR OF BOTTLENOSE DOLPHINS IN THE KVARNERIC (NORTHERN ADRIATIC SEA)

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Behavioural seasonality of a bottlenose dolphin (*Tursiops truncatus*) community living in Croatian inshore waters was investigated from spring to fall over a 3-year period (1992-1994). A total of 9,270 3-min behavioural samples were collected during daytime from small inflatable craft, following a standard procedure. The analysis focused on eight major behavioral categories, that were found to contain discriminant properties and accounted for 96.5% of the total behavioural budget: Travel, TravelSlow, Socialize, SocialTravel, Dive, DiveTravel, Dive/TravelSlow, and Dive/FollowingTrawler. Although the overall behavioural budget for each of the three years was similar, dramatic seasonal variations within and among years reflected wide behavioural changes.

None of the eight behavioral categories considered had a consistent seasonal pattern, and most showed remarkably different seasonal trends from one year to another. Peaks and drops in social activity were related to changes in calving activity, while other behaviours appeared to change widely supposedly in response to fluctuations of variables that could not be quantified during the study, such as the availability, distribution and kind of food prey. In spite of wide water temperature ranges between summer and winter, peaks in feeding-related behaviours did not seem to occur as a mechanism for building up fat stores in preparation to declining water temperatures.

It has been stressed that a useful study of dolphin behaviour should be conducted full-time for at least one year. In the Kvarneric, particularly as far as seasonal patterns are concerned, it appears that a much longer period would be required in order to highlight behavioral trends, if any. The opportunistic behavior of the bottlenose dolphin in coastal habitats, further documented by this study, perhaps contributes to the survival of this species in the largely degraded northern Adriatic Sea, in striking contrast to the fate of the once abundant common dolphin (*Delphinus delphis*), possibly a species less flexible behaviourally, which has disappeared from this region during the last decades.

BEHAVIOUR OF PUPS AND ADULT FEMALE HARBOUR SEALS (*PHOCA VITULINA*) DURING LATE LACTATION AND FIRST POST WEANING PERIOD

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Returns of flipper tags show that incidental catches in fishing gear is an important cause of death for harbour seals *Phoca vitulina* at the Norwegian coast. Mortality in fishing gear is significant in late lactating and post weaned juveniles, and may control population growth. This study focuses on the behaviour of juvenile seals and mother-pup interactions at sea during late lactation and first post weaned periods.

Six adult females and six pups were tagged using VHF radio transmitters (produced by ATS, Isanti, MN). The tagged animals included two mother-pup pairs, two adult females with still born pups, two females with untagged pups and four pups with untagged mothers. Flipper tags (modified Rototags) were applied to the radio tagged pups. In addition, a larger sample of flipper tagged pups were available.

Two automated directional VHF radio receiving stations (assembled at SMRU, St. Andrews, UK) were used to identify horizontal movements and haul out bouts. In addition, a hand-held radio station was used to describe dive time and dive intervals when seals were at sea.

Although the capability of swimming and diving developed rapidly during first part of the lactation period, strong site fidelity of pups was recorded throughout the lactation period. The mother-pup ties changed during this period. The first days after parturition, mothers remained with their pups on land or in water close to haul out sites. The pups had short lasting dives, and the dives were often synchronised with dives of the mother. Later, the pups were left on shore or close to haul out sites when mothers were at sea. Mothers of still born pups remained at the whelping site for about 48 hours until they resumed to alternate between haul out and trips at sea. During the last part of lactation, pups were at sea simultaneous with the mothers.

This poster presents behavioral aspects during lactation and post weaning. As information on incidental mortality in the total sample accumulates, behaviour of radio tagged seal will be examined for possible links between differences in juvenile behaviour and vulnerability for incidental mortality in fishing gear.

REACTIONS OF SEALS TO KILLER WHALE SOUNDS

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Marine mammals might develop various techniques to defend themselves from killer whale predation. During telemetry studies of foraging behaviour we tested the reactions of free-ranging seals to playbacks of killer whale sounds (0-10 kHz, 129 dB r1 µPa/v&m). Trials were conducted off the Norwegian coast where killer whales occur and in the Baltic where they do not. Two harbour seals, fitted with acoustic depth, speed and heart rate transmitters, were tested in Norway, and one grey seal fitted with a UHF depth/speed transmitter was tested in the Baltic. Playback trials were also carried out at two Norwegian harbour seal, and two Baltic grey seal, haul-out sites.

The instrumented harbour seals reacted immediately, swimming rapidly away from the sound source, towards the nearest shallow, breaking water. Diving patterns differed from typical foraging behaviour. In one trial 10 other seals arrived at the shelter area within 15 minutes of the playback. A profound, but short lived, bradycardia coincided with the playback. In two trials, separated by two hours, the Baltic grey seal showed no apparent change in diving behaviour and continued to feed in open water. Seals near haul-out sites reacted initially with splashy dives, but were observed within 50m from the UW-speaker at each site during the playbacks.

Norwegian harbour seals appeared to show a functional response; to run for shelter when exposed to killer whale sounds out in open water, but to stay in the kelp when exposed at the haul-out site. The lack of response by the Baltic grey seal may indicate that the escape response is a learned behaviour. The result implies that killer whales should hunt for the harbour seals in silence. Such foraging tactics contrast with the intense vocalisation of Norwegian killer whales feeding on herring, and might explain the presence of a carnivorous ("transient") group of killer whales found among 400 photo-identified killer whales off the Norwegian coast.

BETWEEN-YEAR FIDELITY TO BREEDING SITES IN HARBOUR SEALS

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Between-year fidelity to breeding sites has been shown for several pinniped species and may have important consequences for the degree of relatedness within and between populations. Previous studies have shown that harbour seals exhibit site fidelity during a season. This study aimed to determine whether they exhibit site fidelity between breeding seasons. Harbour seals differ from other species in that they mate in the water and females spend a large proportion of lactation in the water with their pups.

During 1992 / 1993, seals captured at haul-out sites in the Moray Firth were permanently marked using hot iron branding. During daily counts and observations, at one of three pupping sites, in the '92 to '94 pupping seasons, the presence and location of marked seals at the haul-out site was recorded.

95% of marked seals observed at the pupping site (7 adult females, 6 adult males, 8 juvenile females, 1 juvenile male) were present throughout at least 2 consecutive seasons. Of seals marked in 1992, 100% of adult females (n=4) and 67% of adult males (n=6) used the same haul-out site throughout 3 consecutive seasons. There was little evidence of fidelity to specific areas of the haul-out site within or between seasons. All marked seals used at least 2 areas of the haul-out site within a season. Three females with pups showed preference for one area of the haul-out site within a season (65%, 86% and 90% of locations) but used a range of different areas with their pups the following season.

This study indicates that both female and male harbour seals exhibit fidelity to one haul-out site over successive breeding seasons. As such, seals may encounter the same individuals over a number of years. Site fidelity may be established prior to maturity. Fidelity to specific areas of the haul-out site, as observed in other species, may be less important in a species which does not remain ashore throughout lactation and / or mates in the water.

TEMPERATURE DOES NOT AFFECT THE TACTILE SENSITIVITY OF MYSTACIAL VIBRISSAE OF HARBOUR SEALS

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Mystacial vibrissae provide Pinnipeds with tactile information primarily in the aquatic environment, which is characterised by its great potential cooling power. Studies on thermal effects on human tactile sensitivity revealed that cooling below normal skin temperature always impairs tactile sensitivity. Though the vibrissal follicles of seals are basically endowed with the same types of mechanoreceptors as are known from the human skin, the present study shows that harbour seals are capable of maintaining the tactile sensitivity of their vibrissal system when exposed to cold water temperatures and how they have solved the problem.

In a two-alternative forced-choice procedure two seals were trained to discriminate square plates with gratings of alternating grooves and ridges by means of their mystacial vibrissae (ridge width: 2 mm; groove width: 5-2 mm, in steps of 0.5 and 0.1 mm). For a surface of 2 mm groove width the upper difference threshold was determined underwater by a modified method of limits. During trials the seals were blindfolded. We took advantage of the natural difference in ambient temperature between summer and winter. Mean water temperature was 22°C (± 2.0°C) in summer, while in winter it was a relatively constant 1.2°C (± 0.3°C). Additionally, during the cold season the thermal status of both seals has been examined thermographically with an infra-red sensitive camera system.

Texture discrimination capabilities of both seals remained essentially unaltered under both test conditions. At 22°C as well as at 1.2°C the animals were capable of detecting a groove width difference of < 0.19 mm (9%). The thermography at -7°C air temperature revealed that mystacial and supraorbital vibrissal pads are clearly defined areas of selective heat supply, showing a substantial higher degree of thermal emission than do adjacent skin areas. O bviously no vasoconstriction occurred in the sinus system of the follicles during cold adaptation, so that a relatively constant working temperature for mechanoreceptors is maintained. This investment of body temperature in a thermally hostile environment may give some idea as to the biological importance of this sensory system for these animals.

A TECHNIQUE FOR INVESTIGATING THE SPATIAL RELATIONSHIPS OF INDIVIDUAL KILLER WHALES (*ORCINUS ORCA*) IN A POD

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Spatial relationships are an important factor in categorising and interpreting behaviour states in cetacean groups. We describe a technique which can provide accurate distance measurements between individuals in a group.

Observations were made from a vantage point on a small island in Tysfjord, Northern Norway. The method involved the combination of a manual theodolite and Hi-8 video camera with high power zoom. The position of a reference object within the video frame was obtained with the theodolite and subsequent positions of other animals in the frame were obtained on analysis of digitised video images applying simple trigonometric functions.

Positions of all individuals in a group were obtained with a mean error of 0.98 m (±0.74 S.D.) for distances up to 2km. To calibrate this technique, we used a line of buoys attached to the research vessel, with known distance intervals (2 m, 3 m, 5 m and 10 m). Positions of the buoys and the subsequent distance intervals were then measured as the boat travelled through different distance and directional transects. The calibration of this technique shows there to be no compromise in accuracy with increasing distance (within the working range of 2 km), or direction of travel relevant to observation site. Measurements of inter-buoy distances of <=5m (2m, 3m & 5m), however, had a mean error of 0.7 m ±0.59 S.D. (n = 194), corresponding to a 22% error of mean inter-buoy distances. Whereas, measurements of inter-buoy distances of >5m (8 m, 10 m, 15 m, 18 m and 20 m), had a mean error of 1.37m ±0.78 S.D. (n = 129), which corresponds to a 10% error of mean inter-buoy distances.

This method has been used to investigate changing spatial relationships, by looking at mean nearest neighbour distances, and pod geometry, of killer whale pods in varying conditions of boat traffic intensity.

CLOSE ENCOUNTERS OF FOUR KINDS: MOVEMENT PATTERNS OF RECENTLY WEANED ELEPHANT SEAL PUPS FROM MACQUARIE ISLAND

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Phocid seal pups use the energy provided by their mothers to stay alive until they find food. The amount they need is determined in part by the time it takes them to locate prey. How do they locate suitable foraging areas? There is no obvious way parents can direct pups to foraging areas but such information could reduce the demands placed on the mother. Using purpose built data logger/transmitters and the Argos system, we followed naive weaned elephant seal pups after they departed Macquarie Island, in December 1995 and 1996, for periods up to 6 months until some of them returned to Macquarie or other islands.

Pups moved long distances after leaving the island. However, the tracks did not apparently radiate randomly in all directions. Some of the animals (18 of 28) travelled to the east and south forming a broad band of tracks which took them to locations over the southern end of the Pacific-Antarctic Ridge. Another group (8) travelled out to the Southwest to areas over the Mid-Indian Rise. Some of the locations which they visited coincided with those used by adults or other pups from Macquarie in the same or previous seasons. The directed nature of the outward movements and the fact that some pups returned to Macquarie by direct routes suggest well developed navigational skills. Other encounters and coincidences are even more intriguing. Some pups followed the same tracks as others but were always separated in time, by several days. At other times, animals repeatedly arrived at the same position in the open sea but got there by different paths. Some pups moved in an apparently directed way to distant, isolated islands to which they had never been before. These observations suggest that specific information which shapes the pup's movements might be obtained after they leave the beach, either as communication from conspecifics or other sources. As yet, we have little idea of what these sources might be are or how they are used. But their existence may have important consequences for both reproductive strategies and the effects on the population of environmental variation.

COMPARING BEHAVIOUR OF INSHORE BOTTLENOSE AND COMMON DOLPHINS IN THE EASTERN IONIAN SEA THROUGH FOCAL GROUP SURFACING PATTERN ANALYSIS

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A focal group sampling technique was adopted in order to compare the surfacing pattern of a community of common dolphins (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncatus*) sharing the same inshore waters near the Greek island of Kalamos. Focal group respiration sampling represented an interesting alternative to focal individual sampling, as the surfacing pattern of focal individuals - particularly as far as common dolphins were concerned - was often difficult to record consistently in the field throughout long sampling sessions.

Surfacing intervals for all group members were recorded from small craft on a continuously running tape-recorder, and then timed by means of a dedicated software. The surfacing pattern and the "density" of surfacings within 3-min samples were then compared with behavioural sampling data recorded at 3-min intervals through a standard procedure. The focal group respiration pattern was related to variables such as the dolphin surfacing mode, their directionality and speed of movement, the group formation, and the presence of fish near the surface, thus providing a useful tool for the description and understanding of dolphin behavioural patterns. Bottlenose dolphin groups surfaced significantly less frequently and performed dives that were significantly longer than those of common dolphins. Moreover, the surfacing pattern of bottlenose dolphins was often characterised by tight sequences of surfacings followed by long dives, while "looser" and more irregular surfacing intervals were recorded for common dolphins during most activities.

Differences in surfacing pattern and surface behaviour indicated that the two species, although sympatric- have adopted remarkably different foraging strategies. Common dolphins often engage in surface feeding and seem to rely on pelagic schools of small fish found or driven near the surface, whilst bottlenose dolphins - who invest considerable energy in long dives and are rarely observed feeding at the surface - appear to focus their search on deep water prey. Evidence provided by this study is strongly suggestive of a separation of ecological niches that may reduce the occurrence of direct competition for food resources in the area.

SOCIAL ORGANISATION OF AN ISOLATED GROUP OF BOTTLENOSE DOLPHINS ON THE FRENCH ATLANTIC COAST BETWEEN 1989 AND 1996

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From several long-term studies on bottlenose dolphin (*Tursiops truncatus*), the social organisation of this species is known to be very variable with frequent exchanges of individuals between different sub-groups in a widely dispersed community. In the Arcachon lagoon on the coast of the Bay of Biscay, field research between 1989 and 1996 has demonstrated that this area is frequented by one highly isolated group of 6 Bottlenose dolphins seemingly without any other contact with conspecifics. The group was composed of one reproductive female with her female calf, two adult females, one sub-adult female and one adult of unknown sex.

Social organisation of the group has been evaluated by photo-identification of association patterns. During the eight years of monthly surveys 8,200 photos of associations have been taken and association indices ("Simple ration index", Ginsberg and Young, 1992) for every dolphin duo have been calculated. Data show an unusual evolution of the social organisation of the group during the eight years:

1. The mother-calf relationship, usually documented to become weaker after three to five years in other studied areas, remained very strong for the calf's first eight years.

2. The only change in group composition occurring during the investigation period, was the death of one of the adult females in August 1995. The sociability of this very old dolphin decreased continuously during the last years before her death.

3. The individual of unknown sex at first showed the behaviour of a pilot, swimming mostly at the periphery of the group, but increased its sociability over the years and was observed more and more often inside the group.

4. The only sub-adult female was less sociable than the other group members and stayed frequently alone inside the lagoon, interacting occasionally with boats and swimmers.

In comparison to observations of great fluidity in other dolphin populations, our results seem very unusual and reflect marked isolation of the Arcachon dolphins. This isolation is related to historical and geographical factors which characterise the situation of dolphins in the studied area. Furthermore, these results may be related to a general decrease of the populations of small cetaceans along French and other European coasts.

THE DIFFERENTIAL USE OF HABITAT SUBAREAS BY BOTTLENOSE DOLPHINS

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A population of bottlenose dolphins (*Tursiops truncatus*) uses the Sado estuary, Portugal, on a daily basis. As the estuary can be divided in different subareas according to substrate, distance to the sea, water circulation and quality, depth, abundance and type of prey species, this study focused on a quantitative analysis of how activity patterns vary with habitat subarea.

A total of 1,650 independent observations (more than 1 hr apart) were analysed. These data were obtained during the months of April to June 1995, recording the dolphin groups location and behaviour. Since socialising and resting were seldom observed inside the estuary, activity patterns considered for this analysis were travelling, travelling/foraging, disperse foraging and surface feeding. Contingency tables were tested for independence using simulation statistics, showing that the two variables are not independent ($p<0.001$).

In the lower and deeper sections of the estuary the dolphins were mostly observed travelling. In the upper sections the most significant activities were those related to bottom foraging. In the section near the city harbour only surface feeding was highly significant, a clear consequence of the frequent episodes of mullet predation near the city sewage.

Previous research had shown how dolphins spend their time differentially in the habitat subareas. This study examined how the various subareas are used by the dolphins for different activities. Both types of results may help to define better conservation strategies for this resident population.

CEREBRAL ASYMMETRIES OF VISUAL FUNCTIONS IN BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*)

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For a long time, cerebral asymmetries were treated as a peculiarity of the human brain. In the last decades, there has been increased evidence for lateralisation of several functional systems in vertebrates, especially in birds and mammals. So far, for dolphins there are only anatomical findings and behavioural observations that point at lateral specialisations. Dolphins are very apt for studying cerebral asymmetries of visual functions in behavioural experiments due to the apparently total decussation of the optic nerve. Temporary occlusion of one eye ensures that information entering through the unobstructed eye is processed mainly by the contralateral hemisphere.

Two different behavioural tasks with three adult bottlenose dolphins were chosen to test for lateral specialisations of visual functions.

In one experiment, after successful learning in a three-choice experiment on spatial orientation and memory, a dolphin was required to carry out the same task with the left and right eye alternately occluded. In the first two session blocks, she achieved 58% correct responses with the right eye whereas the performance with the left eye was only slightly above chance level (37%). The same experiment was repeated with a second dolphin, confirming these lateral preferences. The performances of both animals showed significant differences for the two monocular situations (ANOVA, Fs (1,4) = 106.66, $p<0.05$). In the continuation of the experiment, the monocular performances aligned and finally reached those of the binocular situation (75%).

In a second study, a third dolphin was tested in a two choice discrimination task. After successful discrimination performance on seven stimulus pairs using both eyes, monocular recognition tests were performed. The results show a left hemisphere advantage while monocular recognition. Mean accuracy was 88.6% for stimuli discrimination using both eyes, 87.1% for stimuli presented to the right eye and finally 71.4% for the same stimuli presented to the left eye. An ANOVA tested left-right eye recognition differences and proved to be significant: Fs (1,12) = 12.12, $p<0.05$.

In accordance with behavioural observations, these results reveal a right eye preference, and they suggest a dominance of the left hemisphere in the processing of learned visual information.

MOTHER-PUP INTERACTIONS & EARLY NEONATAL DEVELOPMENT IN BEARDED SEALS (*ERIGNATHUS BARBATUS*)

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Bearded seals give birth and rear their young in the free-floating pack-ice zone. This habitat is extremely unstable both spatially and temporally. During the last five years, we have conducted a variety of projects designed to explore the influence of this breeding habitat on the development of neonatal bearded seals and the nature of the mother-pup bond. We have captured 85 pups and 18 mothers. Seven pups and 4 mothers have been equipped with satellite-linked TDRs and MK(5 or 6) TDRs have been deployed on an additional 11 pairs. Recaptures have been achieved on 23 pups providing longitudinal growth records. Additionally, an intensive behavioural study was conducted in 1995, in which over 100 hours of observations were made on mother-pup pairs.

Nursing bearded seal pups in our study have ranged in mass from 27 kg up to 120 kg. The average birth mass is approximately 40 kg, although birth mass is quite variable. Likewise weaning mass is also quite variable, ranging from 75 kg to over 120 kg. The average rate of growth during the nursing period was 3.3 ± 0.4 kg/day. Mothers are attentive to their pups, but spend only an average of 7% of their time on the ice surface with them. Pups are fed approximately every three hours throughout the lactation period which lasts approximately three weeks. Mothers attend pups most of the time, laying in the water adjacent to the floe on which their pup is resting. Female bearded seals feed during lactation, frequently leaving their young pups at the surface during these excursions.

Neonatal bearded seals swim and dive with their mothers at a very early age. Maximum depth recorded for nursing pups is 90 m and maximum duration is approximately 6 min. Pups become increasingly independent with age, initiating dives with or without their mother's accompaniment by the time they are about two weeks old. The development of precocial swimming and diving skills is probably a response to polar bear predation, which is a significant source of mortality for bearded seal neonates.

DYNAMICAL SYSTEMS THEORY APPLIED TO THE EVALUATION OF CHANGES IN BREATHING PATTERN IN CETACEANS.

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Assuming that dolphins have not the breathing reflex (Ridgway, 1972; Garcia-Hartman, 1994), we take the breathing pattern as an ethological variable, measured as apnea duration between breaths. This pattern is exposed to changes that do not depend on physiological demands. Captivity offer us the possibility to register data in two different conditions. The first pattern was obtained during a quiet (Q) behaviour of two females with their both one year old calves of bottlenose dolphins (*Tursiops truncatus*) swimming in a round pool. This breathing pattern was compared to the shown in a stress episode (S) while the pool was being emptied, where their behaviour was obviously nervous. We have seen changes in their breathing patterns looking at the data set plots, but they are impossible to asses using traditional statistics. For this reason we have employed techniques from Dynamical Systems Theory, that show some differences between conditions. This kind of statistical analysis may be useful to asses the impact of possible causes of stress on free ranging cetaceans like noise, whale-watching or drilling platforms.

FORAGING RESPONSES OF FUR SEALS TO CHANGES IN THE MARINE ENVIRONMENT

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The foraging behaviour of female fur seals may be expected to change throughout lactation because of (i) increasing demands of pup rearing and (ii) annual and seasonal variation in the marine environment. This study examined the relative contribution of these intrinsic and extrinsic factors on the foraging behaviour of female Antarctic fur seals (*Arctocephalus gazella*) at Bird Island (54°S 38°W) during three austral summers (1994-96). Time-depth recorders were used to record the diving behaviour of 72 individuals during a total of 385 foraging trips, totalling 1,964 days at sea. The frequencies of krill, fish and squid in the diet were estimated from prey items contained in scats. Foraging behaviour showed systematic changes within breeding seasons. Foraging trip duration, attendance duration and dive frequency increased throughout 1995 and 1996 ($R2 = 0.07$-0.22, $p<0.001$). This suggested that females were able to match increasing pup demands by increasing both time feeding at sea and energy delivery to the pup on land. However, the increased availability of prey during greater periods of darkness, as seen by a reduction in dive depth throughout the season, was likely to reduce foraging costs when pup demands were greatest. In 1996 females made shorter foraging trips, fewer dives and spent more time ashore than in 1994 ($p <0.05$). Pup growth rates were also greater in 1996 than in the previous two years ($p <0.03$). Females made no deep or long duration daytime dives in 1996 and this was associated with the absence of fish and squid from the diet. Sea surface temperature within the foraging range was less variable in 1996 than in the previous two years. Differences in prey abundance and diet of fur seals caused by oceanographic changes across years could therefore be detected by shifts in foraging behaviour.

SCARRING IN A LIVING POPULATION OF DENSE BEAKED WHALES (*MESOPLODON DENSIROSTRIS*) OFF GREAT ABACO ISLAND, THE BAHAMAS: LEVELS, CAUSES AND INSIGHTS PROVIDED ON THE NATURAL HISTORY OF THE SPECIES.

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Scarring is a highly visible feature of *Mesoplodons*; however, to date it has only been examined in stranded specimens. This is the first study to examine scarring from living, non-stranded individuals of a *Mesoplodon* species. The type, level and body position of scarring was examined in 18 individuals of *Mesoplodon densirostris* and a comparison between four age/sex classes was made. Mature and sub-adult males differed significantly in the levels of intraspecific scarring from mature females and calves ($Chi^2=14.22$, d.f.=1, $p<0.01$). Mature males had the highest level of intraspecific scarring, which generally consisted of many overlapping deep furrows in the skin mostly on the head and anterior body. Sub-adult males had lower levels of intraspecific scarring than mature males, which consisted of overlapping white unpigmented lines, rather than deep furrows, again mostly on the head and anterior body. Mature females and calves had the lowest levels of scarring, which consisted of white unpigmented lines which did not overlap and were never found on the head. Since only males are capable of causing intraspecific scarring, the variation in scarring individual animals reflects a difference in the way males interact with different age/sex classes.

Aggressive interactions between males (sub-adult and mature age classes) are of a higher intensity and may consist of a series of passes with each animal initially orientated head to head and dorsum to dorsum. In contrast, aggressive interactions between males and mature females or calves are of much lower intensity and result in no scarring on the head suggesting that females and calves do not 'face off' with males. The distribution of intraspecific scarring between age/sex classes in *M. densirostris* is similar to that found in sperm whales indicating that *M. densirostris* may have a similar reproductive system, where mature males rove between receptive females. The level and body position of other types of scarring, such as predatory scars and cookie-cutter shark scars, did not differ significantly between age/sex classes.

BETWEEN- AND WITHIN-YEAR SITE FIDELITY IN MALE SOUTH AMERICAN FUR SEALS

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Site fidelity in male otariids has been shown for several species. However, no studies have examined the extent to which male return to particular territories within the same season. Male South American fur seals may return to breed for over consecutive three years and some individuals may return to the breeding site up to five times within a season. This study examined the extent to which males returned to the same location on the breeding site both within and between years. The study was carried out at Punta San Juan, Peru. The locations of territorial males were recorded every 30 mins, 6 hours/day, throughout their tenure.

Minimum convex polygons were calculated to estimate territory areas. Site fidelity was measured for the 19 males which defended territories in 1992-1994 and for the 19 males which returned to the breeding site multiple times within the breeding season of 1994. Site fidelity was measured using preference indices (S) which were calculated from the area of overlap between previous and subsequent territories expressed as a proportion of the larger territory. Indices #1 indicated no preference. 84% and 95% of males returning in 1993 and 1994 respectively showed preference for their previous site with indices ranging up to S=90. 90% of the males which defended multiple tenures in 1994 returned to their previous sites with indices reaching S=65.

This study indicates that males show extreme preference for particular territories at this site. Such strong site fidelity may confer advantages in terms of knowledge of the resources they contain e.g. water. It may reduce aggression through familiarity with neighbours. Further, males which use the same site may become acquainted with potential mates which may influence female mate choice. The question arises as to how males which return mid-season successfully retrieve their preferred territory.

USE OF PUPPING SITES IN THE EXPANDING GREY SEAL BREEDING COLONY AT THE ISLE OF MAY, SCOTLAND

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Annual pup production at the Isle of May, Firth of Forth has increased from <10 to around 1,400 in the last 20 years. This colony afforded an opportunity to test the hypothesis that a mother's pupping site within a colony may affect her pupping success. We recorded use of pupping sites by a known population of animals during 1987-94 and compared this to site use by the whole population over the same period to determine factors important in colony development. We were particularly interested in whether (1) pupping areas increase by expansion from centres; (2) known females in the colony used high density (traditional) sites; (3) known females showed inter-annual site fidelity; (4) known females have greater pupping success than the colony in general.

Pupping sites of seals were recorded from a series of large format aerial photographs taken each season to estimate pup production. Pupping locations of known animals were recorded to the nearest 3m on standard maps. The null (random) distribution for inter-annual comparisons used a sample of distances between possible pupping sites, derived by defining areas potentially accessible to seals according to site topography and access.

(1) Initially the principal areas used were the same each year. Recently, new areas were used as the season progressed. An index of the area used by seals increased from 0.44 in 1988 to 0.64 in 1994. Additional small seed' groups appeared at previously unoccupied areas on the island.

(2) Known females showed 2 breeding patterns: older animals used high density areas; younger animals used peripheral areas at first then moved into central positions in later years.

(3) Known females showed significant ($P<0.01$) site fidelity, with median distances of 20m between pupping sites in successive years (median for random site use ë 160m). This site fidelity was maintained over the course of the study.

(4) Mean annual pre-weaning pup mortality in the colony was 12% compared to 9.8% observed for study animals, suggesting that the apparent preference for the same central positions within the colony conferred a marginal advantage to known females in pup survival.

ASYNCHRONOUS DIVING PAIRS OF HUMPBACK WHALES: IMPLICATIONS OF A NEWLY DESCRIBED BEHAVIOUR OBSERVED IN THE NORTH ATLANTIC WINTERING GROUNDS

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During 1992 and 1993, North Atlantic humpback whales were studied in their principal West Indies wintering grounds as part of an international project known as the Years of the North Atlantic Humpback (YONAH). Behavioural data were collected from 4,795 animals to better describe the mating system and to evaluate heterogeneity issues within the extensive genetic (n=1,307 unique individuals) and photographic (n=1,373 unique individuals) samples obtained. Behavioural classes were assigned to individuals based on their group size, composition and stereotypical behaviours previously described for the wintering grounds. Animals were considered to be associated if they maintained close proximity to one another and exhibited synchronous surfacings.

During YONAH sampling in 1992, we observed pairs of individuals which were clearly associated, but were asynchronous for one or more dives within a cycle. Of 780 individuals observed in pairs during the following year, 134 (17%) were classified as asynchronous, with one animal typically on longer dives than its partner. The degree of asynchrony between individuals varied both within and between pairs, ranging from one to more than 15 mins. Long diving (defined here as dive times greater than 10 mins) was observed in 34% of the asynchronous pairs, slightly higher than that observed in synchronous pairs (22%). Genetic sampling performed on both whales in 28 asynchronous pairs show them to be similar in sex to synchronous pairs (79% male/female and 21% male/male)

Female whales were the longer divers in 68% of the male/female pairs; however, the observation of longer diving males in some male/female and male/male pairs suggests a non-reproductive function of this behaviour. Videotaped underwater observations indicate that, like synchronous pairs, longer diving asynchronous pairs are typically motionless. Therefore, long diving may be a resting behaviour for whales which are rarely observed lying motionless at the surface in their wintering grounds. With additional study, asynchronous behaviour may shed light on group behavioural transitions. The occurrence of asynchronous pairs is also significant to management, as they could easily be mistaken for three individuals in most sighting surveys (one singleton and one pair), thus creating a potential bias in those results.

MATERNAL VIGILANCE AND AGGRESSIVE BEHAVIOUR AFFECTS GREY SEAL PUP SURVIVAL IN INTERACTIONS WITH GREATER BLACK-BACKED GULLS

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As in most mammalian species, care of grey seal young is the sole responsibility of the mother. Seals have few predators in the UK, but North Rona, Scotland has a significant resident population of greater black-backed gulls Larus marinus. These are the largest British gull and have a flexible diet which ranges from scavenging to predation on rabbits, puffins, shearwaters, shags and occasional lambs. Greater black-backs often attend seal births on North Rona and scavenge for the placenta. However, gulls had been observed attacking newborn pups. We quantified the extent of these interactions and identify their impact. We tested the hypothesis (a) that mothers would assess risk (the presence of gull(s) near their pup(s) similarly. We also tested the hypothesis (b) that all mothers would defend their pups equally.

In 1996 we recorded 22 seal births on video and recorded seal/gull interactions within a 4 m radius of the focal mother/pup pair in the immediate postpartum period. The number, species and age of gulls and their distance to the focal mother/pup pair were recorded every 20 seconds, as well as behaviours occurring within that period. Seal/gull interactions were recorded for all 22 births. The median number of gulls present in the study area was correlated to the daily birth rate ($r=0.56$). The number of gulls visible in scans around newborns ranged from 1-29 and the number of mother/gull interactions was related to the number of gulls present ($r=0.72$). There were significantly more gulls in an area if a dead pup was present ($p<0.001$). Adult gulls accounted for 65% of all seal/gull interactions.

A total of 203 attacks occurred in the 22 births: 52.7% were directed at mothers, usually to retrieve fragments of placenta, with the hind part of the pup the most frequent target, followed by the head and umbilical area. One of the 22 pups died during the study. (a) The mode of maternal reactive distance occurred when gulls were 0.5-0.25BL from pups, but there were significant differences ($p<0.001$) between mothers in their median reactive distances. (b) There were 629 gull/seal interactions which produced a maternal response, gulls retreated in 76% of these cases, however the effectiveness of mothers at making gulls retreat varied from 0-100%. Despite the presence of greater black-backs at the Isle of May breeding colony, only one attack on a mother/pup pair was recorded during the 1996 season.

PATTERNS IN SOCIAL ORGANISATION AND OCCURRENCE AMONG KILLER WHALES PHOTO-IDENTIFIED IN NORTHERN NORWAY

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A six year (1988-93) photo-identification study was conducted on killer whales (*Orcinus orca*) in northern Norway, to describe patterns in social organisation and occurrence and to estimate the numbers of killer whales in the wintering area of herring (*Clupea harengus*). The results were compared to the social organisation of other killer whale populations as well as other dolphin species for a better understanding of the underlying factors explaining social structure among killer whales. 445 different killer whale individuals and 45 pods were identified. 221 of the identified killer whales were well-marked and they dominated the sightings data (73% of sightings). Most of the identification pictures were taken in fall-winter in the wintering area of Norwegian spring-spawning herring.

Based on a mark-recapture estimate, 550 killer whales (95% C.I.=507-593) were present in the study area during this season. Killer whales were encountered less often during summer months and the average group size was smaller in summer than in fall, possibly as a response to smaller school size of herring. The average and mean group size were within the range of group sizes documented for other fish feeding killer whale populations and larger than those reported for killer whales feeding on marine mammals. The killer whales occurred in stable units and based on earlier data collected in the area some of the bonds between individuals were shown to have persisted for more than 10 years. An analysis of companions of two well known adult females indicated a presence of matrilineal groups. The presence of stable kin groups is common among killer whales and a similar social system has been documented among pilot whales (*Globicephala* sp.). Pilot whales and killer whales are closely related species sharing many life history parameters, which is suggested to be an explanation why similar social structure is found among two ecologically divergent species.

FORAGING BEHAVIOUR OF SUB ADULT GREY SEALS

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Diving behaviour and foraging success of free-ranging grey seals (*Halichoerus grypus*) were studied. We used novel techniques to collect detailed behavioural data via ARGOS satellite transmitters in conjunction with acoustic telemetry for stomach temperature. Dive types, locations, behavioural parameters and feeding events were analysed, as well as foraging success. During the summer 1996 six sub-adult grey seals were caught in the northern Bothnian sea, Sweden. After routine measurements the seals were equipped with a modified SRDL (Satellite Relayed Data Logger) and a stomach temperature tag. The SRDL's were programmed to collect and transmit fine scale data of the diving behaviour. Data were received both by ARGOS satellites and a boat-based telemetry receiver. Directional hydrophones were used to receive the signal from the ultra sonic acoustic stomach transmitter. Continuous measurement of diving behaviour (speed, time, depth), feeding events (stomach temperature) and positions (differential GPS) were logged for a total of 90 hours.

Thirty-three distinct feeding events were recorded during the tracking period (ë 0.36 events / hour). These events were distributed over 12 feeding bouts (ë 0.13 bouts /hour). Night time feeding events were almost exclusively linked to a particular dive behaviour (8 of 10). These were dives to the mid-water column (plateau) where it rapidly increases and decreases velocities, followed by a descent to the bottom and then back to the surface. The depth at which the plateau occurred became progressively deeper in the early morning. Successful feeding events during the day light were associated with periods of benthic diving. This pattern of feeding may be connected to the diurnal behaviour of herring (*Clupea* spp.), which have been described as the main prey among juvenile grey seals in Baltic.

ACOUSTIC CLUES ABOUT THE AQUATIC MATING SYSTEM OF THE HARBOUR SEAL

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Understanding a species' mating system provides vital clues to unravelling their lifetime reproductive strategies. Though, the aquatic mating systems of most pinnipeds remain poorly understood, recent advances have been made in the study of the harbour seal. VHF telemetry has shown that females are widely dispersed and males perform stereotypic underwater vocalisations and dive displays within small ranges during the mating season. Male vocalisations offer a novel opportunity to use acoustics to study their underwater distribution and behaviour.

We used land-based and boat-bound arrays to determine the distribution and behaviour of males at different scales. Acoustic recordings were made of males over a $600m^2$ area every few days in July 1995-97. A wider scale survey of the Moray Firth, Scotland (700 km^2) was undertaken in July 1996 recording vocalisations for 10 minutes every 2 km^2. Positions of males were determined using SIGNAL. Seasonal, tidal and diurnal variations were observed by recording throughout July 1995-97 at five sites in the Moray Firth using sonobuoys.

Results from the land-based array showed that two males used the $600m^2$ area occupying display areas of 106.4 m^2 and 81.4 m^2 respectively. Males used the same areas throughout the season and between years. The wide scale survey confirmed preliminary suggestions (from VHF telemetry) that males were displaying throughout the whole of the female distribution, from haul-out sites, to feeding grounds and transit routes between the two. There was no overlap between individual display areas. Seasonal variation showed that males started vocalising in early July and ceased in mid August. Analysis of tidal variations showed a significant decrease in vocalisations during low tide. Acoustics have played an integral part in the development of our understanding of the harbour seal mating system and have potential to be useful in studying other aquatic mating species.

SOME PECULIARITIES OF EMIGRATION AND IMMIGRATION PROCESSES IN NORTHERN FUR SEAL POPULATIONS

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As known, northern fur seals (NFS) show strong philopatry (homing). Nevertheless, some part of them moves to other rookeries and breeding islands. Sometimes, they even establish new rookeries (on the San Miguel, Bogoslov, Commander and Kuril Islands).

Primarily bachelor haulouts appear in new places, then bulls and females begin coming there. New colonies first grow exclusively at the expense of immigrants from other rookeries whose proportion gradually declines with increase in a new colony. Thus, analysis of NFS origin on the newly-established north-western rookery on the Commander Islands based on tag return data shows that the proportion of immigrants decreased from 91.9% to 7.2% between 7th and 34th years after appearance of their first harems.

The study of NFS movement from the Robben Island (Okhotsk Sea) based on analysis of tags returned from over 15,000 bachelors of 14 year classes, tagged there as pups and taken later on all breeding islands, shows that their emigration activity (EA), *i.e.* proportion of young males in generations emigrating from a natal rookery (calculated with account of tagging and tag loss coefficients), clearly correlates with the number of live pups in them ($r = 0.61$).

Every generation has its specific level of EA which is formed evidently at the pup stage during August-October, and directly depends upon on-land pup density. The proportion of bachelors leaving a natal rookery increases with age, averaging 0.25%, 0.87%, 1.14% and 1.94% among ones aged 2, 3, 4 and 5 yrs respectively. Total number of bachelors emigrating to other rookeries reaches 3.5% in the most abundant generations and falls to almost zero when the number of pups born declines below 30-40% of its maximum population level. EA of young females is nearly twice as low as males. NFS emigrating from natal rookeries usually move to those ones where the number and density of animals are lower at the moment. An influx of immigrants can play a significant role in the dynamics of small NFS populations, especially ones that have declined sharply or colonised new places, etc. Thus, immigrants comprised up to 25-30% of those recovering rookeries of the Commander and Kuril Islands in 1960s - early 1970s, providing a rapid increase in these populations.

THE SOCIAL ECOLOGY OF A COASTAL POPULATION OF BOTTLENOSE DOLPHINS IN WESTERN AUSTRALIA

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Bottlenose dolphins are distributed world-wide in a variety of habitats. Comparative studies between populations facing different environmental conditions may help determine how differences in behaviour are related to differences in local ecology. A 26-month boat-based survey study was conducted to examine the behavioural ecology of dolphins inhabiting the coastal waters of Perth, Western Australia.

The study area covered 140 km of coastline containing patchy limestone reef, sandy beaches and seagrass meadows. Between March 1991 and July 1993 165 surveys were conducted and 194 group sightings were recorded. Dolphins were sighted throughout the year with no significant difference noted between seasons ($Chi^2 = 5.3$, $p>0.1$). Group size ranged from 1 to 60 with a mean of 9.1± 9.5 and varied seasonally (KW = 9.6, p =0.02). Larger groups were noted in summer (12.0 ±9.7) and smaller groups in spring (7.4 ±8.2). Foraging was observed in several habitats indicating consumption of a variety of prey items. Co-operative foraging was observed in open waters and solitary foraging in sand flats and near reefs. 271 individuals were identified using photographic techniques. A half weight coefficient of association was used to calculate degree of association between dolphins sighted three or more times (N=93). Coefficients were generally low (meaní 0.31±0.17), however high coefficients (up to 1.0) were detected between some individuals. These findings indicate a low degree of association and high group fluidity. The low number of resights, length of time between resights and high number of new individuals identified throughout the study suggest a variety of residency patterns, and that at least some individuals may not be resident but pass through the area occasionally.

Preliminary results suggest that the behavioural ecology of this population is similar to that of the coastal population of southern California. Both are open populations with a high rate of emigration and immigration, in which individuals may cover extensive ranges. By identifying individuals and providing baseline data on group dynamics, this study provides a basis for future research effort, perhaps with conservation implications in the field of habitat use.

ACOUSTICS

RHYTHMIC DIMENSION IN SPERM WHALE ECHOLOCATION CLICK TRAINS: IDENTIFICATION AND COMMUNICATION?

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INTRODUCTION Gregarious cetacean species, which form long-lasting social bonds, collaborate when foraging and demonstrate complex social systems. They are known to produce both whistles and pulse sounds. *Physeter* as a notable exception is one of the species, which uses clicks both for echolocation and communication.

Although Watkins (1980) argued that regular clicks could be social signals because they exhibited different characteristics from the clicks of other odontocetes, and because the whales seemed to coordinate their movements underwater, the most recent studies agree that the primary function of usual clicks was echolocation (Gordon, 1987; Whitehead and Weilgart, 1990; Gordon *et al.*, 1992; Goold, 1996).

Sperm whales show a remarkably cohesive structure when foraging. The sperm whale epimelitic behaviour is also notable. It has been systematically observed in all the areas where sperm whales have been studied, that females leave their calves at the surface when looking for food for periods as long as 40 minutes. The calves continue their slow swim in exactly the same direction as the rest of the group while their mothers are gone. Their mothers eventually join them, sometimes several kilometers away from the point where they left them. During those two processes, both related to the search of food, the whales never stop producing series of usual clicks (André, 1997). The foraging behaviour of the sperm whale alternates long dives averaging 40-50 minutes, and 10-15 minutes resting periods at the surface where they are usually silent. Not all the members wihthin the same social group surface together, for series of usual click trains are permanently audible (Worthington and Schevill, 1957).

The social character and the cohesive behaviour of the sperm whale, indicates a continuous exchange of information which cannot rely on visual cues, due to the great distances separating the whales while looking for food. Studies of the spatial organisation of foraging groups in the South Pacific (Jaquet, 1996; Jaquet and Whitehead, 1996) and the Canary Islands, demonstrated that the maximum distance between the most separated members within the same social group, was less than 10 kilometers. This distance is within the acoustic range of sperm whale echolocation clicks and may indicate that these clicks also serve a communication function.

This data would mean that all the members of a social group could hear continuously the vocalizations of their pod members when they are diving and at the surface. Since the only vocal exchange heard during this process consists of the series of usual (echolocation) clicks, these signals must as well carry communication components.

Some authors have detected regular variation in click rates over periods of many minutes (Whitehead and Weilgart, 1990; Gordon *et al.*, 1992), and proposed an explanation based on the use of clicks for echolocation. Taking into account this variation in click rates, the present study proposes to complete the analysis and take it further by considering that click rates are also of utmost importance for communication. The temporal aspects of signals are crucial for information transfer, since pulse timing is less subject to environmental distortion (Morton, 1975). The results presented here attempt to show that those temporal aspects, and not the signal in itself, can be used to define usual click series. In such a definitive, a cohesive longitudinal structure is present in the apparent irregular succession with a cyclic trend of sperm whale clicks.

MATERIALS AND METHODS OF PROCESSING The recording equipment used during the study, consisted of a hydrophone, including a tubular structure where two transducers connected to two pre-amplifiers, towed 100 metres behind the research vessel. The output of the system was connected to a Digital Audio Tape Recorder. Due to the bandwidth constraints of the equipment (15 kHz), the analysis was accordingly restricted to the time concatenation aspects of the clicks.

1. **Results of the analysis of individualised sequences of click trains**

The clicks analysed in this current study, were recorded while a group of 12 sperm whales were foraging a few kilometers off the Canary Islands. The chaotic tangle of sperm whale click trains has been unravelled by cross-correlating the click wave shapes (Kamminga *et al.*, 1993). This method compares the waves shapes within a sequence of clicks and look for the possible matches between two distintive clicks. This very simple technique allows to actually follow the distortion of the signals and classify them as separated individuals. Thus, at the end of this process, isolated individual sequences of every single whale that was vocalising during the recording were obtained. This method permitted the separation of a number of four individuals from an 85.5 second sequence of usual clicks. The sequence includes a total of 269 clicks, 120 from subject 1 (cach1), 76 from subject 2 (cach2), 65 from subject 3 (cach3) and 8 from subject 4 (cach4, not represented here). Figure 1 shows the recovered click repetition pattern of three sperm whales over a 50s time span. It should be noted that out of the pool of twelve sperm whales, only four individuals were vocalising during our period of observation.

The pulse repetition frequency (PRF) of the three sperm whales shows a more or less random succession of click intervals. For (approximately) 50 seconds, cach1 did not interrupt its vocalisation, while the two other whales stopped clicking for about seven seconds. Cach1 showed a more or less regular PRF, while the others presented marked variations.

From the interval between two successive clicks, or Inter-Click Interval (ICI), also a tachogram can be constructed, similar to that used in cardiology (Ivanov *et al.*, 1996). In this case, the tachogram represents the ICI versus the number of the interval.

Figure 2 shows the tachogram of cach1 over 119 intervals, which is equivalent to a total duration of 85,10 seconds. The appearance of the tachogram shows a rather dis-organised succession of the pulses. The average PRF was calculated to be 84 clicks/minute, which corresponds to an average frequency of 1.44 Hz in the whole sequence. The same analysis for the other whales gave the average frequencies of 1.62 and 1.97 Hz.

This analysis looks very similar to those conducted previously by other authors (Backus and Schevill, 1966; Weilgart and Whitehead, 1989, Gordon *et al.* 1992). The only, but striking difference is that now the average frequencies were obtained after separating - from the same sequence of click trains - a number of four vocalising individuals.

To investigate whether a correlation (linear dependence) was present between a given interval and the next one in the sequence, we used a method which looks at the deterministic structure in time series (Packard *et al.*, 1980). The linear dependence permitted a quick look at what was actually happening in the sequence. The geometric construction used in this analysis considers a plot of the nth interval between two successive events and the next (n+1)th interval in the sequence. If the lengths of the intervals are constant, the intersection points will be centred in the same point. If the succession of intervals is random, the intersection points will be distributed over the whole xy dimension. If, instead, there is a linear dependence in the sequence, the intersection points will be organized in a positive correlation.

Figure 3 represents the ICI +1 of cach1 versus ICI, where a clear correlation appears. Constructing the plots ICI +2, up to ICI + 7, versus ICI, the same structure was present but weaker, indicating a Markov Chain of a limited order.

This construction shows for the first time a deterministic structure in the sperm whale usual click trains, which has not been described in any previous study. In order to define the dimension of this structure, the sequence of intervals was considered as a random point process, and a Fourier transform was applied to this series of -functions. The result (Fig. 4) shows a strong modulating frequency centred at 0.128 Hz for cach1. The same analysis was followed for the other whales and again a modulating frequency appears in the order of 0.110 to 0.167 Hz. Figure 5 shows, in a normalised diagram, the modulating frequencies of the whales in their click train.

This modulating frequency confirms the linear dependence found in the geometrical analysis and points out definitively that the production of usual clicks is not a more or less random point process. The result shows that the production of usual clicks is rhythm dependent and implies that this rhythm will be different for every sperm whale. We believe that this deterministic modulation, or rhythmic structure found in usual click trains, represents the acoustic signature of each sperm whale. This acoustic dimension, which we have called RIME (Rhythmic Identity Measurement), is learned behaviour and is known by all the members of a same group. Further, it identifies each individual through the rhythm as a time parameter of its acoustic signals and not through the shape of the signal wave forms. The echolocation function of the usual clicks is not affected by the existence of RIMEs. Instead, the RIME allows a whale to distinguish its own echoes against the background of other whale click trains.

2. Results of the analysis of the acoustic hierarchy hypothesis

The interruption of an individual RIME from a whale coming at the surface between two successive foraging dives, indicates to the rest of the group, that this specific individual has temporary left the search. During this break, the whale at the surface continues to listen to its group's vocalisations, thus keeping in contact with the movements of the group. The regular alternation of resting whales at the surface can be interpreted as the common strategy that continuously communicates information on the effort during the foraging process.

Recent analysis of sperm whale acoustic behavioural data, demonstrated that the whales begin to produce usual click trains after fluking up, when they start a new dive, between 25 to 300m deep (Papastavrou, V. *et al.*, 1989; Gordon and Steiner, 1992). Even for a same individual, a temporal correlation between the beginning of the dive and the click production has never been found. It has been suggested that the echolocation function attributed to usual click series could explain this timing difference: the beginning of the echolocation process would vary according to the depth of the sea bottom.

If we consider, however, this timing difference from the RIME perspective, it could be possible that a whale chooses to vocalise at a specific moment in order to enter into what we call a group RIME, and it could be possible that this precise intervention transmits some kind of information to the group.

To investigate whether the ocurrence of individual RIMEs within the same sequence, responds to a deterministic modulation, or is simply a random process, we postulated a possible acoustic hierarchy, defining the dominance relationship among sperm whales within a social group.

Mullins, Weilgart and Whitehead (1988) have demonstrated that mature sperm whale males presented slower click rates than females and juveniles. Assuming that this slower clicking rate is a sign of sexual maturity, and that a mature whale would present a slower click production rhythm, we looked for the time intervals between the series of clicks, taken individually and belonging to the same whales as before.

From the previous analysis of the modulating frequencies, we chose as a virtual dominant whale, the individual presenting the slowest clicking rhythm, which was 0,110 Hz, as a reference to calculate the time interval between its clicks and those of the second and the third whale.

Starting the analysis when the virtual dominant whale produced its first click in the recording, a time series was constructed comprising the time intervals between this first click and the corresponding click of the other whales, then from the second click and so on with all the clicks, to the end of the sequence.

This plot (Fig. 6) shows the result of the construction, again where the x-axis represents the (n) intervals in milliseconds and the y-axis the (n+1) intervals. As with individual click series, a strong correlation appears between the successive intervals.

To complete this analysis and contrast the acoustic hierarchy hypothesis, we constructed the same plots, giving to the other sperm whales in the recording, the virtual dominant character attributed empirically to the individual presenting the slowest clicking rhythm. Following the same steps in the analysis as taken previously, we took as the virtual dominant individual, first, the whale presenting the second slower clicking rhythm, 0.128 Hz (Fig. 7a), and then the whale with the highest value of the modulating frequency, 0.167 Hz (Fig. 7b). In both cases, the distribution of the intervals appears to be completely random. The linear dependence observed in the series of intervals constructed from the vocalizations of the whale with the slowest clicking rhythm, strongly supports the hypothesis of an acoustic dominance within social groups of sperm whales.

CONCLUSIONS Although the results presented here are based on a reduced number of clicks, they have the advantage to demonstrate that the apparent chaotic succession of clicks produced by several sperm whales, and classified by previous researchers as "a cacophony", contains actually structured individualised sequences which are precisely organized in a complete coherent structure.

Most important, this specific acoustic organisation may support the existence of a group RIME, constituted by the deterministic occurence of individual RIMEs. This polyrhythmic structure of the repertoire of a social group, besides allowing group identifications within large aggregations of sperm whales, may carry all the information necessary to maintain the observed cohesion of the group when foraging.

The results presented here offer a new insight into the sperm whale communication system. The research needs to be further completed: to confirm the validity of the RIME hypothesis, the authors are in the process of analysing longer sequences of clicks, in order to be able to acoustically follow individuals and re-capture them (for example the RIME should be preserved throughout entire dives for the same individual). The codas, defined until now as the principal acoustic support of communication, seem to be actually just a part of a whole system articulated by the continuous emission of usual click trains. The acoustic identity of a sperm whale may be permanently available to the rest of the group through the constant and specific rhythm of usual echolocation clicks production, which has been termed RIME. The concept of RIME, demonstrated by the deterministic dimension of the click series, and supported by all information available to date on sperm whale behaviour, opens a new direction in cetacean communication research.

We believe that this acoustic dimension may be present in all of the social toothed cetacean species' repertoires. The recordings of dolphin whistles used for analysis, and the hypothesis of the signature whistle, developed from bottlenose dolphin acoustic studies (Caldwell and Caldwell, 1968), systematically relies on perfect recordings, either of captive animals vocalizing a few meters from the hydrophone, or of free-ranging individuals recorded very close to the research vessel. However, dolphins communicate tens or hundreds of meters apart, and the whistles that the members of a social group receive are far from resembling those of perfect recordings. Instead what they receive, is a succession of dominant frequencies corresponding to the stereotyped repetition of templates present in the "signature" whistle (Caldwell and Caldwell, 1968). Again, what all dolphins can hear, no matter their distance or position from the vocalizing dolphin, is the rhythm of whistle production. The signature whistle hypothesis could be therefore made complete or, perhaps, the RIME hypothesis could be a substitute for it.

The authors believe that the RIME could appear to be in nature a rather wide-spread phenomenon. From a biological point of view, it could answer many unsolved questions and may give a reasonable interpretation of the interspecies communication observed among cetacean species.

REFERENCES

André, M. 1997. *Distribution and conservation of the sperm whale,* Physeter macrocephalus, *in the Canary Islands.* PhD Thesis, University of Las Palmas de Gran Canaria, Spain.

Backus, R.H. and Schevill, W.E. 1966. *Physeter* clicks. Pp. 510-528 In: *Whales, Dolphins and Porpoises* (Ed. K.S. Norris). Univ. Calif. Press, Berkeley. 789pp.

Caldwell, D.K. and Caldwell, M.C. 1968. The dolphin observed. *Nat. Hist.*,77(8): 58-65.

Goold, J. 1996. Time and frequency domain characteristics of sperm whale clicks. *J. Acoust. Soc. Am.*

Gordon, J. 1987. Sperm whale groups and social behaviour observed off Sri Lanka. *Rep.Int.Whal.Commn.*, 37:205-217.

Gordon, J. and Steiner, L. 1992. Ventilation and dive patterns in sperm whales, *Physeter macrocephalus*, in the Azores. *Rep. Int. Whal. Comm.*, 42: 561-5.

Gordon, J, Leapper, R., Hartley, F.G. and Chappell, O. 1992. Effetcs of whale-watching vessels on the surface and underwater acoustic behaviour of sperm whales off Kaikoura, New Zealand. *NZ Science and Research Series*, 52:1-64.

Ivanov, P.Ch., Rosemblum, M.G., Peng, C.K., Mutus, J., Havlin, S., Stanley, H.E. and Goldberger, A.L. 1996. Scaling behaviour of heartbeat intervals obtained by wavelet-based time-series analysis. *Nature,* 383: 323-327.

Jaquet, N. 1996. How spatial and temporal scales influence understanding of Sperm Whale distribution: a review. *Mammal Review,* 26:51-65.

Jaquet, N. and Whitehead, H. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. *Marine Ecology Progress Series*, 135:1-9.

Kamminga, C., van Hove, M.T., Engelsma, F.S. and Terry, R.P. 1993. Investigations on Cetacean sonar X: a comparative analysis of underwater echolocation clicks of *Inia* spp. and *Sotalia* spp. Aquatic *Mammas,* 19(1):31-43.

Morton, E. 1975. Ecological sources of selection on avian sounds. *Amer. Nat.* 109: 17-34.

Mullins, J., Whitehead, H. and Weilgart, L. 1988. Behaviour and vocalizations of two single sperm whales, *Physeter macrocephalus*, off Nova Scotia. *Can. J. Fish. Aquat. Sci.*, 45:1736-43.

Papastavrou, V., Smith, S.C. and Whitehead, H. 1989. Diving behavior of the sperm whale, *Physeter macrocephalus*, off the Galapagos Islands. *Can.J. Zool.*, 67: 839-846.

Shaw, R., Packard, N.H., Crutchfield, J.P. and Farmer, D. 1980. Geometry from a time series. *Physical Review Letters*, 47, p. 712.

Watkins, W.A. 1980. Acoustics and the behavior of sperm whales. Pp. 283-290 In: *Animal sonar systems*, R-G. Busnel and J.F. Fish (eds.), Plenum, New York. 1135pp.

Watkins. W.A., Moore, K. and Tyack, P. 1985a. Codas shared by Caribbean sperm whales. *In*: Abstr. 6th Bienn. Conf. Biol. Mar. Mamm., Vancouver, BC., Nov. 1985. 86 pp.

Watkins, W.A. and Schevill, W.E. 1977. Sperm whale codas. *J. Acoust. Soc. Am.* 62(6):1485-90 + phono. record.

Weilgart, L. and Whitehead, H. 1993. Coda communication by sperm whales (*Physeter macrocephalus*) off the Galapagos Islands. *Can.J. Zool.*, 71(4): 744-752.

Whitehead, H. and Weilgart, L. 1990. Click rates from sperm whales. *J. Acoust. Soc. Am.*, 87: 1798-1806.

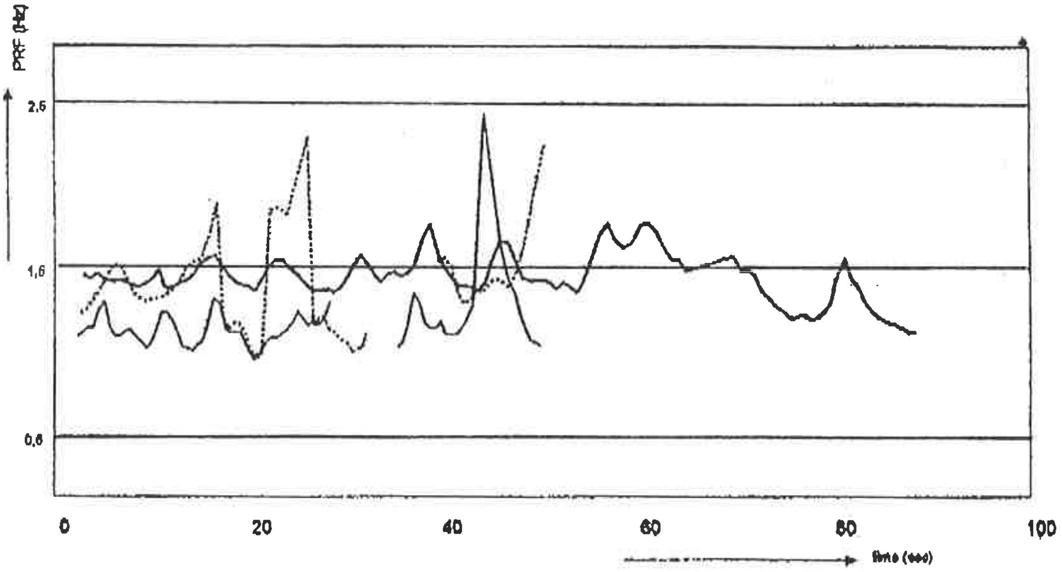


Figure 1. Click repetition patterns of three sperm whales isolated from a group of 12 individuals by means of cross-correlating the click wave shapes.

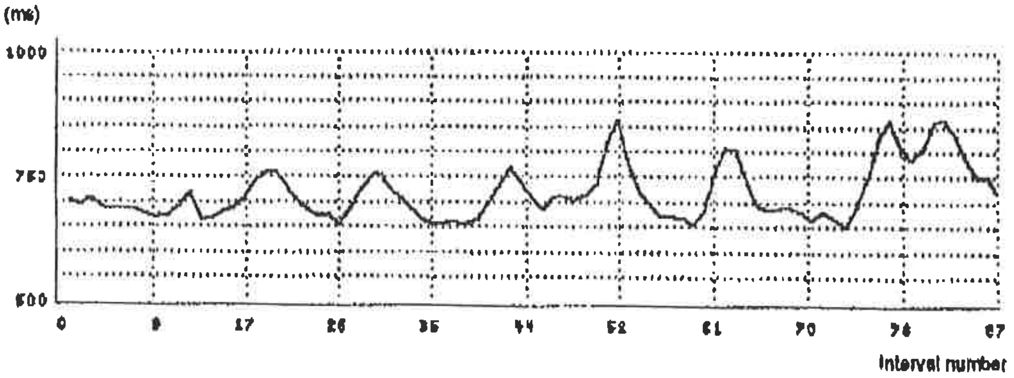


Figure 2. The tachogram of subject "cach 1" over 119 intervals. Total time duration 85.10 seconds. Average PRF is 84 clicks/minute, corresponding to an average PRF of 1.40 Hz. An interruption of 4.17 seconds is represented by interval 88.

Figure 3a:

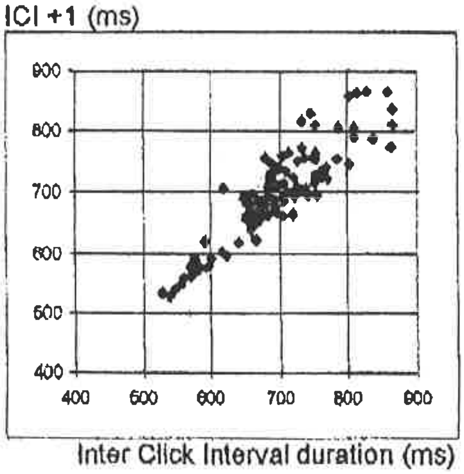


Figure 3b:

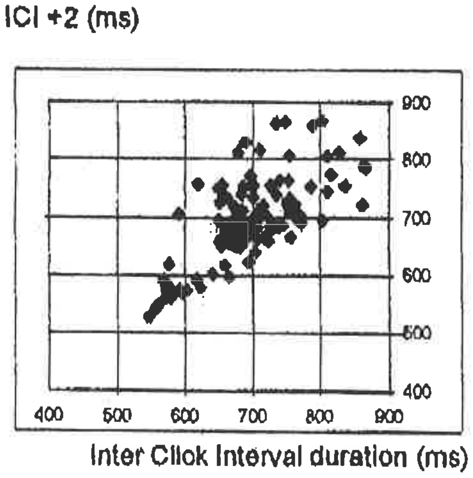


Figure 4:

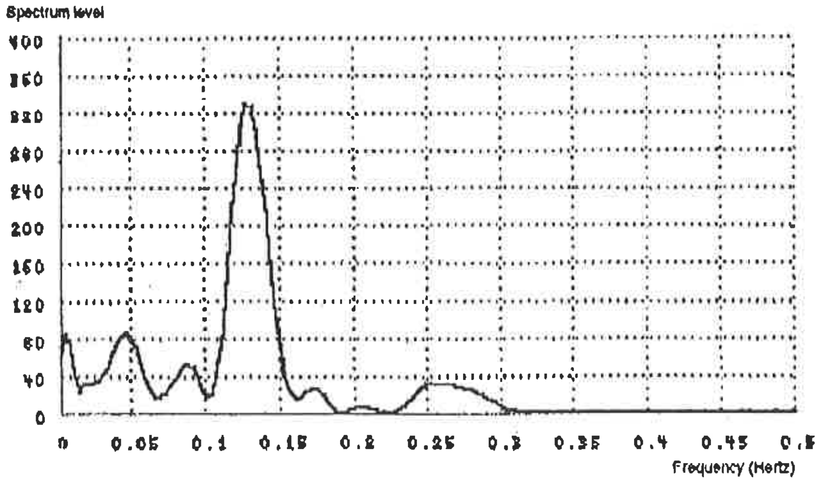


Figure 5:

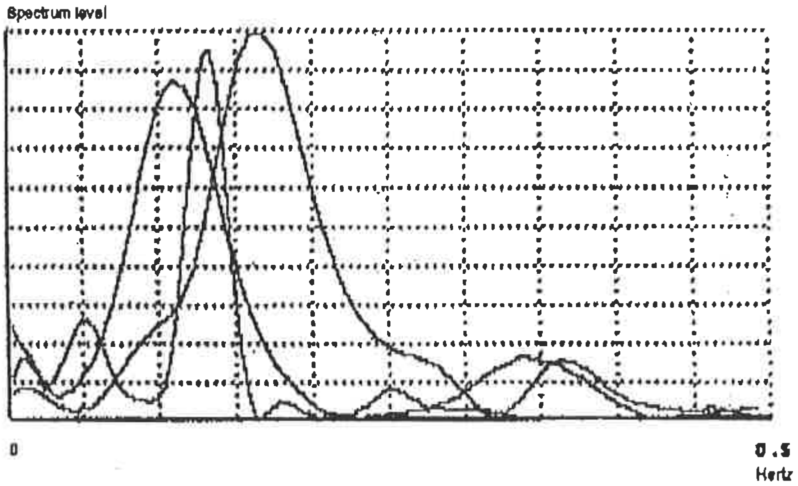


Figure 6:

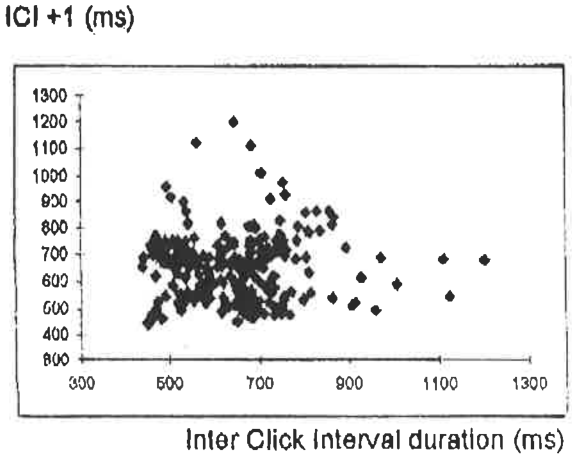
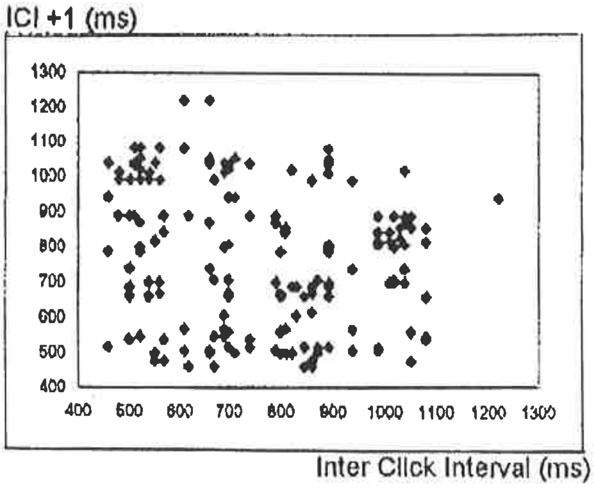


Figure 7ª:



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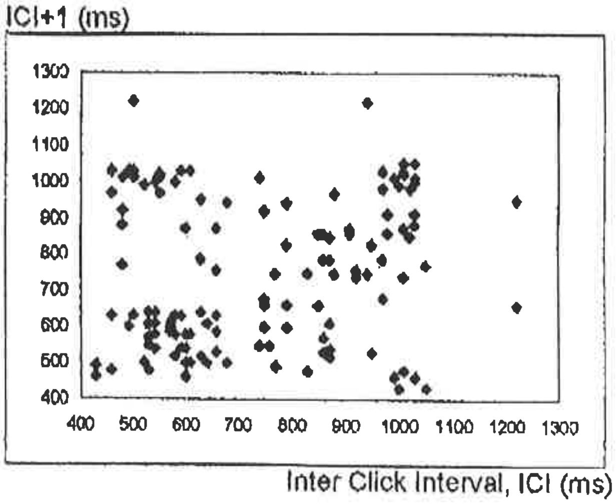

COMPARISON BETWEEN RISSO'S DOLPHIN VOCAL REPERTOIRE IN SCOTTISH WATERS AND IN THE MEDITERRANEAN SEA

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INTRODUCTION The Risso's Dolphin Project started during summer 1995 in coastal waters of the Isle of Lewis, Outer Hebrides. During summer 1996 recordings of Risso's dolphin (*Grampus griseus*) vocalisations were collected with the aim to focus on their acoustic repertoire, that hasnít been extensively studied before, and to produce a catalogue of sounds.

The Centro Interdisciplinare di Bioacustica e Ricerche Ambientali, University of Pavia, Italy, has been conducting, since 1988, summer cruises in the Mediterranean Sea, to study cetacean sounds production, focusing in particular on sperm whales. During this period, Risso's dolphin accidental encounters resulted in a few recordings, now stored in the Cetacean Sound Library of the Centro. A comparison between recordings of Risso's dolphins from Scottish waters and from the Mediterranean Sea has been made to find differences and similarities between these two different areas and to enrich this species' catalogue of sounds.

MATERIALS AND METHODS The survey area in Scotland was situated around the north-eastern part of Isle of Lewis and covered approximately 175Km≤. Recordings were made from a Hardy 24ft (8m) fishing boat, using two stationary Benthos AQ4/Magrec HP/30 hydrophones (200Hz ñ 15kHz ±1.5 dB; acoustic sensitivity -201dB) connected to a pre-amplifier.

From 1994 to 1996, three cruises have been organised in the northwest Mediterranean Sea using auxiliary sailing vessels up to 16m long. A dipole-array of hydrophones (flat frequency range from 5 Hz to 35 kHz, acoustic sensitivity -173dB) was towed at speed up to 14 km/h and listening stations were held on a 24h schedule for at least 5 min. every half an hour. Underwater recordings were made using a portable DAT recorder in both area, and sounds were analysed with the real-time Digital Signal Processing Workstation developed by Pavan, 1994, except for the analysis of whistles recorded in Hebridean waters that was done using Canary v.1.2 (Cornell University's Bioacoustics Laboratory) by Alison Gill. Recordings were just made during animal's sightings.

Sounds have been named according to our acoustic perception, grouped into categories by visual inspection of the spectrograms and by measuring their mean duration, pulse repetition rate and frequency range. Harmonics were used to measure the repetition rate in pulse trains (Watkins, 1967).

Statistical comparisons of measured variables were carried out between the same sounds recorded in both studied areas. Due to the small sample of sounds recorded especially in the Mediterranean sea F test has been used to compare variances, while z test and t test to compare means.

RESULTS Risso's dolphins were sighted and recorded during 12 days in the coastal waters of Isle of Lewis, collecting about eight hours of useful recordings, while four sightings in the Mediterranean Sea resulted in about two hours of recordings. Table 1 shows length of recordings per each encounter.

From the analysis of data collected in the Hebrides, one finds that Risso's dolphins mainly produce eight different kind of sounds that can be basically grouped into three main categories: clicks in discrete series (echolocation clicks, creaks, grunts) whose repetition rate from 37 to 167 pulses/sec. allows to discriminate almost each pulse in the spectrogram; fast sequences of pulses (buzzes, squeaks, squeals, moans) with a high repetition rate, from 187 to 3,750 pulses/sec., that results in harmonics on the spectrogram; and whistles with a mean frequency range from 9,000 to 13,200 Hz (Benoldi *et al.*, 1997). Fig. 1 and 2 show a spectrogram of each category.

According to our acoustic perception six out of eight kind of sounds have been recognised in recordings from the Mediterranean.

In the category of clicks in discrete series we found echolocation clicks and creaks (41-170 pulses/sec.) while there were not any grunts (Table 2).

In the category of fast sequences of pulses we found buzzes (88-450 pulses/sec.), a few squeaks (250-625 pulses/sec.) and squeals (2,250 pulses/sec.) but no moans (Table 3).

Whistles, with mean frequency range from about 7,400 to 11,800Hz, have been found in recordings from the Mediterranean (Table 4).

Nevertheless it is perhaps worth noting that the small sample of data collected can influence presence and absence of sound categories, relative to less behavioural categories observed. Tables 2-4 show measured variables of similar sounds given by distinct location.

Mean duration, variance and frequency range of similar sounds recorded in both studied areas were compared using statistical tests in order to assess if the different value found can be considered significant of a real difference. Statistical analysis pointed out that the majority of compared sounds present significantly different variables (Table 5). All the observed differences in mean duration were found to be significant at the 0.01 confidence level apart from squeaks mean duration that resulted very similar. Again the small sample size of squeaks from the Mediterranean Sea should be noted. All the whistle frequencies resulted significantly different at the 0.01 confidence level except for difference between maximum frequency means that can be considered significant at the 0.05 confidence level.

CONCLUSIONS Risso's dolphins' vocalisations, in Scottish waters, were recorded during different behaviours (apparent feeding activity, resting, travelling) and were used to produce a preliminary catalogue of sounds that confirmed previous research by other authors (Caldwell *et al.*, 1969; Schevill and Watkins, 1962; Watkins *et al.*, 1994). In the Mediterranean sea Rissoís dolphins' recordings were not made on a regular basis and no detailed notes on behaviour were taken. The small sample of data just permitted to investigate whether recordings from the Mediterranean fitted with the more representative sample from the Hebrides.

According to our acoustic and visual perception in both studied areas were found similar kind of sounds but a more accurate statistical analysis showed that duration, pulse rate and frequency range of similar sounds recorded in Scotland and in Italy are different. Although these results rely on too small a sample of data to be significant, they are worthy to be considered in future studies of Risso's dolphin sounds. Further recordings are necessary to confirm our data, in particular giving more attention to related behaviours in order to have a more representative sample of data.

ACKNOWLEDGEMENTS The hydrophones and DAT recorder were provided by Dr. J. Gordon (IFAW) and by the Defence Research Agency. Funding for the fieldwork in Scotland was provided by WDCS, The Carnegie Trust for Universities of Scotland, The Manifold Trust, The Scottish International Education Trust and Università degli Studi di Milano. The boat was loaned from Mr and Mrs Henriques. Special thanks are due to Tim Atkinson and Lori Lawson for their help with fieldwork, and to Guido Gnone for his encouragement.

REFERENCES

Benoldi, C., Evans, P.G.H., Manghi, M., Pavan, G. and Priano, M. 1997. Risso's dolphin acoustic survey in the Hebridean waters, Scotland. In *European Research on Cetaceans - 11*. Proc. 11th Ann. Conf. ECS, Stralsund, 10-12 March, 1997 (Eds P.G.H. Evans, E.C.M. Parsons & S.L. Clark). European Cetacean Society, Cambridge, England. 314pp.

Caldwell, D.K., Caldwell, M.C. and Miller, J.F. 1969. Three brief narrow-band sound emissions by a captive male Rissoís dolphin, Grampus griseus. *Bull. Soc. Calif. Acad. Sci.*, 68(4): 252-256.

Pavan, G. 1994. A digital signal processing workstation for bioacoustical research. Abstracts of the 6th "Convegno italiano di ornitologia". *Mus. Reg. Sci. Nat. Torino*: 227-234.

Schevill, W. E. and Watkins, W. A. 1962. *Whale and porpoise voices, a phonograph record.* Woods Hole Oceanographic Institution, 24pp.

Watkins, W. A. 1967. The harmonic interval: fact or artifact in spectral analysis of pulse trains. Pp. 15-44. In *Marine Bioacoustics.* Vol 2. (Ed. W.N. Tavolga) Pergamon Press, NY.

Watkins, W. A., Daher, M. A. and Sbradlin, T. R. 1994. *Analysis of Marine Animal Sound Data for the Mediterranean.* Report for DRA, Farnborough, UK.

Table 1 Recording duration per encounter in Scottish waters and in the Med.

Date	Encounter N°	Recording duration (minutes)	Date	Encounter N°	Recording duration (minutes)
HEBRIDES					
28/07/96	-	-	11/08/96	7	-
01/08/96	-	-	03/09/96	8 9	34 46.12
02/08/96	1	-	10/09/96	10 11	13.36 -
06/08/96	-	-	11/09/96	-	-
07/08/96	2	45.42	12/09/96	12	5.38
08/08/96	3	11	13/09/96	13	36.38
09/08/96	4	62.33	14/09/96	14	56.49
10/08/96	5	32.1	21/09/96	15	101
THE MED.					
08/07/91	1	27.38			
07/10/91	2	43.57			
09/04/94	3	50			
06/20/95	4	9.50			

Table 2 Clicks in discrete series' mean duration, standard deviation and pulse rate from different areas.

Name	**CREAK**		**GRUNT**	
Location	Hebrides	Med.	Hebrides	Med.
Mean duration	663.1 ms	1159.9 ms	104.5 ms	-
st. dev.	291.6	700.1	58.1	-
Pulse rate	54-167/sec	41-170/sec	37-78/sec	-

Table 3 Fast sequences of pulses' parameters from both studied areas.

Name	**BUZZ**		**SQUEAK**		**SQUEAL**		**MOAN**	
Location	Hebrides	Med.	Hebrides	Med.	Hebrides	Med.	Hebrides	Med.
Mean duration	402.4 ms	152.5 ms	143.6 ms	142.0 ms	542.2 ms	757.5 ms	1578.0 ms	-
st. dev.	128.9	66.8	59.4	55	108.5	37.5	2185	-
Pulse rate	250-625/sec	88-450/sec	400-1031/sec	250-625/sec	2000-3750/sec	2250/sec	187-560/sec	-

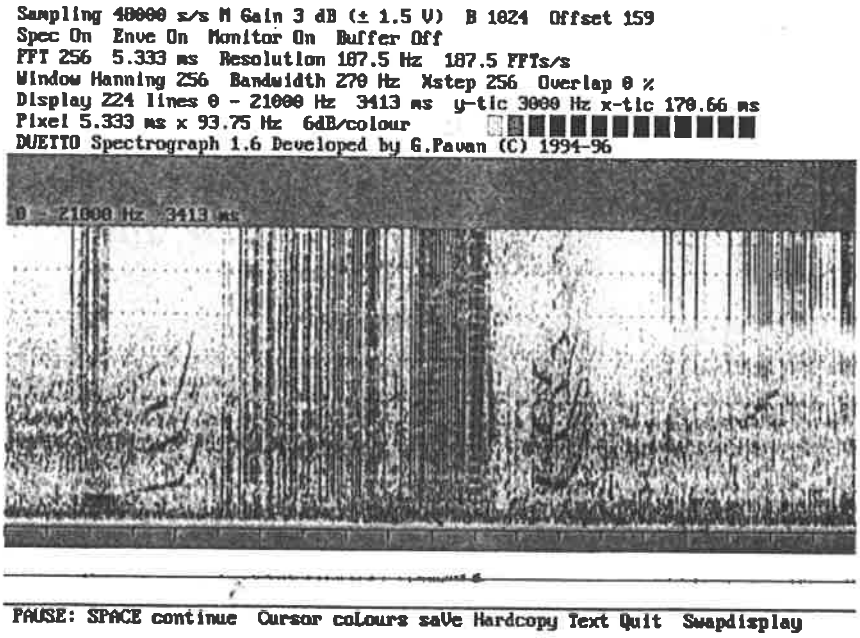
Table 4 Whistles' parameters from different location

WHISTLE		Min. freq. Hz	Max. freq. Hz	Start freq. Hz	End freq. Hz	duration ms
Hebrides	Mean	9003.6	13241.4	12047.1	11128.7	565.5
	st. dev.	2626.1	2328.7	2714.3	6267.6	259.6
Med.	Mean	7449.2	11813.4	9625.6	8736.1	394.5
	st. dev.	3630.4	4134	3849.9	4230	278.3

Table 5 Results of statistical tests.

Duration ms	**CREAK**	**BUZZ**	**SQUEAK**	**SQUEAL**
F test	F = 0.2 P> 0.05	F = 3.7 P< 0.05	F = 1.1 P> 0.05	F = 8.4 P> 0.05
t test	t = 9.2 P< 0.01		t = 0.08 P< 0.01	t = 2.6 P< 0.01
z test		z = 22.5 P< 0.01		

WHISTLE	Duration ms	Hz min.	Hz max.	Hz start	Hz end
F test	F = 0.9 P< 0.05	F = 0.5 P> 0.05	F = 0.3 P> 0.05	F = 0.5 P> 0.05	F = 0.5 P> 0.05
t test	t = 3.7 P< 0.01	t= 3.0 P< 0.01	t = 2.8 P< 0.01	t = 4.5 P< 0.01	t = 3.4 P< 0.01



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Spec On  Enve On  Monitor On  Buffer Off
FFT 256  5.333 ms  Resolution 187.5 Hz  187.5 FFTs/s
Window Hanning 256  Bandwidth 270 Hz  Xstep 256  Overlap 0 %
Display 224 lines 0 - 21000 Hz  3413 ms  y-tic 3000 Hz x-tic 170.66 ms
Pixel 5.333 ms x 93.75 Hz  6dB/colour
DUETTO Spectrograph 1.6 Developed by G.Pavan (C) 1994-96
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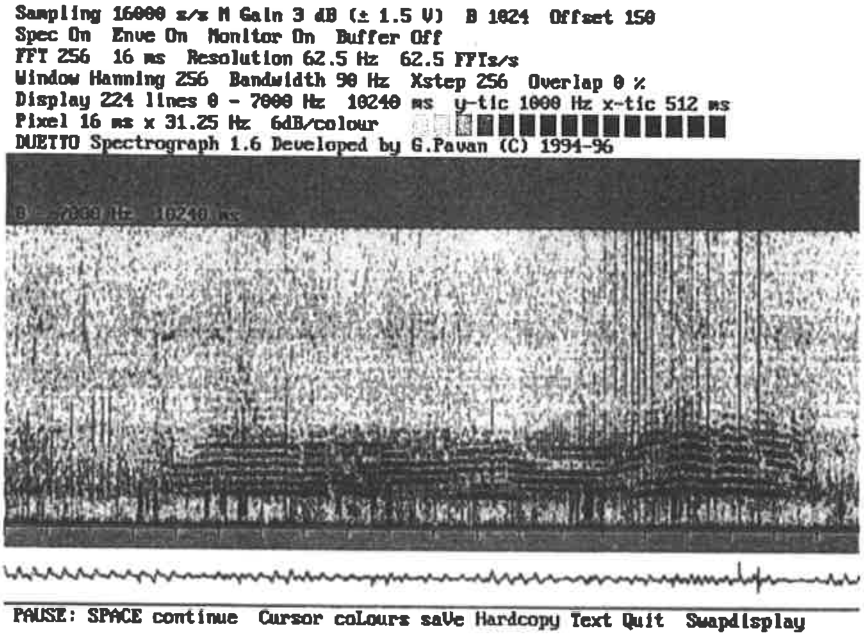
Fig. 1 Clicks in discrete series (Creaks) and Whistle.



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Sampling 16000 s/s M Gain 3 dB (± 1.5 V)  B 1024  Offset 150
Spec On  Enve On  Monitor On  Buffer Off
FFT 256  16 ms  Resolution 62.5 Hz  62.5 FFTs/s
Window Hanning 256  Bandwidth 90 Hz  Xstep 256  Overlap 0 %
Display 224 lines 0 - 7000 Hz  10240 ms  y-tic 1000 Hz x-tic 512 ms
Pixel 16 ms x 31.25 Hz  6dB/colour
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Fig. 2 Fast sequences of pulsed sounds (Moan).

'ACOUSTIC ETHOGRAM' OF THE BOTTLENOSE DOLPHIN IN CAPTIVITY

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INTRODUCTION It is well known that bottlenose dolphins (*Tursiops truncatus*) can produce a huge repertoire of sounds. Due to their habit, it is almost impossible to give a complete description of their acoustic behaviours in the wild, although some correlations have been made (Connor *et al.*, 1996; dos Santos *et al.*, 1990; Herzing, 1996; Smolker *et al.*, 1993). The individuals producing the sound can hardly be identified and the context is also often unknown. Observation in captivity, correlated with video-acoustic recordings, can give some important answers, although new problems may arise.

Three bottlenose dolphins, two adults and a new-born, were observed for one year at the Genoa Aquarium and about 150 hours of video-acoustic recordings were collected.

The first aim of our research was to give a complete description of all their vocalizations along with the movements eventually associated to the sound. The second and final aim was to find correlations between the acoustic behaviours and the context in order to speculate on the function of each vocalisation.

MATERIALS AND METHODS Underwater acoustic recordings were obtained by means of a spherical hydrophone (ITC-1089C, 1 Hz-350 KHz) connected to a DAT recorder through an amplifier (EG & G113) which was set with a high-pass frequency filter. Sounds were recorded in a range from 110 Hz to 22 KHz. Video recordings were taken with a video-camera set outside the tank, in front of a large (24 m x 5 m) transparent acrylic wall. Video and sounds were integrated in a S-VHS video recorder.

Recordings were carried out following two different schedules. In the first schedule the observer followed a strict recording program, independent from the activity in the pool ('fixed schedule'). In the second one the observer freely started the recordering when he chose to ('free recordings'). The 'fixed schedule' was used in order to describe and measure the behaviour, while the 'free recordings' were taped in order to store those behaviours which might not occur in the 'fixed' periods.

Recordings were carried out every week in the first six months and one week out of two during the second six months. In total, 150 hours of images and sounds were collected, 80 with the 'fixed schedule' and 70 with the 'free recordings'

Sound analysis on the recorded sequences. To identify possible correlations between vocals and visually observable behaviours, the sounds were analysed with a Digital Signal Processing Workstation developed by Pavan (Pavan and Borsani, 1997), which shows a real-time spectrogram. This spectrographic analysis was superimposed on the video sequences using a video-mixer. From every S-VHS tape was obtained a second tape with the embedded spectrographic analysis. Such association between images, sounds and spectrographic analysis made the identification of the individual vocalising easier (Fig. 1).

Identifications were carried out using both revealing elements of the dolphin vocalizing (bubbles from the blowhole, body movements, closeness to the hydrophone, etc.) and revealing elements of the individual non vocalising (breathing coincidence, head out of the water, long time motionless resting behaviour at the surface, etc.).

All the videotapes were accurately browsed and 80 behavioural categories were identified: 52 acoustic and 28 non-acoustic. The 53 hours of recording obtained during the first six months period with the "fixed schedule" were divided into 3,137 periods lasting one minute each. The presence of each category within each period (1 min.) was checked following a 1-0 sampling technique. When statistically meaningful, the coincidence of two or more categories within the same period was used as an index of association. The statistical significance of such coincidence was checked calculating the Chi^2 value within a 2x2 contingency table.

RESULTS What follows is our complete acoustic ethogram, resulting from the analysis of 150 hrs of acoustic recordings. Fifty-two acoustic categories were identified through their spectrographic image and divided within three supercategories (modulated sounds, impulsive sounds, sounds produced with the body). For each category are given: the spectrogram, the individual probably producing the sound, the number of one minute periods where such category was found on the total of the "fixed" periods analysed (in the first six months), the association with one or more of the 28 non-acoustic behaviours and the Chi^2 value obtained with the 2x2 contingency table.

CONCLUSIONS Fifty-two categories of vocal behaviours were identified and described in our "*Tursiops truncatus* acoustic ethogram". Eleven acoustic categories were positively associated to at least one context; other six also showed at least one strong association, but the small sample suggests deeper analysis. Our study in captivity turned out to be useful in order to collect vocal behaviours and give a formal description of the different vocalisations. The functional description of the same behaviours, which can be partially gathered from some association, may also be useful as an indication for future research.

ACKNOWLEDGEMENTS Thanks to Alenia-Elsag Sistemi Navali for technical support and to Fondazione Cetacea for references. Thanks also to Fabio Campitelli.

REFERENCES

Connor, R.C. and Smolker, R.A. 1996. "Pop" goes the dolphin: a vocalization male bottlenose dolphins produce during consortships. *Behaviour*, 133: 643-662.

dos Santos, M.E., Caporin, G., Moreira, H.O., Ferreira, A. J., Coelho, J.L.B. 1990. Acoustic Behavior in a Local Population of Bottlenose Dolphins. In *Sensory Abilities of Cetaceans* (Eds J. A. Thomas and R. A. Kastelein). Plenum Press, New York

Herzing, D. 1996. Vocalizations and associated underwater behavior of free-ranging Atlantic spotted dolphins, Stenella frontalis and bottlenose dolphins, *Tursiops truncatus*. *Aquatic Mammals*, 22(2): 61-79.

Smolker, R.A., Mann, J. and Smuts, B.B. 1993. Use of signature whistle during separations and reunions by wild bottlenose dolphin mothers and infants. *Behav Ecol. Sociobiol.*, 33: 393-402.

Pavan, G., Borsani, J.F. 1997. Bioacoustic research on cetaceans in the Mediterranean Sea. *Mar. Fresh.Behav. Physiol.*, 30: 99-123.

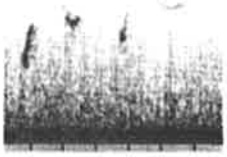
Figure 1 Acoustic ethogram of captive bottlenosed dolphins

Notes:
"found" means "found samples" in the data set.
"Fix. sched." means recorded with "fixed schedule".
All the reported associations are POSITIVE (If the chi-square is higher than 3.84, the association is considered meaningful).
The question-mark (?) preceds a data resulted using an "Expected frequency" lower than 5.

modulated sounds

all the spectrograms :
frequency vertical axis: 0 - 21.000 Hz;
3000 Hz between dotted lines
time scale: 170.66 ms between ticks


Whistle Cleo 01
found 2 Fix. sched.


Whistle Cleo 02
found 0 Fix. sched.


Whistle Cleo 03
found 2 Fix. sched.

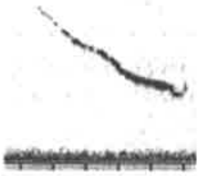

Whistle Cleo 04
found 0 Fix. sched.


Whistle Cleo 05
found 0 Fix. sched.


Whistle Cleo 06
found 12 Fix. sched.
associations:
with *approaching* (?19.43)


Whistle Cleo 07
found 0 Fix. sched.


Whistle Cleo 08
found 0 Fix. sched.

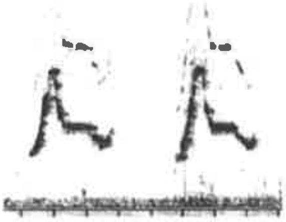

Whistle Cleo 09
found 26 Fix. sched.
associations:
with *abandon* (?518.7)


Whistle Cleo 10
found 0 Fix. sched.


Whistle Cleo 12
found 0 Fix. sched.


Whistle Cleo 13
found 2 Fix. sched.

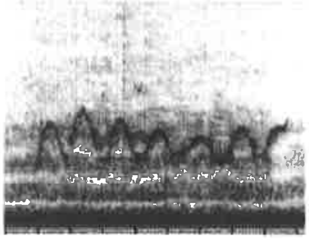

Whistle Cleo 14
found 3 Fix. sched.


Bonnie's signature whistle
found 176 Fix. sched.
associations:
with *suckling* (45.31),
wiht *pointing* (221.1),
with *separation* (33.03)

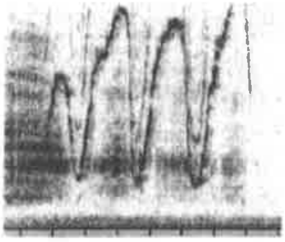

Bonnie's half signature whistle
found 117 Fix. sched.
associations:
with *suckling* (66.23)

Cupola
found 39 Fix. sched.
associations:
with *suckling* (?31.7),
with *separation* (?17.04),
with *approaching* (?19.04)

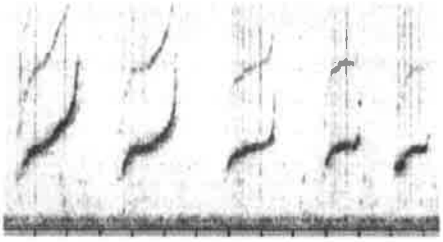
Micha's signature whistle
found 2 Fix. sched.



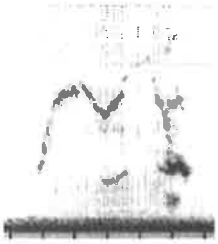
Sinusoidal whistle
found 65 Fix. sched.
associations:
with *pointing* (159)



Abnormal sinusoidal whistle
found 20 Fix. sched.

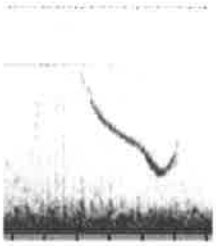


"S" whistle
found 2 Fix. sched.

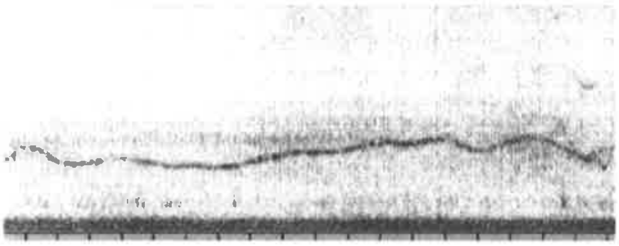


"M" whistle
found 0 Fix. sched.

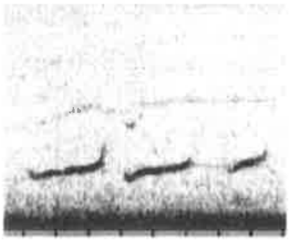
"U" whistle
found 0 Fix. sched.



"V" whistle
found 5 Fix. sched.

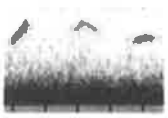


Long uniform whistle
found 10 Fix. sched.
associations:
with *pointing* (?37.11)



Interrupted long whistle
found 0 Fix. sched.

Medium uniform whistle
found 7 Fix. sched.

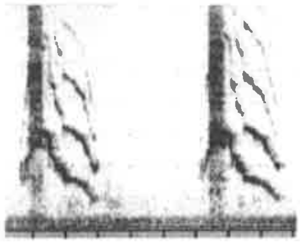


Small "U"s
found 6 Fix. sched.

Comma whistle
found 3 Fix. sched.

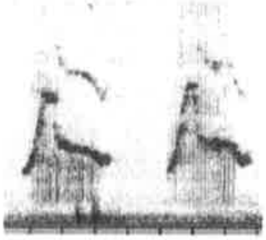
Sweep 01

found 35 Fix. sched.
associations:
with *pointing* (27.18)

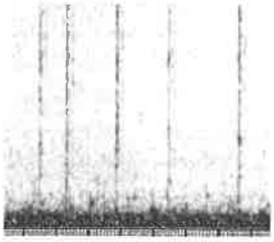


Exasperated whistle
found 7 Fix. sched.

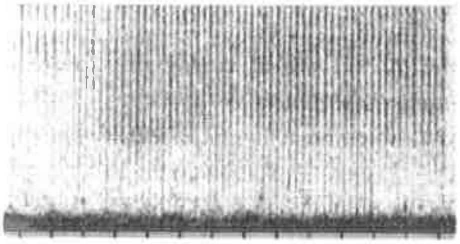
impulsive sounds



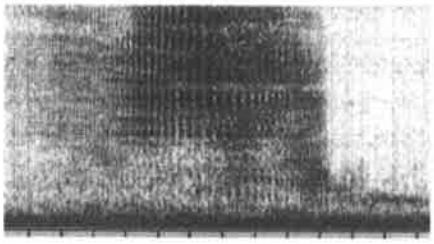
Whistles with clicks
found 55 Fix. sched.
associations:
with *separation* (25.44)



Run
found 287 Fix. sched.
associations:
with *survey* (9.25),
with *escape* (16.43),
with *pointing* (276.81)

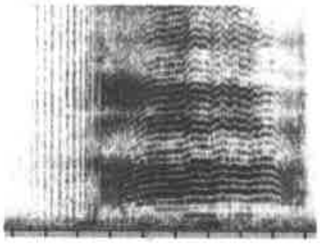


Regular clicks
found 192 Fix. sched.
associations:
with *survey* (17.78),
with *escape* (26.2),
with *pointing* (146.83)



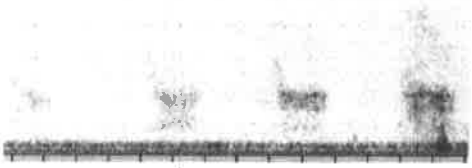
Creak
found 552 Fix. sched.
associations:
with *escape* (82.25),
with *pointing* (384.3),
with *separation* (127.8),
with *approaching* (84),
with *push* (13.35),
with *survey* (36.56),
with *play* (42.03),
with *jump* (83.35),
with *aggression* (?34.5)

Squawk
found 70 Fix. sched.
associations:
with *pointing* (12.74),
with *jump* (?148.9),
with *aggression* (?522.7)

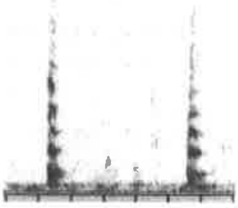


Moan
found 204 Fix. sched.
associations:
with *escape* (270.26),
with *pointing* (296.4),
with *survey* (7.24),
with *jump* (15.16),
with *play* (28),
with *aggression* (?14.59),
with *push* (?15.8)

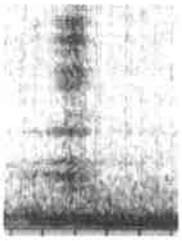
Burst
found 24 Fix. sched.



Croak
found 368 Fix. sched.
associations:
with *swim around alone* (7.17)
(7.67 if Micha),
with *jump* (51.14),



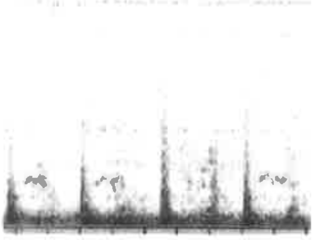
Sweep 02
found 12 Fix. sched.
associations:
with *pointing* (?8.5)



Genital buzz
found 0 Fix. sched.

Sob
found 14 Fix Sched.

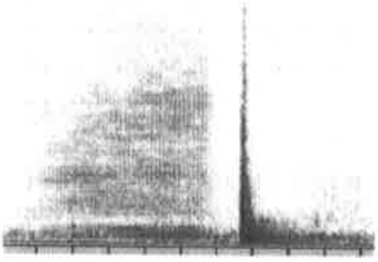
Feeding sound
found 3 Fix. sched.



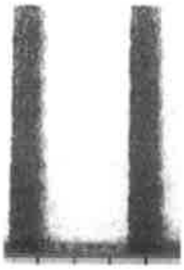
Pop
found 0 Fix. sched.

Cleo's raspberry
found 15 Fix. sched.
associations:
with *pointing* (?26.4)

sounds produced with the body



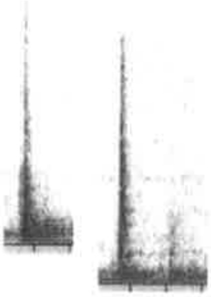
Tail-slap
found 6 Fix. sched.



Down-stroke
found 3 Fix. sched.

Deep tail-slap
found 15 Fix. sched.

Jaw-clap
found 15 Fix. sched.



Breach along with
Half-breach (lower image)
found 105 Fix. sched.

Blow
found 47 Fix. sched.

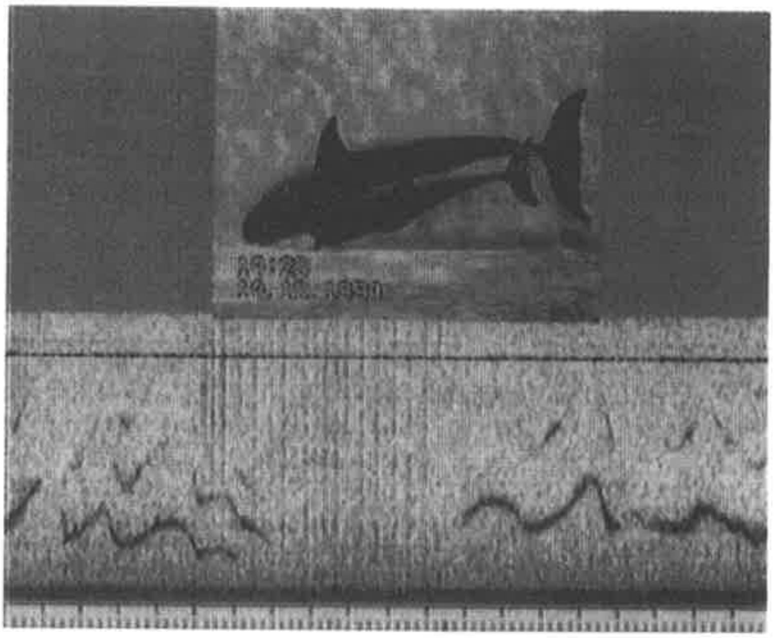


fig.1

COMPARISON OF THE DISTRIBUTION OF ODONTOCETES OBTAINED FROM VISUAL AND ACOUSTIC DATA IN NORTHWESTERN MEDITERRANEAN

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INTRODUCTION Passive acoustics has been recently used for shipborne cetacean abundance survey both as complementary equipment or as a unique method of assessment (Chappell *et al.*, 1995; Sturtivant and Datta, 1997; Gillespie, 1997). The towed hydrophone array is a very efficient material for detecting and locating the sperm whale, a highly emissive source performing extensive dives day and night, and can be used for smaller odontocetes (Notarbartolo di Sciara and Gordon, 1997). However, in the case of many dolphin species, the acoustic survey results are more complicated to analyse, since delphinids are not very loud sources, and may remain silent for protracted periods. Furthermore, certain emissions types may be essentially restricted to a given activity (e.g. echolocating signals during feeding sessions). It is therefore very interesting to compare the results obtained by acoustics to those coming from visual observation during a given survey. The GREC has undertaken combined acoustic and visual surveys in the Mediterranean since 1994 (Gannier, 1996; Gannier and Gannier, 1997). We compare here the distribution results obtained from visual and acoustic data recorded during an abundance survey in the summer of 1996.

MATERIAL AND METHODS The platform is a motor sailing boat of 12 metres length with a 80 hp diesel engine. This boat sustains an average speed of six knots under various sea conditions, and accommodates a crew of six persons. The specific equipment consists of a dual channel towed hydrophone with two Benthos AQ-4 captors (frequency response linear at 2 dB from 1 Hz to 25 kHz). Each one feeds a pre-amplifier with a built-in 200 Hz high pass filter which is connected to a Sony TCD-30 cassette stereo recorder (frequency range of 20 Hz - 16 kHz). One observer sits in the cockpit and is in charge of the acoustic sampling. Three other observers share the frontal sector: one searches the ±45° frontal sector from ahead of the mast, two others search the 30° to 90° sector each side from the roof top. We interrupted the survey when the wind speed exceeded 10 knots. A series of nine legs was covered from 16th July to 15th August, with a total effective sampling effort of 1,765 km (Gannier and Gannier, 1997). Sampling was conducted on diesel propulsion only, and excluded the area inshore of the 200 metres depth line.

Visual data were collected following a line transect method protocole. Every two miles, the complete set of environmental and navigational data was logged, and one minute of acoustic listening was performed, with the speed slowly decreasing to below 3 knots (or less if the hearing of a very weak signal demanded a lower noise level). The sound was recorded, whenever cetaceans were heard. In every case, the signal and overall noise were logged using a three level scale.

For the processing of the striped dolphin data, five cases of visual and acoustic detection were statistically analysed by considering co-variates (school size, activity, wind, underwater noise level and time):

-case H+V+H: the visual detection is preceded and followed by a positive acoustic sample (*double combined*)
-case H+V+nH: the visual detection is preceded by a positive acoustic sample and followed by a negative acoustic sample (*combined left*)
-case nH+V+H: the visual detection is preceded by a negative acoustic sample and is followed by a positive acoustic sample (*combined right*)

-case H+nV (or nV+H): the positive acoustic sample is not followed or preceded by a visual detection (*acoustic single*)

- case nH+V+nH: the visual detection is preceded and followed by a negative acoustic sample (*visual single*)

RESULTS AND DISCUSSION 118 groups of odontocetes were sighted during the survey, including 109 primary detections of striped dolphin, five of pilot whale, two of Risso's dolphin, and two of sperm whale. Groups of more than 30 striped dolphins were rarely encountered, and schools were sometimes sighted less than two miles from the coast (Fig. 1). On a total of 535 acoustic samples, 13 were primary detections of sperm whale, and 134 were detections of striped dolphins (Fig. 2). Pilot whales were detected three times and Risso's dolphins four times, but both off-effort.

Combined acoustic and visual detections of striped dolphins occurred in 80 cases, whilst 24 detections involved only visual detections. The case of sole visual detection is more frequent (Chi^2, p=0.13) either when dolphins are travelling (37% of the sightings) or when resting (29% of the sightings) (Table 1). It seems to be weakly correlated to the school size (Chi^2, p=0.55), but without any noticeable tendency (Table 2). Abnormally low acoustic detection rate sometimes accounts for a high noise level environment occuring in 14% of the samples, or for very distant (2 km) visual detections. Fifty detections were solely acoustic. We know that visual detection rate is generally affected by wind speed (Gannier, 1995): here, Beaufort 3 wind accounts for 52% of exclusive acoustic detections cases (it should be noted that multiple detections of a given school influence this figure). The time influence was investigated by dividing the daylight period into four: before 9am (early morning), from 9am to 1pm (late morning), from 1pm to 5pm (afternoon), and after 5 pm (evening). The "detection case" versus "time period" analysis indicates that both variables are probably linked in some way (Chi-square, p=0.425). Case analysis shows that single acoustic detections are more frequent in early morning and late evening, and less frequent from the late morning to the afternoon. On the contrary, single visual detections are less frequent in early morning and late evening and more frequent during late morning and afternoon (Table 3).

Seventy-seven percent of visual detections of striped dolphins were linked to an acoustic detection: this is more than the 33% figure estimated by Chappell *et al.* (1995) for the harbour porpoise. Combined detections of striped dolphin occur in the majority of the cases. Visual singles remain common when the striped dolphin schools seem silent: mostly during the resting and travelling period, typically in late morning and afternoon. But during the early morning and evening, the striped dolphins are often highly vocal, due to echolocation activity. They are visually inconspicuous during feeding activities: when they feed upon deep prey, and when dive times are in the 4-5 mins range. This species is essentially a night feeder in this region (Gannier, 1996). On the other hand, resting dolphins are often slowly swimming at the surface, which makes them easy to detect visually. Travelling striped dolphins are often conspicuously swimming in compact schools, breathing frequently. The relationship between the acoustic detectability and the school size is a complex issue.

The pilot whale may sometimes remain silent during the day: this is particularly true for resting schools in the afternoon and for travelling groups. The Risso's dolphin is often acoustically discrete, emissions being often restricted to clicks or pulses trains.

CONCLUSION The acoustic technology is not an infaillible detector for most odontocetes, but is is very efficient fro the sperm whale. In the near future, abundance surveys of small odontocetes must rely essentially on visual detection. But acoustics is very useful to obtain ancillary data on the cetaceans, for example on activity patterns, such providing valuable information for enhancing the analysis of survey results.

ACKNOWLEDGEMENTS We thank the Ministère de l'Environnement and the Conseil Régional de Provence Alpes Côte d'Azur for having funded our work from 1995 to 1997. Thanks are due to the IFAW for the longterm loan of a towed hydrophone.

REFERENCES

Chappell, O.P., Leaper, R. and Gordon, J.C.D. 1995. Development of an automated harbour porpoise click detector. Pp. 75-80. In: *European Research on Cetaceans- 9.* (Ed. P.G.H Evans & H. Nice). Proc. Ann. Conf. ECS, Lugano, Switzerland, 9-11 Feb 1995. European Cetacean Society, Kiel, Germany. 302pp.

Gannier A., 1995. *Les cétacés de méditerranée nord-occidentale: estimation de leur abondance et mise en relation de la variation saisonnière de leur distribution avec l'écologie du milieu.* Phd thesis, Ecole Pratique des Hautes Etudes (Montpellier). 437pp.

Gannier A. and Gannier O., 1997. From an acoustic aided survey in the Mediterranean Sea to a future acoustic census system. Pp. 223-225. In: *European Research on Cetaceans - 11.* (Ed. P.G.H. Evans, E.C.M. Parsons and S.L. Clark). Proc. Ann. Conf. ECS, Stralsund, Germany, 10-12 Mar 1997. European Cetacean Society, Kiel, Germany. 314pp.

Gannier A., 1996. Etude de la fréquentation diurne et nocturne des abords du littoral provençal par les cétacés. *Proceedings of the international conference rimmo 5* (Antibes, November 1996): 26-29.

Gannier A., 1997. Summer abundance estimates of striped dolphins and fin whales in the the area of the future international marine sanctuary (NW Mediterranean). Pp. 95-98. In: *European Research on Cetaceans - 11.* (Ed. P.G.H. Evans, E.C.M. Parsons and S.L. Clark). Proc. Ann. Conf. ECS, Stralsund, Germany, 10-12 Mar 1997. European Cetacean Society, Kiel, Germany. 314pp.

Gillespie D. 1997. An acoustic survey for sperm whales in the Southern Ocean Sanctuary conducted from the RV Aurora Australis. *Rep. int. Whal. Commn*, 47: 897-907.

Notarbartolo di Sciara, G. and Gordon, J.C.D. 1997. Bioacoustics: a tool for the conservation of cetaceans in the Mediterranean Sea. *Mar. Fresh. Behav. Physiol.*, 30: 125-146.

Sturtivant C.R. and Datta, S., 1997. An acoustic aid for population estimates. Pp. 213-215. In: *European Research on Cetaceans - 11.* (Ed. P.G.H. Evans, E.C.M. Parsons and S.L. Clark). Proc. Ann. Conf. ECS, Stralsund, Germany, 10-12 Mar 1997. European Cetacean Society, Kiel, Germany. 314pp

Table 1. Combined detection cases and activity of striped dolphins

detection cases activity	nHVnH	nHVH+HVnH	HVH	Total
resting	4	1	5	10
socialising	1	4	4	9
feeding	2	6	14	22
traveling	7	5	11	23

Table 2. Combined detection cases and school size of striped dolphins

detection cases school size	nHVnH	nHVH+HVnH	HVH	Total
1 to 5 ind.	3	5	14	22
6 to 12 ind.	9	11	12	32
13 to 20 ind.	5	4	10	19
more than 20 ind.	2	5	8	15

Table 3. Combined detection cases and period of the day

detection cases time period	nHVnH	nHVH+HVnH	HVH	Total
5am to 9am	1	4	8	13
9am to 1pm	9	10	14	33
1pm to 5pm	6	7	9	22
5pm to 9pm	3	5	16	24

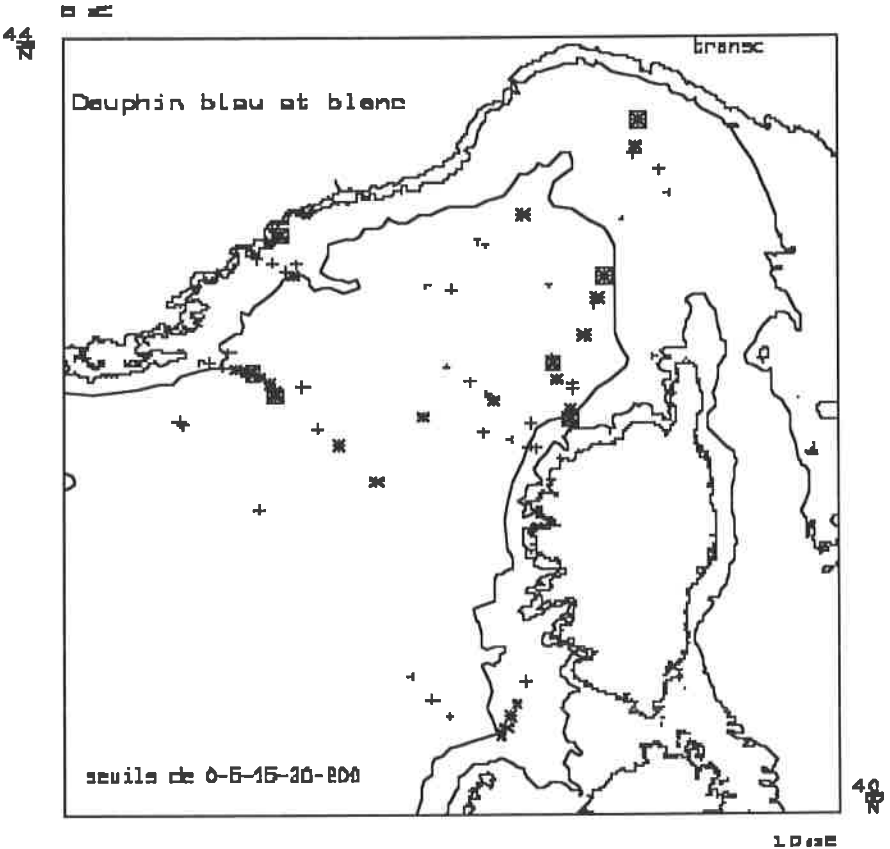

Fig.1: Visual detections of striped dolphins (school size on a four scale range)

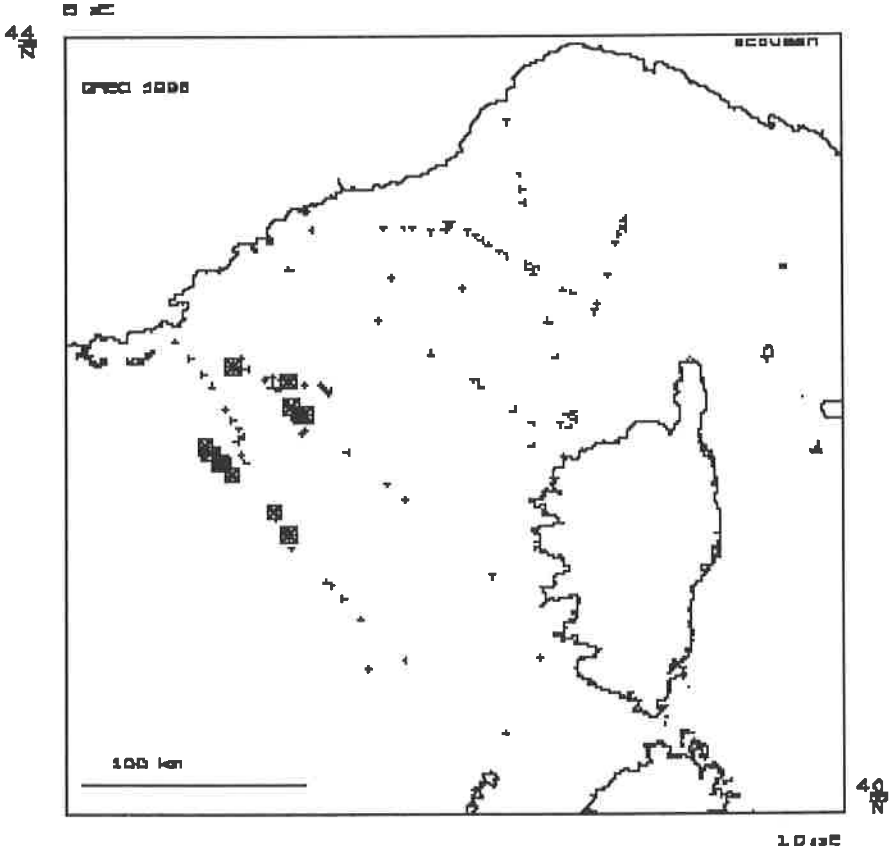

Fig.2: Acoustic detections of odontocetes (square= sperm whale, cross=striped dolphin)

ACOUSTIC AND VISUAL METHODS IN THE ODONTOCETES SURVEY: A COMPARISON IN THE CENTRAL MEDITERRANEAN SEA

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INTRODUCTION About ninety days at sea, during four years (1994-97), were spent on vessels ranging from 12 to 18 metres, in the Central Mediterranean Sea with the purpose of increasing the knowledge of presence and distribution of odontocetes in general and sperm whales (*Physeter macrocephalus*) in particular. Both acoustic and visual surveys were carried out, and relevant data about the effort required and the expected results in the area were obtained. Acoustic surveys are known to be less tiring than visual ones, and allow a 360° coverage. When using an array of hydrophones, a certain amount of directionality (according to the geometry of the array), allows the researcher's attention to be raised for the expected location of a sighting. This permits smaller crews and lower costs than a visual based survey with less observers. As with other variables, the acoustic range of detectability is often superior to the visual, and it is scarcely influenced by meteorological conditions that heavily affect sightings (Notarbartolo di Sciara *et al.*, 1997). The acoustic survey was performed in bad weather up to Beaufort 4 and also during the night, with little or no changes in the reliability of the results. The visual survey was interrupted with sea states higher than Beaufort 3.

EQUIPMENT The on-board equipment used in this research included towed and stationary hydrophones, DAT digital tape recorders, GPS for positioning, a laser range-finder, a digital signal processing workstation for real time sound analysis, standardised LOGs for full notations, a low power stereo radio-transmitter in order to broadcast between the surveyors, and a video camera recording the surface behaviour of the animals, on the ship's deck, the underwater sounds.

The towed hydrophone was a custom-made high-quality "dipole" (flat frequency range from 5 Hz to 35 kHz and sensitivity at 10 kHz of -173 dB) connected to a 150 metre cable; the stationary hydrophones were commercially available pre-amplified ITC 8073.

THE SURVEY During the cruises the towed array of hydrophones was used for 476 hours. Listening stations were held at least every 30 mins, 24 hrs a day, while cruising at 7-9 km/h. Six skilled researchers carried out both daytime-visual and around-the-clock acoustic surveys with a 4 ON/8 OFF or a better 5 ON/10 OFF duty schedule. Audio digital recordings, as well as photos, were taken when storage and/or analysis was considered useful. The observers started their "visual survey" as soon as the ship had left the moorings, while the "acoustic survey", due to the length of the hydrophone, was started when the seabed was at least 250 m. away. In a total of 476 hrs of towing (2,100 nautical miles), 302 hrs of which were in daylight, we had 144 acoustic contacts with different ('new') schools or animals, and 72 sightings. During the acoustic survey the school or the animal was classified 'new' when at least 30 minutes of silence divided the preceding contact from the one being evaluated. The researchers reported only three times the sighting of odontocetes without a preceding acoustic contact; on all these occasions, the animals were striped dolphins (*Stenella coeruleoalba*), and at all these times, it occurred c. 20 mins (1.5 nm) after the previous listening station. The subsequent acoustic samples were positive for these animals. This suggests the sampling interval for the "listening stations" should be decreased to 20 mins (or about one mile if travelling at variable speed), when using hydrophones with similar sensitivity.

RESULTS We are currently processing the apparently relevant data in order to develop a database intended to allow a correlation between the presence of animals and other variables (geophysical, biological, antropic) in particular areas where sperm whales were present (Jaquet, 1996). We produced graphs showing the bathymetric profiles of our tracks, the distances from the nearest coast, and the distances from the 200 metres isobath (continental shelf in the area). The contacts with animals are then reported on these graphs.

In order to acoustically classify the detected sounds we have been discriminating, among the small odontocetes considered common in the area, "WD - high-pitched whistling dolphins" (striped dolphin, bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphi*) which produce echolocation clicks and whistles mostly high-pitched as social behaviour) and "MD - meowing dolphins" (Risso's dolphin (*Grampus griseus*) and long-finned pilot whale (*Globicephala melas*), which mostly produce "creaks", "squeaks" and "meows", as well as echolocation clicks). This discrimination was made both with the "listener perception" and a real-time spectrographic analysis. We collected 126 acoustic contacts with "WD - whistling dolphins", while, during 61 daylight sightings, we counted 371 dolphins (359 striped dolphins, 12 bottlenose dolphins). We did not perform any active tracking of animals belonging to this group.

We had three acoustic contacts with "MD - meowing dolphins", and the acoustic tracking of them led to three daylight sightings. We counted 33 animals (all Risso's dolphins).

We collected 15 acoustic contacts with 29 Sperm whales in four years (the number of animals is estimated by the analysis of their sounds). Eight of these animals were acoustically tracked and then approached. Five animals were photo-identified taking a picture of their flukes [one whale was the same in two different years (see Table 1 in Pavan *et al.*, 1998, this volume).

CONCLUSIONS An extensive or continuous monitoring of underwater sounds has been shown to be a good way to evaluate cetacean presence and abundance, even if it is still difficult to discriminate among sounds produced by some species. The acoustic investigation, supported by the visual one, produced in this area about twice the results of an hypothetical visual-only survey, showing it to be indispensable to maximise the data collection. This approach is particularly important in the study of sperm whales. Up to now, no longterm acoustic monitoring has been carried out in the Mediterranean (probably excluding Anti Submarine Warfare, whose data are usually not available nor suitable). Some hot-spots can be selected where a year-round remote monitoring system used to estimate the presence and movements of some species is desirable and technically feasible. The deployment of remote hydrophones that could transmit wide-band high-quality audio signals should now be planned.

REFERENCES

Notarbartolo di Sciara, G. and Gordon, J.C.D. 1997. Bioacoustics: a tool for the conservation of cetaceans in the Mediterranean Sea. *Mar. and Freshw. Behav. and Physiol.*, 30(2) : 125-146.

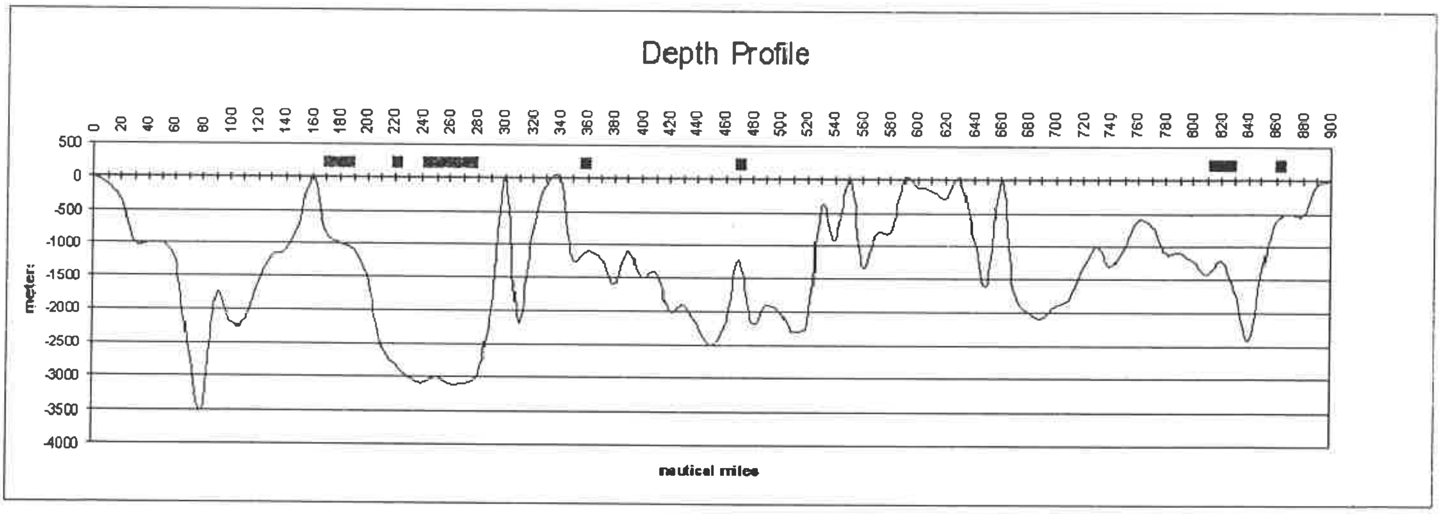
Jaquet, N. 1996. How spatial and temporal scales influence understanding of Sperm Whale distribution: a review. *Mammal Rev.*, 26(1): 51-65.

Table 1 Results using the two different techniques of "visual survey" and "acoustic survey".

"WD" = "whistling dolphins" and "MD" = "meowing dolphins" as stated in the text.

"PMs" = sperm whale. schools or animals are considered 'new' when at least 30 mins of silence divide the considered sample from a preceding positive one.

Cruise :	06/94	09/94	06/95	09/96	06/97	Totals
miles cruised	768,5nm	451,9nm	360,5nm	435nm	919,1nm	**2935nm**
visual survey	104h50 '	58h	73h20'	70h20'	129h	**435h30'**
acoustic survey	112h44'	62h25'	81h40'	72h35'	146h36'	**476h**
daylight acoustic survey	76h55'	42h40'	47h30'	57h25'	77h10'	**301h40'**
acoustic contacts with new schools or animals	**36** (35 WD + 1 PM)	**14** (12WD + 1MD + 1PM)	**20** (18WD + 1MD + 1PM)	**27** (22WD + 1MD + 4PM)	**47** (39WD + 8PM)	**144** (126WD + 3MD + 15PM)
daylight acoustic contacts with new schools or animals	**21** (21WD)	**13** (12WD + 1PM)	**12** (12WD)	**24** (20WD + 4PM)	**31** (25WD + 6PM)	**101** (90WD + 11PM)
visual contacts with schools or animals	**15** (14WD (14Sc) + 1PM)	**18** (16WD (16Sc) + 1MD(Gg) + 1PM)	**8** (6WD(6Sc) + 1MD(Gg) + 1PM)	**14** (9WD (8Sc + 1Tt) + 1MD(Gg) + 4PM	**17** (16WD (15Sc + 1Tt) + 1Pm)	**72** (61WD (59SC + 2Tt) + 3MD (3Gg) + 8PM)



night-time ■ Sperm whale acoustic contact

Graph 1 Sample of the depth profile of the June 1997 cruise, with Sperm whale acoustic contacts noted.
All cruise data are reported on these kind of graphs showing dpeth profiles, distance from the nearest coast and distance from the -200m isobath.

ACOUSTIC MEASURE OF BODY GROWTH IN A PHOTO-IDENTIFIED SPERM WHALE (*PHYSETER MACROCEPHALUS* L.)

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INTRODUCTION According to Arnbom (1987), sperm whales can be individually identified through photographs of their flukes. By organising the photos of flukes into a catalogue, it is possible to have a useful tool for capturing-recapturing sperm whales by utilising natural markings (Hammond, 1986; Whitehead, 1990; Whitehead *et al.*, 1992).

In June 1995, an isolated sperm whale, designated SW0695, was acoustically detected, tracked, and recorded for more than seven hours in the Ligurian Sea. It was sighted eight times at the surface, and photographs of its fluke were taken and included in the photo-ID catalogue which we have been collecting since 1994 (Priano *et al.*, 1997). The fluke catalogue can be seen on the web at the address: http://cibra.unipv.it/flukes.html.

In September 1996, we detected seven different whales off Cap Corse (France), and we were able to take photographs of the flukes of three whales. Among them, we identified the same individual which we recorded and photo-identified in 1995. This whale, designated SW0996A, was sighted only once; while surfacing it was silent and it began to emit clicks just after fluking up. Since we identified its vocalisations, we were able to track and record it for more than four hours. The visual estimate of the body length gave a value ranging from 12 to 13 m. for both the 1995 and the 1996 sightings (Table 1).

Because we were able to identify the underwater sounds belonging to the whale, we compared the recordings with those made one year before.

Norris and Harvey (1972) were the first to make hypotheses on the sound production mechanism in sperm whales. They described the structure of sperm whale clicks as a first intense pulse (P1) and a number of reflections (P2, P3, ...Pn) generated in the head of the whale. They supposed the Inter Pulse Interval (IPI) to be correlated with the length of the spermaceti organ and thus with the overall body length. Clarke (1978) provided some data on the relation between spermaceti length and total body length. Adler-Fenchel (1980) was the first to use IPI measurements to assess the distribution in length of a stock of sperm whales.

Gordon (1991) tried to reliably relate IPI with body length; he developed two equations, one (1) relating total body length (TL) to spermaceti length (SL - which can be derived from IPI) by using Clarke's data and one (2) relating body length to IPI directly from visual estimates of body length:

(1) $TL = 9.75 - 0.521SL + 0.068SL^2 + 0.057SL^3$
where SL = Spermaceti Length [IPI x sound speed in spermaceti / 2]

(2) $TL = 4.833 + 1.453\, IPI - 0.001\, IPI^2$

Goold (1996) developed a computerised semi-automatic cepstrum-based method to measure the IPI in long sequences of clicks. Goold *et al.* (1996) considered the acoustic transmission properties of the spermaceti oil under different temperature and pressure conditions to accurately assess the spermaceti length.

In 1996, we developed a program to show IPIs graphically in real-time, to possibly make the whale length remote estimation fast, easy, and reliable. The software is based on the cepstrum analysis proposed by Goold (1996), and shows in real-time the spectrogram (spectrum vs time) and the cepstrogram (cepstrum vs time) simultaneously. By using this software, we demonstrated the stability of IPIs across several dive cycles and thus their reliability for spermaceti length estimation and for whale discrimination (Pavan *et al.*, 1997b).

RESULTS By comparing photographs according to the method proposed by Dufault and Whitehead (1992), we determined a very good match among fluke-IDs of the two whales SW0996A and SW0695. For the first time in the Mediterranean Sea, the same sperm whale was photo-identified two times in consecutive years (15 months lapse). Unfortunately, there is no way to know its movements in the period between the two sightings as migration patterns in the Mediterranean Sea are still unknown, even if several data show that they regularly appear in the Thyrrenian Sea and Ligurian Sea in late spring, summer, and early autumn.

We compared the recordings by measuring the IPI on a large number of clicks and assessed the whale length by applying the equations (1) and (2); with eqn. (1), we assumed the speed of sound in spermaceti was 1430 m/sec, as suggested by Goold (Goold, 1996; Goold *et al.*, 1996). As statistical analysis (Table 2) shows that the two samples have low standard deviations relative to the difference in the means (D=0.218 msec with standard devns. 0.0681 and 0.0415, respectively), we can reliably say that a significant increase occurred, at least in the spermaceti length. Figure 1 shows the distribution of IPI measurements along with the IPIs of other whales we recorded.

In the first sighting (SW0695), Inter Pulse Intervals (IPI) measured 5.17 ms on average giving a body length of 11.63 (Eqn. 1) or 12.32 metres (Eqn. 2). In the second sighting (SW0696A), the IPIs measured 5.39 ms on average corresponding to a body length of 12.01 or 12.63 metres; both equations indicate a total length increase of about 30 cm (28 or 31 cm, respectively) (Table 3).

The results match the visual estimation. Both the body length and the growth measure match well with the data published by Berzin (1971) for male sperm whales aged 9-10 years.

CONCLUSIONS Sperm whales in the central Mediterranean Sea are quite rare (Pavan *et al.*, 1997a); they are sighted frequently in summer in the Ligurian-Corse Sea (Notarbartolo di Sciara *et al.*, 1993) where our animal designated SW0695/SW0996A was acoustically contacted, recorded, tracked, sighted and photo-identified in two successive years. The combined results of this research give us an important information about size, age, sex, and growth of the observed whale. As far as we know, this is the first time a sperm whale has been recaptured in the Mediterranean Sea and also the first time a growth rate has been measured using an acoustic technique.

Our research demonstrates the importance of the integration of traditional methods (Photo-ID) and study techniques with the acoustic ones (Pavan *et al.*, 1997a, 1997b; Priano *et al.*, 1997). Although the correspondence between IPI and animal size has not been fully established, the IPI data provide additional information for discriminating click series from different animals when more than one animal is present, and for evaluating a possible change in length when a whale is recaptured. Moreover, the real-time approach proved to be an useful tool for data analysis in the field as well as in the laboratory.

By further developing these acoustic methods and extending the study areas, we hope to get a better knowledge of the Mediterranean stock structure of sperm whales. This will hopefully help in setting up and tuning conservation strategies.

ACKNOWLEDGEMENTS The research cruises have been made with the cooperation of the Italian Navy in 1995 and of the association Ambiente Mare in 1996.

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REFERENCES

Adler-Fenchel, H.S. 1980. Acoustically derived estimate of the size distribution for a sample of sperm whales (*Physeter catodon*) in the western North Atlantic. *Can. J. Fish. Aquat. Sci.*, 37: 2358-61.

Arnborm, T. 1987. Individual identification of sperm whale. *Rep. int. Whal. Comm.*, 37: 201-204.

Berzin, A. 1971. *The Sperm Whale.* Translated from Russian. Israel Program for Scientific Translations, Jerusalem.

Clarke M.R., 1978. Structure and proportions of the spermaceti organ in the sperm whale. *J. mar. biol. ass. UK*, 58: 1-17.

Dufault, S. and Whitehead, H., 1992. An assessment of changes with time in the marking patterns used for photo-identification of individual sperm whales, *Physeter macrocephalus. Mar. Mamm. Sci.*, 11(3): 335-343.

Goold, J.C.,1996. Signal processing techniques for acoustic measurement of sperm whale body lengths, *J. Acoust. Soc. Am.*, 100(5): 3431-3441.

Goold, J.C., Bennell, J.D., and Jones, S.E. 1996. Sound velocity measurements in spermaceti oil under the combined influences of temperature and pressure. *Deep-Sea Research*, 43(7): 961-969.

Gordon, J.C.D. 1991. Evaluation of a method for determining the length of sperm whales (*physeter catodon*) from their vocalisations. *J. Zool.*, Lond., 224: 310-14.

Hammond, P.S., 1986. Estimating the size of naturally marked whale populations using capture-recapture techniques. *Rep. int. Whal. Commn* (special issue 8): 253-82.

Norris, K.S. and Harvey, G.W. 1972. A theory of the function of the spermaceti organ of the sperm whale *Physeter catodon*. Pp 397-417. In *Animal Orientation and Navigation* (Eds. S.R. Galler, K. Schmidt Koenig, G.J. Jacobs, and R.E. Belleville). NASA Spec. Publ. 262.

Notarbartolo di Sciara, G., Venturino, M.C., Zanardelli, M., Bearzi, G., Borsani, J.F., and Cavalloni, B. 1993. Cetaceans in the central Mediterranean Sea: distribution and sighting frequencies. *Boll. Zool.*, 69: 131-38.

Pavan, G. and Borsani, J.F. 1997a. Bioacoustic research on cetaceans in the Mediterranean Sea. *Mar. Fresh. Behav. Physiol.*, 30: 99-123.

Pavan, G., Priano, M., Manghi, M., and Fossati, C. 1997b. Software tools for real-time ipi measurements on sperm whale sounds. Pp. 157-164. In *Proc. Underwater Bio-sonar and Bioacoustics Symposium*. Proc. I.O.A., 19 (Part 9), Loughborough, UK.

Priano, M., Pavan, G., Manghi, M., and Fossati, C. 1997. The cetacean sound library of the interdisciplinary centre for bioacoustics and environmental research of the University of Pavia. Pp. 245-259. In *Proc. Underwater Bio-sonar and Bioacoustics Symposium*. Proc. I.O.A., 19 (Part 9), Loughborough, UK.

Whitehead, H. 1990. Mark-recapture estimates with emigration and immigration. *Biometrics*, 46: 473-79.

Whitehead, H., Waters, S., and Lyrholm, T. 1992. population structure of female and immature sperm whales (*Physeter macrocephalus* l.) off the Galapagos Islands. *Can J. Fish. Aquat. Sci.*, 49: 78-84.

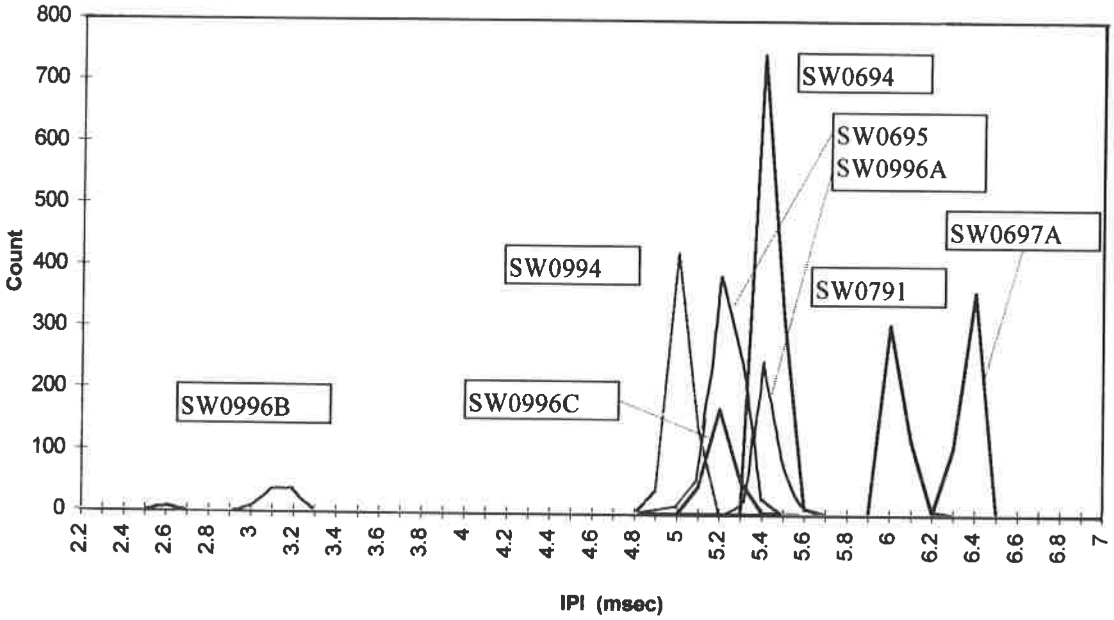

Figure 1 - Inter Pulse Intervals (IPI) related to the whale SW0695/SW0996A are shown together with measures on other sperm whale recordings stored in the Cetacean Sound Library. The height of the peaks depends on the sample size.

Table 1. Position of the photo-identified whale, tracking duration, number of observed surfacings, visual estimate of size, date and location.

Whale-ID	Lat	Long	Tracking	Sightings	Length (visual)	Date	Location
SW0695	043∞46'	009∞20'	8h 25m	8	12-13 m	June 95	off La Spezia (I)
SW0996A	042∞43'	008∞52'	4h 20m	1	12-13 m	Sept. 96	off Calvi (Corse, F)

Table 2 Summary of statistics and single factor ANOVA with alpha 0.01. IPI measurements in milliseconds. Coefficient of Variation (CV) is computed as Standard Deviation / Average.

Groups	Count	Sum	Average	Variance	Std Dev.	CV	Min	Max
SW0695	756	3909.63	5.171468	0.004635	0.0681	0.0132	4.8072	5.3062
SW0996A	334	1800.073	5.389441	0.001725	0.0415	0.0077	5.1247	5.4421

Source of Variation	SS	df	MS	F	P-value	F critical
Between Groups	11.00643	1	11.00643	2939.387	0	6.658183
Within Groups	4.073976	1088	0.003744			
Total	15.0804	1089				

Table 3 Estimation of body length. From left to right: whale-id, number of analysed clicks (N), number of analysed dives (ND), average IPI and coefficient of variation, spermaceti length (SL), total body length (TL), age and sex (estimated by using data computed with equation 2).

Whale-ID	N	ND	IPI (msec)	CV	SL (m)	TL (m)		AGE	SEX
						equation 1	equation 2	Berzin 1971	
SW0695	756	2	5.1715	0.0132	3.6976	11.63	12.32	9	M
SW0996A	334	2	5.3894	0.0077	3.8534	12.01	12.63	10	M
						D= 0.28	D= 0.31		

IDENTIFYING THE SOUND SOURCE IN MYSTICETES

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INTRODUCTION Mysticetes are very vocal mammals, producing sounds primarily in the low frequency range (see review in Richardson *et al.*, 1995). How these sounds are generated and modified, however, remains unknown, particularly as they were thought to lack vocal folds (e.g., Hosokawa, 1950; Purves and Pilleri, 1983; Haldiman and Tarpley, 1993). This lack of knowledge is partly due to the difficulty in obtaining anatomical material for study. Here, we examine the larynges of 15 mysticete specimens from three genera (*Balaenoptera, Megaptera, Eubalaena*). Any structures which may play a role in low frequency sound production are discussed.

MATERIALS AND METHODS Fifteen specimens representing four species (*Balaenoptera acutorostrata*, N = 3, *Balaenoptera physalus*, N = 6, *Eubalaena glacialis*, N = 2, and *Megaptera novaeangliae*, N = 4) were used for this study (see table 1). Permission to obtain material from postmortem, beach-stranded specimens was granted through members of the National (United States) Marine Mammal Stranding Network. Specimens were usually dissected where they beach stranded. The larynx was removed from each specimen and brought back to our laboratory for further examination. The tissues were dissected and photographed, and then preserved by immersion in formalin.

RESULTS AND DISCUSION Three structures are present which could potentially vibrate to generate sound: laryngeal folds, laryngeal sac, and corniculate flaps.

Laryngeal Folds As per our new findings (see Laitman and Reidenberg, this volume), paired laryngeal folds, which we believe to be homologous to the vocal folds of terrestrial mammals, are found within the laryngeal lumen. The folds (left and right) are joined ventro-caudally in the midline, forming a continuous, U-shaped laryngeal fold (U-fold). The U-fold is oriented with the curve of the U directed caudally, and the opening between the arms of the U directed rostrally. When viewed from its dorsal (lumenal) surface, the U-fold appears as a raised, thick ridge of tissue that spans between the arytenoid cartilages. Its thickness varies with different species, being thickest in *Eubalaena* (northern right whale). The curved portion at the bottom of the U contains a ligament and can be stretched. As this ligament holds the caudal tips of the arytenoids together in the midline, they cause the U-fold to take on a V-shaped appearance when the arytenoids are separated rostrally. The U-fold surrounds an opening into a ventrally located laryngeal sac.

The mysticete U-fold differs in appearance from the laryngeal fold of odontocetes, in which a thin (usually single) fold is located in the midline (Reidenberg and Laitman, 1988). Each lateral portion of the U-fold is supported by an inferiorly projecting portion of the arytenoid cartilage that resembles the arytenoid's vocal process in terrestrial mammals. This configuration, as well as the U-fold's placement relative to the laryngeal sac, may indicate homology with the vocal folds of terrestrial mammals.

The mysticete arytenoid cartilage is fused to the corniculate cartilage superiorly, and at its midpoint is attached caudally to the cricoid cartilage by a curved, synovial joint. Movement of the aryteno-corniculate complex at this joint may occur in multiple planes. These movements appear to control the U-fold's ability to regulate the size of the opening between the laryngeal lumen and the laryngeal sac, thus regulating airflow. For example, a lateral movement of the corniculate tip may cause medial movement (adduction) of the arytenoid "vocal" process and thus bring the walls of the U-fold in opposition. A rostral movement of the corniculate tip may cause caudal movement of the arytenoid "vocal" process and thus elongate and tense the U-fold. When the lateral walls of the U-fold are approximated, they resemble two opposed lips. These "lips" may vibrate with airflow to generate low frequency sounds.

Laryngeal Sac The laryngeal sac is a large, bag-like structure located ventrally in the midline. Its walls are distensible and are comprised largely of muscles. Its lumen is wider cranially, and tapers caudally to a blunt cul-de-sac. The cranial portion is continuous with the lumenal surface of the epiglottis. Although unpaired, this sac may be the evolutionary result of fusion of two lateral saccules. As such, it may be homologous to the paired laryngeal ventricles of terrestrial mammals or the multiple small laryngeal air sacs of odontocetes.

The laryngeal sac surrounds a space that may be expanded with air from the trachea channelled through the U-fold in the laryngeal lumen. Its muscular wall may function to compress and collapse the enclosed space, forcing air out cranially through the space between the epiglottis and the pair of corniculate flaps, or back to the laryngeal lumen though the gap surrounded by the U-fold. In this manner, it may provide the pressurization necessary for vocalisations generated by U-fold or corniculate flap vibrations. Alternatively, the sac may be a reservoir for air passed through the U-fold from the laryngeal lumen. The laryngeal sac may affect frequency or amplitude through variations in the volume of the resonant airspace or tension of the walls. For example, sac expansion may decrease the frequency, as larger volumes resonate with longer wavelengths. The sac may also be used as a transducer for vibrations generated by pulsations at the U-fold. Pulsatile contractions of the muscular walls of the sac itself may also generate sound. As the sac is surrounded externally by the ventral throat pleats, sac inflations and deflations by any mechanism could expand and contract these pleats, thus transferring sound waves into the surrounding water.

Corniculate Flaps The corniculate flaps were only found in rorqual whales. They consist of a pair of thick, flexible tissues which project rostrally from the corniculate cartilages. The corniculate flaps were of variable size, being largest in *Balaenoptera* (particularly the minke whale) and modest in size in *Megaptera* (humpback whale). They were not found in *Eubalaena* (northern right whale). The flaps appear capable of approximating each other in the midline. It is not clear whether they contain any musculature capable of controlling their tension or movements. These flaps may be passively vibrated by an airstream passing between the larynx and the nasal cavities, in turn, generating sound. They may also function in laryngeal protection by adding another layer to the barrier of the lateral aspect of the laryngeal inlet. In this manner, they may aid the aryepiglottic folds (which are short compared to many terrestrial mammals) in shielding the laryngeal inlet by keeping swallowed material lateral to the larynx in the piriform sinuses (lateral food channels).

DISCUSSION Our data indicate that laryngeal folds, laryngeal sac and, in some species, corniculate flaps are present and optimally suited to serve as generators of fundamental frequencies. Air from the lungs entering the trachea and then the laryngeal lumen may be directed either ventrally between the gap surrounded by the U-shaped fold, or dorso-rostrally between the corniculate flaps. Arytenoid movements controlling the U-fold aperture may regulate airflow between the laryngeal lumen and the laryngeal sac. Vibrations of the U-fold during airflow may generate sound waves in air. The laryngeal sac may modify the amplitude or frequency of the sound waves by varying parameters such as wall rigidity, airspace volume or shape. Sac contraction may recycle air back for the next vocalisation. Back-flowing air may also cause U-fold vibration resulting in sound production.

The energy from waves propagating through the laryngeal sac airspace may be transferred to its walls, in turn causing them to vibrate (e.g., pulsatile expansion and contraction of the sac). Alternatively, U-fold movements may directly vibrate the attached sac walls, thus causing waves to propagate within the walls from dorsal to lateral to ventral. The musculature of the laryngeal sac may also be capable of initiating sac pulsations through contraction, and thus sound generation. Movements of the sac walls by any of these mechanisms may transfer the sound waves directly to the expandable tissues of the ventral throat region which, in turn, may pass them into the water for propagation. The corniculate flaps, when present, may also regulate airflow. They are ideally positioned to control airflow between the laryngeal lumen and the nasopharynx. As these flaps are only present in rorquals, their role in sound production may be secondary for mysticetes. Corniculate flap vibrations may be coupled to the nasal region, using the paired nasal cavities as resonating chambers, with vibrations passing directly to the skull and surrounding tissues and then radiated to water.

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REFERENCES

Haldiman, J.T. and Tarpley, R.J. 1993. Anatomy and Physiology. Pp. 71-156. In *The Bowhead Whale.* (Ed. J.J. Burns, J.J. Montague, and C.J. Cowles). Special Publication Number 2, The Society for Marine Mammalogy, Allen Press, Lawrence, KS.

Hosokawa, H. 1950. On the cetacean larynx, with special remarks on the laryngeal sack of the sei whale and the aryteno-epiglottideal tube of the sperm whale. *Sci. Rep. Whales Res. Inst.* (Tokyo, Japan), 3: 23-62.

Purves, P.E. and Pilleri, G.E. 1983. *Echolocation in Whales and Dolphins.* Academic Press, New York.

Reidenberg, J.S. and Laitman, J.T. 1988. Existence of vocal folds in the larynx of Odontoceti (toothed whales). *Anat. Rec.*, 221: 884-891.

Richardson, W.J., Greene, C.R., Jr., Malme, C.I., and Thomson, D.H. 1995. *Marine Mammals and Noise.* Academic Press, New York.

Table 1. Specimens studied

Genus species	Common name	N	Age	Sex
Balaenoptera acutorostrata	minke whale	1	Infant	Female
		2	Juvenile	Female
Balaenoptera physalus	fin whale	1	Juvenile	Male
		2	Juvenile	Female
		2	Adult	Male
		1	Adult	Female
Megaptera novaeangliae	humpback whale	1	Infant	Male
		2	Juvenile	Female
		1	Adult	Female
Eubalaena glacialis	northern right whale	1	Adult	Unknown
		1	Adult	Male

BEHAVIOURAL SIGNIFICANCE AND STRUCTURE OF WHISTLES FROM WILD KILLER WHALES (*ORCINUS ORCA*) IN THE WATERS AROUND VANCOUVER ISLAND, BRITISH COLUMBIA

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INTRODUCTION Killer whales (*Orcinus orca*) off Vancouver Island, British Columbia, produce two classes of sounds which function in underwater communication: whistles and burst pulsed calls (Ford 1989). As yet, research on killer whale communication has focused mainly on stereotyped, group specific burst pulsed calls (Ford 1989, 1991). Preliminary investigations on whistles, on the other hand, have indicated that these sounds are variable and graded (Ford 1989). Furthermore, whistles are most frequent during social interactions within the pod (Thomsen *et al.*, 1996). This led to the conclusion that whistles are emotive signals indicating the emotional state of the signaller during close range interactions (Thomsen *et al.*, 1996). Despite these first results there are many questions remaining on the function of whistles. It is unknown if whistles appear only in interactions within the pod or also when different pods meet. Further, the analysis of whistle structure is still in it's infancy. In this study the behavioural significance and structure of whistles are analysed in more detail.

MATERIALS AND METHODS Simultaneous underwater recordings and surface behavioural observations were made on northern resident killer whales in the Johnstone Strait, British Columbia between July and October 1996 and 1997. Earlier sound and behavioural recordings, conducted by one of us (J.K.B. Ford) between 1978-83, were included in the analysis. The surface behaviour of killer whales was classified into three “non-social“ (*travelling, slow travelling* and *foraging*) and two “social“ behaviour categories (*socialising* and *slow travelling in mixed groups with body contact*) (Fig. 1). The recordings were analysed with the RTS (Real-Time-Spectrogram) and SIGNAL-Bioacoustic-Software-Program (Engineering Design, Belmont, MA). For the 1996 recordings a whistle index (*WI*) was calculated to quantify whistle activity across behaviours (adapted from Barrett-Lennard *et al.*, 1996). The whistle index was the average percentage of time that an individual whale present in a recording session emitted whistles and was calculated as follows:

$$WI = 100 \quad d / sn$$

where d is the sum of durations of all the whistles in a session, s is the recording session duration and n is the number of whales present in a session. Whistle index values across behavioural categories were compared with a Mann Whitney U-test and an ANOVA (Kruskal Wallis test with multiple comparison after Dunn's method).

RESULTS A total of 865 whistles were counted in 67 different recording sessions from the summer of 1996 (total length 970 mins). Killer whales whistled significantly more during social behaviours (WI = 1.01 0.28 SE, n = 16) than during non-social behaviours (WI = 0.14 0.08 SE, n = 51, $p < 0.001$ Mann Whitney U-test). Whistle emission was significantly higher during socialising than during travelling, slow travelling and foraging, regardless of group composition ($p < 0.05$, ANOVA, Kruskal Wallis, multiple comparison after Dunn's method) (Fig. 1). The second highest whistle emission was found when whales from different pods were travelling in close body contact (Fig. 1). Most of the whistles recorded in 1996 were variable and complex. But about 20% of whistles from one group, containing pods with related dialects (A-Clan), were stereotyped and stable over time (Fig. 2). These stereotyped whistle forms were often emitted in regular sequences. These sequences were stable over time, found in recordings from A-Clan whales over a period of 17 years (Fig.3).

DISCUSSION Variable (graded) acoustic signals with an emotive function have been described in detail for primates (Marler and Tenaza 1977; Goodall 1986). There, graded-emotive sounds are associated with close proximity of group members. They are often used in combination with visual and tactile signals, to increase the accuracy of communication (Marler and Tenaza 1977; Goodall 1986). The complexity or intensity of the graded signal correlates with the arousal level of the signaller (Goodall 1986). We speculate that whistles in wild killer whales could serve a similar role as emotive signals of land mammals. Variable whistles probably indicate internal emotional states such as level of arousal friendliness, aggressiveness of the signaller during socialising. The emotional level of the sender is probably encoded in the length and the number of frequency modulations of the whistle. Further, variable whistles are used in intrapod as well as in interpod communication (Fig. 1). Stereotyped whistle sequences, similar to those shown in Fig. 3, were found in southern resident killer whales (Hoelzel and Osborne 1986). There, a basic whistle pattern, described as "melodious series of whistles", was recorded over a period of three summers (Hoelzel and Osborne 1986). Stereotyped whistle sequences might carry specific messages across individuals during socialising. It is possible that a sequence initiates a specific response in the receiver. Therefore, whistle sequences might be important in co-ordinating interactions during socialising. On the other hand, in some populations (e.g. the 'southern community' off Washington State), most of the whistle calls produced are discrete and consistent in call structure. They were also recorded during most behavioural activities in that population (Hoelzel, *pers. comm.*).

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REFERENCES

Barrett-Lennard, L.G., Ford, J.K.B. and Heise, K.A. 1996. The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. *Anim. Behav.*, 51: 553-565.

Ford, J.K.B. 1989. Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver Island, British Columbia. *Can. J. Zool.*, 67: 727 -745.

Ford, J.K.B. 1991. Vocal traditions among resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia. *Can. J. Zool.*, 69: 1454-1483.

Goodall, J. 1986. *The chimpanzees of Gombe. Patterns of behavior.* The Belknap Press of Harvard University Press, Cambridge, MA (Pp. 357-386).

Marler, P. and Tenaza, R. 1977. Signalling behavior of apes. Pp. 965-1033. In: How animals communicate (Ed. T.A. Sebeok). Indiana University Press, Bloomington & London.

Hoelzel, A.R. and Osborne, W. 1986. Killer whale call characteristics: implications for cooperative foraging strategies. Pp. 373-400. In: *Behavioral biology of killer whales.* (Eds. B.C. Kirkevold & J.S. Lockard). Alan R. Liss, Inc., New York.

Thomsen, F., Ford, J.K.B. and Franck, D. 1996. Whistles as close range emotive signals in wild killer whales off Vancouver Island, British Columbia. Pp. 12-15. In: *European Research on Cetaceans - 9.* (Eds. P.G.H. Evans & H. Nice). Proc. 9th Ann. Conf. ECS, 9-11 Feb, 1995, Lugano, Switzerland. European Cetacean Society, Kiel, Germany. 302pp.

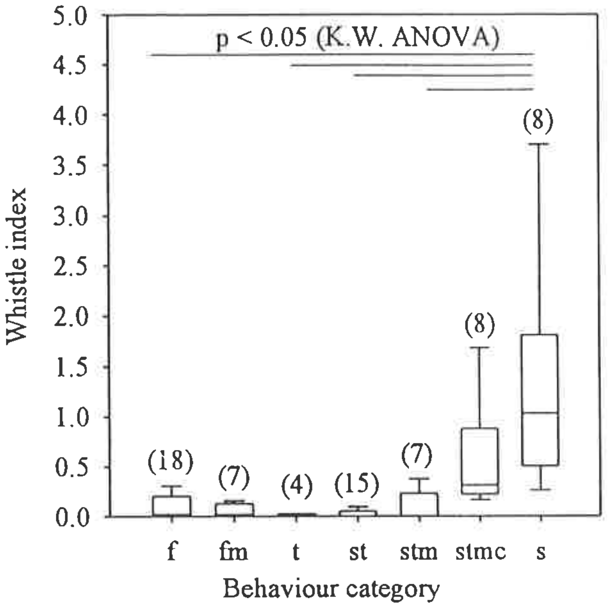

Figure 1. Whistle index values for resident killer whales by behavioural activity. Boxes represent interquartil. Vertical lines represent 95% confidence interval. Solid horizontal line represents the median. Number of sessions analysed in each category are in parentheses. Abbreviations: f = foraging, fm = foraging in mixed groups, t = travelling, st = slow travelling, stm = slow travelling in mixed groups, stmc = slow travelling in mixed groups with interactions in close contact, s = socializing.

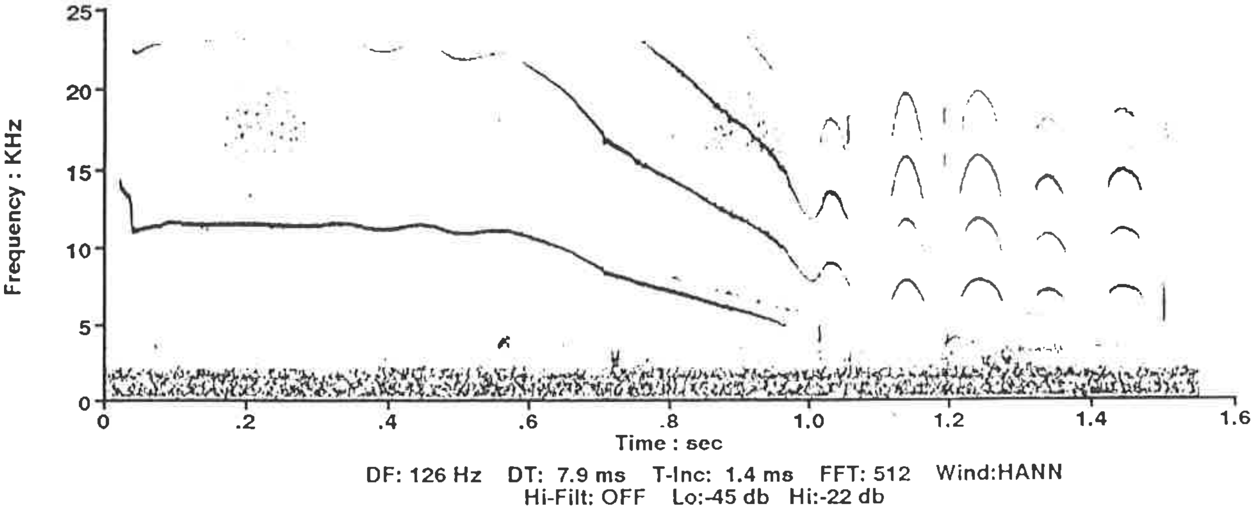

Figure 2. Spectrogram of a repetetive and clan specific whistle recorded in 1996 from a member of the A1 pod (northern resident community). The whistle starts at 15 kHz descends to 5 kHz with frequency modulations at the end. We termed this whistle Triller. The Triller was found in recordings from A-Clan whales in 1980, '83, '94, '96 and '97.

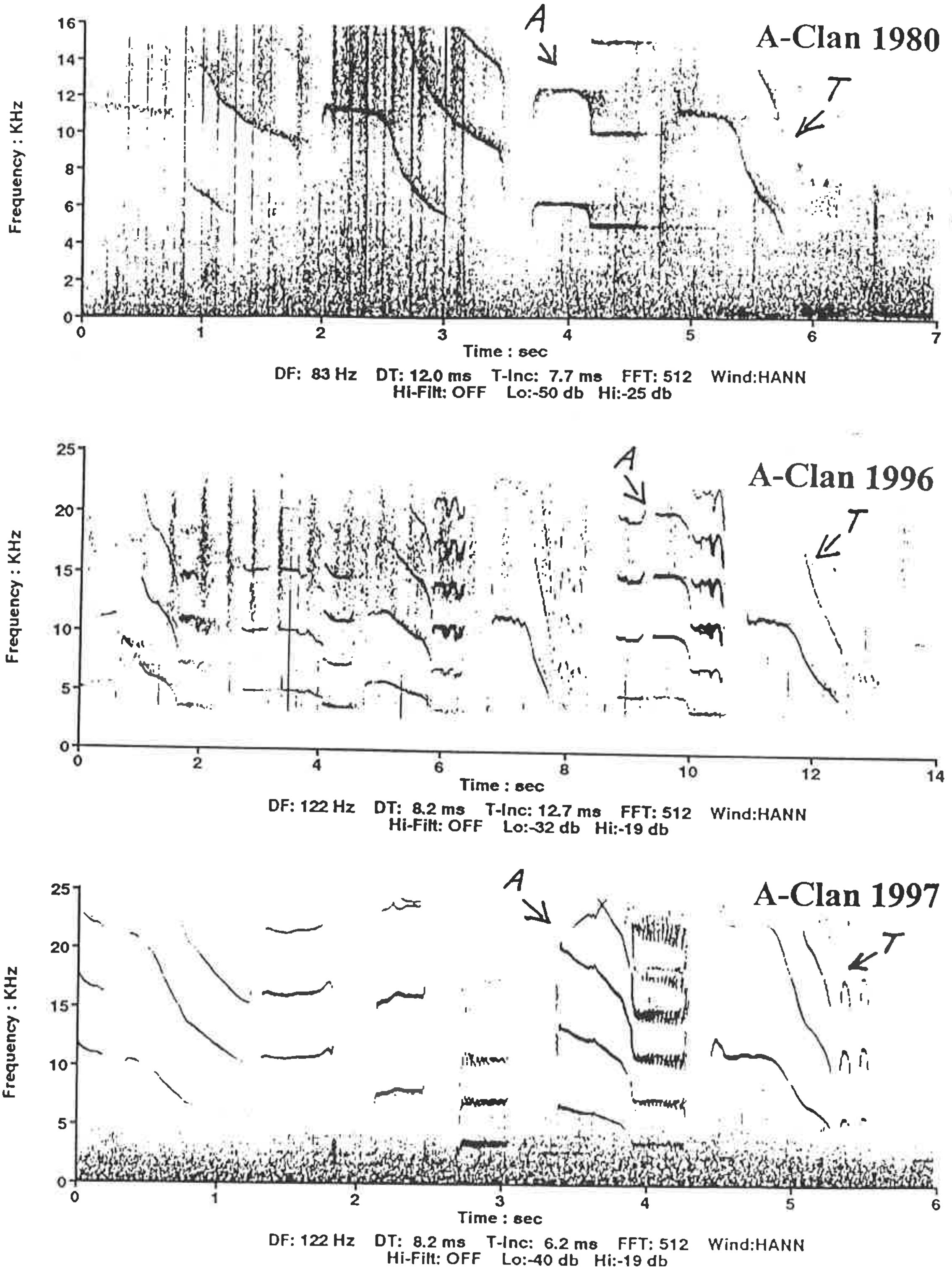

Figure 3. Three spectrograms of repetetive whistle sequences recorded from A-Clan whales in 1980, 1996 and 1997. All spectrograms show a regular pattern of stereotyped forms. In this sequences a flat then descending tone (A) is always followed by the Triller (T).

WHISTLE USE IN AGONISTIC INTERACTIONS OF BOTTLENOSE DOLPHINS

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INTRODUCTION Marine mammals are well known for their highly advanced vocal system, and a special part of it is the system of 'signature whistles' used, for example, by bottlenose dolphins (*Tursiops truncatus*). 'Signature whistles' are individual-specific signals, produced with a high degree of stereotypy, and their proposed function is to serve individual recognition and group cohesion. In situations of isolation, they are the almost exclusively produced whistle vocalisations (review in Caldwell *et al.*, 1990; see also Janik and Slater, this volume). Beside this signal system, bottlenose dolphins produce many other types of whistles, especially when socially interacting. However, as opposed to 'signature whistles', no associations between specific whistles and specific contexts could be shown so far.

In this paper, I will report on the use of these types of whistles, and I will label them as 'remainder whistles'. I will concentrate on the occurrence of specific 'remainder whistles', that were produced in the context of agonistic chases within a group of spontaneously interacting bottlenose dolphins. The 'signature whistles' of all the subjects of this study were known and are described elsewhere (Veit, 1995).

MATERIALS AND METHODS Data were collected in summer 1994 in a period of 15 consecutive weeks at the Dolphin Reef, Eilat, Israel. The Dolphin Reef is a semi-free confinement in the Gulf of Aqaba, Red Sea (for details see Todt and Hultsch, 1996). A group of six bottlenose dolphins lived at the site, supplemented by two calves born that summer. The animals, including adults of both sex (2,3), were maintained without separation of single individuals or subgroups. This means that in periods like the mating season or when births occurred, all the animals stayed together, allowing the development of a complex social network. Recordings were made with two hydrophone systems (B&K 8103 hydrophones, placed 27 m apart, and B&K 2635 preamplifiers), connected to a video camera (Sony CCD-V6000E). The camera was mainly positioned on an observational tower 10 m above sea level, overlooking the whole dolphin area (ca. 10,000 m2). The Red Sea with its clear water allowed to follow long sequences of interactions, even when they were observed from above the water.

The occurrence of three whistle types, belonging to the group of 'remainder whistles', were analysed for the context of agonistic chases between adult individuals. The main characteristic of agonistic chases was, that two or more animals were swimming rapidly, one behind the other and without changes of roles within one episode. The interaction could include physical attacks like bites or body slams. After the chase, the recipient of the interaction typically avoided the actor for longer periods (up to several days), which was possible because of the size and diverse structure of the area, giving the animals the chance to space out. Further compared are different sub-contexts of chases, defined by the involved individuals and their respective role, either pursuing or being pursued. Analysed were whistle vocalisations from the onset of the interaction until one minute after its end. As a control, 45 randomly selected samples of 20 minutes (= 900 min), during which no agonistic behaviours occurred, were analysed for the occurrence of the three whistle types. The control samples covered a broad spectrum of conditions, like play, foraging, or resting, and accordingly had variable whistling rates, partially well above those of chasing episodes. Categorisation of the whistle vocalisations was done by visual inspection of the spectrograms.

RESULTS Whistles "Remainder whistles" were frequently produced during agonistic interactions. Fig. 1 shows spectrograms for the three types under investigation, termed *Type-1*, *Type-2*, and *Type-3*. They were discrete types, that is, parametric variation within the types was much smaller than between them. A common feature of these whistles, and unusual for whistles of the species, was, that they were produced almost exclusively as single loops. That means, repetitive loops were separated by silent intervals. Only six multilooped whistles (continuing repetitive loops) occurred, all with *Type-1* structure. The total number of the three whistle types in the sample was 244.

Contexts Of the five adult dolphins of the group, four were involved in chases: the two males (termed Male-1 and Male-2), and two of the females. A very close association existed between these two females, which gave birth within a few hours that summer. They synchronised their activities during most times of the day for the whole data sampling period. This was also true in chasing episodes. When, for instance, one was chased by a male, the second female often swam at her side. Therefore, it was often impossible to decide, to whom of the two the aggression was directed. Thus, for the analyses in this paper, I did not differentiate between them and treated them as one unit (termed Females). Table 1 shows the three sub-contexts, that occurred. Male-1 and Male-2 both acted as pursuers in this dyad. The Females were only the recipients of chases, and only Male-1 was pursuing them.

Occurrence of Whistles As a first step, the number of chasing episodes and control samples are compared, in which at least one of the three whistle types were produced at all. In only three of the 45 control samples, one of the whistles occurred (always one of *Type-1*). None of the whistles occurred in any of the eleven chasing episodes of Male-2 behind Male-1. The majority of all the three whistle types occurred, when Male-1 was the actor. They were produced in 87.5% of the chases behind the Females, and in 62.5% of the chases behind Male-2. The differences in the occurrence of the whistles (*Type-1, -2, -3*) for the compared contexts were significant (Chi^2 test for "goodness-of-fit", = >200, $P<0.01$, 1df). These trends would become even more evident, when the total numbers of the whistles are compared for the contexts.

Altogether 241 of the specific whistles occurred, when Male-1 was the actor: 53 when he was pursuing Male-2, and 188 when he was pursuing the Females. Fig. 2 shows how the occurrence of the three whistle types differs for these two contexts. Taking into account the different duration of the two contexts, the relative frequency of the whistle types in relation to the total number of these whistles in each context is plotted. A significant difference existed in the production of the whistles for the two contexts (Chi^2 = 10.071, $P<0.01$, 2df). When Male-1 was pursuing Male-2, *Type-1* whistles were produced significantly more frequent (binomial test, Bonferroni corrected, two-tailed, $Z = 2.323$, $P<0.05$), and when he was pursuing the Females, it was the *Type-3* whistle ($Z = -2.149$, $P<0.05$).

Before continuing with the results, another short excursion to the social relationships within the group has to be made. In many of the chasing episodes, other animals than the directly involved ones (actor and recipient) accompanied the interaction. This was, for example, the case in ten of the 24 chases of Male-1 behind Male-2, when one or both Females joined Male-2 during the interactions by swimming parallel to him, and forming a subgroup with him just after. In Fig.3, again the relative frequency of the three whistle types is shown for the context of Male-1 pursuing Male-2 (left graph of Fig.2), but the context is split according to the behaviour of the Females, that is, swimming with Male-2 or not. When no Female joined in chases of Male-1 behind Male-2, only Type-1 whistles occurred (left graph of Fig.3). When the Females joined in the interaction, all three whistle types were produced. This means, that *Type-2* and *Type-3* whistles occurred exclusively, when the Females were involved in a chasing episode, either directly pursued by Male-1 (right graph of Fig.2), or joining Male-2 while he was pursued by Male-1 (right graph of Fig.3).

Question of Signaller In general, the method of data collection did not allow the identification of the signalling individual. Nevertheless, indications of the identity of the sender were often given, mainly by two means: First, through the comparison of time and amplitude differences of a given signal at the two channels, and second, through correlation between the relative changes of the position of a subject to a hydrophon with the relative changes of the amplitude in a series of whistles. This is especially the case in interactions like the investigated chases, where animals move in high speed and keep apart during most of the interaction and afterwards. Whenever it was possible to determine the animal which produced one of the three whistle types analysed here, it was Male-1. Indications of its identity were found in 18 out of the 29 chasing episodes, in which the whistle types occurred, translating into 188 of the recorded whistles (68 *Type-1*, 17 *Type-2*, and 103 *Type-3*).

DISCUSSION

Three discrete whistle types were presented, which in the studied group were given in the context of chasing. They showed a degree of stereotypy comparable to "signature whistles" of the species, and this stereotypy even counted for their loop number, as they were produced almost exclusively in single loops. Yet repetitions of the signals did happen, as the whistles were often produced in series. All three whistles were closely associated to agonistic contexts, and are therefore labelled "agonistic whistles". The occurrence of specific whistles (*Type-1, -2, -3*) was related to details of the context of chasing, for example the presence of females (Fig. 2 and 3). These close associations between whistle types and social contexts suggests, that they indeed serve a particular communicative function. In all known cases, the whistles were produced by the same individual (Male-1), and only when he was the pursuer. This male was the dominant animal of the group for most of the observational period (Veit and Bojanowski, 1996). Male-2 did not seem to produce comparable signals when pursuing.

Recently, few types of low-frequency sounds were described for both, wild and captive bottlenose dolphins, which showed a close correlation to specific social contexts. Connor (1996), for example, described "pops" produced by males during consortship behaviour in a wild population, and McCowan and Reiss (1995a) interpreted "thunks" emitted by females in one captive group as an aggressive contact vocalisation towards infants. As mentioned above, no such associations were found for whistle vocalisations previously - excluding the so-called "distress whistles" described by Lilly (1963), which were later interpreted as the probable "signature whistles" of the investigated animals, likely to be produced in distressing situations (Herman & Tavolga, 1980).

The results of this paper suggests, that, for a better understanding of the communication system of bottlenose dolphins, more attention should be paid to the big group of signals, that are labelled here as "remainder whistles". It will be most challenging, to find well structured groups with a rich repertoire of interactional patterns, which at the same time will provide good observational conditions (the latter will be the main obstacle in wild populations), as well as finding reliable ways for sender-identification without isolating individuals (proposals see, for example, Tyack and Recchia, 1991; McCowan and Reiss, 1995b).

ACKNOWLEDGEMENTS Warm thanks to Roni and Maya Zilber as well as to all the trainers from Dolphin Reef, for their support in the research from the first day. The research projects in Eilat are supported financially by "BLAS Airport Service", the "Deutsche Umwelthilfe", and the "Gesellschaft zum Schutz der Meeress uger" (GSM).

REFERENCES

Caldwell, M.C., Caldwell, D.K. and Tyack, P.L. 1990. Review of the signature-whistle hypothesis for the Atlantic bottlenose dolphin. Pp. 199-234. In *The bottlenose dolphin.* (Eds. S. Leatherwood and R.R. Reeves). Academic Press, San Diego. 653pp.

Connor, R.C. and Smolker, R.A. 1996. "Pop" goes the dolphin: a vocalization male bottlenose dolphins produce during consortship. *Behaviour*, 133: 643-662.

Herman, L.M. and Tavolga, W.N. 1980. The communication system of cetaceans. Pp. 149-209. In *Cetacean Behavior: mechanisms and functions.* (Ed. L. M. Herman). Wiley, New York. 463pp.

Lilly, J.C. 1963. Distress call of the bottlenose dolphin: stimuli and evoked behavioral responses. *Science*, 139: 116-118.

McCowen, B. and Reiss, D. 1995a. Maternal aggressive contact vocalizations in captive bottlenose dolphins (*Tursiops truncatus*): wide band, low frequency signals during mother/aunt-infant interactions. *Zoo Biol.*, 14: 293-309.

McCowan, B. and Reiss, D. 1995b. Quantitative comparison of whistle repertoires from captive adult bottlenose dolphins (Delphinidae, *Tursiops truncatus*): A re-evaluation of the signature whistle hypothesis. *Ethology*, 100: 194-209.

Todt, D. and Hultsch, H. 1996. Projects and perspectives of a research programme established at the Dolphin Reef Eilat, Israel. Pp. 287-290. In *European Research on Cetaceans - 9.* Proc. 9th Ann. Conf. ECS, Lugano, 9.-11. February 1995 (Eds. P.G.H. Evans & H. Nice), European Cetecean Society, Kiel, Germany. 302pp.

Tyack, P.L. and Recchia, C.A. 1991. A datalogger to identify vocalizing dolphins. *J. Acoust. Soc. Am.*, 90: 1668-1671.

Veit, F. 1995. *Zum Signalverhalten männlicher Großer Tümmler* (Tursiops truncatus) *während der Veränderung ihrer Dominanzbeziehung, unter besonderer Berücksichtigung von Pfifftypvariationen.* Diplom thesis, Unpubl. Freie Universität Berlin.

Veit, F. and Bojanowski, E. 1996. Behaviours accompanying a change in the dominance hierarchy of bottlenose dolphins (*Tursiops truncatus*), with respect to adult males. Pp. 202-204. In *European Research on Cetaceans - 9.* Proc. 9th Ann. Conf. ECS, Lugano, 9-11 February, 1995 (Eds. P.G.H. Evans and H. Nice). European Cetecean Society, Kiel, Germany. 302pp.

Table 1. The three contexts of chases, that occurred, with the individuals involved and their respective roles. Indicated are the number of recorded episodes (n), their total duration (d) and mean duration (mean), supplemented by the control samples.

Actor	Recipient	n	d	mean
MALE-1	MALE-2	24	55'31	0'35
MALE-1	FEMALES	16	55'11	1'23
MALE-2	MALE-1	11	44'12	1'54
Control (non-agonistic)		45	900'	[20']

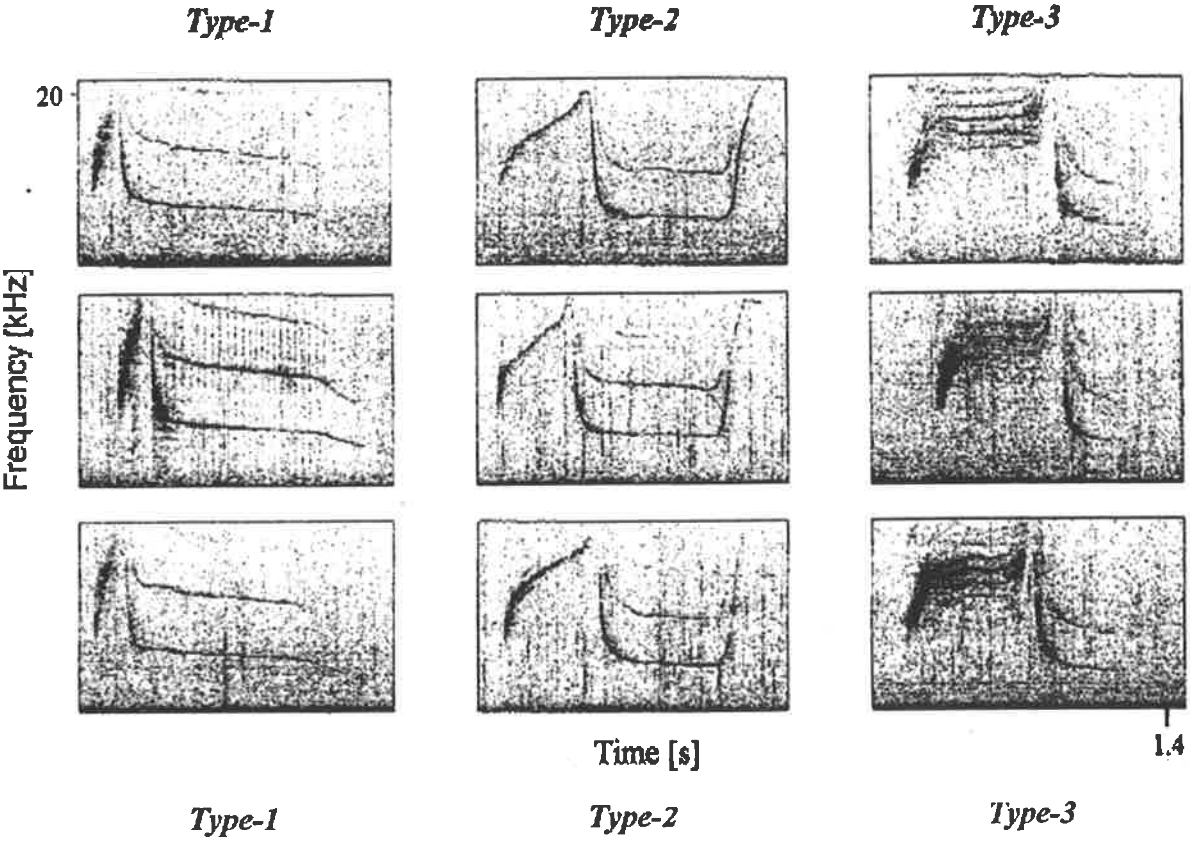

Fig. 1 Spectrograms of examples of the three whistle types under investigation. Belonging to the group of 'remainder whistles', they were termed *Type-1*, *Type-2*, and *Type-3*.

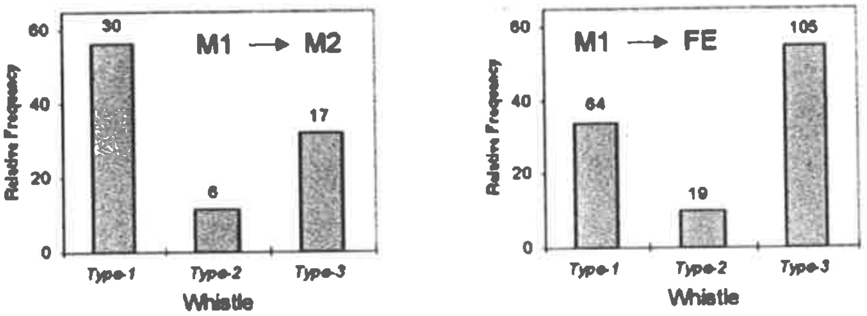

Fig. 2 Relative frequency of the whistles (*Type-1, -2, -3*) for the two contexts, in which MALE-1 was the pursuer. Left graph: MALE-2 is pursued; right graph: FEMALES are pursued. Frequencies refer to the total number of these whistles in each context (given above columns). Further explanations see Fig. 2.

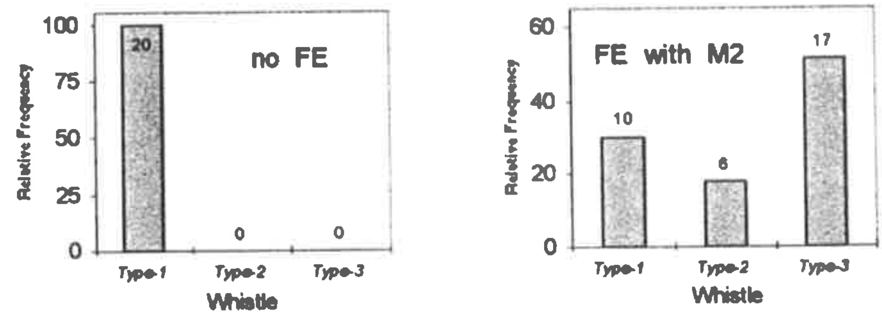

Fig. 3 Relative frequency of the whistles (*Type-1, -2, -3*) for chases of MALE-1 behind MALE-2 according to the behaviour of the FEMALES. Left graph: no FEMALES joined the interaction (n=14); right graph: FEMALES joined MALE-2 during and after the interaction (n=10). Frequencies refer to the total number of these whistles in each situation (given above/in columns). Further explanations see Fig. 2.

ARCHITECTURAL DESIGN CHALLENGES AND POTENTIAL SOLUTIONS FOR CAPTIVE CETACEANS FACILITIES

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Cetaceans are subjects of increasing interest to the general public, and despite controversy about their display, the number of facilities housing cetaceans is steadily rising. The School of Architecture at the National University of Singapore (NUS) has undertaken an interdisciplinary research project with the Tropical Marine Science Initiative (NUS) on the architectural design of cetacean facilities. The aim of this project is to provide existing and future facilities with design and maintenance guidelines in order to improve the welfare of the animals and the staff in charge of their care.

A 30-page questionnaire was sent to 157 facilities in 37 countries to identify successful design and husbandry features as well as recurrent deficiencies affecting cetaceans in their captive environment and the work of their keepers. Information was requested on facilities status and environment, pools and enclosures, animal care, husbandry features, Life Support System and food storage and preparation. A total of 28 questionnaires from 13 countries were completed and returned.

Many participating facilities reported similar challenges in the design of gates and channels, the allocation of space for specific behaviours such as parturition and nursing, and specialised equipment for husbandry and medical care. Acoustic and lighting performances of pools and buildings, as well as outdoor access for animals are examples of challenges encountered in indoor facilities. Facilities with sea pens reported concerns about the protection against pollution and natural hazards as well as the possible entanglement of animals in fence nets. Data also show that the lack of husbandry and medical care facilities is correlated with a limited use of husbandry and medical training of the animals, especially in geographical areas like Asia. Potential solutions suggested by facilities such as adjustable underwater platforms, lifting pool bottom, successful design of gates, and alternatives to the use of nets in sea pens will be presented.

UNDERWATER MATING AND VOCALISATIONS OF GREY SEALS

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In spite of extensive observation of the mating behaviour of grey seals (*Halichoerus grypus*) on land, a discrepancy remains between the observational measures of male mating success and paternity, as determined by DNA fingerprinting. On the breeding beaches, dominant males exclude subordinates and so increase their chances to mate with a female when she comes into oestrus. Dominant males are therefore expected to be highly successful and father most pups. Surprisingly, they do not. Fertilisation outside the colony has been suggested to explain the disparity between the observations and the DNA data. One possible explanation is that significant matings occur in the sea below the surface around breeding islands. We will show videos of evidence of an underwater copulation and sonagrams of water-borne calls, which could be used for mate attraction, recorded during the breeding season of October 1996 off the island of Faray, Orkney Islands, Scotland. Grey seals were observed to produce wave-like body movements during vocalisation, similar to the ones described by Schwartz *et al.* (1995) for harbour seals. The majority of calls are repetitive with an auxiliary structure and usually found in triplets (86.8 % of calls) with most energy below 4000 Hz. These calls might advertise sexual availability and/or function in territorial defence. Additional recordings of underwater calls are needed to investigate their function in the social and sexual behaviour of grey seals.

ACOUSTIC EMISSIONS AND ACTIVITY PATTERNS IN BOTTLENOSE DOLPHINS

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The acoustic characteristics of communication and echolocation signals used by bottlenose dolphins (*Tursiops truncatus*) in captivity and in the wild have been described by many authors. Information is lacking particularly on the uses of these signals in natural environments, and on the relative importance of passive listening for prey detection.

This study focused on the acoustic emissions of the bottlenose dolphins resident in the Sado estuary, Portugal. Recordings were made with a B&K 8101 hydrophone and a Sony TCD-D10 Pro DAT recorder, during boat-based behaviour observations. Spearman rank correlations, Kruskal-Wallis ANOVA and simulation statistics were used on a selection of 447 one-minute samples recorded in different contexts in terms of group size, activity and area.

Acoustic production in general was lower than expected: 37% of the one-minute samples had less than five emissions. The group size class with the highest number of emissions was 8-12 animals. The number of emissions (of any category) was not correlated to group size, suggesting that some social restriction mechanism is at work. The number of sonar click trains per sample was strongly correlated with the number of whistles, and the number of bray sequences was also correlated to the number of other pulsed sounds, suggesting that a group's acoustic emissions increase globally in any aroused context rather than in specific activities. Foraging on bottom prey is a common and predominantly silent activity, suggesting that passive listening and other sensory modes are preferentially used. Feeding on schooling fish near the surface yielded the highest number of emissions, including sonar click trains. Underwater noise level, rated on a subjective scale, did not appear to influence acoustic emissions.

BEHAVIOURAL AND PHYSIOLOGICAL RESPONSES OF HARBOUR (*PHOCA VITULINA*) AND GREY (*HALICHOERUS GRYPUS*) SEALS TO SEISMIC SURVEYS

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Despite their wide application and concerns over possible harmful effects, there is little information on the responses of marine mammals to seismic surveys. Since 1995 we have directly monitored behavioural and physiological responses of free ranging seals during experimental seismic surveys, using combinations of acoustic, VHF and satellite telemetry. We recorded movements, dive profiles, swim speeds, stomach temperatures and heart rates (HR) of harbour seals in Scotland, and grey seals in the Baltic. Seals were followed to foraging areas and exposed to simulated seismic surveys. One 10 in^3 or an array of 3x30 in^3 airguns (source levels 215-224 dB. re-1 µm Pa-m) were used with harbour seals and one 10 in^3 airgun was used with grey seals.

Harbour seal reactions varied. Seal 1 responded immediately to the 3x30 in^3 array, at a range of 2.5 km, in 70-100 m deep water. In tests two days apart, he moved rapidly away from the source swimming just below the surface for extended periods. He reverted to typical foraging dives immediately firing stopped. Coincident with the first blast, his HR fell to 10 beats/min, staying low for 55 secs, followed by a typical pre-surfacing tachycardia. No other intense bradycardia events occurred. At the other extreme, Seal 3 showed no response to the same array in 50 m water, even when it passed within 500 m.

All grey seals showed an avoidance reaction. They moved away from the source, increased swim speed and/or dive duration and switched from benthic foraging dives to predominantly V shaped transit dives. All seals either remained in, or returned at least once to, the foraging area where they had been tested. Excluding two seals which hauled out after testing, behaviour appeared 'normal' 2.1 hours (range 0 - 11.5, n=10) after firing stopped.

The results indicate that seal behaviour was affected by airgun noises. Seals generally took avoiding action, but responses were short lived with no apparent long term effects. However, the guns were small and firing sequences were short. Commercial surveys fire larger arrays (up to 5000 in^3) for longer periods. Reactions to commercial surveys may be more extreme, longer lasting and occur at greater range.

CUES FROM RESPONSES OF BOTTLENOSE DOLPHINS TO WHISTLE PLAYBACK

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The majority of publications on acoustical signals of bottlenose dolphins (*Tursiops truncatus*) deals with the so-called signature whistle which is considered to encode a particular individual's identity and to serve thereby as a kind of contact call. Currently, however, a growing number of investigators extended the research focus to the repertoires of whistle types and analysed, for example, relationships between signal parameters and features of social contexts. We have supplemented these studies by an approach which included a series of playback experiments designed to elucidate the potential meaning of particular whistle parameters by an analysis of the dolphins' responses.

Our study was conducted at the Dolphin Reef, Eilat, Red Sea (size of site: >10.000m^2; size of group: 5 adults (1/4), 3 calves (2/1); for details, see Todt and Hultsch, 1996, *European Research on Cetaceans- 9*: 287-291). Playbacks were done through an underwater loudspeaker placed at the northern part of the net around the site. Specifically synthesised whistles served as auditory stimuli (control: signature whistle of a dolphin who had left the group some weeks before the experiments).

As a prerequisite for the start of a given test, we ascertained that all dolphins were assembled (e.g. for fishing) in a distance of about 50 m apart from the loudspeaker. This allowed us to assess especially whether and how quickly which dolphin approached the sound source. Our data showed that the number of adults who approached the loudspeaker and also their response latency depended on the frequency contour of the played whistle type. The signature whistle and down-sweeps had a stronger effect than up-sweeps. However, subjects finally habituated towards the playback, and this effect concerned all types of whistles. No dishabituation occurred when new whistles were used. Our results suggest that reinforcement of responses to auditory signals is a prerequisite for their persistence

LIFE HISTORY, PHYSIOLOGY & ANATOMY

EVOLUTIONARY PLACE OF THE CETACEAN LUNG SURFACTANT SYSTEM

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INTRODUCTION Lung surfactant is the surface active lipoprotein material lining the pulmonary alveoli. Being on a liquid-gas interface. the lung surfactant reduces surface tension and hence prevents alveolar collapse at the end of expiration. The pulmonary surfactant has been found in animals of all four air-breathing vertebrate classes - reptiles, amphibians, birds and mammals (Clements *et al.*, 1970). First of all, the surface alveolar layer was demonstrated as common to all classes, although some distinctions in the layer structure were also marked (Welsch *et al.*, 1986). Besides the lining layer, another key part of the lung surfactant system was discovered in animals of all the above-mentioned groups - these were intracellular lamellar bodies of different types, representing the storage and secretory granules of the surfactant. It has been determined that the chemical contents of the surfactant are similar between the classes although there are some quantitative differences (Clements, 1971). Existing data indicated that the amount of surfactant is connected mainly with respiratory surface area and breathing parameters and does not reflect the phylogenetic position of the animals (Clements., 1970; Birkun *et al.*, 1981). Also, there are some data on identical surfactant systems in animals of the same class but which are adapted for different ecological conditions (Welsch *et al.*, 1986).

All the above-mentioned findings suggest the hypothesis that the sustainable lung surfactant system evolved as an adaptation for air-breathing. Cetaceans have several respiratory adaptations for living in water and are among the most specialised of diving animals. A study of the cetacean lung surfactant system can enable one to test the above hypothesis. Previous data (Artov, 1990; Artov, 1996) showed the presence of the surfactant in the lungs of cetaceans, and determined some of its characteristics. The question for cetaceans is whether the lung surfactant system has changed during the adaptation process, or remained stable, similar to other air-breathing vertebrates. The aim of the present study was to analyse the functional activity of the cetacean lung surfactant system to estimate the system from point of view of the evolutionary sustainability.

MATERIALS AND METHODS The lungs of three cetacean species were investigated - bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*) and harbour porpoise (*Phocoena phocoena*). To compare data with terrestrial mammals, lungs of rat and pig were also investigated. Lung parenchyma was sampled to receive isotonic saline extracts. In some cases, lavage (irrigation) fluid was obtained. Surface activity of isolated surfactant fraction was studied using the Wilhelmi-Langmuir balance. Two main functional parameters were estimated - minimum surface tension and stability index.

RESULTS The lung surfactant is characterised by a low value of minimal surface tension and a high one of Clements stability index. The index reflects the functional capacity of the surfactant layer, and the surface activity is estimated as high if the index value is not lower than 0.75 (Birkun *et al.*, 1981). Most of the values obtained can be found in or close to areas of high surface activity (Fig.1). These relate to data from two cetacean species and terrestrial mammals in the same pool. All individual data where averages could be presented show rather broad ranges (Table 1). This is partly caused by sampling from different areas of large lungs (the surfactant system is functionally flexible). Two animals, common and bottlenose dolphins, are characterised by lower surface activity. Values for the common dolphin range from a lower surface activity to a higher one. A possible cause of this may be disturbance of the surfactant system operating in some areas of the lung. With reference to bottlenose dolphin, the findings may not reflect the species at large (these are difficult to determine because only one animal could be studied). Specific findings of the functional capacity indicate a relatively high surface activity for cetaceans (excluding bottlenose dolphin) compared with terrestrial species (Fig.2). The data reveal very similar surfactant functional activites for cetaceans and terrestrial species. These data do not agree with earlier assumptions that dolphin surface activity is lower than in terrestrial animals (Artov, 1996). Thus, at least during breathing at the water surface, the cetacean surfactant prevents alveolar collapse during expiration. On the other hand, the functional role of the surfactant system during submersion (when at least two factors - pressure and apnea have an influence) remains unclear.

CONCLUSIONS The study revealed that cetaceans have a lung surfactant system functionally similar to terrestrial mammals. We have not seen that adaptation to diving has changed the functioning of this system. The data obtained support the hypothesis that the lung surfactant system has evolved in a similar way for all air-breathing animals. However, investigations of the cetacean surfactant system require further analysis of similar data on the structure and chemical composition, along with detailed comparative studies of air-breathing vertebrates.

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REFERENCES

Artov, A. 1990. The characteristics of the cetacean lung surfactant. P. 2. In *Marine mammals.* Proc. 10th All-Union Conf. on study, protection and rational use of marine mammals, Kaliningrad, 2-5 October, 1990 (Eds.V.A.Zemsky *et al.*). Moscow. 357pp. (In Russian).

Artov, A. 1996. Surfactant of cetacean lungs. Pp. 233-235. In *European Research on Cetaceans - 9.* Proc. 9th Ann. Conf. ECS, Lugano, 8-10 February, 1995 (Eds. P.G.H.Evans & H. Nice). European Cetacean Society, Kiel, Germany, 1996. 302pp.

Birkun, A.A., Nesterov, Ye.N., and Kobozev, G.V. 1981. *The Lung Surfactant.* Zdorov'ya, Kiev. 160pp. (In Russian).

Clements, J.A. 1971. Comparative chemistry of lungs. *Arch.Intern.Med.*, 127: 387-389.

Clements, J.A., Hellenbogen, J., and Trahan H.J. 1970. Pulmonary surfactant and evolution of the lungs. *Science*, 169(3945): 603-604.

Welsch, U. and Aschauer, B. 1986. Ultrastructural observations on the lung of the emperor penguin (*Aptenodytes forsteri*). *Cell and Tissue Research*, 243:137-144.

Table 1. Parameters of surface activity of the lung surfactants.

Animals	Number of samples	Minimal surface tension, mN/m	Clements index stability, relative units
Common dolphins			
no. 1	5	24.832.46 (20.93-31.74)	0.6600.075 (0.869-0.402)
no. 2	4	22.911.01 (21.00-25.76)	0.7260.033 (0.811-0.673)
no. 3	3	20.410.56 (19.61-21.48)	0.8470.067 (0.944+0.719)
no. 4	6	20.900.46 (19.88-23.06)	0.9400.022 (1.003-0.844)
Bottlenose dolphin	5	29.371.16 (27.56-33.88)	0.6620.025 (0.699-0.567)
Harbour porpoises (lavages)			
no. 1		19.86	0.738
no. 2		21.54	0.897
no. 3		22.38	0.849
no. 4		22.13	0.831
Pig	6	19.060.56 (17.70-21.50)	1.0100.028 (1.092-0.923)
Rats			
no. 1 (lavage)		21.82	0.813
no. 2 (extract)		21.74	0.695

* Values in parentheses show ranges

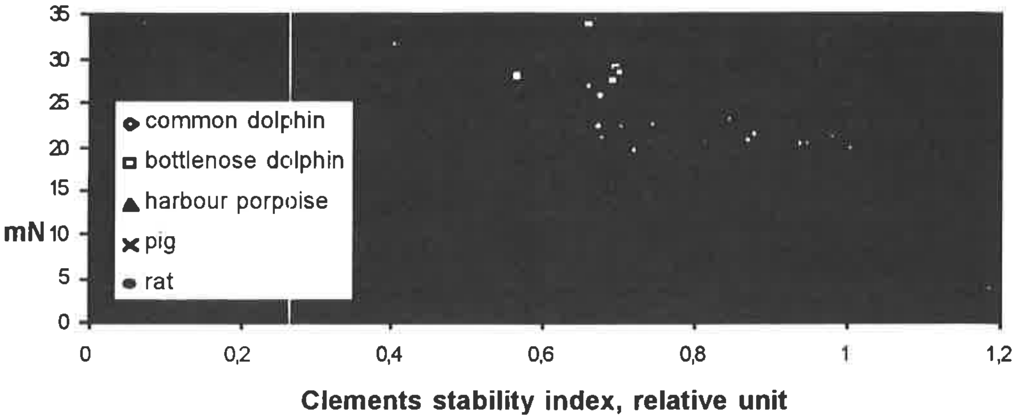

Fig 1. Distribution of obtained data on the lung surfactant surface activity. Figures circled by dash line present values of the high activity.

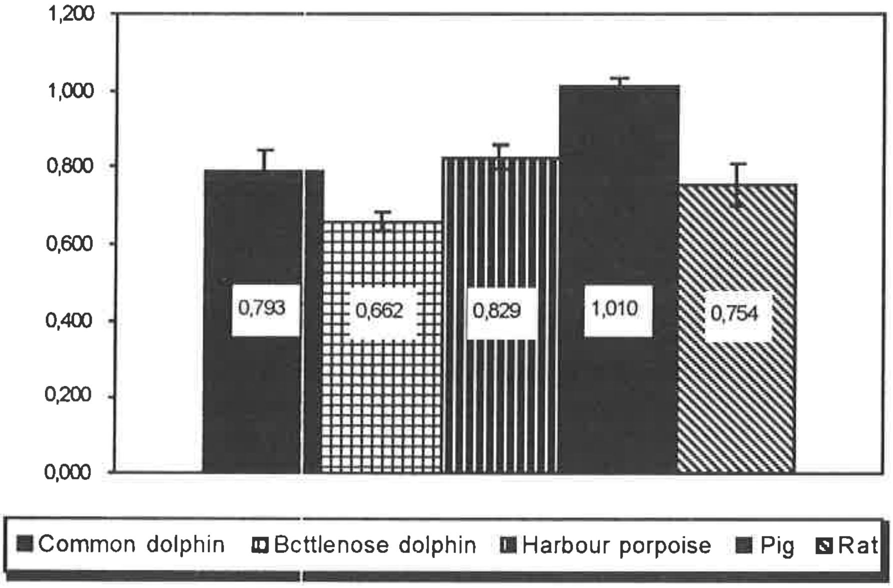

Fig. 2. Specific data of Clements stability index, means ±SE

SPERM WHALE - BALEEN WHALE - RELATIONSHIP: A MORPHOLOGICAL APPROACH

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INTRODUCTION Sperm whales and baleen whales are among the most highly derived (apomorphous) representatives of the order Cetacea which is commonly accepted as a monophyletic group (Fordyce and Barnes, 1994; Klima and Oelschläger, 1994; Thewissen, 1994). The paleontology and morphology of toothed whales (odontocetes) is comparatively well-documented (Fordyce and Barnes, 1994; Heyning, 1997; Oelschläger, in press); by contrast, our knowledge of baleen whales (mysticetes) is rather limited.

On the basis of DNA analyses, Milinkovitch (1995), Milinkovitch *et al.* (1996) and Milinkovitch (1997) suggested that sperm whales (physeterids) are more closely related to baleen whales than to the non-physeterid odontocetes. Cranford et al. (1996), however, have shown that all extant odontocetes are united by the anatomic complexity and structural geometry of the forehead region, which is extremely asymmetric in physeterids. The odontocete forehead includes the nasal air sacs, a peculiar facial musculature, the melon, the dorsal bursae (or spermaceti organ in physeterids), the monkey lips, and an associated structural complex. The entire ensemble is thought to function in the generation of biosonar signals. Baleen whales, by contrast, do not exhibit these sophisticated structures and they do not echolocate by means of ultrasonic click trains. The suggestion of a mysticete "melon" by Heyning and Mead (1990) has not been substantiated thus far.

RESULTS In Table 1, we present a synopsis of major morphological and functional criteria from different organ systems all over the head (hard and soft tissues, including the brain and cranial nerves). These features may serve as a basis for future discussions. Characteristics of the common ancestors (Archaeoceti), which are diphyletic or polyphyletic, are listed in the box below. Unfortunately, some of the features are only known for either *Physeter* or *Kogia* but not for both of the genera. Nevertheless, it may be expected that there are no major differences concerning these features between the species of the Physeteridae.

The criteria presented in Table 1 (Nos. 1-19) can often be related to functional aspects:

1 - 12	to the existence or non-existence of the sonar system [**13**] in toothed whales (Odontoceti) and baleen whales (Mysticeti), respectively.
2 - 5	(Cranford *et al.*, 1996).
4	right side of facial region dominant (Cranford *et al.*, 1996).
6	may be explained with the need of dampening bone conduction from the skull to the ear for better hearing; concomitantly, both ears are isolated from each other, a prerequisite for directional hearing under water (Kasuya, 1973; Oelschläger, 1986, 1990).
7	(Hosokawa *et al.*, 1969; Seki, 1985; Schulmeyer, 1992; Schulmeyer and Oelschläger, in press).
8	(Ogawa and Arifuku, 1948; Seki, 1985)
9- 10	indicate differences in the audiograms [medial superior olive: lower frequencies (sound, whistles); lateral superior olive: high frequencies (ultrasound; clicks)] (Ogawa and Arifuku, 1948; Seki, 1985).
11	stands for a well-developed blowhole musculature in *Physeter* and in smaller toothed whales (compared to baleen whales) which is involved in the emission of sonar signals (Clicks) (Morgane and Jacobs, 1972).

12 right nucleus dominant, in correlation with the hypertrophy of the right side of the nasal (blowhole) region (Seki, 1984).

13 emission of the sonar signals via the epicranial complex; their perception via the thin lower jaw and a fat body in the wide alveolar canal, which is connected to the tympanoperiotic complex; processing of the input in the auditory system (Norris, 1968, 1980; Zvorykin, 1963, Ridgway, 1986, Cranford *et al.*, 1996).

14 - 15 seem to be consistent throughout the suborders Odontoceti and Mysticeti (Kemp and Oelschläger, 1997), respectively, but so far have no explanation.

16 In baleen whales, this feature may be correlated with the lack of the sonar system. As adults, these animals retain a small but complete olfactory system (Oelschläger, 1989).
In toothed whales, the sonar apparatus may have displaced the rostral olfactory system (chemoreceptors) by the mechanical irritation of the olfactory mucus membrane via high-energy clicks during echolocation. In toothed whale embryos, the rostral olfactory system (olfactory placodes, nerves, and olfactory bulbs) is established as in other mammals but reduced in early fetal stages (Oelschläger and Buhl, 1985a,b; Buhl and Oelschläger, 1988; Oelschläger and Kemp, in press).

17 - 18 are specific for baleen whales (Purves, 1955).

19 secondary situation; correlates with the hypertrophy of the right posterior dorsal bursa (spermaceti organ [Cranford *et al.*, 1996]) in sperm whales and may stand for a specialisation in the sonar system (range, spectrum and intensity of signals).

CONCLUSIONS A proposal that places the sperm whales closer to the baleen whales than to other toothed whales is unlikely from the standpoint of functional morphology. This would mean that:

(A) ancestral baleen whales would have been echolocators (as are all extant odontocetes investigated to date),

(B) all traces of the highly complicated sonar-generating system be extinguished in extant mysticetes, and

(C) the most specialised odontocetes (with respect to the forehead region) would be the sister group of filter-feeders.

Ontogenetic studies have not detected any indication of forehead asymmetry in the prenatal development of baleen whales.

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REFERENCES

Buhl, E.H. and Oelschläger, H.A. 1988. Morphogenesis of the brain in the harbour porpoise. *J. Comp. Neurol.*, 277: 109-125.

Cranford, T.W., Amundin, M., and Norris, K.S. 1996. Functional morphology and homology in the odontocete nasal complex. Implications for sound generation. *J. Morphol.*, 228: 223-285.

Fordyce, R.E. and Barnes, L.G. 1994. The evolutionary history of whales and dolphins. *Ann. Rev. Earth Planet. Sci.*, 22: 419-455.

Heyning, J.E. 1997. Sperm whale phylogeny revisited: Analysis of the morphological evidence. *Mar. Mammal Sci.*, 13: 596-613.

Heyning, J.E. and Mead, J.G. 1990. Evolution of the nasal anatomy of cetaceans. Pp. 67-79 In: *Sensory Abilities of Cetaceans* (Eds. J. A. Thomas and R. A. Kastelein). Plenum Press, New York.

Hosokawa, H.S., Igarashi, S., Kamiya, T., and Hirosawa, K. 1969. Morphological characteristics and myelinization of acoustic system in the dolphins (*Stenella caeruleoalba*). *Sci. Rep. Whales Res. Inst.*, Tokyo, 21: 95-123.

Kasuya, T. 1973. Systematic consideration of recent toothed whales based on the morphology of the tympanoperiotic bone. *Sci. Rep. Whales Res. Inst.*, Tokyo, 25: 1-103.

Kemp, B. and Oelschläger, H.A. 1997. Lebenskünstler im Wasser. *Biologie in unserer Zeit*, 4: 226-234.

Klima, M. and Oelschläger, H.A. 1994. Phylogenie und Systematik der Cetacea. Pp. 31-48. In: *Handbuch der Säugetiere Europas* (Eds. J. Niethammer & F. Krapp), Vol. 6: *Meeressäuger* (Eds. D. Robineau, R. Duguy & M. Klima). Aula-Verlag, Wiesbaden.

Milinkovitch, M.C. 1995. Molecular phylogeny of cetaceans prompts revision of morphological transformations. *Trends Ecol. Evol. (TREE)*, 10: 328-334.

Milinkovitch, M.C., LeDuc, R.G., Adachi, J., Farnir, M.G., and Hasegawa, M. 1996. Effects of character weighting and species sampling on phylogeny reconstruction: A case study based on DNA sequence data in cetaceans. *Genetics*, 144: 1817-1833.

Milinkovitch, M.C. 1997. The phylogeny of whales: A molecular approach. Pp. 317-338. In: *Molecular Genetics of Marine Mammals* (Eds. A. E. Dizon, S. J. Chivers & W. F. Perrin). Society ofMarine Mammalogy.

Miller, G.S. 1923. The telescoping of the cetacean skull. *Smithson. Misc. Coll.*, 76: 1-70.

Morgane, P.J. and Jacobs, M.S. 1972. Comparative anatomy of the cetacean nervous system. Pp. 117-244. In: *Functional Anatomy of Marine Mammals*, Vol. 1 (Ed. R. J. Harrison).

Norris, K. 1968. The evolution of acoustic mechanisms in odontocete cetaceans. Pp. 297-324. In:*Evolution and Environment* (Ed. E. T. Drake). Yale Univ. Press, New Haven.

Norris, K. 1980. Peripheral sound processing in odontocetes. Pp. 495-509. In: *Animal Sonar Systems* (Eds.: R.-G. Busnel and J. F. Fish). NATO ASI Series A, Vol. 28. Plenum Press, New York

Oelschläger, H.A. 1986. Comparative morphology and evolution of the otic region in toothed whales (Cetacea, Mammalia). *Amer. J. Anat.*, 177: 353-368.

Oelschläger, H.A. 1989. Early development of the olfactory and terminalis systems in baleen whales. *Brain, Behav. Evol.*, 34: 171-183.

Oelschläger, H.A. 1990. Evolutionary morphology and acoustics in the dolphin skull. Pp. 137-162. In:*Sensory Abilities of Cetaceans* (Eds. J. A. Thomas and R. A. Kastelein). Plenum Press, New York.

Oelschläger, H.A. In press. Morphological and functional adaptations of the toothed whale head to aquatic life. *Historical Biology*.

Oelschläger, H.A. and Buhl, E.H. 1985a. Development and rudimentation of the peripheral olfactory system in the harbor porpoise, (*Phocoena phocoena*)(Mammalia: Cetacea). J. Morphol., 184: 351-360.

Oelschläger, H.A. and Buhl, E.H. 1985b. Occurrence of an olfactory bulb in the early development of the harbor porpoise (*Phocoena phocoena* L.). Pp. 695-698. In: *Vertebrate Morphology. Fortschritte der Zoologie*, Band 30 (Eds. H.-R. Duncker and G. Fleischer). Gustav Fischer Verlag, Stuttgart.

Oelschläger, H.A. and Kemp, B. In press. Ontogenesis of the sperm whale brain. *Journal of Comparative Neurology*.

Ogawa, T. and Arifuku, S. 1948. On the acoustic system in the cetacean brain. *Sci. Rep. Whales Res. Inst.*, Tokyo, 2: 1-20.

Purves, P.E. 1955. The wax plug in the external auditory meatus of the mysticeti. *Discovery Rep.*, 27: 293-302, plates: XIV-XVIII.

Ridgway, S.H. 1986. Physiological observations on dolphin brains. Pp. 31-59. In: *Dolphin Cognition and Behavior: A Comparative Approach* (Eds. R. J. Schusterman, J. A. Thomas & F. G. Wood).Lawrence Erlbaum Assoc., London.

Schulmeyer, F.J. and Oelschläger, H.A. In press. Specialized sound reception in dolphins - a hint forthe function of the dorsal cochlear nucleus (DCN) in mammals. *Historical Biology*.

Schulmeyer, F.J. 1992. Morphologische Untersuchungen am Hirnstamm der Delphine unter besonderer Berücksichtigung des La Plata-Delphins, *Pontoporia blainvillei*. Diss. Med. Fak. Univ. Frankfurt a. M. 101pp.

Seki, Y. 1984. Anatomical studies on the cell column located closely medial to the nucleus of the spinal root of the trigeminal nerve in the sperm and the pygmy sperm whales. *Sci. Rep. Whales Res. Inst.*, Tokyo, 35: 47-56.

Seki, Y. 1985. Anatomical observations on the lower brain stem of the right whale. *Sci. Rep. Whales Res. Inst.*, Tokyo, 36: 49-87.

Thewissen, J.G.M. 1994. Phylogenetic aspects of cetacean origins: a morphological perspective. *J. Mammal. Evol.*, 2: 157-184.

Zvorykin, V.P. 1963. Morphological substrate of ultrasonic and locational capacities in the dolphin *Arkh. Anat. Gistol. Embriol.*, 45: T647-T654.

Table 1 Characteristics of Cetacean SubOrders

Differences between and uniting features of sperm whales and other extant

Mysticeti		*Physeteridae*	*Odontoceti*
caudal type	**(1) telescoping of skull [a]**	**rostral type**	**rostral type**
2	**(2) blowholes**	**1**	**1**
-	**(3) epicranial complex present [b]**	+	+
-	**(4) directional asymmetry of facial region**	+	+
-	**(5) spermaceti organ**	+	**⇦dorsal bursa [c]**
-	**(6) periotic processes reduced**	+	+
+	**(7) auditory system very well developed**	++	++
-	**(8) superior olive very large**	***Kogia***	+
+	**(9) medial superior olive larger**	-	-
-	**(10) lateral superior olive larger**	***Kogia***	+
x 1.5	**(11) number of facial nerve axons**	**x 4.5 (*Physeter*)**	**x 1 [d]**
-	**(12) different size of facial nuclei**	***Kogia***	**?**
-	**(13) sonar system**	+	+
+	**(14) trilobar shape of brain**	-	-
-	**(15) trapezoid shape of brain**	+	+
+	**(16) rostral olfactory system present**	-	-
+	**(17) baleen present**	-	-
+	**(18) glove finger/ear plug present**	-	-
-	**(19) rostral position of blowhole**	**+ (*Physeter*)**	**⇦ -**

Sources of the criteria given (1-19) are listed in the References.

Archaeoceti

no telescoping
bony nares in intermediate position
primary sinuses of nose reduced (⇨ R!)
olfactory bulbs and olfactory tracts thin and small
sagittal and nuchal crests high
heterodont dentition for cutting prey
masticatory apparatus well developed
zygomatic arch slender but complete
⇨ widening of mandibular canal
⇨ periotic uncoupled from skull wall
tympanoperiotic complex present
sigmoid process on tympanic bulla
auditory ossicles stout and heavy

a) definition: cf. Miller (1923)
b) definition: cf. Cranford et al. (1996)
R! = reduction
c) right posterior dorsal bursa
d) average of six smaller species [37,600 axons] = 1
⇦/⇨ = morphofunctional or allometric trend

EVOLUTION OF THE VOCAL FOLDS IN CETACEANS

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INTRODUCTION The prime sound generators in terrestrial mammals are the vocal folds. Historically, such folds have been presumed absent in cetaceans (e.g., Hosokawa, 1950; Purves and Pilleri, 1983, Reidenberg and Laitman, 1987). Accordingly, the role of the larynx in sound production has been unclear. This study presents our new findings on laryngeal structures which may be homologous to the vocal folds (vocal "cords," or "true" vocal folds) of terrestrial mammals.

MATERIALS AND METHODS 101 cetacean specimens were examined in this study. This sample represents 3 genera of mysticetes and 13 genera of odontocetes. These specimens were compared to 8 genera of non-cetacean aquatic mammals as well as our large sample of terrestrial specimens. The species used are listed in table 1. All specimens were obtained post mortem as either whole heads or excised larynges with attached soft tissues. Whole heads were frozen and bisected in the midsagittal plane to reveal laryngeal position relative to surrounding soft tissue and skeletal structures. Isolated larynges were further examined for intrinsic laryngeal anatomy.

RESULTS AND DISCUSSION **Non-Cetacean Condition** The vocal folds (vocal "cords") each traverse rostrally from the arytenoid cartilage to meet in the midline in a "V" attaching to the thyroid cartilage. The vocal folds lie in the transverse plane, oriented perpendicular to the long axis of the trachea. Vocal fold movements regulate airflow through the larynx and generate the fundamental frequencies used in vocalization. Each vocal fold is supported medially by an underlying ligament. The ligament attaches dorsally to the vocal process of the arytenoid cartilage and rostrally to the thyroid cartilage. The arrangement, movements, and structure of vocal folds in non-cetacean aquatic mammals is similar to that seen in terrestrial mammals (Laitman and Reidenberg, 1997; 1998).

Mysticete Condition A U-shaped fold ("U-fold") is present bordering the opening between the laryngeal lumen and a ventrally located laryngeal sac. This fold lies close to the horizontal plane, running parallel to the long axis of the trachea. The right side of the U-fold can be seen traversing caudally from the arytenoid cartilage into the laryngeal lumen, where it meets the left one in the midline. At this point, there is no direct attachment to the thyroid cartilage ventrally. Rather, the attachment appears to be via a raphe (seamlike union between the muscle fibers of the left and right sides) that extends along the midline of the laryngeal sac; it first runs caudally, then turns and runs rostrally to meet the thyroid cartilage.

The U-fold appears homologous to the vocal folds of other mammals. This is based upon attachments, movements and composition. Each side of the U-fold is supported by an extension of the arytenoid cartilage which resembles the vocal process of terrestrial mammals. Movements of the arytenoid cartilages appear to adduct and abduct the left and right arms of the U-fold, and pivot the U-fold ventrally or dorsally. There is a ligament within the U-fold attaching to the arytenoid cartilages which resembles the vocal ligament of terrestrial mammals. Unlike the condition in terrestrial mammals, however, this ligament does not attach the U-fold to the thyroid cartilage. Rather, the U-fold is "free-floating" between the laryngeal lumen dorsally and the laryngeal sac ventrally. If the U-fold is homologous to the vocal folds of terrestrial mammals, then the loss of the ventral thyroid attachment may be explained as the result of laryngeal sac development.

While paired laryngeal sacs develop in some terrestrial mammals by laterally extending each laryngeal ventricle (an air space located just above each vocal fold), in mysticetes these two spaces are fused ventrally into one midline laryngeal sac. Caudo-ventral elongation of the thyroid attachment of the vocal folds may produce the midline out-pocketing that becomes the laryngeal sac. The stretched thyroid attachment itself may explain the presence of a midline ridge on the laryngeal sac that extends from the bottom of the U-fold curvature back to the thyroid cartilage.

Odontocete Condition Characteristic of most odontocetes is a midline laryngeal fold which attaches along the lumenal aspect of the epiglottis, continues over the thyroid cartilage, and extends caudally to attach to the inferior termination of the arytenoid cartilages (see also Reidenberg and Laitman, 1988). At this point, the arytenoid cartilages meet in the ventral midline. This midline fold may be elevated vertically in the midsagittal plane. Its orientation is parallel to the long axis of the trachea. Rostral and caudal movements of the arytenoid cartilages appear to cause the caudal portions of the midline fold to be tensed and elevated into the airstream, or relaxed and recessed closer to the ventral lumenal surface. When the superior aspect of the arytenoid is rotated rostrally, the inferior portion pivots caudally, thereby extending the length of the attached midline fold, tensing it, and thus elevating it into the airstream. This same movement also has the effect of opposing the corniculate cartilages (which are fused superiorly to the arytenoid cartilages) towards the epiglottis, thus narrowing the rostro-caudal diameter of the air passageway through the elongated laryngeal spout. Lateral and medial movements of the arytenoid cartilages appear to have very little effect on the midline fold, but can abduct and adduct the fused arytenoid and the corniculate cartilages. This, in turn, can have the effect of regulating the lateral diameter of the air passageway through the elongated laryngeal spout. Adduction of the arytenoid-corniculate cartilages dorsally may cause airflow to be restricted to a narrow channel in the ventral region, where air is forced to pass along either side of the midline fold. Histology of the midline fold in three specimens (*Delphinapterus*, *Kogia*, and *Mesoplodon*) revealed the presence of a large component of collagen and elastic tissue, as well as mucous glands and muscle fibers. Although the condition of preservation did not allow definitive evaluation of whether the muscle fibers were skeletal or smooth, the presence of elastic tissue indicates the ability to stretch and recoil, and mucous glands may indicate surfaces that encounter friction and thus need lubricating. These structural characters indicate that the midline fold is probably involved in a vibratory function, such as vocalisation.

The attachments, movements, and composition of the midline fold indicate homology with the vocal folds of non-cetacean mammals. The unusual appearance of only one fold, rather than two opposing folds, may be explained by fusion of the two folds along the midline. Evidence for this is an intermediate configuration found in at least one species (*Kogia breviceps*, pygmy sperm whale), in which only the rostral portion of the fold is fused, but the caudal portion is bifurcated. Midline fold orientation parallel to airflow may be explained by superior elongation of the epiglottis and inferior extension of the arytenoid cartilages, thus pivoting the fold 90 degrees from its position perpendicular to airflow in a terrestrial mammal. In addition, the presence of lateral folds and intervening air sacs is similar to the arrangement in non-cetacean mammals. The lateral laryngeal folds may be homologous to the vestibular folds, while the air sacs may be homologous to the laryngeal ventricles.

CONCLUSIONS Homologous structures to the vocal folds in terrestrial mammals are present in odontocetes and, as per our new findings, mysticetes as well. While showing homology to the folds of terrestrial mammals, those in mysticetes and odontocetes appear to have diverged considerably in morphology and potential function. These differences may reflect an adaptation to different sound niches (low frequency for mysticetes, high frequency for odontocetes).

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REFERENCES

Hosokawa, H. 1950. On the cetacean larynx, with special remarks on the laryngeal sack of the sei whale and the aryteno-epiglottideal tube of the sperm whale. *Sci. Rep. Whales Res. Inst.* (Tokyo, Japan), 3:23-62.

Laitman, J.T. and Reidenberg, J.S. 1997. The human aerodigestive tract and gastroesophageal reflux: An evolutionary perspective. *Am. J. Medicine*, 103:3-11.

Laitman, J.T. and Reidenberg, J.S. 1998. Comparative and developmental anatomy of laryngeal position. In: *Head and Neck Surgery - Otolaryngology*. Vol. 1. (Ed. B.J. Bailey). J.B. Lippincott Co., Philadelphia.

Purves, P.E. and Pilleri, G.E. 1983. Echolocation in Whales and Dolphins. Academic Press, New York.

Reidenberg, J.S. and Laitman, J.T. 1987. Position of the larynx in Odontoceti (toothed whales). *Anat. Rec.*, 218: 98-106.

Reidenberg, J.S. and Laitman, J.T. 1988. Existence of vocal folds in the larynx of Odontoceti (toothed whales). *Anat. Rec.*, 221: 884-891.

TABLE 1. Specimens studied

Genus species	Common name
Terrestrial specimens	
Equus caballas	horse
Odocoileus virginianus	white-tailed deer
Antilocapra americana	pronghorn antelope
Capra hircus	goat
Ovis aries	sheep
Sus scrofa	pig
Canis familiaris	dog
Vulpes vulpes	common red fox
Felis domestica	cat
Procyon lotor	raccoon
Didelphis virginiana	opossum
Oryctolagus cuniculus	rabbit
Sylvilagus floridanus	cottontail rabbit
Marmota monax	woodchuck
Cavia porcellus	guinea pig
Mesocricetus auratus	hamster
Tamias striatus	chipmunk
Sciurus carolinensis	gray squirrel
Rattus norvegicus	Norway rat
Liomys (Acomys) sp.	spiny mouse
Mus musculus	mouse
Myotis thysanodes	little brown bat
Scalopus aquaticus	E. American mole
Primate specimens	
Tupaia glis	tree shrew
Nycticebus coucang	slow loris
Saguinus oedipus	cottontop tamarin
Saimiri sciureus	squirrel monkey
Ateles paniscus	black spider monkey
Cercopithecus aethiops	vervet monkey
Erythrocebus patas	patas monkey
Macaca arctoides	stumptail macaque
Macaca fascicularis	cynomolgus monkey
Macaca mulatta	rhesus macaque
Papio anubis	olive baboon
Pan troglodytes	chimpanzee
Homo sapiens	human

Genus species	Common name(s)
Non-cetacean Aquatic specimens	
Trichechus manatus	Florida manatee
Zalophus californianus	California sealion
Callorhinus ursinus	northern fur seal
Phoca vitulina	harbor seal
Enhydra lutris	sea otter
Lutra canadensis	river otter
Castor canadensis	beaver
Ondatra zibethica	muskrat
Cetacean specimens	
Balaenoptera acutorostrata	minke whale
Balaenoptera physalus	fin whale
Megaptera novaeangliae	humpback whale
Eubalaena glacialis	n. right whale
Physeter macrocephalus	sperm whale
Kogia breviceps	pygmy sperm
Kogia simus	dwarf sperm
Mesoplodon europeaus	Gervais' beaked (Gulf Stream beaked whale)
Mesoplodon mirus	True's beaked
Mesoplodon densirostris	Blainville's bked (Dense-beaked whale)
Orcinus orca	killer whale
Pseudorca crassidens	false killer whale
Globicephala melas	long-finned pilot
Delphinapterus leucas	beluga whale
Grampus griseus	Risso's dolphin [Grampus)
Lagenorhynchus acutus	Atl. white-sided
Lagenorhynchus obliquidens	Pac. white-sided
Lagenorhynchus albirostris	white-beaked
Stenella coeruleoalba	striped dolphin
Delphinus delphis	common dolphin
Tursiops truncatus	bottlenose
Phocoena phocoena	harbour porpoise

THE TAIL FLUKE SHAPE AND SKIN STRUCTURE OF THE HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) AND COMMON DOLPHIN (*DELPHINUS DELPHIS*)

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INTRODUCTION The dolphin tail as a thrust producer must have certain hydrodynamical properties. These properties depend on the one hand upon the shape of the tail flukes and on the other hand on its mechanical properties. The latter depend from skin minute histological structure. Previous investigations have shown the existence of a linear relationship between tail fluke shape and skin morphology of the harbour porpoise *Phocoena phocoena*. In this connection, a comparative study of the common dolphin *Delphinus delphis* and harbour porpoise as contrasting examples of the speed capabilities of small cetaceans is worthwhile.

MATERIALS AND METHODS Cross sections and skin samples of tail flukes of stranded carcasses were studied. Left flukes fixed in 10% neutral formalin have been cut by ten cross sections with equal intervals. Profile length, profile thickness and the distance from the leading edge to maximum profile thickness were measured from each cross section. Profile thickness as well as thickness of a main body or fluke central core on each cross section was located at 20 points with a 5% profile length interval. At these points, values of epidermal thickness, thickness of subpapillary layer of the dermis, and blubber thickness were obtained by vertical histological sections. At the same points, the following measurements were made on horizontal histological sections: values of dermal papillae number per unit area; angles formed by the long axis of the body along dermal ridges; angles formed by the long axis of the body with structures within the subpapillary layer. Data obtained were analysed with standard techniques of correlation analysis. For comparisons of parameter means, t-tests were used.

RESULTS AND DISCUSSION The tail flukes from harbour porpoise and common dolphin differ in length, width, thickness and the angle of the wing. In spite of these differences, the distribution of tail fluke thickness is very similar. The significant resemblance of the dimensions of fluke sections is shown in Figs. 1 and 2. The negligible difference in curvature of lines A and B are caused by differences in fluke width and the angle of the wing. The characteristics of fluke sections similar to that of harbour porpoise were also found in Dall's porpoise *Phocoenoides dalli* (Pershin, 1975). There are general regularities for all these species: relative profile thickness (% profile length) and relative profile length (% fluke length) decrease from the base of the tail fluke to its dorsal surface. The distance from the leading edge to the relative maximum profile thickness (% chord length) also increases in the same direction.

There are similar correlations between skin morphology parameters and fluke thickness in both species (Table 1). In the harbour porpoise and common dolphin, the fluke thickness has the highest correlation coefficient with other parameters. On the other hand, in both cases, epidermal thickness has the lowest correlation coefficient with other parameters. The only difference is the significantly lower correlations between epidermis and other parameters in common dolphin.

A comparison of skin morphological parameters of both species indicates close correlations (Table 2). The highest correlation coefficient was found in the distribution of fluke thicknesses and the lowest in the distribution of epidermal thicknesses.

The absolute values of various morphological parameters show significant differences between the two species (Fig. 3). The mean values of subpapillary layer thickness, blubber thickness, and the number of the dermal papillae per unit area in the common dolphin are significantly higher ($p<0.01$) than in the harbour porpoise. On the other hand, the epidermal thickness of common dolphins is markedly lower than in the harbour porpoise.

The ratio of skin layers and fluke central core thickness to the fluke total thickness was compared for both species. Besides the marked differences in central core thickness, the ratio of the skin layers of common dolphin differs from that of harbour porpoise (Fig. 4). It finds expression in a decrease of the mean epidermal thickness and an increase of the mean values of the subpapillary layer and blubber. At the same time, the mean subpapillary layer thickness of the common dolphin exceeds by the same order of magnitude that of the harbour porpoise.

Similar changes of the structure of the subpapillary layer in relation to fluke thickness were revealed for the common dolphin as with the harbour porpoise. At the base of the tail fluke, the structure of the subpapillary layer becomes more regular, whilst chaotically arranged collagen fibres aggregate to the parallel bundles. There are densely packed adipocytes between bundles. The structure of the subpapillary layer is similar to that of the dermal-epidermal interface of the dolphin skin. Within the skin of the species investigated, both the epidermis divided by dermal ridges and the subpapillary layer divided by collagen bundles have general peculiarities. In both cases, the structure shows a marked anisothropy and is divided into stripes of tissue having different resilient properties. These features probably have a general cause. The presence of separation of the epidermis into stripes by dermal ridges has previously been shown (Babenko, 1980). If the disturbances at the boundary layer actually reach their maximum at the base of the fluke, the subpapillary structure changes may be considered a hydrodynamic adaptation of the tail fluke.

As has been previously observed (Pavlov, 1997), the integrity of morphological parameters describing the epidermis thickness, number of the dermal papillae per unit area, and blubber thickness may be considered a measure of the resilient properties of the tail fluke skin. Taking into account the results of morphometric studies, the skin of common dolphins appear to have a wider range of resilient properties than in the harbour porpoise. These peculiarities and the more structuralised subpapillary layer with its higher degree of anisothropy in the common dolphin may be considered as skin adaptations for fast swimming dolphins. Babenko (1980) found that the distribution of the epidermis and the skin structure along the body were determined by flow characteristics. Probably the significant differences in absolute values of skin morphological parameters between the harbour porpoise and the common dolphin are reflected in the differences in characteristics of the boundary layer of the flow.

CONCLUSIONS

1. There is a convergence of parameters relating to the hydrodynamics of tail flukes from representatives of the genera *Phocoena* and *Delphinus*.

2. No regularities in the distribution of various skin morphological parameters on the tail flukes are revealed, and these are considered to be specific characters of high and low speed abilities respectively of the two species investigated.

3. Significant differences in the skin structure of the fast moving common dolphin compared with the slower moving harbour porpoise are related to the ratio in the dimensions of the skin layers and to the density of the dermal-epidermal interface.

4. The presence of similar peculiarities of tail fluke structure within both species suggests the existence of some common hydrodynamic adaptations of the small cetacean tail fluke.

ACKNOWLEDGEMENTS Our thanks go to J. Laschenko for invaluable help throughout the course of this work.

REFERENCES

Babenko, V.V. 1980. About oscillating mass of dolphin integuments. *Bionika*, 14: 57-64 (In Russian).

Pavlov, V. 1997. Some morphological features of harbour porpoise *Phocoena phocoena* tail fluke in terms hydrodynamics. P.306-308. In *European Research on Cetaceans - 10.* Proc. 10th Ann. Conf. ECS, Lisbon, Portugal, 11-13 March 1996 (Ed. P.G.H. Evans). European Cetacean Society. Kiel, Germany. 334pp.

Pershin, S.V. 1975. Hydrodynamic analysis of dolphin and whale fins. *Bionika*, 9: 26-36 (In Russian).

Table I. Correlations between fluke thickness and skin morphology parameters

	common dolphin	harbour porpoise
Z/TE	r=-0.01, *	r=0.68, p<0.01
Z/TBLB	r=0.87, p<0.01	r=0.84, p<0.01
Z/TSPL	r=0.81, p<0.01	r=0.88, p<0.01
Z/NDP	r=0.77, p<0.01	r=0.76, p<0.01
Z/	r=-0.73, p<0.01	r=-0.67, p<0.01
Z/	r=-0.71, p<0.01	r=-0.52, p<0.01

Table II. Correlations between the same parameters from both species

TE	r=0.31,	p<0.01
TBLB	r=0.85,	p<0.01
TSPL	r=0.88,	p<0.01
NDP	r=0.80,	p<0.01
Z	r=0.98,	p<0.01
	r=0.99,	p<0.01
	r=0.98,	p<0.01

* - not significant
Z - fluke thickness
TE - thickness of epidermis
TBLB - thickness of blubber
TSPL - thickness of subpapillary layer
NDP - number of dermal papillae per 1 mm^2
- angle formed by body long axis with dermal ridges
- angle formed by body long axis with structures of subpapillary layer

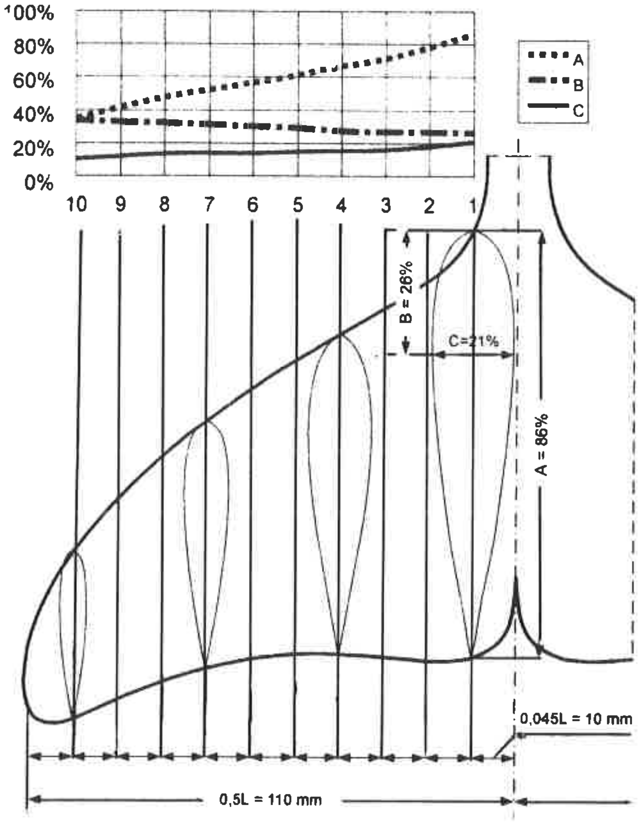

Fig.1. Scale draw of the harbour porpoise tail fluke

A = % from fluke length
B = % from profile length
C = % from profile length

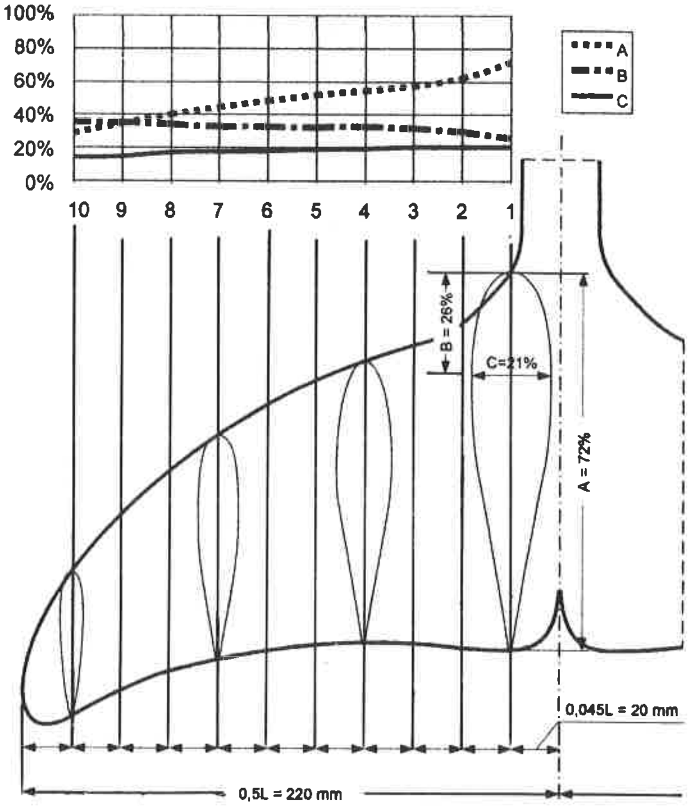

Fig.2. Scale draw of the common dolphin tail fluke

A = % from fluke length
B = % from profile length
C = % from profile length

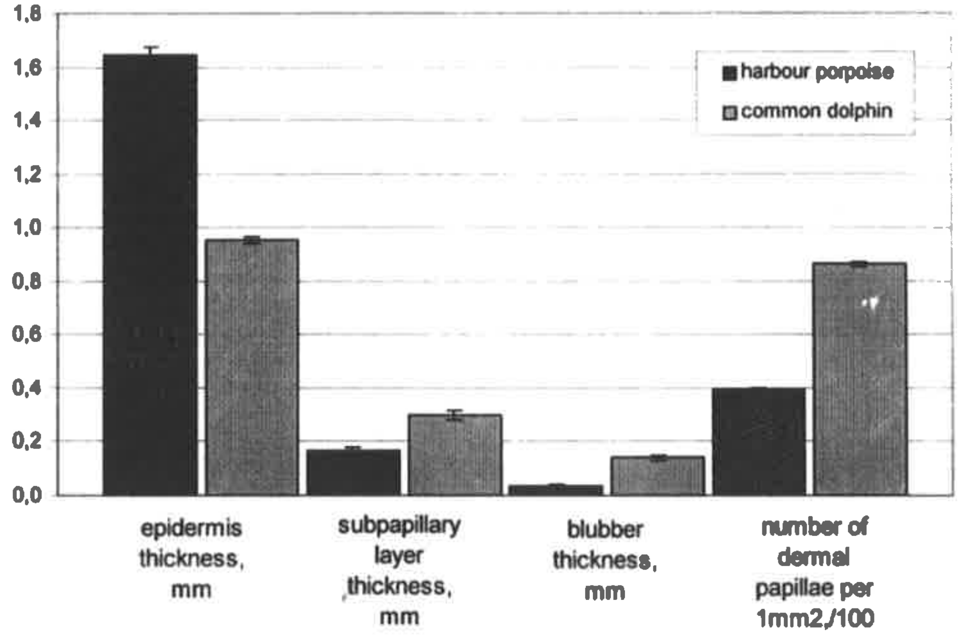

Fig. 3. Skin morphology parameters, means ± SE

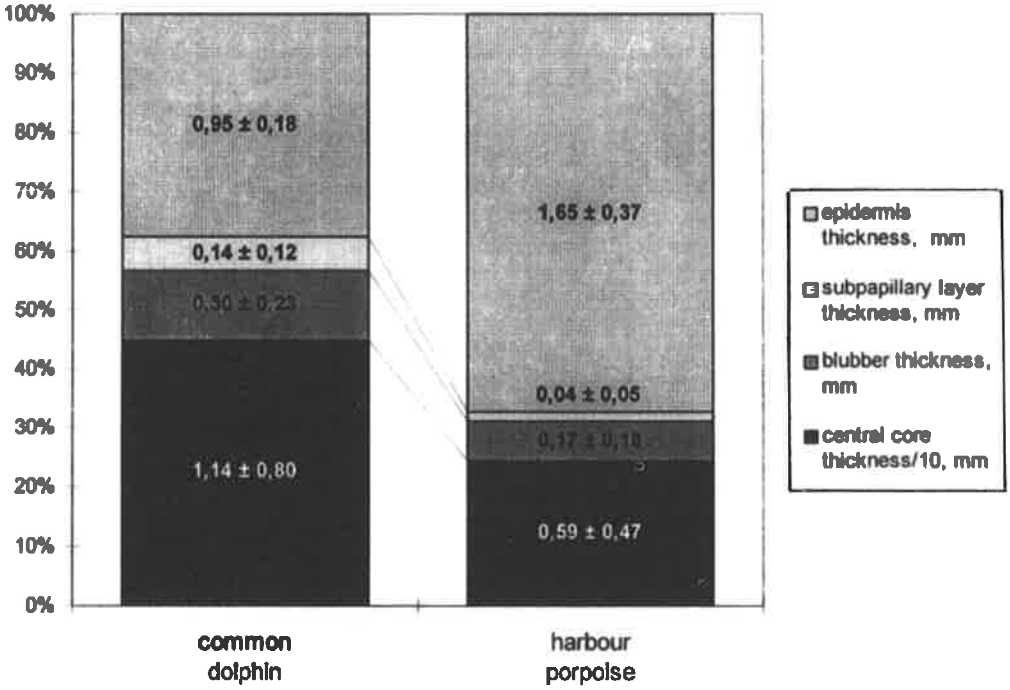

Fig. 4. Ratio of skin layers and central core thickness to the whole fluke thickness, means ± SD

CHANGES IN BODY FAT AND ITS EFFECT ON BASAL METABOLIC RATE IN HARP SEALS (*PHOCA GROENLANDICA*)

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Basal metabolic rate of three adult female harp seals at two different levels of body fattening was measured by use of indirect calorimetry. The different levels of body fattening were achieved by different planes of capelin nutrition, and determined by use of the tritiated water technique. When the seals had attained a state where 42% of body mass (BM) was fat, BMR was 1.2 W/kg, while when only 16% of BM was fat, BMR increased to 2.0 W/kg. This suggests that the subcutaneous deposits of fat in pinnipeds contribute little to the BMR of the animal. This has obvious consequences for predictions of BMR on the basis of BM in seals with seasonal variations in body fat from 20-60% of BM.

REPRODUCTION, SEASONALITY AND LACTATION IN HARBOUR PORPOISES FROM DUTCH WATERS

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Harbour porpoises from the southern (Dutch) North Sea form a separate (sub)population. Females give birth during an parturition period of about four months, with neonates found from May to the end of August and into September. This differs significantly from the short period found in harbour porpoise populations studied elsewhere. Our analysis of historical data from 1935 onwards confirms this. The mating season appears to be extended as well. We found that ovulation and conception may occur as late as September, while spermatogenesis was found in some males in March and November. Near-term foetuses were observed in March and April.

The growth potential of the (sub)population studied may be low in comparison to other populations. As one indicator of the growth potential of a harbour porpoise population, - though based on a relatively small sample size (N=29) - we found only a small number of animals which were both lactating and pregnant. Some females were found to be still sexually immature at age 6.

The criterion "lactating" was studied histologically in detail. Few adult females had fully active mammary glands, while many were histologically in an intermediate secretory stage. This is suggestive of a gradual decrease rather than abrupt termination of lactation, but further investigation is needed.

WHEN DOES THE MEDITERRANEAN MONK SEAL MOULT?

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Unlike any other mammals, members of the tribe Monachini (elephant seals and monk seals), exhibit an unusual moult wherein the hairs are shed along with large sheets of cornified epidermis through which the club hairs penetrate. All other pinnipeds shed their hairs individually. Many studies have information about the progression and timing of the pinniped moult or its histology but, in contrast, information concerning the moulting process for the Mediterranean monk seal is limited to an indirect reference to the moulting season observed in Greece (Yediler *et al.*, 1993) and a description about the coloration of one individual in Peninsula "Cabo Blanco" (Marchessaux, 1989).

To give light to this issue, a study was conducted between 1993-1996 on the Peninsula of"Cabo Blanco" (Western Sahara) in two caves situated in the "las Cuevecillas" area (21°03'32"N-17°03'82"W) and also in the tip of the same Peninsula. Data from a photo-identification catalogue and from direct sightings were used in this study. The majority of pictures and sightings were made when moulting seals were swimming in front of the breeding caves. This information was used to elaborate on individual and population moult cycles. The problem was that all months were not sampled every year. For males, there was little information or it did not exist for January and February. In the case of females information was lacking for February and July.

Moulting males were found from April to October, with a peak in June (Fig. 1). Moulting females could be found throughout the year, however there was a peak in March (Fig. 2). The moulting season in Greece at least January to May, based on collection of hair-samples (one sample in January, one in February, two in March, one in April and one in May) (Yediler *et al.*, 1993). These data are distributed at the end of winter and spring, coinciding with the peak of moulting males and females in "Cabo Blanco" Peninsula. There is not enough data on Mediterranean waters, and that which is available is sporadic and opportunistic. However, it seems that the moulting season of both Greek and Saharan monk seal populations are not different.

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REFERENCES

Marchessaux, D., 1989. *Recherches sur la Biologie, l'Ecologie et le Statut du Phoque Moine, Monachus monachus* GIS Posidonie Publ., Marseille, France. 280pp.

Yendiler, A., Panou, A. and Schramel, P. 1993. Heavy metals in hair samples of the Mediterranean monk seal (*Monachus monachus*). *Marine Pollution Bulletin*, 26(3): 156-159

SONAR-RELEVANT STRUCTURES IN THE FOETAL NARWHAL (*MONODON MONOCEROS*)

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Adult toothed whales possess forehead structures such as the blowhole, nasal air sacs, a peculiar facial musculature, acoustic fat bodies as the melon and dorsal bursae, and monkey lips (Cranford *et al.*, 1996) that are thought to function in the generation and emission of biosonar signals. The signals are reflected and modified in the environment, received by the lower jaw (acoustic fat body), and transmitted via the tympanic bone and the auditory ossicles to the inner ear (Norris, 1968, 1988). The ear bones are united in a tympanoperiotic complex and uncoupled from the skull (acoustic isolation; cf. Oelschläger, 1990).

We investigated sections of a microslide series (coronal plane; thickness: 40 mm) of an early narwhal fetus of 137 mm total length (Hubrecht Laboratory, Utrecht, The Netherlands) in order to determine the morphological status of those structures which presumably are part of the sonar system. The most important observations are as follows:

1. No facial asymmetry; blowhole transverse, in front of cranial vault; no nasal conchae; three buds of nasal air sacs on each side; nasal plugs present; future melon consisting of mesenchyme interlwoven by numerous bands of muscle fibre bundles.

2. Rostrum very short, telescoping of skull in early stage; jugal bone rod-like; dental with large alveolar canal, containing mesenchyme (future mandibular fat body) and Meckel´s cartilage; posterior part of dental as "pan bone".

3. Rudimentary external auditory meatus; tympanic membrane funnel-shaped; middle ear cavity without accessory sacs; plane of incudomallear joint horizontal; tensor tympani and stapedius muscle present. Cochlea large, with two turns; vestibular apparatus comparatively very small; cochlear axis pointing ventrad. Tympanoperiotic complex large; tympanic bone more or less shell-like; uncoupling of periotic incomplete.

In principle, the morphology of this narwhal foetus is intermediate between the mammalian bauplan and the neonate condition. However, many of the future sonar-relevant structures seem to be in an advanced stage of development without being mature histologically. The morphology of the temporal region is impressive, in particular the striking size difference between the cochlea and the vestibular system, which recalls the situation in the adult.

HISTOLOGICAL STRUCTURE OF THE SOUND GENERATION COMPLEX IN DELPHINOID CETACEANS

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Identification of the anatomic site used for generating odontocete biosonar signals has been a focus of investigation for several decades. A variety of controversial theories in the past favoured either laryngeal or nasal phonation. Recent studies have identified a complex of tissue structures in the supracranial nasal passages as the source of odontocete biosonar signals: the monkey lips/dorsal bursae (MLDB) complex.

We reasoned that the repeated stress of producing echolocation signals should cause strain in the tissues which ought to induce adaptations in tissue architecture. Tissues of the whole nasal tract, including the monkey lips and surrounding regions were examined by means of standard dissection, conventional histology and both transmission and scanning electron microscopy, primarily in *Stenella coeruleoalba* but also in other delphinids and phocoenids.

It was found that the monkey lips have an abnormally thickened epithelium, forming a plateau that protrudes into the spiracular cavity upon dorsal and ventral slopes. In contrast to surrounding tissue, the subepithelial surface of the monkey lips are furrowed with parallel ridges oriented along the direction of air flow and perpendicular to the long axis of the lips. We will further present the laminar fibrous complex (LFC), a sheet of dense connective and elastic fibres attaching to elements of the sound generation apparatus. The thickened, protruding surface of the monkey lips, along with the ultrastructure of their subepithelial foundation, and the fibrous connections of the LFC to MLDB elements suggest a potential suitability for intense vibrations and rapid repetition rates as known to occur in delphinoid biosonar.

HORMONAL, CYTOLOGICAL AND BEHAVIOURAL INDICATIONS OF OESTRUS IN GREY SEALS FROM TWO BREEDING SITES IN THE UK

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Grey seals in the UK typically have a clearly defined reproductive period ashore, comprising choosing a breeding site, giving birth, feeding the pup, mating and returning to sea, all of which occurs in around 20 days. However, recent work suggested that mating patterns predicted by observed behaviour of grey seals at North Rona, Scotland does not explain the paternities of pups produced at the colony. In an attempt to explain this disparity we tested the hypothesis that behavioural and physiological oestrus may not necessarily occur contemporaneously. Free-ranging mothers of known-age pups were immobilised at the start and end of lactation at North Rona and the Isle of May in 1996. Blood samples and cervical smears were taken at each capture. Plasma hormones (progesterone and oestradiol 17) were assayed using standard ELISA kits and cell populations in smears were categorised according to morphology. Mother-pup pairs were observed from a hide for 6-8 hours per day on alternate days during the study. The interval between samples ranged from 6-14 days. In both colonies the levels of plasma progesterone decreased between samples, with a single exception, but individual variation in concentrations was substantial (mean difference 42.2 nmol/l, S.D.=45.7, n=11). Oestradiol levels increased (mean difference 987 pmol/l s.d.=586, n=11) but individual variation was again substantial. Vaginal cytology indicated that in general, leucocyte populations decreased and cornified cells increased in occurrence as lactation progressed. However there were differences between the colonies: mothers on North Rona reached highest levels of cornified cells 2-3 days later than mothers on the Isle of May. This corresponds with the fact that mean duration of lactation was longer on North Rona (19.6 d) than at the Isle of May (18.0 d). Attempted and successful copulations were observed after day 14, but successful copulations occurred later on North Rona than on the Isle of May. There were individual differences in aggressive behaviour around the time of oestrus. These results indicate inter-colony differences in the timing of oestrus, but possible explanations for this include differences in the ease of access to the water at the two sites and different maternal sizes.

BODY COMPOSITION OF STELLER SEA LION PUPS (*EUMETOPIAS JUBATUS*) AND THE RELIABILITY OF CALIPERS TO MEASURE BLUBBER THICKNESS

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Twelve dead Steller sea lion pups (*Eumetopias jubatus*) were recovered from rookeries in south-eastern Alaska. They were believed to be less than two weeks old at their time of death and represented a wide range of body sizes and conditions (small to large and fat to no-fat). Many of the pups lacking blubber were significantly lighter for a given length compared to those that were fat at their time of death. Volume exceeded mass by a factor of 1.3% with density averaging 0.987 g cm^{-3}. Skin was thinnest on the head and around the flippers (3 mm), and became thicker towards the rump (5 mm). It did not differ between dorsal and ventral sides, unlike blubber which was thickest on the pups' underside (7 mm). The healthy pups that died of trauma all had about 13% skin and 10% body fat (expressed as a proportion of total body mass). Pups that had no fat reserves lost an estimated 43% of their core mass before dying. Body condition was assessed with a set of Rosscraft Slimguide skinfold calipers. Average error of measurement was an acceptable 5.4%, but the skin and blubber of the pups were highly compressible. Skinfold thickness increased with body mass, but did not necessarily reflect the development of fat, given that pups with no fat also showed an increase in skinfold thickness with increases in body mass. Skinfold thickness of sea lion pups appears to correlate with body size, not with body condition, making it difficult if not impossible to develop a simple index of body condition or a calculation of percent-body fat from caliper measurements.

STRANDING OF A BLAINVILLE'S BEAKED WHALE (*MESOPLODON DENSIROSTRIS*) PREGNANT FEMALE IN THE CANARY ISLANDS

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The Blainville's beaked whale (*Mesoplodon densirostris*) together with the rest of the Ziphiidae family is a species rarely known and observed in its natural habitat. The geographical distribution of the species is in general based upon the ones stranded. In the Canary islands, the species is known by several strandings and only recently by sightings in the south-western part of Tenerife island. In April 1997 we attend a stranded female with 4.25 meters length in the island of La Palma. The advanced decomposition state of the specimen didn't allow us to make a detailed post-mortem examination though there was evident the presence of a 1.70 metres length foetus. In this paper we present the stranding characteristic and a relation with the main morphometrics measurements of both whales. Based upon the identification of the stomach contents, we analysed the food habits of the adult specimen.

EFFECT OF DATES ON SEX-RATIO AND MASS AT BIRTH IN CAPE FUR SEAL, (*ARCTOCEPHALUS PUSILLUS PUSILLUS*), IN NAMIBIA

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Birth sex-ratio and mass at birth are important life-history traits for mammals. Cape fur seal (*Arctocephaluspusillus pusillus*) are born between 15th November and 1st January. The daily sex ratio and mass at birth of newborn pups were monitored in Namibia during the pupping season over 7 years (from 1989/90 to 1996/97). During the pupping season 1996/97, we concentrated on an area containing 509 males and 483 females tagged at birth, providing a representative pupping season with numbers of males and females born each day. This provided a good description of the birth phenology of this poorly known species.

Over the 1989 to 1996 period, logistic regression shows that daily sex-ratio is affected by dates ($Chi^2 = 283$, df=1, $p<0.001$), but neither by years ($Chi^2 = 10.3$, df=5, p =0. 07) nor by interaction between years and dates ($Chi^2 = 2.74$, df=5, p =0.74). This means that the logit of the proportion of males is a function of the date for the different years, slope and intercept are similar every year but the date has a very strong effect on males proportion. For the 1996/97 season, the median date of birth are 3rd December for the females and 4th December for the males, whereas the averages are respectively 3rd and 6th December. The birth distributions not being normal ($p<0.001$ for the males,p=0.01 for the females) the difference between the medians is tested using Kolmogorov-Smirnov test (max diff. = 0.108, p =0.006) and the median test (T = 18.7, df=1, $p<0.001$).

Those two methods confirm that males are born later than females. At birth, males are heavier than females. Masses at birth differ from year to year, but there is no relation between mass and date of birth. There is no trend in the mass at birth, neither for males ($R^2 = 0.022$), nor for females ($R^2 = 0.069$). The possible causes to this time lag are different date of conception, different date of implantation and/or different gestation length. The last hypothesis supported by the different masses at birth for males and females.

The absence of a trend in mass at birth shows that if there is a different gestation time, it is in average that it is longer for the males and not only that the first females are born early or last males born late. Further investigations on foetal growth are needed to support this hypothesis.

THE AGE AT SEXUAL MATURITY OF NORTH ATLANTIC MINKE WHALES (*BALAENOPTERA ACUTOROSTRATA*) IN THE PERIOD 1972 - 1979

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The question of whether age at sexual maturity (tm) is density dependent has been addressed in many studies of the Southern minke whale. In this study t_m of North Atlantic minke whales from IWC West Greenland (WG), Central Atlantic (CA) and North Eastern Atlantic (NEA) management areas was examined using three approaches: 1) fitting a linear regression line to the number of ovulations vs. age for each area (t_{mo}); 2) fitting a logistic regression curve to the age vs. proportion of sexually mature individuals (t_{mm} 50%); and 3) calculating the mean t_m for each area from individual t_m's (t_{mi}).

The study was based on 476 pairs of tympanic bulla and ovaries which were sampled as part of the Norwegian minke whale research programme in the period 1972 to 1979. Laminae in the bulla were counted by two to five independent readers, who each read up to five thick etched sections from each whale. The reader's variability was found to increase proportionally with the number of laminae counted. Estimated tm using method 1 (t_{mo}) was: WG: 9.8 years, 95% C.I.(9.73-9.87), CA: 10.1 years, 95% C.I.(9.63-10.57), and NEA: 8.5 years 95% C.I.(8.42-8.58). The observed difference in t_{mo} was significantly greater in WG than NEA and CA than NEA. Estimated t_m using method 2 (t_{mm} 50%) was: WG: 7,4 years, CA: 8.1 years, and NEA: 7.3 years). Estimated t_m using method 3 (t_{mi}) was WG: 2.3 years 95% C.I.(1.4-3.3), CA: 8.3 years 95% C.I.(6.6-10.0), and NEA: 5.7 years 95% C.I.(5.0-6.5).

The estimated t_m using methods 1 and 2 coincides in magnitude and order, whilst method 3 contradicts these results probably because the ageing errors from ageing old individuals carries greater weight in this method. Methods 1 and 2 are therefore preferred as methods for estimating t_m. The difference in tm observed between areas could be a result of changes in population density caused by different exploitation levels in the three areas, and it could indicate that IWC West Greenland, Central Atlantic, and North-eastern Atlantic management areas are representative of biologically separate stocks.

ASPECTS OF THE BIOLOGY OF NORTHEAST PACIFIC PILOT WHALES

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A sample of 74 North Pacific short-finned pilot whales (*Globicephala macrocephalus*), derived mainly from strandings off the coast of California, were examined for sex, age from tooth sections, length, girth, body weight and other morphological characteristics. Biological data for this stock of pilot whales is of importance because its abundance has dropped precipitously during the early 1980s.

The data analyses were confounded by the fact that while skulls and teeth were available for all animals, sex and length were not always recorded, and weight and girth on even fewer occasions. Therefore a potential inter-relationship between skull mandibular and condylo-basal lengths and overall body length was investigated in order to calculate body length. The correlation was high between log skull dimensions but showed less consistency when log body length was included ($r^2 = 0.78$), to the extent that, apart from very young specimens, could not be used routinely for estimating body length with reliability. Therefore, only part of the sample could be used for certain morphometric analyses.

The age distribution showed a modal peak for age class 3 yr, with the oldest age of 46 yr. The decline in year class strength showed an absence or low numbers of animals in the age classes 8-14 yr and again from 17-21 yr. Analogy with other studies suggests that these age groups probably correspond with age close to sexual maturation in females (8-12 yr) and in males (>17 yr).

Similar age class deficiencies have been observed for schools of Faroese long-finned pilot whales and short-finned pilot whales off coastal Japan. Plots of length at age indicated an adult (age >30 yr) mean size of 4.6 m in females and 5.8 m in males. Lengths at age 10 yr correspond with 3.8 m in females and 4.4 m in males. Body weight (W in kg) and length (L in cm) showed close correlation ($r^2 = 0.96$) where $W = 0.0001184L\ 2.6078$. Mean adult lengths corresponded with weights of 1,905 kg and 1,041 kg for males and females respectively.

Generally, the age distribution, age parameters and size were consistent with data for the larger northern form of short-finned pilot whales from Japan.

IS GUT LENGTH AND TRANSIT TIME OF DIGESTA REALLY RELATED TO DIVING HABIT IN SEALS?

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To test the hypothesis of Krockenberger and Bryden (*J. Zool.* (1994) 234: 229-234) that the intestinal length and transit time of digesta in phocids are related to their diving pattern, the relative intestinal length (intestinal length/body length) and internal area, were determined in crabeater (*Lobodon carcinophagus*), Weddell (*Leptonychotes weddellii*), Ross (*Ommatophoca rossi*), leopard (*Hydrurga leptonyx*), harp (*Phoca groenlandica*), ringed (*Phoca hispida*) and hooded (*Cystophora cristata*) seals.

The transit time of digesta was determined in two juvenile harp seals and two juvenile hooded seals by use of X-ray and radio opaque polyethylene rings of 4 mm diameter as marker of the solid phase, and Cr-EDTA as marker of the liquid phase. No significant correlation ($P>0.05$) between the average relative small intestinal length and available data on maximum dive duration for each species was found. But small intestinal internal area was significantly ($P<0.05$) related to body length. This strongly suggests that gut dimension is not related to diving habit, but instead, as is to be expected, to body size.

Preliminary results of gastrointestinal transit time in a non-diving situation indicate a much shorter transit time for the liquid phase than for the solid phase. The time between dosing and first recovery of Cr-EDTA in the faeces was 1 hr, reaching a peak 4.5 hours after dosing. The polyethylene rings, on the other hand, first appeared in the colon after 11-15 hrs, and were sometimes retained in the colon for several hours before defaecation. The effects of diving on digesta passage time is currently under investigation.

EXTRADURAL INTRAVERTEBRAL VENOUS BLOOD FLOW IN DIVING HARP SEALS (*PHOCA GROENLANDICA*)

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Ronald *et al.* (In: *Functional Anatomy of Marine Mammals*, (1977) Academic Press, London) have postulated that the direction of flow in the extradural vein changes from running towards the heart before diving to the opposite during diving. The possible advantage of this would be that the oxygen-depleted venous effluent from the brain would be routed to the posterior parts of the hepatic sinuses and the caval vein and, hence, be prevented from mixing with the more oxygen-rich venous blood in the anterior parts. We have re-examined this hypothesis in the harp seal, by use of modern Doppler flowmetry. A catheter-tip flow probe was introduced through a venous catheter into the extradural vein of two sub-adult harp seals.

Measurements were made before, during and after dives lasting for 5 minutes. Preliminary results show that in 6 of 13 dives blood was flowing towards the head, in three dives, blood was flowing away from the head, while in four dives, flow alternated in both directions. Likewise, during air breathing, when blood flow was much higher, the direction of flow was variable for no obvious reason, aside from the fact that that is to be expected in a system of anastomosing, valveless veins. Thus, our results do not support the hypothesis of Ronald and co-workers (1977) concerning functional changes of extradural venous blood flow during diving in harp seals.

REPRODUCTIVE PARAMETERS OF THE MEDITERRANEAN MONK SEAL: NEW DATA FOR AN OLD SPECIES

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Despite being one of the animals first to be described, the endangered Mediterranean monk seal (*Monachus monachus*) still remains one of the most unknown. The strong decline in its population numbers combined with the inaccessibility of the remaining populations has hampered the study of basic reproductive parameters. However, in the peninsular of cabo blanco (western Sahara), the species can still be found preserving its ancient colonial structure, which has enabled us to gather data which sheds new light on the reproducive parameters and behaviour of the species.

The main population ocupies two reproducive caves, 1.5 km apart. From 1993 to 1997 data was colected in that area by combining direct observations with observation from fixed cameras of the interior of the caves. Births were detected throughout the whole year, although a slight decrease was produced in winter. In concordance, mating was oserved to occur throughout the whole year. The interval between two consecutive births was calculated for seven females to be 375 days and pregnancy was apparently related to the lactation period (c. 100 d) since two females which lost their pups presented short intervals (359 and 362 d). The reproducive stucture of the species is still unknown although the species is characterised by a sexual dimorphism and by a defense of aquatic territories by adult males aginst other males, both at the entrance and surrounding of the caves. A TDR deployed during 51 days to an adult males combined with photo-identification, observation and GPS positioning, evidenced that tenure of aquatic territories extended throughout the whole year and, in some cases, for periods of several years.

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PHYSIOLOGICAL EFFECTS OF SEA WATER DRINKING IN ADULT HARP SEALS

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Behavioural and experimental observations suggest that harp seals (*Phoca groenlandica*) on occasion may drink fresh- or sea water. The present study was undertaken to examine the physiological effects of sea water drinking and how harp seal handle the excess salt load and whether the harp seal is able to gain water from drinking sea water. Adult harp seals (n=3) were fasted for 48 hours and given 1,000 and 1,500 ml of sea water by stomach tube. Blood and urine samples (urinary catheter) were collected for a period of 12 to 20 hours after sea water administration, and analysed for osmolality, Na^+, Cl^-, K^+, Mg^{2+} and urea. The sea water administration had little effect on the level of urine osmolality, but resulted in diuresis and marked increase in urine concentration of Na^+, Cl^- and Mg^{2+}, and hence marked increases in the excretion of these ions. Urine urea concentration decreased after sea water administration.

The seals maintained homeostasis throughout the experiments, as evidenced by only minor changes in the plasma osmolytes. The maximum urine concentration of Na^+ and Cl^- were 484 and 554 mM, respectively, being higher than the concentration of these ions in the sea water, thus indicating a theoretical possibility water gain from sea water drinking. Twelve hours after the sea water administration, only 50% of the water and the ions in the administered sea water had been excreted. However, a similar experiment with 1,000 ml of physiological saline administration, revealed that the harp seal retained all the water and ions of the solution. This suggests that the harp seals were in a state of absolute dehydration in the transition between regular feeding and fasting, and that they retained much of the solutes and the ions of the sea water, and hence needed sea water during fasting

A COMPARISON OF THE CHANGES IN BODY SHAPE AND SIZE IN THE HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) AND BURMEISTER'S PORPOISE (*PHOCOENA SPINIPINNIS*)

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Patterns of growth in marine mammals are influenced by properties which govern thermal regulation in an aquatic habitat. Differences in growth patterns and final body shape/size of related species should reflect differences in thermal regimes. To explore these differences, patterns of growth were examined in harbour porpoises (n =404) and Burmeister's porpoises (n =92) which inhabited waters of 6-19°C and 15-22°C respectively. A principal components analysis of standard measurements produced eigenvector coefficients which reflected growth in relation to overall shape/size.

Additionally, a model was developed to predict the size of the body core (inside the blubber layer) allowing a comparison between growth of external form and the body core. Surface area to volume ratios (sa/v) were calculated from standard measurements, while morphometric measurements of sexually mature individuals were compared between species analyses of covariance.

For both species and sexes, body shape became slimmer as body size increased due to a proportional decrease in external girths. Core girths grew faster than external girths because of a decrease in the relative blubber thickness as body size increased. This effect was greatest in the harbour porpoise where there was an absolute reduction in blubber thickness as length increased. Sa/v decreased as size increased for both species; sa/v at maturity was highest in male harbour porpoises.

Despite a significantly smaller standard length, female harbour porpoises had significantly larger axillary girths (external and core) than female Burmeister's porpoises, while blubber thickness was not significantly different. Core girth was not significantly different between males; external axillary girth was greater in male harbour porpoises due to a significantly thicker blubber layer.

It is apparent that thermal habitat has some influence on body design between the species. The cold habitat of the harbour porpoise has produced wide bodied females with low sa/v and small bodied males with higher sa/v, but thicker blubber. The temperate environment of Burmeister's porpoise has produced longer, thinner bodied individuals with thin blubber abd low sa/v. The extent to which thermal habitat influences body design would require a comparison to warm water congeners, such as the vaquita or the finless porpoise.

AGE-SPECIFIC MORPHOLOGY AND REPRODUCTIVE ACTIVITY OF NORTHERN FUR SEAL MALES

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Data were collected from 280 male northern fur seals on the Bering Islands between 1984-89 during the commercial harvest and several special kills of males. We discovered four phases of spermatogenesis of northern fur seal males: the Golgi phase, Cup phase, Acrosome phase, and Maturation phase.

The principal characteristics of the spermatogenesis of northern fur seals appears to be similar to other mammals. The main feature of northern fur seal spermatogenesis is the formation of many microvilli from the surface of the acrosome, which are necessary to provide nutrients to the nucleus during the fast maturation of the sperm in the late stage of development. There are no holes in the testis of males of 10 days old, the type of tubules being of the first type. Seminiferous tubules of 2-3 year-old males are larger than pup males, whilst the number of tubules of second, third and fourth types also increase. 3-4% of fifth type tubules can be seen in the testis of 4 year-old males that contain mature sperms. Active spermatogenesis was observed in the testis of 5 year-old males.

The high rate of spermatogenesis and maximum rate of hormonal activity of Leydig cells was observed in the testis of 8-9 year-old males. These decreased in the testis of 12-13 year-old males and 14 year-old males especially. The peak of secretor activity was observed in hypophysis of harem 9-10 year-old males. A peak of activity and the process of destruction of the adrenal cortex were found in the adrenals of 8-9 year-old harem males. The maximum diameter of the follicles and a mass of epithelial cells were observed in thyroid glands of 5 year-old males. The decrease in sperm and hormone production was observed in the testis and endocrine glands of older males (12-14 years old).

RINGED SEALS (*PHOCA HISPIDA*) BREEDING IN THE DRIFTING PACK-ICE OF THE BARENTS SEA

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It is usually assumed that ringed seals are the main prey of polar bears. It has been estimated that the population of about 2,000 bears in the Svalbard area needs a population of about half a million ringed seals to be sustained. At the same time the number of ringed seals born annually in the area has been estimated to only about 19,500 based on the assumption that ringed seals only breed in fast-ice areas. Three theories can be put forward to explain the discrepancy between number of bears and number of seals:

1) There is an influx of ringed seals from adjacent fast-ice areas.
2) There is a production of ringed seals in the surrounding pack-ice areas.
3) The polar bears in the area prey on other species than ringed seals.

During a polar bear tagging expedition to the pack-ice of the Barents Sea in spring 1997, we made observations that shed light on the second of the proposed theories.

The expedition was conducted from an icebreaker using an Aerospatial 350-B1 one-engine helicopter. In the period 4th to 6th May, we worked in the middle of the Barents Sea more than 450 km away from the main islands of Svalbard, Franz Josef Land and Novaya Zemlya. The ice in the area consisted of close to compact (7/10-10/10) first-year pack ice with new-frozen ice in between, and is normally drifting in a south-westerly direction with a speed of about 8.6 km/day. Surveys for bears or their tracks were conducted at an altitude of 300 ft and at a speed of 100 knots. When tracks regarded as fresh were observed, these were followed, usually until the bear was found or the tracks were lost. When a kill site was observed, we inspected the site, looking for identifiable remains.

We observed 13 kill sites during 10 hours flying. In all instances, ringed seal lairs had been dug out. In five cases, carcass remains were picked up for further identification. One of these was a carcass with lanugo present. The four others were parts of flippers. Three of these were aged as pups of the year, and one was assumed to be at least one year old. The findings show that there is a production of ringed seals in the pack-ice of the Barents Sea.

ENERGY EXPENDITURE OF SWIMMING BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*)

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Two bottlenose dolphins (176 and 148 kg) were trained between 20th March and 28th May, 1997 in the dolphinarium in Nürnberg Zoo (main basin 15 m in diameter, 3.5 m deep) to perform a variety of activities before surfacing in a respiration chamber linked to O_2 - CO_2 gas analysers. The aim of our investigations was to determine, directly, the energetic costs of a variety of activities without the intermittence of heart rate measurements (as in Williams *et al.*, 1992, *Nature*, 355: 821-2). Via respirometry, we wanted to determine the metabolic rate associated with (1) resting; (2) swimming various distances; (3) swimming at various velocities; and (4) leaping to various heights.

Experiments with the animals were conducted between 28th May and 1st September. During that period, daily activity patterns of the animals were recorded on a two week basis. While preliminary data analysis (dolphin Eva, 176 kg) showed that the oxygen consumption during rest in water (20°C) was 6.9 $ml.kg^{-1}.min^{-1}$, similar to the measurements made by Williams *et al.* (1992) oxygen consumption during swimming at 2.4 $m.s^{-1}$ reached only 9.6 $ml.kg^{-1}.min^{-1}$, or only 64% of the values published previously

GENETICS & EVOLUTION

NEOGENE CETACEAN FAUNA OF THE CARPATHIAN BASIN: A REVIEW

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INTRODUCTION From the last century on, several cetacean fossils have been collected in the territory of Hungary (many localities of which belong to neighbouring countries today). The Miocene has proven to be the richest in fossil cetacean remains. The vast majority of the remains have not been studied, and there has never been a comprehensive study of cetaceans from the Carpathian Basin. We present here the most important findings.

MATERIALS AND METHODS The investigated material belongs to the Geological Institute of Hungary (GIH) and the Hungarian Natural History Museum (HNHM). With few exceptions the fossil remains originate from Miocene deposits. Peaks in the number of cetacean remains as well as in the number of localities can be seen in the Eggenburgian and in the Late Badenian (Table 1). Fossils and localities in their stratigraphical and paleogeographical situation have been evaluated.

RESULTS The Paratethys was formed by the end of the Eocene, ca. 40 m.y. ago. It consisted of three main parts: The Western, Central and Eastern Paratethys (Fig. 1). The Carpathian Mountains and the adjoining Carpathian Basin were tectonically developed in the Central Paratethys. The Neogene cetacean fossils of the Carpathian Basin deposited in the territory of the Central Paratethys 27.5-11.5 m.y. ago. Oligocene - Miocene correlation of the Central Paratethyan stages with the standard time scale is shown in Figure 2.

Egerian - Eggenburgian - Ottnangian age (Fig 3): *Schizodelphis sulcatus* Gervais. A single tooth with crown was found in locality 1 (catalogue number: GIH Ob-3456). The same species has been reported from several localities in Europe e.g. from Vienna and Walbersdorf in Austria (Pia, 1936) and from France (De Muizon, 1988) as well as from three sites in Egypt (Barnes and Mitchell, 1978). Our finding might be a representative of a population living in contact with those represented by the other Early Miocene *Schizodelphis sulcatus* fossils of the Mediterranean.

Patriocetus cf. *ehrlichi* (Van Beneden). The Late Oligocene to Late Miocene family Squalodontidae is of great importance in the early history of odontocetes (Rothausen, 1968). Two teeth of a shark-toothed dolphin originate from Eggenburgian sands (locality 2). The more complete specimen (catalogue number: GIH Ob-2097), a molar tooth most probably from the posterior part of the mandibular bone, is very similar to those found in Early Miocene sandstones of Linz/Austria (Koch, 1904).

"Delphinus" sp. Linnaeus, specimen lost. Two teeth and a caudal vertebra were originally determined as *Delphinus* by Koch (1903) from locality 3. The authors doubt that the systematic position of the remains was determined properly. Both *Orca semseyi* and this small dolphin were found in Eggenburgian nearshore sandy deposits together with shark teeth and molluscs.

Orca semseyi Böckh. There is a fragment of a left upper jaw with four teeth *in situ* which were found in Egerian-Eggenburgian sandstones of locality 4 (catalogue number: GIH Ob-1208). Abel (1905) stated that the fragment belongs to the genus *Physeterula*.

If we accept the view of B^ckh (1899) then *O. semseyi* should be regarded as the oldest killer whale known, since the earliest orcas are reported from the Pliocene of Italy (Bianucci and Landini, 1992). However, the authors support the idea that the fragment represent an early physeterid. Future investigation might clear up its systematic status.

Middle to Late Badenian - ?Sarmatian age (Fig 4):

Mesocetus hungaricus Kadi. The 6.5 m long skeleton is the most important mysticete finding of the Carpathian Basin. The highly fragmentary bones of a young whale were found in Badenian clays of locality 5 in 1899 (original catalogue number: GIH Ob-2081). Many of the bones were reconstructed improperly (Pàpp, 1904).

Heterodelphis leiodontus Papp. The well preserved skeleton from locality 6 (catalogue number: GIH Ob-258) lies in two adjoining blocks of Badenian limestone. The biggest extension of the skeleton is 93 cm (right plate) with the caudal vertebrae and the tip of the rostrum missing. All seven cervical vertebrae are free. On the right plate, there are ten thoracic and five lumbar vertebrae. Breast and pelvic bones are absent. The flipper was long and broad resembling those of recent river dolphins. A partial postcranial skeleton including humerus, radius and ulna of the right flipper have been discovered in Badenian clays of locality 5 (catalogue number: GIH Ob-2307).

"Acrodelphis" letochae Brandt. Altogether three dolphin vertebrae are kept in the collection (catalogue numbers: GIH Ob-257, Ob-3469, Ob-3470, from localities 7, 10) with the label "*Acrodelphis letochae*". The systematic position of the remains is uncertain.

Odontoceti indet. A well preserved dolphin skeleton was found by a private collector in 1993 in locality 8 which has not been described yet (catalogue number: HNHM V.93.2). In addition there are several humeri and other bones which have recently been collected from reworked Pannonian sands in the surrounding area of locality 9. The actual age of the bones is most probably Late Badenian.

SUMMARY The fossil record indicates that cetaceans appeared twice in the Carpathian Basin: first about 20 m.y. ago in the Eggenburgian and later, about 14 m.y. ago in the Badenian. Both periods correspond to transgressive events that allowed marine mammals to enter the Central Paratethys.

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REFERENCES

Abel, O. 1905. Les Odontocetes du Boldérien (Miocène supérieur) d'Anvers. *Mém. Mus. r. Hist. nat. Belg.*, 3: 1-155.

Barnes, L.G. and Mitchell, E. 1978. Cetacea. Pp. 582-602. In *Evolution of African Mammals* (Eds. V.J Maglio. & H.B.S. Cooke). Harvard Univ. Press, Cambridge (Mass.), 641 pp.

Bianucci, G. and Landini, W. 1992. Systematic and biogeographical relationships of some Neogenic Mediterranean groups of marine vertebrates (teleost fishes and odontocete cetaceans). *Paleontologia i Evolucio*, 24-25: 185-197.

Böckh, H. 1899. *Orca semseyi*, eine neue Orca-Art aus dem Unteren Miozän von Salgótarján. *Jb. k. Ung. Geol. Anst.*, 13: 105-110.

Hámor, G. 1995. *Miocene Paleogeographic and Facies Map of the Carpathian Basin I, III.*

Koch, A. 1903. Tarnócz im Komitat Nógrád, als neuer, reicher Fundort fossiler Haifischzähne. *Földt. Közl.*, 33: 139-164.

Koch, A. 1904. Fossile Haifischzähne und Säugetierreste von Felsıesztergály. *Födt. Közl.*, 34: 260-274.

Muizon, Ch. De 1988. Le polyphylétisme des Acrodelphidae, Odontocètes longirostres du Miocène européen. *Bull. Mus. nat., Paris*, 4e sér., 10, section C, no 1: 31-88.

Papp, C. 1904. Kurze Mitteilung über das Skelett des Urwals. *Földt. Közl.*, 34: 284-288.

Pia, J. 1936. Von den Walen der Wiener Miozäns. Kurze Übersicht der Kenntnisse und Fragen. *Mitt. geol. Ges.*, Wien, 29: 357-428.

Rothausen, K. 1968. Die systematische Stellung der europäischen Squalodontidae (Odontoceti, Mamm.). *Paläont. Z.*, 42(1/2): 83-104.

Rothausen, K. 1971. *Cetotheriopsis tobieni* n. sp., deráerste paläogene Bartenwal (Cetotheriidae, Mysticeti, Mamm.) n^rdlich des Tethysraumes. *Abh. hess. L.-Amt Bodenforsch.*, 60: 131-148.

Rögl, F. 1996. Stratigraphic correlation of the Paratethys Oligocene and Miocene. *Mitt. Ges. Geol. Bergbaustud. Österr., Wien*, 41: 65-73.

Rögl, F. and Steininger, F.F. 1983: Vom Zerfall der Tethys zu Mediterran und Paratethys. *Ann. Naturhist. Mus. Wien*, 85/A: 135-163.

Table 1 Number of fossil cetacean remains and localities.

CENTRAL PARATETHYAN MIOCENE STAGE	NR. OF FINDINGS	NR. OF LOCALITIES
Middle to Late Badenian (- Sarmatian?)	89	14
Ottnangian - Karpatian - Early Badenian	2	2
Eggenburgian	9	4
Egerian - Eggenburgian	3	2
Unknown age	11	9
Total	114	31

Fig. 1 The Paratethys in the Neogene of Europe. (After R^gl and Steininger, 1983).
W - Western Paratethys, C - Central Paratethys, E - Eastern Paratethys.

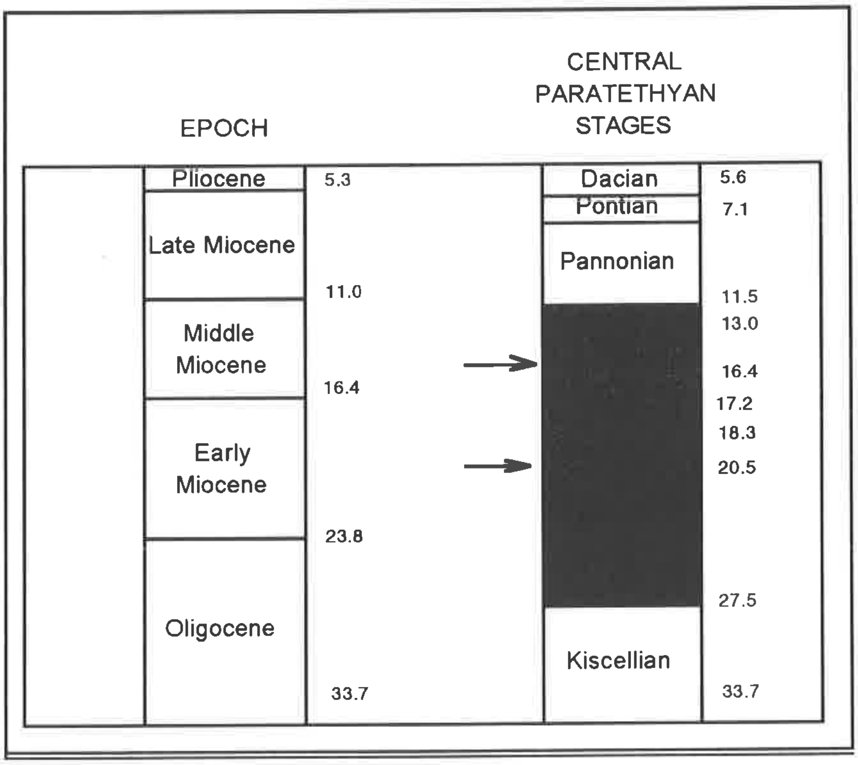

Fig. 2 Oligocene - Miocene correlation of Central Paratethyan stages to the standard time scale. (After Rögl, 1996.) Arrows indicate the main transgressive events that reached the Central Paratethys.
Periods with cetacean findings in the Carpathian Basin are dotted

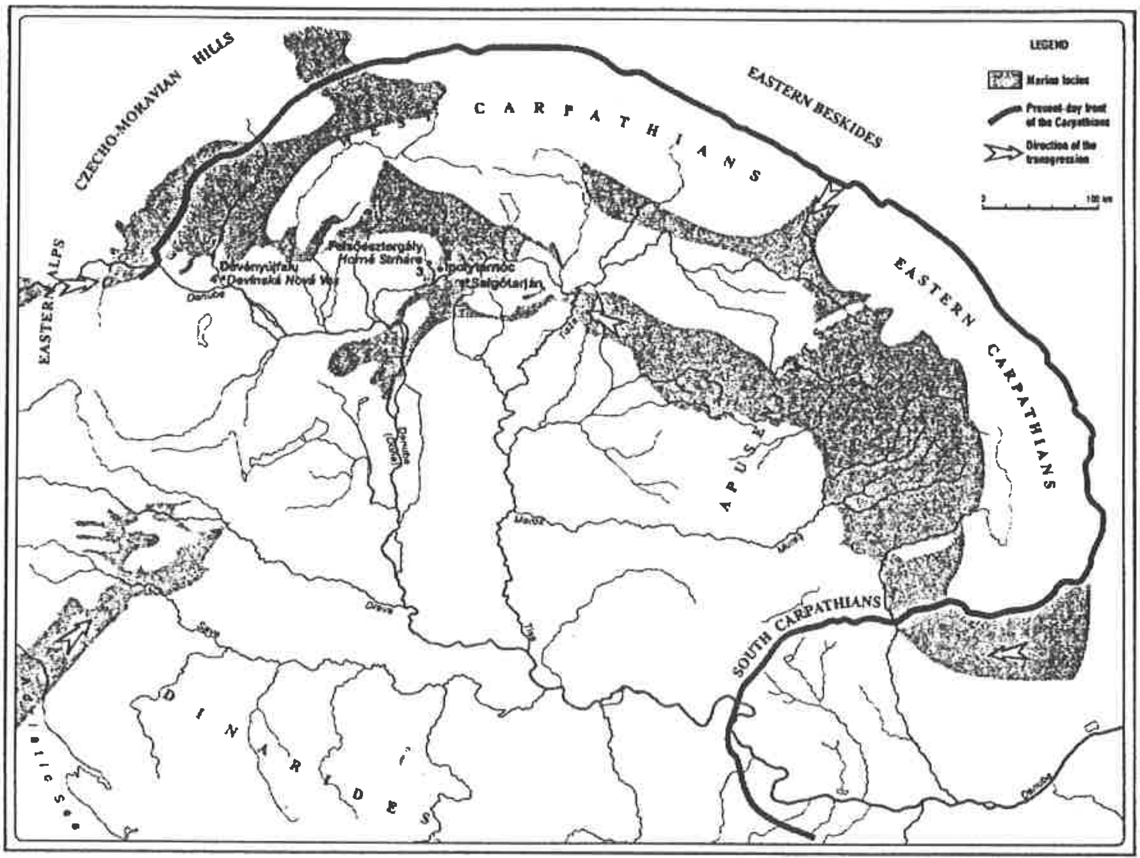

Fig. 3 The Carpathian Basin in the Early Miocene and localities of cetacean fossils of Egerian–Eggenburgian age. (After Hámor, 1995) *(See text for further explanation.)*

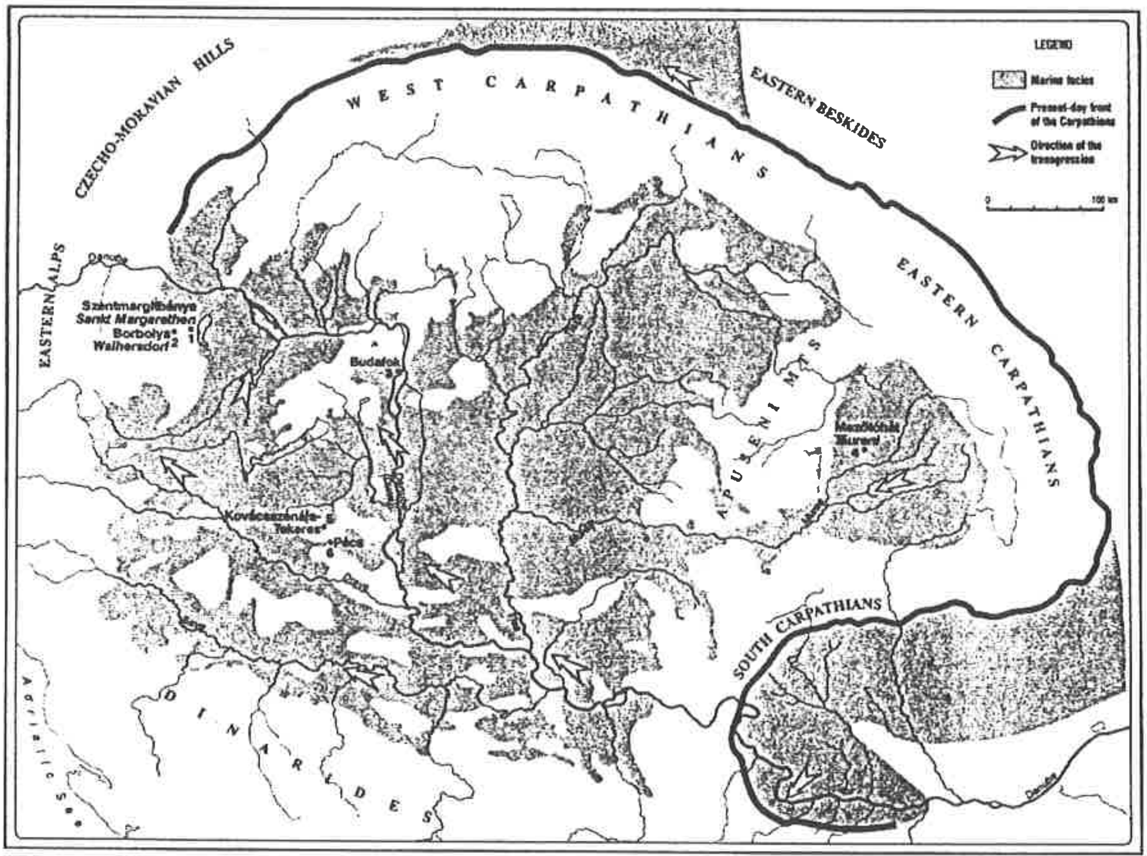

Fig. 4 Map of the Carpathian Basin in the Late Miocene showing localities with cetacean fossils of Late Badenian–Sarmatian–Pannonian age. (After Hámor, 1995) *(See text for further explanation .)*

GENETIC ANALYSIS OF THE NORTH ATLANTIC FIN WHALE: INSIGHTS INTO MIGRATION PATTERNS

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Most mysticetes migrate between feeding and breeding areas. However, migration routes and the location of breeding grounds for North Atlantic fin whales remain unknown. To date, two different and opposing models of segregation on feeding and breeding grounds have been suggested: either a single panmictic population which segregates on summer feeding grounds (as is found for humpback whales), or separate segregated populations which may share common feeding grounds.

This study, based upon the analysis of mitochondrial (mt) and nuclear loci in 407 fin whale skin samples, proposes a third model: segregation on the feeding as well as breeding grounds with limited amount of gene flow between adjacent populations. Furthermore, it is suggested that fin whales in the north atlantic are separate from those inhabiting the mediterranean sea. A higher level of structure was detected in the mt locus relative to the nuclear loci, a difference most likely due to the effective population sizes of the two genomes. The level and distribution of the variation at the mtDNA loci indicates recent population expansion in the western North Atlantic.

EVOLUTION OF GENETIC DIVERSITY AT THE MHC, DQB LOCUS IN PINNIPED SPECIES

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Genes in the human class II MHC at the DR, DQ and DP loci encode alpha and beta glycopeptide chains. These form cell surface heterodimers on antigen presenting cells which bind processed antigen peptide fragments. In many species these loci are highly polymorphic, especially in the second exon of the beta genes, and the variation is thought to be maintained by natural selection through heterozygote advantage or frequency dependent selection. However, it has been suggested that the pathogen environment of marine mammals may provide a diminished selective pressure for maintaining MHC polymorphism, due to a relatively low prevalence of infectious disease in the marine environment.

We investigated DNA sequence variation at the putative antigen recognition site of the Class II MHC, DQB locus in six pinniped species, including two congeneric phocid and four congeneric otariid seal species. Polymorphism in several species was high and comparable to that seen in human populations, while one phocid, the northern elephant seal (*Mirounga angustirostris*), has been through a severe population bottleneck and exhibited much less variation at this locus.

Phylogenetic comparisons suggested the maintenance of alleles over long periods of evolutionary time, and a comparison of sequence patterns suggested that variation had been maintained by balancing selection, and that some variation had been generated through recombinational events, primarily within genera.

These results suggest a similar pattern of evolution of immune system genes in pinniped as in terrestrial mammal species. They are not consistent with the theory that marine mammal species should show diminished levels of variation at these loci.

POST-GLACIAL ORIGIN AND EXPANSION OF ARCTIC AND TEMPERATE CETACEAN POPULATIONS IN THE NORTH ATLANTIC

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Marine populations of cetaceans in the North Atlantic Ocean are characterised by relatively little of phylogeographic structure and low levels of divergence among populations. The lack of structure has in general been attributed to wide ranges of movement suggested by the extensive seasonal migrations recorded in some cetacean species, thus presumably resulting in high rates of exchange among populations. However, most populations studied to date spend all or part of the year in arctic and temperate waters, areas that were inaccessible to cetaceans during the most recent glaciations.

Based upon the analysis of more than 3,700 (mt) mitochondrial control region nucleotide sequences from six different cetacean species (beluga, blue whale, fin whale, humpback whale, minke whale and narwhal), we propose a post-glacial origin and thus recent divergence of temperate and arctic populations of beluga, fin whale, minke whale and narwhals followed by a rapid increase in abundance. The present more southern located populations of fin whales, as well as the long-range migrants, i.e., the humpback and the blue whales, appear not to have undergone such expansions, most likely because these populations were founded prior to the retreat of the ice.

The proposed hypothesis is consistent with all genetic data presented so far, and readily explains the low levels of divergence, the modest degrees of variation in multiple species, and closely related intra-specific mt nucleotide sequences observed within arctic and temperate populations. However, the existence of significant levels of heterogeneity among some populations in these areas which thus have been generated during the short time span since the recent glaciations argues that cetaceans have much more limited ranges of movements, excepting the seasonal migrations, than previously thought. This observation is in addition supported by behavioural, telemetry and genetic studies which have documented predictable site-fidelity to specific summer and winter areas in numerous species despite extensive seasonal migrations.

GENETIC POPULATION STRUCTURE OF SOME GREY SEAL BREEDING COLONIES FROM AROUND THE UK, NORWAY, AND THE BALTIC

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Approximately 40% of the total world population of grey seals *Halichoerus grypus* inhabit the seas around the UK, mainly around Scotland. It has been found, by the use of satellite tracking techniques, that they are capable of travelling journeys of hundreds of kilometres. However, observations at several breeding sites over a number of years have shown that adult animals show a high fidelity to a given site by returning annually to breed. It is assumed that pups, when they themselves are mature, tend to return to their birth sites to breed. Thus it would be expected that genetic markers such as mitochondrial DNA (mtDNA) which is inherited maternally would show differentiation among breeding sites.

Blood or skin biopsy samples were obtained from over 200 seal pups or mothers from breeding colonies in the UK and other European sites namely, England (Cornwall, Scillies, Donna Nook), Wales (Pembroke), Scotland (Isle of May, North Rona, Faray, Eriboll, Helmsdale), Norway (Trondheim area) and Sweden (Baltic coast). Following DNA extraction about 500 bp of the control region of mtDNA (from the Pro-tRNA end) was amplified by the polymerase chain reaction (PCR). 300 bases of the PCR product from all animals were directly sequenced using dideoxy sequencing methods. Genetic relatedness between and among populations was examined using the computer programmes AMOVA (PhiST statistics) and ARLEQUIN (conventional FST). The results show that many of the genetic distances between the possible pairwise inter-population comparisons are statistically significantly different, providing further evidence that grey seals are philopatric.

PATHOLOGY & MEDICINE

EVIDENCE OF MORBILLIVIRAL DISEASE IN BLACK SEA COMMON DOLPHINS

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INTRODUCTION In the third quarter of 1994, a peak of Black Sea common dolphin (*Delphinus delphis*) strandings was reported on the coast of Crimean peninsula (Birkun *et al.*, 1996). More common dolphins stranded in this quarter than in any other quarter since systematic recording of cetacean strandings was started in that area in 1989 (Fig. 1). To try to determine the cause of the common dolphin die-off in the Black Sea, multidisciplinary laboratory examinations were carried out on two of the 47 stranded dolphins recorded. Although it was not possible to isolate a virus, the immunohistochemical, histological, and electron microscopical findings were consistent with morbilliviral disease, which was confirmed also by the detection of morbillivirus RNA. This is the first time that morbilliviral disease has been diagnosed as a cause of death in common dolphins wherever they are inhabiting, and in cetaceans of Black Sea region.

MATERIALS AND METHODS Clinical examination was carried out on six of the 47 stranded dolphins. Pathological, immunohistochemical, virological, and toxicological examinations were carried out on tissues from two animals (male and female) beached near Yalta, South Crimea. Routine haematological analysis was carried out on a blood sample collected 8.5 hr before death from one of these. Samples for histological, immunohistochemical, and electron microscopical examination were fixed in 10 per cent formalin. Samples for virus isolation procedures, antigen capture, organochlorine and trace metal analysis were frozen at -18C until use. Both formalin-fixed and frozen tissues were used for morbillivirus RNA detection by the reverse transcriptase polymerase chain reaction (RT-PCR).

Immunohistochemical staining was carried out on paraffin-embedded tissue sections, using an avidin-biotin-complex immunoperoxidase method. A rabbit polyclonal antiserum to measles virus was used as the primary antibody. Positive control sections from the brain of a canine distemper virus-infected dog were tested concurrently. For needs of virus isolation, a 10 per cent suspension of spleen, liver and lung from dolphins was prepared and incubated with Vero and seal kidney cell lines. Lung homogenates were incubated with dolphin lymphocytes. During an incubation period of seven days, these cultures were monitored daily for cytopathic changes. It was attempted also to detect morbillivirus antigen in the above organ suspensions by use of an antigen capture ELISA and RT-PCR.

The concentrations of PCBs, heptachlorepoxide, aldrin, and o,p'-DDE were measured in the lipid fraction of samples of liver, kidney, muscle and blubber. Polar lipids were extracted with a hexane-acetone mixture (9:1 v/v) for 10 hr at 75C in a Soxhlet apparatus; the extracted lipids were weighed after evaporation. Organochlorine concentrations were determined by liquid gas chromatography with a capillary column and electron capture detector. The concentration of PCBs was expressed as the sum of 11 congeners: #28, #31, #52, #101, #118, #138, #153, #156, #170, #180, and #194. The detection limit per 1 g sample was 1 to 3 ng/g dry weight (dw) for individual PCB congeners, 15 ng/g dw for PCB, and 0.5 ng/g dw for the other organoclorines.

The concentrations of mercury (organic and total), zinc, lead, nickel, cadmium, iron, chromium, copper, and selenium were determined in samples of heart, lung, liver, testis, ovary, mesenteric lymph node, kidney, brain, and muscle. The concentration of organic mercury was determined by gas liquid chromatography with an electron capture detector. The concentrations of total mercury and other trace metals were determined by atomic absorption spectrophotometry. The detection limit per 1 g sample was 15 ng/g dw for total mercury, 8 ng/g dw for organic mercury, 0.01 g/g dw for copper, 0.33 g/g dw for zinc, and 0.22 g/g dw for cadmium.

RESULTS Between July and September 1994, 26 common dolphins were reported stranded along the coast of the Crimean peninsula; in addition, 21 common dolphins were reported stranded from other parts of the Black Sea coast. No information on cetacean strandings was available from Turkey and Georgia. Nineteen of the 26 dolphins (73%) stranded on the Crimean coast were found alive. Five of these died within 1 hr of stranding. Five animals were transported to open sea and released. Their fate is unknown. Three dolphins were transported to nearby rehabilitation centres, but died within 3 to 72 hr of arrival. The fate of the remaining six is unknown.

Clinical signs included lethargy, weakness, decreased mobility, unco-ordinated movements, and floating at the water's surface. One dolphin had tachycardia (74 to 156 beats/min) and two dolphins had tachypnoe (1.5 to 3 respirations/min). The haematological data from one animal were: 158 g Hb/l.; 5.9×10^{12} erythrocytes/l; 4.1×10^{9} leukocytes/l; 61% mature neutrophils; 30% band neutrophils; 1% lymphocytes; 8% monocytes; and 0% eosinophils.

The two dolphins that were examined by **necropsy** were emaciated, with visible atrophy of the back muscles. The abdominal skin of the male had a few irregularly-shaped plaques resembling those caused by *Candida sp.* infection. Both cases had a necrotic stomatitis, with large irregularly-shaped yellow to yellow-gray areas on the oral mucosa, which easily sloughed. The male had a necrotic gastro-enteritis, characterised by well-demarcated round superficial gray foci, 0.5 to 2 cm in diameter, in the mucosa of the cardiac and pyloric stomach, and of the first part of the intestine. In the female, similar lesions were found in the middle part of the intestine for a length of about 2 m. The male had ascites, with about 0.5 l. of clear serous fluid in the abdominal cavity. The spleen of both animals was atrophied, and had thickened scarred capsule. The mediastinal and mesenteric lymph nodes in both cases were oedematous and had multiple haemorrhages. Haemorrhages were also present in the adrenal cortex of the male. This dolphin had also an encapsulated bean-shaped tumour on the surface of the right testis, connected to the testis capsule by a thin stalk.

According to **histological examination**, both dolphins had broncho-interstitial pneumonia. The lumina of alveoli and bronchioles contained many macrophages, some neutrophils, and very few multinucleate syncitial cells. Acidophilic inclusion bodies were detected in the nuclei of few macrophages. The epithelium of some alveoli and bronchioles was missing; other alveoli had a lining of cuboidal cells, characteristic of type II epithelial cell hyperplasia. Many alveolar walls were thickened by mononuclear cells, neutrophils, and oedema fluid. A suppurative bronchopneumonia, characterised by many closely-packed neutrophils in distended alveoli and bronchioles, was also present in male dolphin. Mineral grains and Gram-positive and -negative rod-shaped bacteria were present in some alveoli of the female.

Both cases had severe lymphoid depletion of the spleen. The male had multiple subcapsular siderotic nodules, consisting of multifocal depositions of haemosiderin, surrounded by a thick layer of fibroblasts and few multinucleate syncitial cells with the nuclei contained acidophilic inclusion bodies. Both animals had multiple haemorrhages, oedema and severe lymphoid depletion of the mesenteric lymph nodes. In addition, the mesenteric lymph node of the male had sinus histiocytosis, few multinucleate giant cells in the medulla, and a suppurative lymphadenitis, characterised by infiltration with neutrophils, eosinophils, and macrophages.

The male had lesions in the cerebrum, characterised by degeneration and necrosis of neurons, gliosis, diffuse oedema, and multifocal non-suppurative meningitis, with small foci of mononuclear cells in the pia mater. This dolphin had also a chronic pericholangitis and bile duct hyperplasia. Some bile ducts had necrotic epithelial cells, and their lumina were distended by necrotic cells. Rarely, intranuclear inclusion bodies were detected in the bile duct epithelium. The surrounding connective tissue was oedematous and infiltrated by neutrophils, fibroblasts, and mononuclear cells, including lymphocytes. There was moderate lipidosis of the hepatocytes. The kidney of this case had a focus of lymphocytes and few multinucleate syncitial cells in the interstitium of the cortex. The testicular tumour was a fibroma, consisting of sheets of fibroblasts with variable amounts of fibrous stroma in between cells. In contrast to normal fibroblasts, many fibroblasts in the tumour had more acidophilic cytoplasm, multiple nuclei, and larger nuclei, often with acidophilic inclusion bodies. There were multiple foci of lymphocytes and very few multinucleate syncitial cells.

The stomach of the female had multifocal degeneration and necrosis of the superficial epithelium, with congestion and neutrophils in the subjacent lamina propria. Lesions were limited to mucus-secreting cells, most of which had one to two acidophilic inclusion bodies in the nucleus and finely granular acidophilic cytoplasm. The necrotic foci in the intestine of the male had no villi, and the underlying lamina propria was infiltrated by few lymphocytes, macrophages, and rare multinucleate syncitial cells.

Specific **immunohistochemical staining** was found in lung, cerebrum, stomach, intestine, liver, kidney, adrenal gland, spleen, mesenteric lymph node, testis, and testicular fibroma. It consisted of dark brown staining of intracytoplasmic and intranuclear inclusion bodies, superimposed on diffuse light brown staining of cytoplasm. The number of inclusion bodies in cytoplasm and nucleus varied. The highest prevalence of intranuclear inclusion bodies was seen in mucus-secreting cells of the stomach and fibroblasts of the testicular fibroma. Cytoplasm of multinucleate syncitial cells and lymphocytes generally had the darkest specific staining. In the lungs, macrophages and many epithelial cells of alveoli and bronchioles with predominantly mononuclear exudate had specific staining. In the cerebrum, astrocytes and degenerate and necrotic neurons in the gray matter, and many lymphocytes and fibroblasts in inflammatory foci of the pia mater had specific staining. In the stomach, specific staining was seen predominantly in mucus-secreting cells; specific staining was limited to those cells that had eosinophilic cytoplasm and intranuclear inclusion bodies. Few chief cells and parietal cells, subjacent to positive mucus-secreting cells, also had specific staining

In the intestine, multinucleate cells and few lymphocytes and fibroblasts in the lamina propria had specific staining. In the liver, specific staining was limited to bile duct epithelium cells. In the kidney, one focus of multinucleate cells and lymphocytes and tubular epithelial cells of a few adjacent tubules, probably proximal convoluted tubules, had specific staining. In the adrenal gland, very few mononuclear cells in the cortex and medulla had specific staining. In the spleen, the fibroblasts and multinucleate syncitial cells around siderotic nodules and multiple foci of lymphocytes had specific staining. In the mesenteric lymph node, lymphocytes, histiocytes, macrophages, multinucleate syncitial cells, and few fibroblasts had specific staining. In the testis, single spermatogonia in one seminiferous tubule, and few cells, possibly Leydig cells, in the interstitium, had positive staining. In the fibroma of the testis, fibroblasts, lymphocytes, and multinucleate syncitial cells had specific staining.

As a result of **electron microscopical study**, regularly-shaped particles about 22 nm in diameter were found in nuclei of stomach epithelial cells that stained positive for morbillivirus antigen.

Results of **virological examination**.Virus was not isolated, morbillivirus antigen was not detected by antigen capture ELISA, nor was morbillivirus RNA detected by RT-PCR in any of frozen tissues examined. The presence of morbillivirus RNA was detected in formalin-fixed paraffin-embedded samples of testicular fibroma (direct RT-PCR) and stomach wall (nested RT-PCR); other tissues gave negative results. Identity of RT-PCR products was confirmed by hybridisation with an oligoprobe.

The **trace metal and organochlorine concentrations** were comparable with the published data in cetaceans from the North Sea, North Atlantic Ocean, and Baltic Sea except for the o,p'-DDE concentrations. The male had 225.6 g/g dw o,p'-DDE in the blubber, which is much more higher than the mean level found in common dolphins from other regions, suggesting that there is still contamination with DDT, of which o,p'-DDE is a metabolite, in the Black Sea.

DISCUSSION AND CONCLUSIONS The lesions and distribution of specific staining for morbillivirus antigen in these common dolphins is similar to those found in other cetacean species with morbilliviral disease (Kennedy *et al.*, 1992; Domingo *et al.*, 1992; Duignan *et al.*, 1992; Lipscomb *et al.*, 1994). Specific staining for morbilliviral antigen and the detection of morbilliviral RNA in the diseased tissues confirms that a morbillivirus was the primary cause of the most lesions, and suggests that a morbillivirus infection could be a cause of the increased stranding rate of Black Sea common dolphins in the third quarter of 1994.

Previous studies provided evidence that morbilliviral disease occurs in common dolphins. A common dolphin stranded on the coast of Britain in the autumn of 1988 had histologic lesions consistent with morbilliviral infection (Baker, 1992), but lung samples from this animal were negative for morbilliviral antigen by immunoperoxidase test using a monoclonal antibody to the haemagglutinin protein of phocine distemper virus as the primary antibody (S. Kennedy, *pers. comm.*). Neutralising antibodies to porpoise morbillivirus and dolphin morbillivirus were found in 10 of 22 common dolphin sera from the western Atlantic, collected between 1980 and 1994 (Duignan *et al.*, 1995). Those findings suggest that infections with these or closely related morbilliviruses are widespread in common dolphins.

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REFERENCES

Baker, J.R. 1992. Causes of mortality and parasites and incidental lesions in dolphins and whales from British waters. *Vet. Rec.*, 130: 569- 572.

Birkun, A., Jr., Krivokhizhin, S. and Stanenis, A. 1996. The Black Sea common dolphin epizootic in 1994. Pp. 266-268. In *European Research on Cetaceans* - 9: Proc. 9th Ann. Conf. ECS, Lugano, 9-11 February, 1995 (Ed. P.G.H. Evans). European Cetaceans Society, Kiel, Germany. 306pp.

Domingo M., Visa J., Pumarola M., Marco A.J., Ferrer L., Rabanal R. and Kennedy S. 1992. Pathologic and immunocytochemical studies of morbillivirus infection in striped dolphins (*Stenella coeruleoalba*). *Vet. Pathol.*, 29: 1-10.

Duignan P.J., Geraci J.R., Raga J.A. and Calzada N. 1992. Pathology of morbillivirus infection in striped dolphins (*Stenella coeruleoalba*) from Valencia and Murcia, Spain. *Can. J. Vet. Res.*, 56: 242-8.

Duignan P.J., House C., Geraci J.R., Duffy N., Rima B.K., Walsh M.T., Early G., St.Aubin D.J., Sadove S., Koopman H. and Rhinehart H. 1995. Morbillivirus infection in cetaceans of the western Atlantic. *Vet. Microbiology*, 44: 241-9.

Kennedy S., Kuiken T., Ross H.M., McAliskey M., Moffett D., McNiven C.M. and Carole M. 1992. Morbillivirus infection in two common porpoises (*Phocoena phocoena*) from the coasts of England and Scotland. *Vet. Rec.*, 131: 286-90.

Lipscomb T.P., Schulman F.Y., Moffett D. and Kennedy S. 1994. Morbillivirus disease in Atlantic bottlenose dolphins (*Tursiops truncatus*) from the 1987-1988 epizootic. *J. Wildl. Dis.*, 30: 567-71.

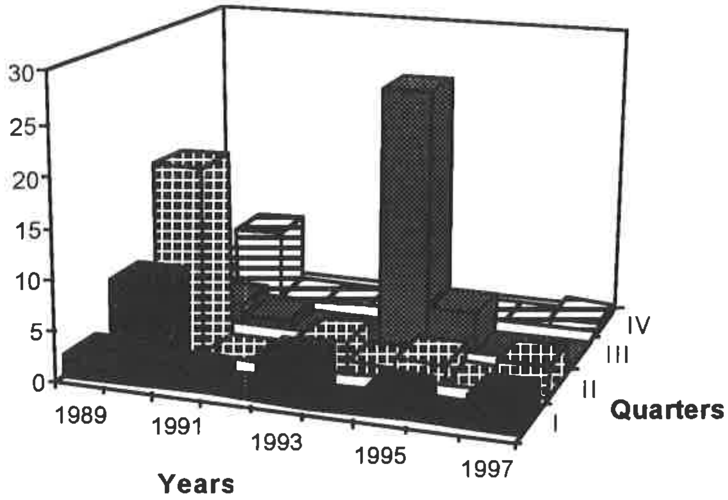

Fig.1. Quarterly rate of common dolphin strandings on the Crimean coast

ORGANOCHLORINE COMPOUND LEVELS IN COMMON DOLPHINS FROM THE ATLANTIC AND MEDITERRANEAN WATERS OFF SPAIN

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INTRODUCTION The objectives of the present study were to assess the composition and level of HCB, DDTs, and PCBs concentrations present in the tissues of common dolphins (*Delphinus delphis*) from the western Mediterranean and the eastern North Atlantic and investigate possible differences between the two populations.

METHODS Samples from the western Mediterranean were obtained from 23 dolphins entangled in fishing nets in the south-western Mediterranean in 1992 and 1993. Samples from the eastern North Atlantic were collected using a biopsy dart, as designed by Aguilar and Nadal (1984), from 54 bow-riding common dolphins off the north-western Atlantic coast of Spain in 1995.

Organochlorine analysis was performed as follows. Lipids were extracted from blubber using hexane as a solvent in a Soxhlet apparatus, and tissue lipid content was determined gravimetrically. Determination of organochlorine compounds (OCs) using capilar GC-ECS was carried out following procedures described by Borrell *et al.* (1997). Congeners were quantified by their weight percentage in Aroclor 1260 (Safe *et al.*, 1987) using a standard of Aroclor 1260. All congeners were quantified individually and summed to obtain total PCB (tPCB). Since OCs are highly apolar compounds, concentrations in this paper are expressed in parts per million (mg/kg) calculated on the basis of the weight of the extracted lipids (lipid basis).

Gender of samples obtained through biopsies was determined using a technique based upon amplification by PCR of ZFX and ZFY, two specific sex chromosomes DNA regions which present slight differences in their nucleotide sequence (Bérubé and Palsboll, 1996). Individuals were considered mature when their body length was longer than 1.8m.

Statistical calculations were carried out using the SPSS-X statistical package. Data were tested for normality with a Kolmogorov-Smirnov test of goodness of fit. Because some data sets did not distribute normally, differences between groups were examined using non-parametric tests (Kruskal-Wallis and non-parametric multiple comparisons with unequal sample size at $p<0.05$).

RESULTS AND DISCUSSION

Concentrations

Table 1 details the lipid content and concentrations of tPCB and DDTs (mg/Kg lipid) of the different groups split by sex, sexual maturity (when known) and locality.

Intrapopulation variations

Atlantic. Males presented significantly higher concentrations than females for all pollutants analysed, except for HCB and opDDE (Fig. 1). The ratios ppDDE/tDDT and tDDT/PCB were also statistically different between the two sexes. This pattern of differences in pollutant concentrations corresponds to the usual pattern observed in most marine mammals and is due to the pollutant transfer from mother to calves during pregnancy and lactation. None of the ratios **Individual Congener/tPCB** presented any difference, which indicates that PCB profiles are similar in all the individuals.

Mediterranean No significant differences between the two sexes were detected, although this results is likely to be the consequence of the biased representation of age-classes in the sample set. Thus, of the 12 females sampled, only two were mature, and of the 11 males only three were mature. Juvenile specimens usually do not present distinguishable levels between sexes. It is noticeable that, in spite of the reduced number of mature male samples, concentrations in adult males were significantly higher than in immature males, while those from immature and mature females were statistically indistinguishable.

Interpopulation variation

Because of the reduced sample of mature specimens obtained from the western Mediterranean, and the lack of precise information on the age composition of the biopsied dolphins from the Atlantic, it was not possible to take intrapopulation variation into account when comparing the two geographical areas, so the comparison had to be made between the two complete, uncorrected, sample sets.

Mediterranean specimens presented significantly higher levels of all DDT forms than their conspecifics from the Atlantic, while the concentrations of tPCB and of the majority of specific congeners were similar in both areas (Fig. 2).

On the other hand, the relative frequency of the different PCB congeners in relation to the total PCB load were quite different in the two areas (Fig. 3), which suggests that the source of PCB pollution is different or that the time scale when the input of PCBs has occurred is dissimilar, or both. Whatever is the case, it appears clear that the two populations feed on different areas and do not intermingle, at least on a short or medium time scale. Thus, the difference detected both in levels of pollutants and their ratios between the two populations can be used to discriminate home ranges.

REFERENCES

Aguilar, A. and Nadal, J. 1984. Obtención de biopsias hipodérmicas de cetáceos en libertad. *Investigación Pesquera*, 48(1): 23-29.

Bérubé, M. and Palsboll, P. 1996. Identification of sex in cetaceans by multiplexing with three ZFX and ZFY specific primers. *Molecular Ecology*, 5: 283-287.

Borrell, A., Block, D., and Desportes, G. 1995. Age trends and reproductive transfer of organochlorine compounds in Long-finned pilot whales from the Faroe Islands. *Environmental Pollution*, 88: 283-292.

Safe, S., Safe, L., and Mullin, M. 1987. Polychlorinated biphenyls: Environment Ocurrence and Analysis. Pp. 1-13. In: *Polychlorinated biphenyls (PCBs). Mammalian and environmental Toxicology.* (Ed. S.Safe). Environmental Toxin Series Vol 1.

Table 1: Concentration (ppm, lipid basis) of organochlorine compounds in the blubber of Atlantic and Mediterranean common dolphins split by sex and reproductive category (n.d.=not determined).

	MEDITERRANEAN				*ATLANTIC*	
	Males		Females		Males	Females
	immature	mature	immature	mature		
n	8	3	10	2	33	18
HCB	n.d.	n.d.	n.d.	n.d.	0,36 ± 0,30	0,33 ± 0,33
op DDE	n.d.	n.d.	n.d.	n.d.	0,32 ± 0,30	0,23 ± 0,27
pp DDE	12,96 ± 4,55	95,07 ± 55,57	32,05 ± 47,42	13,61 ± 16,27	5,83 ± 3,13	2,67 ± 1,87
op DDT	1,52 ± 0,75	8,54 ± 5,16	2,94 ± 3,55	1,29 ± 1,56	0,72 ± 0,30	0,46 ± 0,29
pp TDE	1,94 ± 0,86	4,70 ± 1,79	3,21 ± 3,66	0,96 ± 1,00	1,29 ± 0,40	0,96 ± 0,70
pp DDT	2,85 ± 1,84	10,38 ± 5,20	4,13 ± 4,42	1,52 ± 1,65	1,35± 0,55	0,87 ± 0,64
tDDT	19,27 ± 7,02	18,68 ± 67,07	42,33 ± 57,83	17,36 ± 20,48	9,51 ± 4,23	5,12 ± 3,22
PCBs	20,82 ± 8,30	82,61 ± 42,49	38,28 ± 43,35	22,26 ± 23,81	38,27 ± 19,19	24,20 ± 17,97

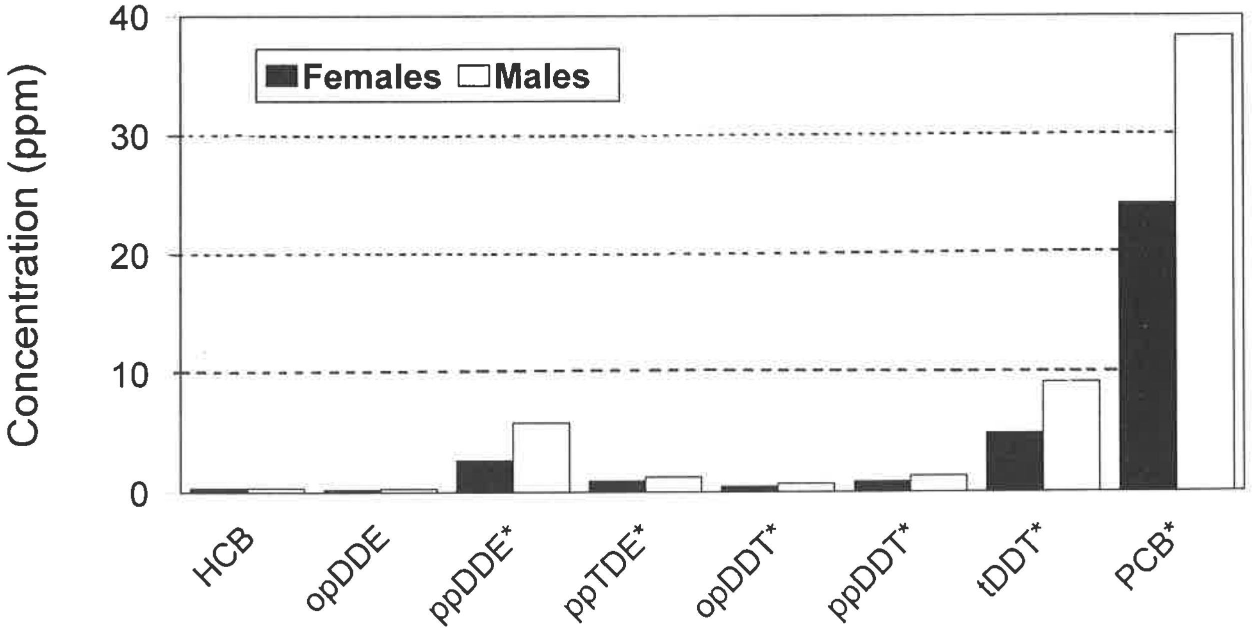

Fig.1. Mean levels of HCB, DDT's and PCB from Atlantic males and females.

* statistically different ($p<0.05$)

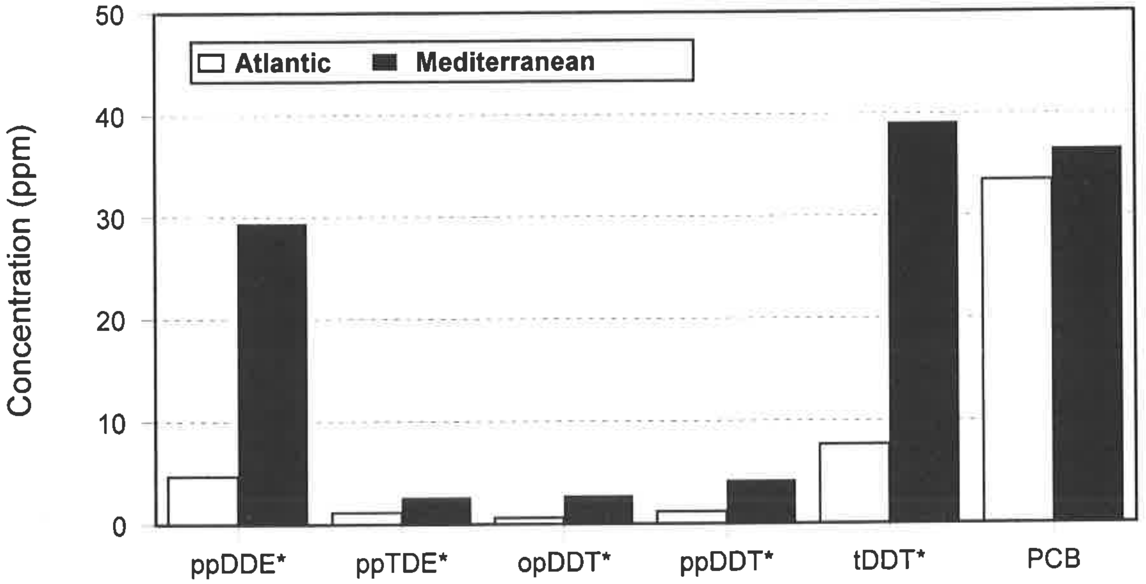

Fig. 2. Mean levels of DDTs and PCB from Atlantic and Mediterranean dolphins

* statistically different ($p<0.05$)

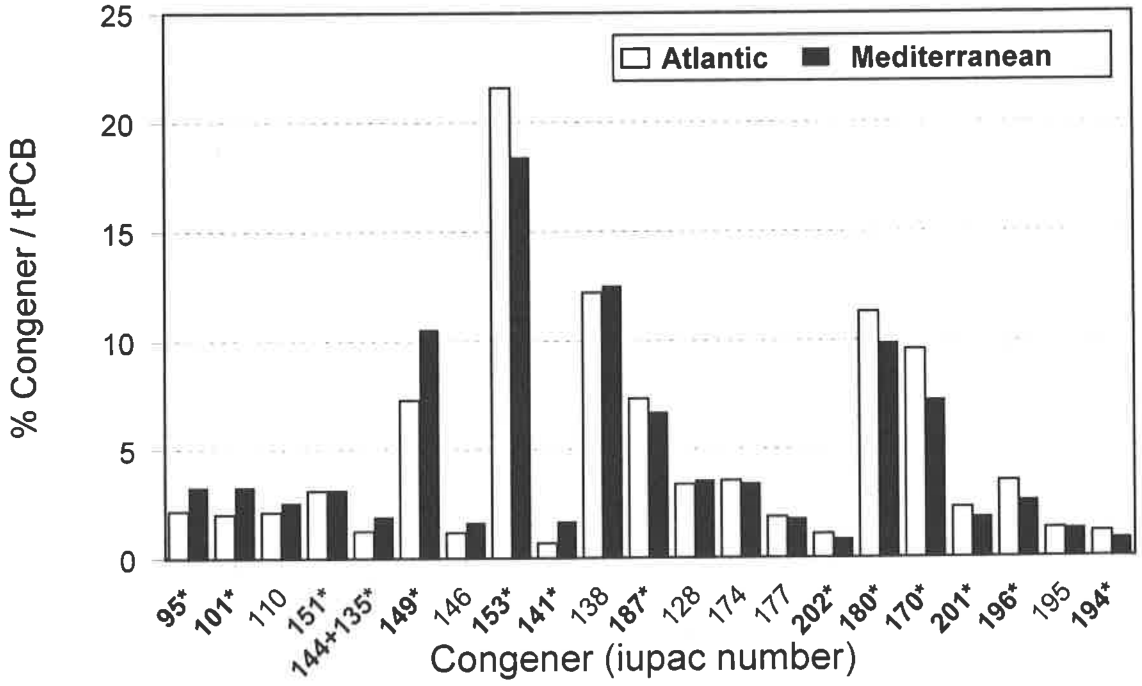

Fig. 3. Mean percentage of each PCB congener in relation to total PCB.

* statistically different ($p<0.05$)

A RARE, ATYPICAL MASS STRANDING OF CUVIER'S BEAKED WHALES: CAUSE AND IMPLICATIONS FOR THE SPECIES' BIOLOGY

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Cuvier's beaked whale (*Ziphius cavirostris*) seems to be abundant in the East Ionian Sea (Mediterranean Sea), as indicated by strandings and sightings, recorded from 1992 to 1997 (Politi *et al.*, 1994; Frantzis, 1997; Pulcini, 1997; Frantzis, unpubl. data). This species is a deep diving, pelagic cetacean, that rarely mass strands (Heyning, 1989). Worlwide, only seven strandings of more than four individuals have been recorded since 1963. On these occasions, the number of stranded individuals were 5, 6, 6, 10, 12, 15, and 19 respectively (Tortonese, 1963; Erdman et al., 1973; Robinson et al., 1983; Miyazaki, 1989; Simmonds & Lopez-Jurado, 1991). In the specific area of the Kyparissiakos Gulf, the average number of individual whales stranded per half-year is 0.7 (sd=0.9, n=11), with the exception of a mass stranding that occured on 12th-13th May 1996 (Fig.1).

From the morning of 12th May until the afternoon of 13th May, we recorded 12 Cuvier's beaked whales stranded alive along the coasts of the Kyparissiakos Gulf. The whales were spread along 38.2 km of coast (Fig. 2) and were separated by a mean distance of 3.5 km (sd=2.8, n=11). One more animal was found dead on a remote beach of the neighbouring Zakynthos Island, 57 km away from the closest stranding on the mainland. This spread in time and location was atypical, as whales usually mass-strand at the same place and at the same time (e.g. pilot whale mass strandings). Typical as well as atypical mass strandings of Cuvier's beaked whales exist in literature (Robinson *et al.*, 1983; Vonk and Martin, 1989). Sex and age class composition of the stranded animals were quite unusual: nine immature males with unerupted teeth (total body length from the tip of the upper jaw to the notch in the flukes 4.40 to 5.20 m), two females (4.70 and 5.10 m) and one animal of unidentified sex. In order to test the hypothesis that the stranded animals, although not spatially cohesive, could originate from the same "social group", genetic kin-relationship analyses are presently being conducted. This is theoretically possible as schools are often composed of three to ten individuals and groups of as many as twenty five individuals have been reported (Leatherwood and Reeves, 1983).

None of the stranded animals had wounds nor signs of interaction with fisheries. Necropsies were carried out on eight of them but no apparent abnormalities were found. Stomach content analysis revealed undigested cephalopod flesh indicating recent feeding. Parasite loads were consistent with normal wild cetacean populations and tests for morbillivirus and herpes antibodies were negative. In any case, epizootics and pathogenic factors infecting wild populations are unlikely causes of strandings of this nature, as their effect lasts longer and has no sudden end. The same is valid for chemical pollutants as they should affect other marine species as well. In addition, the general robust condition of the stranded animals is not consistent with the above possible causes. Unusual tectonic activity, geochemical or geophysical events were not recorded before or during the stranding and no significant magnetic anomalies were found in the area.

Mass strandings of live whales have been explained by proposing many different "natural" or human related causes as those described above (Geraci and Lounsbury, 1993). After looking for other possible causes of the mass stranding, we discovered that "sound-detecting system trials" had been performed by the NATO research vessel "Alliance" from 24:00 11 May to 24:00 15 May 1996 (Warning to mariners 586 of 1996, Hellenic Navy Hydrographic Service) a period that encompassed the mass stranding. Also, the officially declared area of the sea trials had been carried out enclosed all coordinates of the stranding points.

The tests that NRV Alliance performed were for Low Frequency Active Sonar (LFAS), a system for the detection of quiet diesel and nuclear submarines. This system generates extremely loud, low frequency sound (maximum output ≥ 230 dB re 1 mPa, broadband waveforms centered at frequencies which range from 250 to 3000 Hz), which enables long detection ranges (Anonymous, 1993; Anonymous, 1997). Research on LFAS began in 1981 (Anonymous, 1993) and a statement on its environmental impact was formally initiated in July 1996 by the US Navy. The adverse effects of low frequency sound on whales are poorly studied (Richardson & Würsig, 1997) but many specialists warn that at high levels, as occurs with LFAS, they could be dramatic.

The proximity of military manoeuvres has been suspected of causing three previous mass strandings of Cuvier's beaked whales, spread over wide areas of the Canary Islands (Vonk and Martin, 1989; Simmonds & Lopez-Jurado, 1991). In those mass strandings as well as in the Kyparissiakos Gulf case, the stranding characteristics were atypical. This suggests that the cause had a large synchronous spatial extent and a sudden onset. Such characteristics are shown by sound in the ocean. Also deep-diving whales seem to be especially affected by low-frequency sounds, even at quite low received levels (Watkins et al., 1985; Bowles, 1994). Strong escape reactions (e.g. moving rapidly away from the source) have been also observed for some cetaceans species, especially when the animals were not frequently or never exposed before to the sound they were facing (Cosens and Dueck, 1993, Richardson and Würsig 1997).

Accordingly, behavioral responses to high intensity acoustic transmissions (such as startle reaction, escape reaction, "stampeding" and panic) could be the mechanism that drove the whales ashore in the Kyparissiakos Gulf, especially if they were found between the source and the coast at the moment that loud transmissions suddenly started. Once found in the shallows the animals could easily get stranded, as the Kyparissiakos Gulf presents characteristics of a "natural trap" for pelagic whales (a shallow sandy bottom extends half a mile from the coast).

We know that LFAS was used in the Kyparissiakos Gulf and loud, low frequency sounds, probably new for Cuvier's beaked whales of the area, were transmited (226 and 228 dB re 1 mPa for 3 kHz and 600 Hz respectively). We also know that no other LFAS tests or mass strandings have occured in the Greek Ionian Sea, since 1981. Taking the past 16.5-year period into account, the probability of a mass stranding occuring for other reasons, during the period of the LFAS tests is less than 0.07%. Although pure coincidence cannot be excluded, it seems improbable that the two events were independent. Little is known about whales' reactions to LFAS to obtain definitive answers. More information needs to be gathered but unfortunately, most of the data about the use of LFAS were subject to military secrecy, until very recently.

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REFERENCES

Anonymous 1993. *Endeavour and achievement.* NATO-SACLANT Undersea Research Centre, La Spezia, Italy. 36pp.

Anonymous 1997. *Saclantcen Newsletter* 4, NATO-SACLANT Undersea Research Centre, La Spezia, Italy. 4pp.

Bowles, A. E., Smultea, M., Würsig, B., DeMaster, D. P. and Palka, D. 1994. Relative abundance and behavior of marine mammals exposed to transmissions from the Herald Island Feasibility Test. *J. Acoust. Soc. Am.* 96: 2469-2484.

Cosens, S.E., Dueck, L.P. 1993. Icebreaker noise in Lancaster Sound, N.W.T., Canada: Implications for marine mammal behavior. *Mar. Mamm. Sci.* 9(3): 285-300.

Erdman, D.S., Harms, J. and Flores, M.M. 1973. Cetaceans records from the Northeastern Caribbean Region. *Cetology* 17: 1-14.

Frantzis, A. 1997. Cetaceans and cetology in the Hellenic Seas. Pp. 114-118. In *European Research on Cetaceans* - 10. Proc. 10th Ann. Conf. ECS, Lisbon, 1996 (Ed. P. G. H. Evans). European Cetacean Society, Kiel, Germany.

Geraci, J.R. and Lounsbury, V.J. 1993. *Marine Mammals Ashore. A Field Guide for Strandings.* Texas A&M Sea Grant Publication, Galveston, Texas. 305pp.

Heyning, J.E. 1989. Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. Pp. 289-308. In *Handbook of Marine Mammals*, vol. 4 (Eds S. H. Ridgeway and R. J. Harrison). Academic Press, London. 430pp.

Leatherwood, S., Reeves, R.R. 1983. *The Sierra Club Handbook of Whales and Dolphins.* Sierra Club Books, San Francisco. 302pp.

Miyazaki, N. 1989. [Stranding records of cetaceans on the Japanese coasts.] *IBI Reports* 1: 21-25 [International Marine Biological Research Institute] [in Japanese].

Politi, E., Airoldi, S., Notarbartolo di Sciara, G. 1994. A preliminary study of the ecology of cetaceans in the waters adjacent to Greek Ionian Islands. Pp. 111-115. In *European Research on Cetaceans* - 8. Proc. 8th Ann. Conf. ECS, Montpellier, France 1994 (Eds. P. G. H. Evans). European Cetacean Society, Cambridge, England. 288pp.

Pulcini, M. 1997. Note about the presence of Cuvier's beaked whale *Ziphius cavirostris* in the Ionian Islands of Greece. Pp. 176. In *European Research on Cetaceans* - 10. Proc. 10th Ann. Conf. ECS, Lisbon, 1996 (Ed. P. G. H. Evans). European Cetacean Society, Kiel, Germany. 334pp.

Richardson, W.J. and Würsig, B. 1997. Influences of man-made noise and other human actions on cetacean behaviour. *Mar. Fresh. Behav. Physiol.* 29: 183-209.

Robinson, G., Koster, F. and Villa, J. 1983. Strandings of Cuvier's beaked whales on Baltra. *Noticias de Galapagos* 38: 16-17.

Simmonds, M.P. and Lopez-Jurado, L.F. 1991. Whales and the military. *Nature* 337: 448.

Tortonese, E. 1963. Insolita comparsa de cetacei (*Ziphius cavirostris* G. Cuv.) nel golfo di Genova. Natura 54: 120-122.

Vonk, R. and Martin, V. 1989. Goose-beaked whales *Ziphius cavirostris* mass strandings in the canary islands. Pp. 73-77. In *European Research on Cetaceans* - 3. Proc. 3rd Ann. Conf. ECS, La Rochelle, 1989 (Eds. P. G. H. Evans and C. Smeenk). European Cetacean Society, Cambridge, England. 132pp.

Watkins, W. A., Moore, K.E. and Tyack, P. 1985. Sperm whale acoustic behaviors in the southeast Carribean. *Cetology* 49: 1-15.

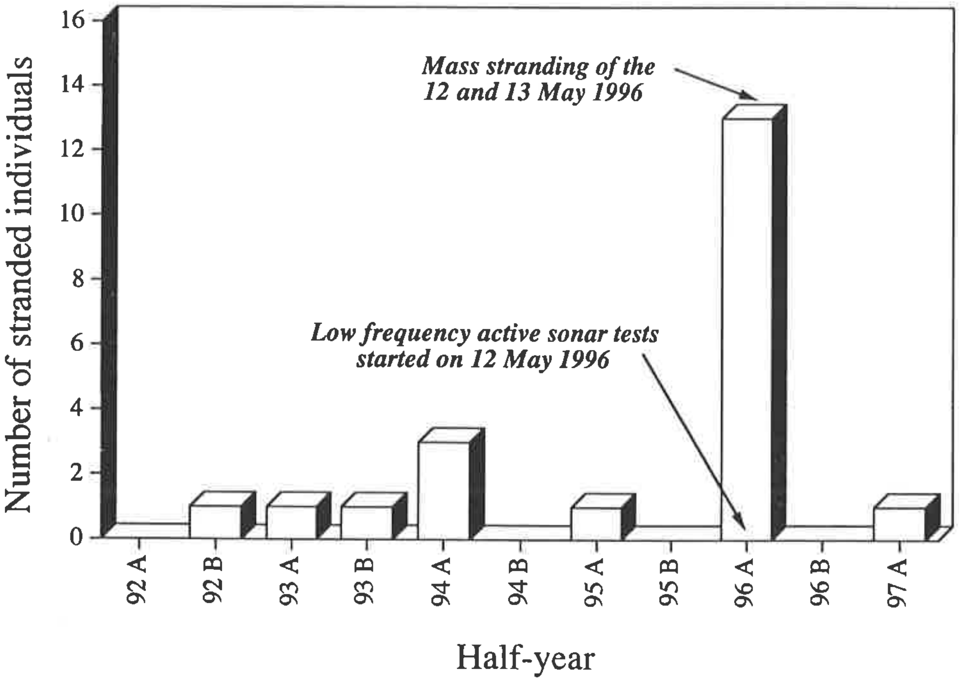

Fig. 1. Cuvier's beaked whale strandings in the Kyparissiakos Gulf, 1992-97. All individuals stranded during 1996 (half-year A) belong to the mass stranding of 12-13 May 1996.

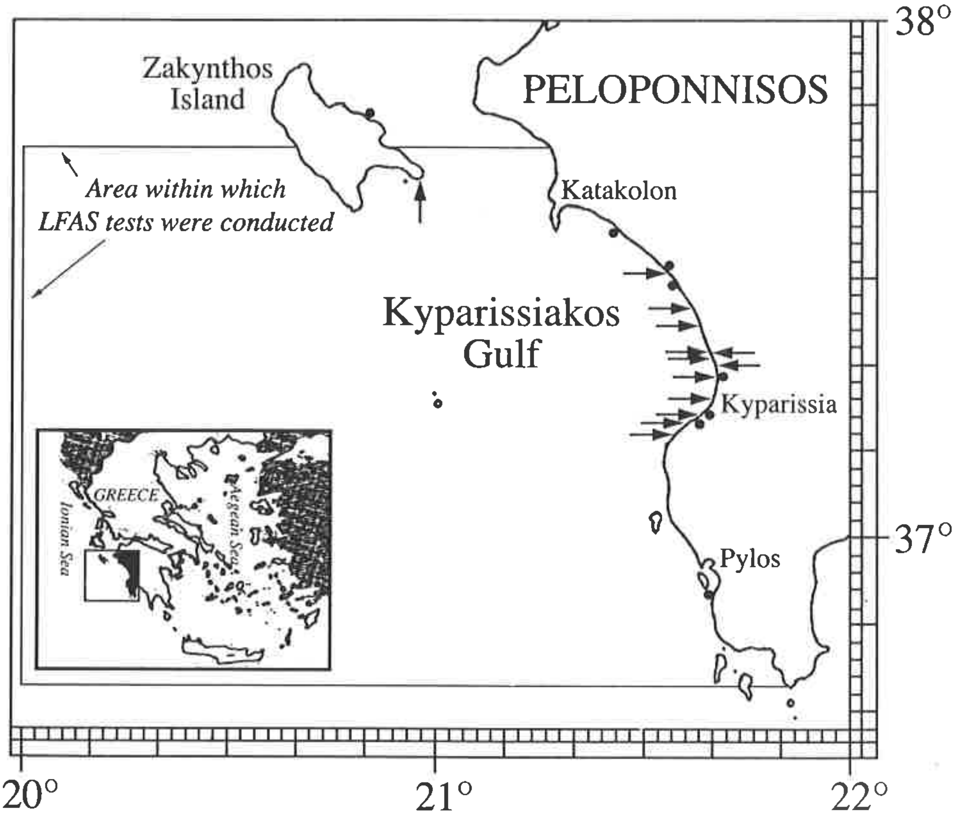

Fig. 2. Area of Low Frequency Active Sonar tests and stranding positions of Cuvier's beaked whales. Arrows indicate positions of the mass stranding of 12-13 May 1996. Dots correspond to all other Cuvier's beaked whales stranded, Jan 1992- June 1997.

MICROALGAE IN CETACEANS: PATHOGENS, PARASITES OR BIOINDICATORS?

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INTRODUCTION The role of microphytic algae is rarely examined in depth in the numerous works that cover ecological interactions of cetaceans. We have been conducting a number of investigations dedicated to understanding microalgal participation in trophic chains, skin growths or the vegetation found in dolphinaria, but there is no integrated picture of rich, heterogenous, and multi-faceted scope of the different links between these important wildlife components of marine ecosystems. Algal vegetation is constantly present in the environment of cetaceans, and is inseparable from their life cycles. Microalgae not only play an important role in nutrition of whales and dolphins but can be a substantial factor in parasitological and pathological ecology of animals. Unfortunately, the characteristics of microalgae as the stimuli of diseases of warm-blooded organisms have been examined in terrestrial species only, and rarely in the aquatic environment. Moreover, even a review of existing theories has not occurred as yet in this subject. Such generalisation combined with a discussion of some aspects of microalgae-cetacean relations is the main subject of this contribution.

MATERIALS AND METHODS The different relationships between microphytic algae and cetaceans which have been reported in the world scientific literature (totalling about 100 references) during this century (1913-97) were analysed. Most of these related to pathological, parasitological, bioindicator and toxicological aspects of the presence of microalgae on the skin of whales and dolphins, in the respiratory system and surrounding environment (trophic constituents were omitted from this review). Our results, obtained from more than 30 wild and captured dolphins in the northern part of the Black Sea since 1988, were used in this study. There were 139 algological samples isolated by way of skin scrapings and smears from different parts of the body. These samples were sown on Gol'dberg medium, or fixed, and then identified. Some bacteriological studies were also conducted. In particular, 120 expirative air samples from 20 dolphins were isolated and inspected (Gol'din, 1997).

RESULTS More than eighty microalgal species and subspecies are known from 14 cetacean species. Most are diatoms, but some green and blue-green algae arealso recorded (Table 1). General aspects of external appearance and localisation depending on the season, geographical factors, site of residence, migrations, and features of individuals (sex, age, nutritional status, etc) were studied in polar and circumpolar seas. Algal skin inhabitants probably have universal occurrence in cetaceans, but their taxonomy, distribution, and reasons for appearance are not well known. Microphytic algae cannot be ascribed to obvious ectoparasites such as amphipods or *Pennella* occupied abrasions, wounds and cuts of the skin surface. Different conditions account for differences in their species composition. Thus, algae are richer in species diversity and were abundant in slow-moving and coastal cetaceans - gray whale (*Eschrichtius robustus*) and humpback whale (*Megaptera novaeangliae*) - than fast-moving balaenopterids. On the contrary, the whales were covered by a film of diatoms in the fatter areas irrespective of speed of locomotion, and differences in skin algal vegetation took place according to their migratory habit: microalgae utilise body the surface as a substrate only (Tomilin, 1970). However, diatoms can use whale skin for their nutrition. For example, the holophyte *Cocconeis ceticola* changes to a partial saprophytic mode of nutrition in atrophied epidermal cells, and to the active parasitic one in living epidermis covering skin scars, whilst *Navicula* sp. can also migrate to the epidermis. The algal cytoplasmic filaments are the means of achieving this migration in such cases (Hart, 1935).

But a series of algae (*Ulothrix,Gomphonema*) also have the special organs of attachment such as a sole, foot, or mucilaginous filaments, and they are not parasites. Furthermore, a number of benthic species (*Navicula*, *Nitzschia*,*Gyrosigma*, *Pinnularia*, *Achnantes*, *Cocconeis* and other diatoms) were described as periphyton species not restricted to one kind of substrate and can be found growing upon macrophytes, plants and constantly moist surfaces - rocks and stones, mosses and lichens. They cannot be parasitic species in contrast to some *Euglenophyceae* and *Dinophyceae* - inhabitants of the intestines of invertebrate, and vertebrate animals or fish gills. On the other hand, there are obligatory heterotrophs possessing colourless plastids among diatoms, such as some *Nitzschia* and *Synedra* species. It is known that the adnate *Cocconeis* takes more of its phosphorus requirement from the host - the macrophyte alga *Najas flexilis*, but*Gomphonema* growing on this macrophyte adsorbs phosphorus from surrounding water (Round, 1992). Several years ago, we found *Synedra crystallina* cells in the scrape from an ulcered gastral wall area of harbour porpoise *Phocoena phocoena*. This diatom possessed a thick testa, and grew upon species of *Zostera*, so the real possibility exists of their accidental penetration of the digestive tract with food.

We isolated some other microalgae from skin injuries and ulcers of bottlenose dolphins *Tursiops truncatus ponticus*: *Licmophora abbreviata* (surface of papula, injured skin in the flukes), *L. Ehrenbergii* (ulcers in the lateral parts of the body and dorsal fin), *Nitzshia seriata* and*Grammatophora marina* (ulcers in the flukes), *Nitzschia tenuirostris* (injured skin near the dorsal fin and ulcers in the caudal part), *Amphora turgida* and *Navicula pennata* var. *pontica* (injured skin in flukes), *Berkeleya rutilans* (injured skin), and *Anabaena* sp. (dermatosis near the dorsal fin). At the same time, most of the wounds, ulcers and injured parts of skin were free of algae. Thus there is the following situation: it is possible to speak about one specialised diatom -*Cocconeis ceticola* or *Bennettella ceticola* - and its varieties tending towards obligatory parasitism of the skin. The other microphytic algae incidentally occupy the cetacean body and in all cases form characteristic algocenosis. Maybe they can be facultative parasites in some cases by virtue of their biological peculiarities.

The role of attendant algal vegetation in cetacean pathology is unclear. Apparently microalgae do not bring appreciable injury to the host but they can penetrate deep into epidermal layers and have a wider distribution in animals with skin injuries than in a healthy one (by five-ten times). There is some evidence for algal participation in tissue damage. The complex interrelations between various epibionts are rarely considered, and their nature has not been determined. It may be different forms of symbiosis in some cases. So we have the isolated adnate *Ulothrix* sp. with *Synedra (Fragillaria) tabulata* growing over it in the skin covering of bottlenose dolphin flippers in Karadag dolphinarium (Crimea). There are also various bacterial, fungal or mixed parasitism in diatoms. Consequently microalgae can be conducive to pathogenic bacteria, fungi, and protozoan intrusions and may hinder the repair process, in particular wound healing.

It is also possible that some inflammatory processes begin most likely as a result of microalgal intrusion in respiratory organs. For example, such cases (acute pneumonia accompanied by necrosis and complicated with tracheobronchitis) were described in long-finned pilot whales *Globicephala melas*, but these algae were not identified: seaweeds aspirated with waste/detritus could also be among them. Diatoms *Chaetoceros* sp., *Triceratium* sp., and a number of unidentified *Bacillariaceae* were found in bronchial fluid samples of by-caught harbour porpoises (in 45 samples from 50 ones) as well as dinoflagellates, *Dinophysis norvegica* , and five unidentified species (in 20 out of 50 samples) and green algae. All of the animals were in good health at the time of death, and the presence of microalgae in distal lung samples suggests that they were inhaled by live harbour porpoises. Microalgae may enter the body through the walls of the digestive tract and then reach the lungs via the blood circulation, although pathological symptoms were not described (Larsen and Holm, 1992). We did not find any microalgal presence in the lungs of ten harbour porpoises by-caught in the Black Sea.

The microalgal toxins of dinoflagellates (brevetoxin, saxitoxin, etc) may be a potential danger for cetaceans as a cause of sublethal and mortal poisoning of fishes, molluscs, birds and mammals during red tides. However, the available facts on cetacean mortality events (bottlenose dolphins *T. truncatus*, humpback whales, and striped dolphins (*Stenella coeruleoalba*) that have taken place hitherto and which have been explained by the high content of algal toxins during feeding, have not been accepted universally by other experts. We cannot confirm assumptions about indirect cyanobacterial, dinoflagellate or diatom toxins action in cetaceans, at least in the Black Sea, because nowadays seasonal red tide stimuli (*Gonyaulax polygramma*, *Prorocentrum cordata*, *P. micans*, *Cerataulina bergonii.*, *Rhizosolenia calcar-avis*, *Leptocylindrus danicus*, *L. minimus*, *Detonula confervacea*,*Chaetoceros lorenzianus*, *Nitzschia delicatissima* and *Skeletonema costatum* as well as some freshwater toxic species (*Skeletonema subsalum*, *Microcystis pulverea*, *Gloeocapsa crepidinum* and *Ankistrodesmus* sp.) do not reach dangerous concentrations.

Microphytic algal vegetation is an important indicator factor of the health of a cetaceans and its environmental status, especially in limited areas of water (such as dolphinaria). Our investigations established that microalgal skin growths appeared most frequently in weak and sick captive bottlenose dolphins. The main reasons for such a situation are lower locomotive activity, unfavourable circulation and low temperature of the water, and saturation of the surrounding water by organic compounds. By contrast, the skin of wild bottlenose dolphins and harbour porpoises is almost devoid of microalgal growths. There is a clear relationship between the establishment of microalgae on the skin and the deterioration in the health of the host. So there is a greater diversity of algal species during contagious diseases in dolphins (bacterial pneumonia, sepsis): this has been confirmed by microbiological examinations. Ten species of algae in the skin can be observed in the presence of*Staphylococcus aureus*, *St. saprophyticus*, *Proteus vulgaris* and *Bacillus* sp. in expirated air samples (Gol'din, 1997).

Moreover, the skin algal vegetation in captive dolphins has its distinctive specific features compared with the common algal growth complex in dolphinaria and pools, whilst algal vegetation of artificial reservoirs differs from that of the adjoining sea area. Some species can serve as indicators of water pollution level: *Oscillatoria* sp. and *Prorocentrum cordata* (organic) and *Bacillaria paradoxa* (chloride).

CONCLUSIONS

1. There is one specialised inhabitant of cetacean skin - *Cocconeis* (*Bennettella*) *ceticola* and its varieties are inclined to obligatory parasitism. Other microphytic algae registered there can appear for a very wide variety of reasons - from accidental carriage to a constant presence. Some of them can form a steady characteristic algocenosis for every host. Maybe they can be facultative parasites in some cases.

2. The pathological process initiated by microalgae is questionable, although they can encourage the penetration of pathogenic bacteria, fungi and protozoans that are always present in algocenosis as symbionts, commensals, or parasites.

3. The composition of algal vegetation is probably the most important bioindicator criterion for the determination of cetaceans health and their environment status, in particular in dolphinaria.

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REFERENCES

Bennet, A.G. 1920. On the occurrence of diatoms on the skin of whales (with an Appendix by E.W.Nelson). *Proc. Royal Soc. London.* Ser.B, 91, 641 B: 352-357.

Birkun, A.A., Jr and Gol'din, E.B. 1997. The microphytic algae in cetacean pathology. *Mikrobiologichny Zhurnal* (The Journal of Microbiology), 59(2): 96-105. (In Russian).

Gol'din, E.B. 1997. Some problems of interrelations between cetaceans and skin microalgae, and their investigation. Pp. 269-271. In *European Research on Cetaceans - 10.* Proc. 10th Ann. Conf. ECS, Lisbon, 11-13 March 1996 (Ed. P.G.H. Evans). European Cetacean Society, Kiel, Germany. 334pp.

Hart, J. 1935. On the diatoms of the skin film of whales and their possible bearing on problems of whale movements. *Discovery Rep.*, 10: 247-282.

Heckmann, R.A., Jensen, L.A.,Warnock, R.G. and Coleman, B. 1987. Parasites of the bowhead whale, *Balaena mysticetus. Great Basin Natur.*, 47(3): 355-372.

Hustedt, F. 1952. Diatomeen aus der Lebensgemeinschaft des Buckelwals (*Megaptera nodosa*). *Arch.fur Hydrobiol.*, 46, 12.

Ivashin, M.V. 1965. Overgrowings and ectoparasites of humpback whales. Pp. 80-86. In Marine Mammals. Nauka (Science), Moscow. 320pp. (In Russian).

Ivashin, M.V. 1975. External parasites in minke whales in Antarctic Region. Pp. 125-127. In *Marine Mammals. Part 1.* Naukova Dumka, Kiev. 223pp. (In Russian).

Klyashtorin, L.B. 1962. The diatom overgrowing of whales of the Far Eastern Seas. *Proc. of the Institute of Oceanology of Academy of Sciences of USSR*, 58: 314-321. (In Russian).

Larsen, B.H. and Holm, C.N. 1996. Microscopical examination of bronchial fluid from harbour porpoises (*Phocoena phocoena* L.) for the presence of marine flora and fauna and mineral grains as a possible method to diagnose by-catch. Pp. 4-9. In *Diagnosis of by-catch in cetaceans.* Proc. 2nd ECS Workshop on Cetacean Pathology, Montpellier, 2nd March 1994 (Ed. T. Kuiken). European Cetacean Society Newsletter, 26. Saskatchewan, Canada. 43pp.

Nagasawa, S., Holmes, R.W. and Nemoto, T. 1990. The morphology of the cetacean diatom genus Plumosigma Nemoto. *Sci. Rep. Cetac. Res.*, 1: 85-91.

Nemoto, T. 1956. On the diatoms of the skin film of whales in the Northern Pacific. *Sci. Rep.Whales Res.Inst.*, Tokyo, 11: 99-132.

Nemoto, T., Best, P.B., Ishimaru, K. and Takano, H. 1980. Diatom films on whales in South African waters. *Sci. Rep. Whales Res. Inst.*, Tokyo, 32: 97-104.

Round, F.E. 1992. Epibiotic and endobiotic associations between chromophyte algae and their hosts. Pp. 593-617. In *Algae and Symbioses* (Ed. W. Reisser). Biopress Limited. Bristol, England. 746pp.

Tomilin, A.G. 1970. Marine mammals and their biogeocenotical connections with other groups of marine fauna. Pp. 169-193. In Programme and methods investigation biogeocoenological waters' surroundings. Nauka (Science), Moscow. 229pp.

Usachev, P.I. 1940. Overgrowing of whales by diatoms. Zoologichesky Zhurnal (Zoological Journal), 19(2): 306-312. (In Russian).

Zinchenko, V.L. 1986. Analysis of minke whales diatom overgrowing in Antarctic Region in connection with their migrations. Pp. 157-158. In 9th All-Union Symposium on the study, protection and rational employment of the marine mammals: Abstr., Arkhangelsk, 9-11 September 1986. Arkhangelsk, Oblstat. 466pp. (In Russian).

Table 1. Algae and their hosts

MYSTICETI	
Balaenidae	
Northern right whale *Eubalaena glacialis* Mller	*Cocconeis ceticola* Nelson , *C. ceticola typica* Nemoto, *C. ceticola arctica* Usachev (Klyashtorin, 1962; Nemoto et al., 1980)
Bowhead whale *Balaena mysticetus* L.	*Cocconeis* sp., *Gomphonema* sp., *Navicula* sp. *Stauroneis* sp. (Heckmann et al., 1987)
Balaenopteridae	
Finback whales Balaenopteridae (non-identified)	*Biddulphia aurita* (Lyngb.) Breb. et Godey, *B. mobiliensis* (Bail.) Grun., *Chaetoceros atlanticus* Cl., *Ch. concavicornis* Mangin, *Ch. densus* Cl. (Nemoto, 1956) *Cocconeis ceticola* Nelson (Hart, 1935; Nemoto, 1956; Nemoto et al., 1980; Zinchenko, 1986) *Coscinodiscus scuttellum stauroneiformis* Nemoto, *C. anguste-lineata* A.S. (Schmidt)= *Thalassiosira anguste-lineata* (A.S.) Fryx. et Hasle, *C. Ktzingii* A.S., *C. radiatus* Ehr., *C. wailesii* Gran. et Angst., *Detonula confervacea*(CL.) Gran., *Gomphonema aestuarii* Nemoto, *G. harti* Nemoto, *Leptocylindrus minimus* Gran., *Melosira sulcata* (Ehr.) Kutz., *Nitzschia (Cylindrotheca) closterium* (Ehr.) W.Sm., *N. tubicola* Nemoto, *Plumosigma Hustedti* Nemoto, *P. rimosum (rumosum)* Nemoto, *Rhaphoneis amphiceros* Ehr., *Rhizosolenia styliformis* Bright., *Rhoicosphenia pallas* Nemoto, *Stauroneis aleutica* Nemoto, *St. aleutica brevis* Nemoto, *St. Omurai* Nemoto, *Synedra camtschatica* Nemoto, *S. Hennedyana* Greg., *S. karcheri* Nemoto, *Thalassionema nitzschioides* Grun., *Thalassiosira anguste-lineata* (A.S.) Fryx. et Hasle = *Coscinodiscus anguste-lineatus* A.S. (Schmidt), *Th. nordenskioeldii* Cl., *Thalassiothrix frauenfeldii* Grun., *Thalassiothrix longissima* Cl. et Grun. (Nemoto, 1956)
Blue whale *Balaenoptera musculus* L.	*Cocconeis ceticola* Nelson, *C. ceticola subconstricta* Nemoto, *C. gauthieri* Cleve, v. H., *C. imperatrix* A.S.(Schmidt), *C. wheeleri* Hart, *Gyrosigma arcticum Gyrosigma* sp., *Licmophora Lyngbyei* (Ktz.) Grun. (= *L. abbreviata* Ag.), *Navicula* sp., *Navicula* sp., *Navicula* sp. (*Stauroneis olimpica* ?), *Pinnularia* sp. (Bennet, 1920; Hart, 1935; Hustedt, 1952; Nemoto, 1956; Nemoto et al., 1980)
Fin whale *Balaenoptera physalis* L.	*Cocconeis ceticola* Nelson (Nemoto, 1956); *C. ceticola arctica* Usachev (Usachev, 1940); *C. ceticola typica* Nemoto (Klyashtorin, 1962)
Sei whale *Balaenoptera borealis* Lesson	*Cocconeis ceticola* Nelson, *C. ceticola arctica* Usachev, *C. ceticola typica* Nemoto (Nemoto, 1956, Klyashtorin, 1962)
Minke whale *Balaenoptera acutorostrata* Lacepede	*Cocconeis ceticola* Nelson, non-identified diatoms (Hart, 1935; Nemoto, 1956; Ivashin, 1975; Nemoto et al., 1980; Zinchenko, 1986)
Humpback whale *Megaptera novaeangliae* Borowski	*Cocconeis wheeleri* Hart, *Licmophora Lyngbyei* (Kutz.) Grun. (= *L. abbreviata* Ag.), *Licmophora onasis* Hust., *Nitzschia barkleyi* Hust., *Stauroneis olimpica* Hust. (Hart, 1935; Hustedt, 1952; Ivashin, 1965)

Eschrichtiidae	
Gray whale _Eschrichtius robustus_ Lilljeborg	_Cocconeis ceticola_ Nelson, _C. ceticola arctica_ Usachev, _C. ceticola typica_ Nemoto (Klyashtorin, 1962)
ODONTOCETI	
Physeteridae	
Sperm whale _Physeter catodon_ L.	_Cocconeis ceticola constricta_ Nemoto (Nemoto, 1956; Nemoto et al., 1980) _C. ceticola_ Nelson, _C. ceticola arctica_ Usachev, _C. ceticola typica_ Nemoto, _Stauroneis aleutica_ Nemoto, _Synedra_ sp., _Licmophora_ sp., _Plumosigma_ sp. (Klyashtorin, 1962); _Plumosigma hustedti_ Nemoto, _P. rimosum (rumosum)_ Nemoto (Nagasawa et al., 1990)
Ziphiidae	
Baird's beaked whale _Berardius bairdi_ Stejneger	_Cocconeis ceticola berardii_ Klyashtorin, _Stauroneis aleutica_ Nemoto (Klyashtorin, 1962) _C. ceticola berardiussi_ Nemoto (Nemoto et al., 1980)
Cuvier's beaked whale _Ziphius cavirostris_ G. Cuvier	_Cocconeis ceticola berardiussi_ Nemoto, _Stauroneis olimpica_ Hust. (Nemoto et al., 1980)
Northern bottlenose whale _Hyperoodon ampullatus_ Forster	_Cocconeis ceticola constricta_ Nemoto (Nemoto et al., 1980)
Strap-toothed whale _Mesoplodon layardi_ Gray	_Stauroneis olimpica_ Hust. (Nemoto et al., 1980)
Delphinidae	
Killer whale _Orcinus orca_ L.	_Cocconeis orcii_ Klyashtorin, _Synedra_ sp., _Licmophora_ sp., _Plumosigma_ sp. (Klyashtorin, 1962); _Stauroneis olimpica_ Hust. (Nemoto et al., 1980)
Bottlenose dolphin _Tursiops truncatus ponticus_ Barabasch-Nikiforov	_Achnantes brevipes_ Ag., _A. longipes_ Ag., _Amphora hyalina_ Ktz., _A. turgida_ Greg., _Berkeleya rutilans_ (Trentep.) Cl., _Fragillaria (Synedra) tabulata_ (Ag.) Ktz., _Fragillaria_ sp., _Grammatophora marina_ (Lyngb.) Ktz., _Licmophora abbreviata_ Ag., _L. Ehrenbergii_ (Ktz.) Grun., _Licmophora_ sp., _Melosira moniliformis_ (O.Mll.), _Navicula cancellata_ Donk., _N. grevillei_ W.Sm., _N. pennata_ var. _pontica_ Mer., _Navicula_ sp., _Nitzschia (Cylindrotheca) closterium_ (Ehr.) W.Sm., _N. hybrida_ f. _hyalina_ Pr.-Lavr., _N. seriata_ Cl., _N. tenuirostris_ Mer., _Nitzschia_ sp., _Pleurosigma rigidum_ W.Sm., _Striatella unipunctata_ (Lyngb.) Ag., _Synedra (Fragillaria) tabulata_ (Ag.) Ktz., _Ulothrix_ sp., _Anabaena_ sp. (Gol'din, 1997; Birkun and Gol'din, 1997)
Phocoenidae	
Harbour porpoise _Phocoena phocoena_ L.	*_Chaetoceros_ sp., _Triceratium_ sp., non-identified diatoms, _Dinophysis norvegica_ Clap. et Lachm., non-identified dinoflagellates (Larsen and Holm, 1992) **_Synedra crystallina_ (Ag.) Ktz., _Scoliopleura westii_ (W.Sm.) Grun.
Non-identified cetaceans	_Cocconeis ceticola_ Nelson, _C. scuttellum stauroneiformis_ Nemoto, _Synedra_ sp. (Nemoto et al., 1980)

Note. Material was isolated from skin except (*) - lungs and (**) gastral wall.

SKULL LESIONS IN STRANDED CETACEANS IN GALICIA (NW SPAIN) DUE TO *Crassicauda* spp.

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INTRODUCTION The most common nematodes infesting tissues of cetaceans are members of the family Crassicaudidae (Dailey, 1985). In many cases *Crassicauda* species produce lesions in the skull of cetaceans, primarily in members of the Delphinidae (Dailey and Perrin, 1973; Dailey and Stroud, 1976; Dailey and Walker, 1978; Perrin and Power, 1980; Raga *et al.*, 1982; Robineau, 1975). The bone lesions have been reported in both stranded and caught cetaceans in different oceans and seas of the world (Dailey and Perrin, 1973; Raga *et al.*, 1982). Nevertheless, identification of the aetiologic agent is not always possible, because most of these lesions are seen as eroded areas in prepared museum skulls.

Members of the genus *Crassicauda* live in the tissue of a number of cetaceans, but very little is known about their biology and pathogenicity. This is partly because revealing the presence of these nematodes involves considerable dissection and, therefore, are often not systematically searched for. The aim of this work was just to recover the skull lesions associated to *Crassicauda* species from an important stranding area. It should allow us to check the occurrence of these lesions and the presence of the etiological agent in different cetacean species.

METHODS The study was conducted along the coast line of Galicia (NW Spain). This report includes data from 1983 to 1997. Sightings of beached cetacean carcasses in the study area were reported by personnel of National and Local Institutions and others to the 24-hour answering services at the C.E.M.MA. As far as possible, the location, date, species, total body length, sex and maturity of each animal observed were registered. Completely intact skull samples were processed and macroscopically examined. The skulls were divided in 5 different areas (Fig. 1). A total of 179 skulls belonging to 10 odontoceti species common dolphin (*Delphinus delphis*), stiped dolphin (*Stenella coeruleoalba*), bottlenose dolphin (*Tursiops truncatus*), Risso's dolphin (*Grampus griseus*), long-finned pilot whale (*Globicephala melas*), harbour porpoise (*Phocoena phocoena*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), killer whale (*Orcinus orca*), pygmy sperm whale (*Kogia breviceps*), and Cuvier's beaked whale (*Ziphius cavirostris*) were examined for parasitic-caused macroscopic lesions.

RESULTS The lesions found could be allocated to 3 distinct morphological types according to its morphology. Basket-like bone lesions (Fig. 2) which appear as marked sunken surfaces; trabecula-like lesions (Fig. 3) consisting in as sunken surfaces with duct systems; and smooth-like lesions (Fig. 4) with undefined borders and flattened ducts.

Lesions were observed in 18.43% of the skulls. Of the species for which a meaningful number of skulls could be examined, the high frequency of bone damage corresponded to *T. truncatus*. Note, however, that all the *L. acutus* and *O. orca* showed such lesions, although the sample size (2 and 1, respectively) is too smalll to draw any conclusion (Table 1). The size of the bone lesions varied from 10 x 5 mm to 50 x 40 mm. Most of the lesions occurred as eroded areas in the frontal-orbitosphenoid and pterygoid regions (Table 2). Nasal and orbitary perforations were observed (Fg. 5), extending into the brain cavity. This study reports for the first time the occurrence of skull lesions in *L. acutus* and *O. orca*.

CONCLUSIONS Although associated parasites have been not found, the similarity of the above lesions as compared to those described in skulls of Risso's dolphin (Raga, 1987), bottlenose dolphin (Robineau, 1975), spotted dolphin (*Stenella attenuata*), spinner dolphin (*S. longirostris*) (Dailey and Perrin, 1973), common dolphin (Walker *et al.*, 1984) and harbour porpoises (Fernández *et al.*, 1990), makes it very likely that the damage was caused by the presence of *Crassicauda* species.

Crassicaudids have been associated with lesions particularly in the developing pterygoid bone of juvenile dolphins (Walker and Cowan, 1981). The absence of residual bone lesions in older animals is strong evidence to conclude that parasitism may constitute a major factor in natural mortality of small cetaceans (Perrin and Powers, 1980; Walker and Cowan, 1981; Geraci and St. Aubin, 1987). Crassicaudids have also caused functional disturbances in the pterygoid sinus involving inflammation of the mucosa, purulent sinusitis and, finally, osteistis (Raga *et al.*, 1982).Whatever the proximate cause of mortality (brain damage, increased susceptibility to predation, etc.), the ultimate cause may be the nematode parasite itself (Perrin and Powers, 1980). Future studies of *Crassicauda* spp. should be included a search for brain histopathology associated with bone lesions to test the role of the parasites as an important mortality factor in this area.

REFERENCES

Dailey, M.D. and Perrin, W.F. 1973. Helminth parasites of porpoises of the genus Stenella in the eastern tropical Pacific, with descriptions of two new species: *Mastigonema stenellae* gen. Et sp. n. (Nematoda: Spiruroidea) and *Zalophotrema pacificum* sp. n. (Trematoda: Digenea) *Fish. Bull.*, U.S.71: 455-471.

Dailey, M.D. and Stroud, R.K. 1978. Parasites and associated pathology observed in cetaceans stranded along the Oregon coast. *J. Wild. Dis.*, 14: 503-511.

Dailey, M.D. and Walker, W.A. 1978. Parasitism as a factor in single strandings of southern California cetaceans. *J. Parasitol.*, 64: 593-596.

Dailey, M.D. 1985. Diseases of Mammalia: Cetacea. Pp. 805-844. In: *Diseases of Marine Animals* (Ed. O. Kinne).

Fernández, M., Kinze, C., Balbuena, J.A., and Raga, J.A. 1990. First record of *Crassicauda* sp. parasitising Atlantic harbour porpoises. Pp. 117-118. In: *European Research on Cetaceans - 4* (Eds. P.G.H. Evans, A. Aguilar and C. Smeenk). Proc. 4th Ann. Conf. ECS, 2-4 March 1994, Paalma de Mallorca, Spain. European Cetacean Society, Cambridge, UK. 140pp.

Geraci, J.R. and St. Aubin, D.J. 1987. Effects of parasites on marine mammals. *Int. J. Parasitol.*, 407-414.

Perrin, W.F. and Powers, J.E. 1980. Role of nematode in natural mortality of spotted dolphins. *J Wild. Manag*, 44: 960-963.

Raga, J.A., Casinos, A., Filella, S., and Raduan, M.A. 1982. Notes on cetaceans of the Siberian coasts. V. *Crassicauda grampicola* Johnston and Mawson, 1941 Nematoda), cause of injuries in the pterygoids of some specimens of *Grampus griseus*. *Säugetierk. Mitt.*, 30 (4): 315-318.

Raga, J.A. 1987. Rédescription de *Crasssicauda grampicola* Johnston et Mawson (Nematoda: Spiruroidea) parasite de *Grampus griseus* (Cuvier, 1812) (Cetacea: Delphinidae). *Vie et Milieu*, 37: 215-219.

Robineau, D. 1975. Lésions osséus lies à la présence du genre Crassicauda (Nematoda, Spiruroidea) sur la face ventrale díun crane do *Tursiops truncatus* (Cetacea, Delphinidae). *Annls. Soc. Sci. Nat.*, 6: 93-97.

Walker, W.A. and Cowan, D.F. 1981. Air sinus parasitism and pathology in free-ranging common dolphins (*Delphinus delphis*) in the eastern tropical Pacific. Administrative Report No. LJ-81-23C. *Nat. Mar. Fish. Serv. Southw. Fish. Center*, La Jolla, U.S.A. 19pp.

Walker, W.A., Hochberg, F.G., and Hacker, E.S. 1984. The potential use of the parasites *Crassicauda* (Nematoda) and *Nasitrema* (Platyhelminthes) as biological tags and their role in the natural mortality of common dolphins, *Delphinus delphis*, in the eastern North Pacific. *NOAA, SFC, Adm. Rep.*, LJ-84-08C: 1-31.

Table 1. Occurrence of skull lesions in different cetacean species

Cetacean	N° individuals examined	Frecuency (%)	Mean (Range)
Delphinus delphis	96	13	2(1-4)
Stenella coeruleoalba	16	0	0
Tursiops truncatus	27	59	2.5(1-6)
Grampus griseus	5	20	1
Globicephala melas	11	0	0
Phocoena phocoena	16	0	0
Lagenorhynchus acutus	2	100	1
Orcinus orca	1	100	1
Kogia breviceps	3	0	0
Ziphius cavirostris	2	0	0

Table 2. Frequency (%) of lesions in different cetacean species within each skull area (For area code see Fig. 1).

Areas	*D. delphis*	*T. truncatus*	*G. griseus*	*L. acutus*	*O. orca*
Area 1:	41	22	0	0	0
Area 2	4	10	0	0	0
Area 3	50	56	0	100	100
Area 4	4	10	100	0	0
Area 5	0	2	0	0	0

Figure 1. Different areas in the ventral skull surface of cetaceans stranded in Galicia (NW Spain).

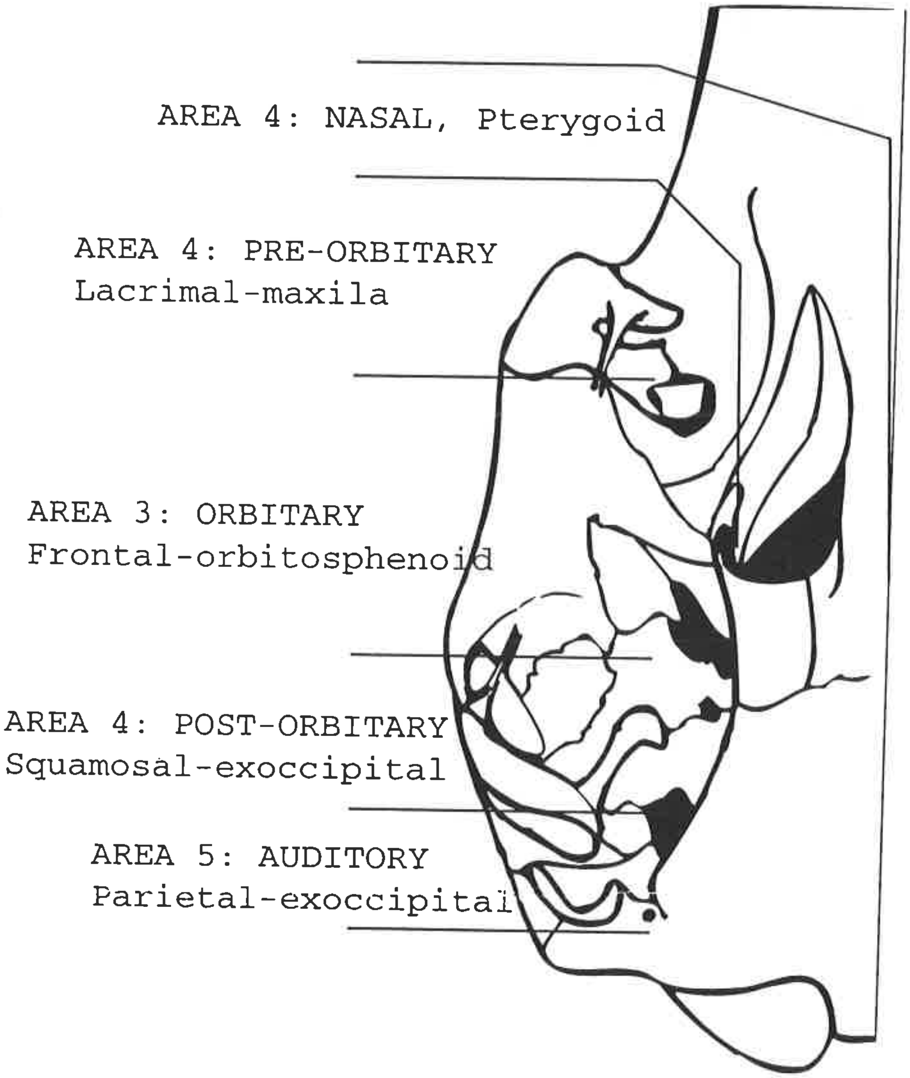

Figure 2 Basket-like bone lesions in *Lagenorhynchus acutus*.

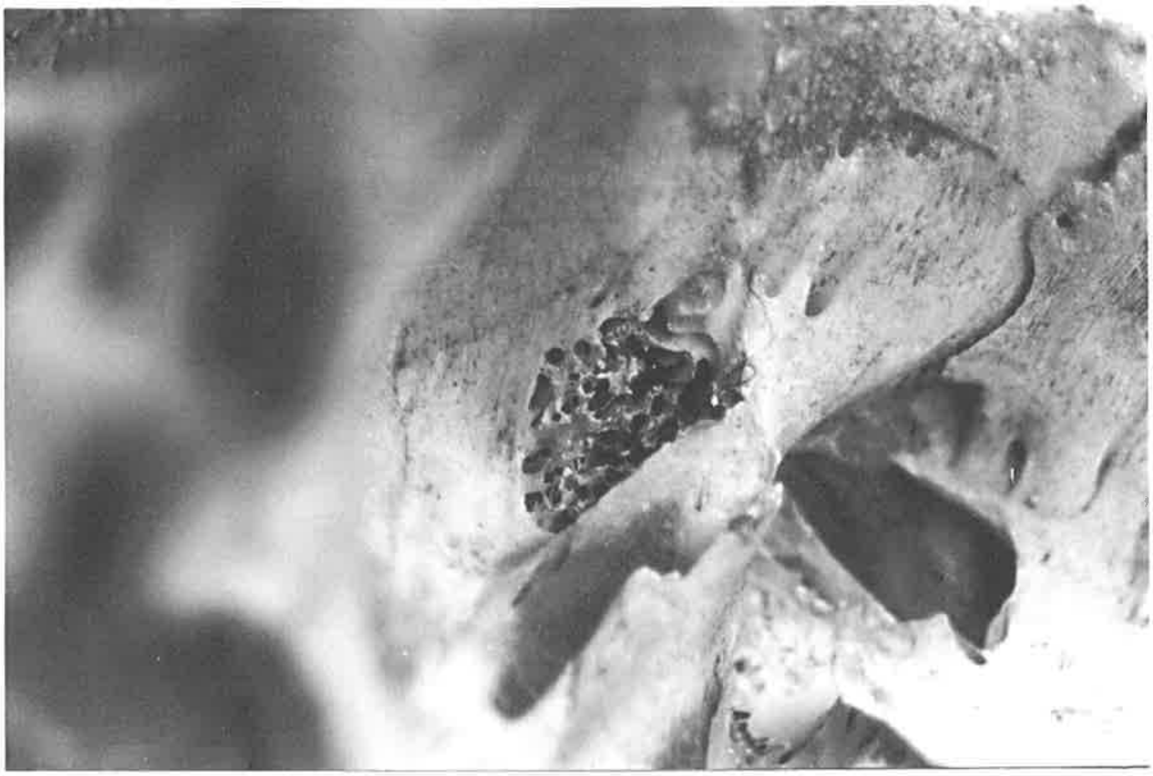

Figure 3 Trabecula-like lesions in *Tursiops truncatus*.

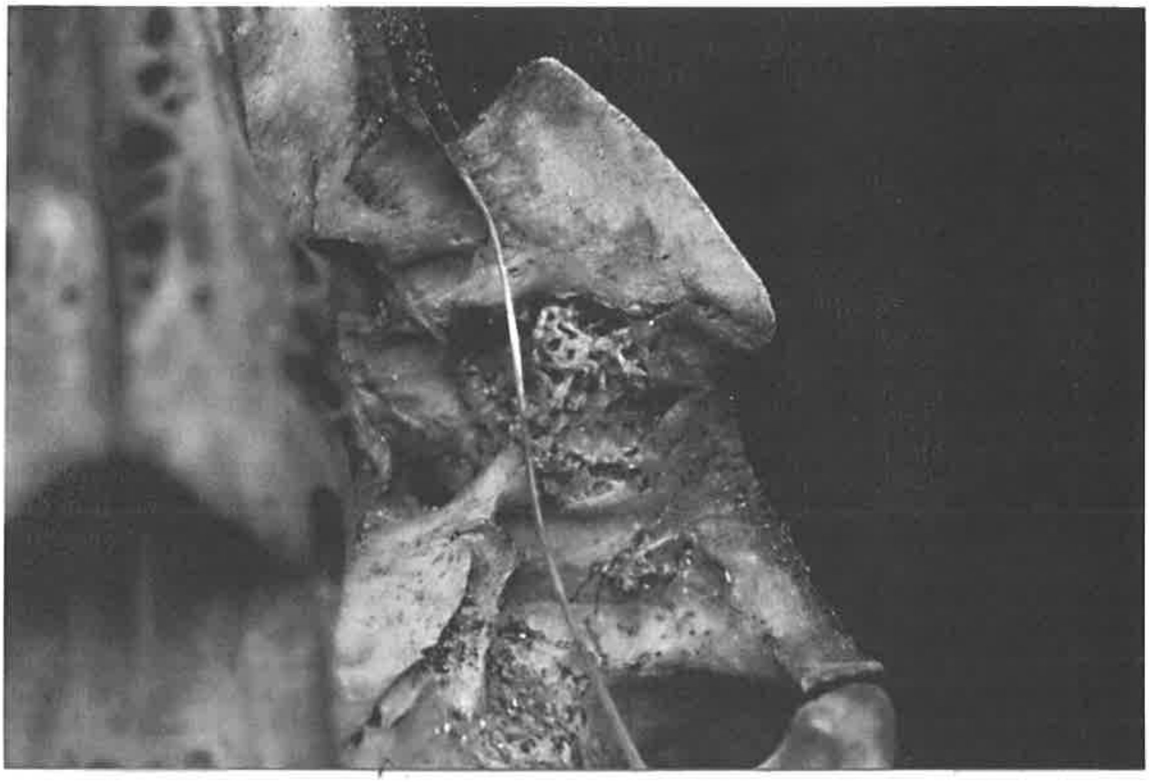

Figure 4 Smooth-like lesions in *Delphinus delphis.*

Figure 5 Nasal and orbitary perforations extending into the brain cavity in *Tursiops truncatus.*

CHARACTERISATION OF ALPHA-1-ACID GLYCOPROTEIN FOR USE AS A MARKER OF HARBOUR SEAL (*PHOCA VITULINA*) HEALTH

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The acute phase response is a cytokine mediated response to tissue damage or infection, one consequence of which is synthesis of a set of acute phase proteins by the liver. One of these acute phase proteins is a1-acid glycoprotein (AGP). Change in serum AGP concentration and glycosylation occur more slowly and persist over a more prolonged period of time compared to the more frequently measured C reactive protein. This suggests that measuring changes in AGP may offer advantages for field studies.

AGP was purified from harbour seal serum. Biochemical properties of harbour seal AGP are comparable to those of dog. A single concanavalin A binding form of harbour seal AGP was observed, this compares to the reports in dogs but not other animals. An assay has been produced using a polyclonal antibody to harbour seal AGP. Significant increases, of a similar magnitude to those seen in other animals, have been found in the serum of animals with clinical signs of inflammation.

AGP is an acute phase protein in seals but only a single glycoform exists. These observations raise interesting questions about the biological role suggested for the different AGP glycoforms observed in humans and rodents.

PAPILLOMAVIRUSES CAUSE GENITAL WARTS IN SMALL CETACEANS FROM PERU

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Papillomaviruses (PVs) cause benign tumours (warts, papillomas or fibropapillomas) of the skin and mucous membranes in a variety of animals including man. Among cetaceans PV infection has been often suspected but could never be confirmed until now. Recently, some of us reported a high prevalence of genital warts in dusky dolphins (*Lagenorhynchus obscurus*), long-beaked common dolphins (*Delphinus capensis*), bottlenose dolphins (*Tursiops truncatus*) and Burmeister's porpoises (*Phocoena spinipinnis*) from Peru. Several characteristics of the tumours were indicative of PV infection but this remained to be ascertained.

To determine unequivocally the aetiology of the lesions we have conducted immunohistochemical and molecular investigations on genital warts from 11 dusky dolphins, four Burmeister's porpoises, and a bottlenose dolphin. Thus, PV DNA could be amplified by polymerase chain reaction (PCR) in a wart from the genital slit of a porpoise (JAS-44) using degenerate primers designed to amplify human genital PVs. Primers derived from the sequence of the amplification products of JAS-44 permitted amplification of PV DNA in genital warts from a bottlenose dolphin, a dusky dolphin and another porpoise. Moreover, group specific PV antigens were detected in a wart sample of JAS-44. These results confirm that papillomaviruses are indeed the aetiological agents of genital warts in Burmeister's porpoises, bottlenose and dusky dolphins from Peru. This is the first time that PVs are demonstrated in cetaceans and that genital PVs are detected in an order other than the Primates.

A PATHOLOGICAL STUDY OF CETACEANS STRANDED IN THE CANARY ISLANDS DURING 1996

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Twenty-two cetaceans were found stranded in the Canary Islands last year. Eight common dolphins (*Delphinus delphis*) and six Atlantic spotted dolphins (*Stenella frontalis*) were the most numerous stranded species. Gross, histological, bacteriological, parasitological, toxicological and virological studies were performed on these animals. The results of these studies will be presented in this communication. Parasitosis was frequent, in some cases even severe. Pulmonary emphysema and pneumonic areas were often observed and a non-purulent encephalitis was observed in five animals. A chronic-active hepatitis was found to be a common histopathological lesion. *Vibrio damsela* was the most significant isolated bacteria. Toxicological studies were performed on 6 stranded cetaceans. 1,2,3,4-tetrahydro-1,1,6-trimethyl-naftalene, a derivated fungicide, was found in the liver of 4 dolphins. A great amount of some heavy metals was found in internal organs such as liver, kidney, etc.

This work was done in collaboration with the Viceconsejería de Medio Ambiente (Gobierno de Canarias, Spain).

POXVIRUS INFECTION IN BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) FROM THE SADO ESTUARY, PORTUGAL

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Recently, epidermal diseases of unknown origin were reported in bottlenose dolphins (*Tursiops truncatus*) from different ocean provinces. Such lesions are common in resident bottlenose dolphins from the Sado Estuary, Portugal. In an attempt to elucidate their origin we conducted a photographic survey among resident bottlenose dolphins from the Sado Estuary between February 1994 and May 1997. Pictures were taken with manual and autofocus cameras and lenses of 75-300mm and 80-200mm.

On 15th April 1996, a 252 cm male bottlenose dolphin (21) was found dead on a beach close to Setúbal. It presented several cutaneous lesions on the head, flank and tail peduncle which were identified as 'tattoos' on the basis of their characteristic macroscopic aspect. As tattoos are caused by poxviruses in other cetacean species including the bottlenose dolphin, we believe that the ones we observed on dolphin 21 were also due to these viruses. This is the first record of cetacean poxvirus infection in the Sado Estuary and Portugal. Careful examination of good quality pictures of free-ranging resident bottlenose dolphins revealed possible tattoo marks in other individuals. Thus, poxvirus infection may affect several residents and cause some of the skin disorders affecting bottlenose dolphins from the Sado Estuary.

CYTOPLASMIC ALPHA-1-ANTITRYPSIN INCLUSIONS IN HEPATOCYTES OF STRANDED DOLPHINS

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Hepatocellular vacuolisation is a frequent histological finding in cetaceans (Moore *et al.*, 1996). A very characteristic large cytoplasmic hyalin inclusion was reported in 33 to 82 per cent of morbillivirus affected dolphins (Domingo *et al.*, 1992, Duiugnan *et al.*, 1992). These inclusions, usually single and occurring in all parts of the lobule, are round to oval, PAS positive and frequently displace the nucleus to the perifery of the cells (Kennedy *et al.*, 1993). An histological, histochemical and ultrastructural study concludes that the inclusions contain glycoprotein (Kennedy *et al.*, 1993).

We used samples of 12 out 25 cetaceans stranded in Canary Islands during 1995-96. We observed in those animals cytoplasmic hyaline inclusions in hepatocytes with very similar features described above. The purpose of this communication is to demonstrate the nature of this cytoplasmic hyalin inclusions observed in hepatocytes in these stranded dolphins. An histochemical and immunohistochemical study has been performed on their livers.

Alpha-1-antitrypsin antiserum was used and the inclusions showed an intensive positive immunoreaction. The corresponding negative and positive controls have been included in the technics.

This study has demonstrated immunohistologically the presence of alpha-1-antitrypsin in hepatocitic cytoplasmic hyalin inclusions frequently found in stranded dolphins.

This work was done in collaboration with the ViceconsejerÌa de Medio Ambiente (Gobierno de Canarias, Spain).

CHRONIC PCB EXPOSURE IS ASSOCIATED WITH INFECTIOUS DISEASE MORTALITY IN HARBOUR PORPOISES STRANDED IN ENGLAND AND WALES 1990-1996

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It has been proposed that bioaccumulation of persistent immunosuppressive contaminants like polychlorinated biphenyls (PCBs) may pose a threat to the health status and viability of cetaceans, including harbour porpoises *Phocoena phocoena* in UK waters where there is evidence for population decline.

To test the hypothesis that chronic PCB exposure may suppress immune function and predispose individuals to mortality associated with infectious disease, concentrations of 25 individual chlorobiphenyls in blubber samples from 29 healthy animals that died due to physical trauma (mainly bycatch) were compared with blubber PCB concentrations from 33 animals that died due to a range of infectious diseases.

All carcasses were freshly dead and the potential confounding variables of age, sex, nutritional status, season, location and year of stranding were included in the regression analyses. It was found that the infectious disease group had significantly higher PCB concentrations than the healthy group ($F_{1,60}=13.2$, $p=0.001$). The mean PCB level (of the total 25 PCB congeners) in animals that died due to physical trauma was 11.3mg kg^{-1} wet weight whereas the mean level in the infectious disease group was 29.4mg kg^{-1}. The multiple regression analyses showed that the relationship between higher PCB levels and the infectious disease group remained highly significant ($p=0.001$) when the potential confounding effects of the other variables were controlled.

In common with previous studies, we also found that amongst sexually mature animals males had significantly higher PCB levels than females ($F_{1,27}=5.4$, $p<0.05$). Our findings support the hypothesis that chronic PCB exposure negatively influences the health status of harbour porpoises in UK waters by pre-disposing individuals to mortality associated with infectious disease.

ORGANOCHLORINE CONTAMINANTS IN CASPIAN AND HARBOUR SEAL BLUBBER

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The Caspian Sea has no outlet and acts as a reservoir for contaminated water in the region. Most pollutants arrive via the Volga, Ural, Terek and Kura rivers. Industrial complexes along the coast, particularly on the Apsheron Peninsula in Azerbaijan also discharge waste directly into the sea. Thus, Caspian seals (*Phoca caspica*), particularly if feeding coastally, could carry a higher contaminant burden in their blubber than phocid species elsewhere.

We compared the blubber levels of lipophilic contaminants (chlorobiphenyls and DDT), on a fat-weight basis, in dead Caspian seals (n=6) stranded on the Apsheron Peninsula, Azerbaijan, with those from dead harbour seals (*Phoca vitulina*) (n=34) stranded around the UK. DDT levels were significantly higher in Caspian than in harbour seals (one-way ANOVA; DDE $p<0.0001$; TDE $p=0.05$; DDT $p<0.05$; total DDTs $p<0.001$). Individual chlorobiphenyl congeners were also compared (on a fat-weight basis). Combining the seven ICES congeners, Caspian seals had significantly lower content than harbour seals (one-way ANOVA; $p<0.0001$). However, levels of two of these congeners (CB28 and CB52) were significantly higher in Caspian seals.

The ratio of DDE to total DDT can indicate whether these pollutants are entering the system; a ratio greater than 0.6 implies the system is relatively stable with no recent input. For UK harbour seals, this ratio ranged between 0.56 and 0.8; for Caspian seals, it ranged between 0.75 and 0.83. Although additional DDTs do not appear to be entering the Caspian Sea system, levels of DDT metabolites in Caspian seals were at least double those in UK harbour seals.

DDT is a persistent pesticide, the use of which was legal in countries surrounding the Caspian Sea until 1988. These results show that Caspian seals carry high DDT burdens which may have an affect on their reproductive performance. In contrast, PCB levels were lower than in UK harbour seals. This may be due to the main sources, industrial transformers and capacitors, still being in use. Inappropriate disposal of these sources in the future could result in high levels of PCBS being introduced into the Caspian Sea ecosystem.

PHYSIOLOGICAL AND IMMUNOLOGICAL EFFECTS OF PCB-EXPOSURE IN HARP SEALS (*PHOCA GROENLANDICA*)

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Polychlorinated biphenyls (PCBs) are highly stable compounds that accumulate and magnify in the food web to potentially toxic levels, particularly in lipid-rich top predators like seals. PCBs are known to interfere with endocrine and immune function in laboratory animals, but little is known about the effects of PCBs in seals. We have experimentally exposed two harp seal (*Phoca groenlandica*) pups to increasing doses of specific PCB congeners during a feeding period, while another two harp seals acted as controls. Five dose levels were used, each dose being administered daily for seven days. Blood samples were collected after each 7-day period and also periodically during a 30 day food-deprivation period.

All seals had higher cortisol- and aldosterone-levels during food-deprivation than during the previous feeding period. Cortisol levels were higher in PCB-exposed seals than in control animals during food-deprivation, which may indicate an adrenal hyperplasia in response to PCB-exposure. PCB-exposed seals also had elevated levels of various liver enzymes (ALAT, ASAT and GGT), compared to control animals late in the feeding period and during the food-deprivation period. Levels of bilirubin increased late in the food-deprivation period in all animals, but the increase was twice as high in PCB-exposed seals compared with control animals. These observations indicate possible hepatocyte damage by PCB-exposure.

Monocyte expression of tumour necrosis factor alpha (TNF-a) was examined as a measure of the potency of the immune system. The monocytes ability to respond to a given stimulus late in the food-deprivation period was greatly diminished in PCB-exposed seals, as compared to the control animals. The present study has shown that short-term exposure to "naturally" occurring high levels of PCB caused detectable physiological and immunological changes in the harp seals, and, that periods of prolonged food-deprivation (during which lipid-bound PCBs are supposedly released) are most critical.

CORRELATION BETWEEN ORGANOCHLORINE CONTAMINANTS AND VARIOUS PARAMETERS IN STRIPED DOLPHINS (*STENELLA COERULEOALBA*) STRANDED ALONG THE COASTS OF ITALY. PROBABLE GROWTH CURVE FOR THE MEDITERRANEAN STRIPED DOLPHIN

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The aim of the present study was to investigate the role of xenobiotics, such as hexachlorobenzene (HCB), dichlorodiphenyltrichloroethane (DDT) and its metabolites, and polychlorobiphenyls (PCBs), in the mortality of striped dolphins (*Stenella coeruleoalba*). It is known that large differences exist in the accumulation of these contaminants in specimens of the same species. These differences are related to parameters such as age, sex, health, nutrition and geographical location. From 1988 to 1994, 62 species of *Stenella coeruleoalba* were collected on the Italian coasts and sent to the Department of Environmental Biology of Siena University for chemical analysis and age determination. The age of the animals was determined by counting dentine growth layer groups in the teeth. A growth curve for Mediterranean *Stenella coeruleoalba* was plotted on the basis of age and body length data. The equation relating length and age is based on a mean length at birth of 90 cm and a mean length of adults (>9 yrs) of 200 cm, ignoring sex differences. The equation of the curve was $Y=200 / [\, 1 + e\ (0.201 - 0.5115\ X)\,]$ where **Y** is body length in cm and **X** age in years. This curve shows that growth was quite slow in the first year and is followed by a rapid increase in size up to a plateau at physical maturity, which seems to be attained at about 8 years.

The curve is similar to that obtained for ocean dolphins; the only difference is the time taken to reach physical maturity. Ocean striped dolphins are larger than their Mediterranean counterparts, and presumably take longer to reach full size. Organochlorine contaminants were analysed in the blubber, liver, brain and muscle of 25 of the dolphins. The analytical method used was high resolution capillary gas chromatography, In all dolphins and all tissues analysed, HCB concentrations (ng/g dry weight) were the lowest and the PCBs were the highest, except in one blubber sample in which total DDTs were higher than PCBs. A high correlation was found between contaminant levels in 25 dolphins of known age and year of death. Organochlorine levels were particularly high in the years 1990 and 1991, which correspond with an epidemic of *Morbillivirus* in the Mediterranean. It is not yet clear whether the disease was a cause of a result of the high levels of fat-soluble xenobiotics in these cetaceans.

AUTHENTIC ALPHA- AND GAMMA HERPES VIRUSES OF PINNIPEDS

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Harbour seals (*Phoca vitulina*) have been shown to host an alpha- and a gamma herpesvirus, designated phocid herpesvirus type-1 and type-2 respectively (PhHV-1,-2). Serosurveys in several pinniped species have revealed the global prevalence of both viruses. PhHV-1 has been shown to be a significant pathogen, which may cause a life threatening disease in seal pups. Signs of disease result from a mild upper respiratory to a generalised fatal infection and correlate inversely with age and immunocompetence of the animal. Antigenic and molecular studies showing that PhHV-1 is closely related to canine and feline herpes viruses, as well as recent developments in the diagnosis and development of a vaccine against PhHV-1 infection, will be presented. So far, PhHV-2 infection has not unambiguously been associated with clinical signs in pinnipeds. Previous molecular studies and further nucleotide sequence data presented here suggest a clustering of PhHV-2, together with its seemingly closest relative, the equine herpesvirus type-2, in a third genus of the gamma-*Herpesvirinae* subfamily.

A COMPARATIVE ANALYSIS OF THE LUNGWORM FAUNA OF STRIPED (*STENELLA COERULEOALBA*) AND COMMON DOLPHIN(*DELPHINUS DELPHIS*)

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The morbidity effects of pseudaliid nematodes are largely unknown, particularly in relation to verifying intensities of lung infestation. In this study, lung parasites were removed from 24 striped dolphins and 75 common dolphins. Dolphins were either stranded or by-caught. The lungworm communities of both host species were found to be similar; Skrjabinalius guevarai was the most abundant parasite within each host sample. In both hosts, the parasite species displayed clumped frequency distributions with overall prevalences of 45.8% in striped dolphins and 43.2% in common dolphins being recorded. With both dolphin species, males had significantly higher burdens than females ($p < 0.001$), and positive correlations were found between parasite burden and length ($p < 0.01$ for striped dolphins; $p < 0.001$ for common dolphins). A significant correlation between parasite burden and age was only found in the common dolphin sample. Stranded animals were found to have significantly higher burdens than those that were by-caught. These latter results may raise questions regarding the relationship between nematode burdens and the cause of strandings in the two dolphin species

MORTALITY AND HAEMATOLOGY OF LAND-BRED BALTIC GREY SEAL PUPS

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The Baltic stock of grey seals breed on packed-ice in February-March. Land breeding, however, occur in years with low ice coverage in the Mid-Baltic. In 1997, an estimated number of 300 pups were born at two sites in Estonia, the islets Innarahu and Allirahu situated at the coast of the Saaremaa Island. There is a record of a distinct difference in mortality between the two colonies. This was also the situation in 1997: in contrast to a very low rate of pup mortality at Allirahu (approx. 5%), of the estimated 200 pups born at Innarahu, 46 corpses were found at the end of the breeding season. Autopsy revealed that the corpses had no subcutaneous layer of blubber, and most pups were less than one week of age, suggesting starvation to be the primary cause of death. Innarahu covers an area of only 1/4 acre, and the birth of 200 pups impose a higher density of seals at that site, presumably causing mortality by failure of, or disturbance to, the mother/pup bound.

Haematology profiles obtained from weaned pups at the end of the breeding season showed two-fold higher total WBC counts (cells/mL) ($P<0.01$) of pups at Innarahu (median: 13.6 x 106, ní19) compared to pups at Allirahu (median: 6.8 x 106, ní9). Increase in total WBC coincided with increase in both neutrophil and monocyte counts. There were no changes in lymphocyte-, eosinophil- and RBC- counts, Hct-, Hb-, MCV-, MHC-, and MCHC- values between the colonies. The increase in neutrophils and monocytes presumably reflect infectious challenge inflicted on the pups by the environment/adult harassment.

As the majority of pups and adults had deserted the islets at the time of sampling (especially was that true for Innarahu), it is, however, yet to be elucidated whether the elevated counts reflect the general health of pups at Innarahu, or the status of weakened pups possible prevented from going into the sea. The low counts at Allirahu suggest that the low rate of mortality is paralleled by a low rate of morbidity.

INTERCOMPARISON STUDIES ON DISTRIBUTION OF CU AND CD IN LIVER AND KIDNEY OF HARBOUR PORPOISE (PHOCOENA PHOCOENA) FROM A POLISH SECTOR OF THE BALTIC SEA, COASTAL WATERS OF DENMARK AND GREENLAND

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Harbour porpoise, although still extremely rare species in a Polish zone of the Baltic Sea, since 15 years has been observed rather more frequently, especially in the Gulf of Gdańsk. However, this mammalian species is the most common cetacean in Danish and Greenland waters. Liver and kidney were isolated from 28, 13 and 45 specimens of Polish sector of the Baltic Sea, Danish and Greenland areas, respectively. After drying to a constant weight at 60°C and homogenisation, three replicate subsamples of each were then prepared. All subsamples were digested using concentrated HNO_3 and triple distilled water. Cd and Cu concentrations were determined by AAS method. The quality of the method used was checked and confirmed in a separate comparative study of metals in a standard reference material.

The concentrations of Cd in liver and kidney increased with age of the specimens analysed. Significant inter-spatial variations in both hepatic and renal levels of Cd were also observed. Average hepatic levels of Cd in Baltic, Danish and Greenland specimens were (age range) 0.05-0.09, 0.12-0.25 and 20.6-51.6 $\mu g\ g^{-1}$ dry wt., respectively.

Such values for renal Cd were as follows: 0.55-0.71, 0.14-1.84 and 0.55-94.3 $\mu g\ g^{-1}$ dry wt. In contrast to Cd, concentrations of Cu in the liver and kidney of specimens from Baltic, Danish and Greenland areas did not indicate such great intra-spatial variability. The average hepatic values amounted to (age range) 14.1-15.5, 22.1-63.6 and 16.3-25.9 6 $\mu g\ g^{-1}$ dry wt. while kidney contained on the average 7.83-8.80, 11.7-16.2 and 11.1-15.7 mg Cu $\mu g\ g^{-1}$dry wt., respectively.

Distributions of the hepatic and renal Cd were significantly different between the three geographical regions explored. The Greenland harbour porpoises contained the highest levels of hepatic and renal Cd, whilst the Baltic specimens were characterised by the lowest its levels. Concentrations of the metal in harbour porpoises from Danish waters were somewhat greater than those for Baltic specimens and significantly smaller as compared with those for Greenland mammals. These inter-spatial variations could be explained by different food composition in the area studied. In the Baltic individuals mainly feed on fish (cod, plaice) contained extremely low muscle levels of Cd.

CETACEAN POXVIRUSES ARE ANTIGENICALLY RELATED TO COWPOX VIRUS

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Poxvirus infect several species of small cetaceans from the North Atlantic and the Eastern Pacific, causing skin lesions known as >tattoosí. Besides being morphologically different from members of the genus Parapoxvirus, the taxonomic status of the "cetacean poxviruses" among the subfamily Chordopoxvirinae is unknown.

Off Peru, dusky dolphins *Lagenorhynchus obscurus*, long-beaked common dolphins *Delphinus capensis*, Burmeister's porpoises *Phocoena spinipinnis* and bottlenose dolphins *Tursiops truncatus* are endemically infected by cetacean poxviruses. In an attempt to characterise these viruses, we have investigated whether they are antigenically related to cowpox virus (CPXV), a member of the Orthopoxvirus genus. Serum samples from 28 *L. obscurus*, 6 *D. capensis*, 8 *T. truncatus* and 17 *P. spinipinnis* were tested for the presence of neutralising antibodies against CPXV. Thus, the sera from all *D. capensis* and *T. truncatus*, of 18 *L. obscurus* and 14 *P. spinipinnis* were positive.

Among 13 dolphins and 7 porpoises, CPXV neutralising tiers ranged between 30 and 1600, and 30 and 100, respectively. Our data indicate that these species are commonly infected by poxviruses antigenically related to cowpoxvirus, which we believe to be identical to the cetacean poxviruses. Indeed, poxviruses always cause skin lesions and, during an extensive study on the aetiology of cutaneous marks in *L. obscurus*, *D. capensis*, *T. truncatus* and *P. spinipinnis* from Peru, poxvirus particles were only detected in typical tattoos. Moreover, prevalence of tattoos is high in these animals (34.7% to 62.3% according to the species) and, consequently prevalence of cetacean poxvirus antibodies should be high too, which we observed.

CYTOCHROME P450 ENZYMES AND PCB CONGENER PATTERNS IN RINGED SEALS (*PHOCA HISPIDA*) FROM SVALBARD, NORWAY

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The cytochrome P450 enzyme system (CYP) is important in contaminant metabolism in mammals. Knowledge of these enzymes is essential since their presence and activity determines both contaminant accumulation patterns and potential biological effects of contaminant exposure. In this study, hepatic CYP in ringed seals were characterised using catalytic activities, selective inhibitors, and mRNA analyses. In addition, congener specific PCB measurements were performed in this species, and related to age, sex, percentage of blubber, and CYP activities.

The results from the CYP activity measurements showed ethoxyresorufin-O-deethylation (EROD) and caffeine demethylation activity, while the pentoxyresorufin-O-depentylation activity was low, indicating the presence of CYP1A isoforms. The activity towards testosterone resulted in several hydroxy-metabolites, characteristic for CYP3A activity. The inhibition of EROD and caffeine demethylation by a-naphthoflavone but not by furafylline suggested that in this seal species only one CYP1A enzyme was present. This was supported by the results from the mRNA measurements, where only one mRNA band cross-hybridised with human CYP1A cDNA probes at the rat CYP1A1 position. The selective inhibition of the formation of the testosterone 2b- and 6b-hydroxy metabolites by ketoconazole suggested that the formation of these metabolites was mediated by a CYP3A-like isoform. The mRNA measurements showed cross hybridisation with human CYP3A cDNA, but not with rat CYP2B1/2 cDNA. Overall these results suggested the presence of CYP1A1, CYP3A, but not CYP2B in ringed seals.

Multiple regression analyses revealed a significant positive effect of age and a negative effect of percentage blubber on the PCB concentrations. In addition, the PCBís considered non-persistent showed a relation with CYP activities. Surprisingly, no effect of sex on the PCB concentrations could be observed, probably because female ringed seals, unlike most other seal species, cover a substantial part of their energy costs for lactation through feeding, resulting in a lower contaminant transfer to their offspring. In agreement with the results from the CYP characterisation, the PCB congener pattern in seals relative to their food showed a decrease in CYP1A and 2B metabolisable PCBís. The decrease in concentrations of the latter PCB's was probably due to the action of CYP3A rather than CYP2B activity.

TECHNIQUES

SKIN BIOPSY AS A NONDESTRUCTIVE TOOL FOR THE TOXICOLOGICAL ASSESSMENT OF MARINE MAMMAL POPULATIONS

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INTRODUCTION It is well known that in all parts of the world marine mammals have been subjected to heavy anthropogenic pressure by direct killing and chemical pollution in the past hundred years. Most studies of contamination and biomarker responses in marine mammals have been conducted using animals killed by hunting, tacitly approving this activity. The development of a series of nondestructive techniques to evaluate biomarker responses and residue levels is strongly recommended for the hazard assessment, protection and conservation of endangered species of marine mammals. The aim of this paper is to develop and validate a method based on nondestructive biological material, the skin biopsy, for the assessment the toxicological risk to populations of pinnipeds and cetaceans. In this paper we present the validation of this methodology for MFO activity, organochlorine and polycyclic aromatic hydrocarbon levels in skin biopsy samples obtained from an endangered population of sea lion (*Otaria flavescens*) living in a heavily polluted harbour (Mar del Plata, Argentina) and a control population (Punta Bermeja, Patagonia, Argentina) and from the Mediterranean cetaceans, the striped dolphin (*Stenella coeruleoalba*) and the fin whale (*Balenoptera physalus*).

MATERIALS AND METHODS **Southern sea lion**: the species studied is the southern sea lion. Its distribution includes the Atlantic and Pacific coasts of south America. The Mar del Plata sea lion colony lives in a fenced area inside the biggest fishing harbour of Argentina, Mar del Plata. The water is heavily contaminated by oil, organic and chemical materials and the remains of fish from fish processing factories. The sea lion colony consists of 600-750 males. A large percentage of the old sea lions have diseases of the skin and mucous membranes with fur loss and baldness. Punta Bermeja, in the San Matias Gulf, Rio Negro Province, was used as "control" environment. In the Punta Bermeja reserve, there is a permanent population of 1,870 sea lions. This is a reproductive colony.

Skin biopsy procedure:

1 Anaesthetic darts were shot with a blow-gun with the assistance of a member of the Fundacion Fauna Argentina (Mar del Plata). Xylazine and ketamine anaesthetics were combined in different proportions: after many trials, a total of 16 sea lions were sampled in the year 1995, using a combination of 2.42 mg/kg xylazine and 2.21 mg/kg ketamine. Skin samples were obtained from the flipper surface;

2 This sampling procedure does not require anaesthetics and is therefore less invasive and dangerous for the animals. The sea lions were sampled on land with a dart having a punch tip (i.d. 8 mm x 40 mm) shot by means of a crossbow. The dart with the biopsy sample were recovered by hand.

The skin samples (about 0.5 g) were divided into cutaneous tissue which was stored in liquid nitrogen and processed in the lab for BPMO analysis, and subcutaneous fat which was stored at -20°C and analysed for chlorinated hydrocarbons and PAHs. Fresh biopsy samples (about 0.1 g) were analysed for PAHs using a HPLC/fluorescence system. Extraction was according to Griest and Caton (1983). and Holoubek *et al.* (1990), with several modifications developed in our lab (Marsili *et al.*, 1997). Quantification was carried out using an external PAH standard from Supelco. Total PAHs were calculated as the sum of naphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene and benzo(g,h,i)perylene.

Mediterranean cetaceans: subcutaneous biopsies of striped dolphins and fin whales were performed by a non invasive method in the Ligurian and northern Tyrrhenian Seas during the summers of 1991-1993. The samples of skin and subcutaneous blubber (about 1 x 2 cm) were obtained from free-ranging whales by means of biopsy darts launched with a crossbow, and from bow-riding dolphins by means of biopsy tips mounted on a 2-m pole (Marsili & Focardi, 1996). The small size of the samples (between 0.200 g and 0.002 g) did not permit isolation of the microsomal fractions. BPMO activity was detected in the whole tissue. BPMO activity was assessed using the incubation mixture proposed by Kurelek *et al.* (1977) incubating each sample (plus the blanks) in a shaking bath for 2 h at 37°C. The activity was expressed in arbitrary units of fluorescence (AUF/h/g tissue). The samples of subcutaneous blubber (about 0.3 g) were freeze-dried and extracted with n-hexane in Soxhlet apparatus for analysis of chlorinated hydrocarbons. The analytical method used was High Resolution Capillary Gas Chromatography with a Perkin-Elmer Series 8700 GC and a 63Ni ECD (Marsili *et al.*, 1996). Capillary gaschromatography revealed the presence of op'- and pp'- isomers of DDT and its derivatives DDD and DDE, and about 30 PCB congeners in the subcutaneous blubber of all the species. The percentage of organic substance (EOM%) extracted from freeze-dried samples was 89.1% ± 15.4 standard deviation (S.D.) for whales and 88.1% ± 16.1 S.D. for striped dolphins.

Statistical analysis: was performed on a PC computer using Statgraphics software (Statistical Graphics Corporation). Differences between specimens were calculated by the non-parametric Mann-Whitney test. Differences were considered significant for $p<0.05$.

RESULTS AND DISCUSSION

Pinnipeds: The main results of the first sampling (June-September 1995), concern the detection of BPMO activity in sea lion skin biopsy samples. Previously, MFO activity (BPMO) has been assayed in skin biopsy samples by Fossi *et al.* (1992) in other marine mammals. Mammal skin MFO activity was known to have (Bickers *et al.*, 1984 ; Mukhtar & Khan, 1989). Experimental confirmation that MFO activities (AHH and 7-EC) are induced in whole skin of neonatal rats by topical application of Arochlor 1254 (Bickers *et al.*, 1982) suggested that this method might be used for the nondestructive testing of marine mammals. BPMO activity in sea lion skin biopsy samples was 4 times higher in the Mar del Plata colony than in one specimen of the control colony. The two groups of samples also differed dramatically in DDT and PCB levels (Fig. 1). In the second sampling (November 1995) we confirmed the dramatic differences in BPMO activity in skin biopsy samples from the two colonies (Fig. 2). In this case we focused the residue analysis on PAHs which are probably the main cause of MFO induction in the Mar del Plata specimens. The levels of the four most carcinogenic PAHs (NRCC, 1983) were several times higher in the Mar del Plata than in the Punta Bermeja colony; levels of total PAHs were five times higher in the harbour colony. Taking the results of the different sampling periods together the dramatic differences in BPMO activity in the two colonies is evident. This data suggests that Mar del Plata colony is subject to constant toxicological risk due to a mixture of lipophilic contaminants that induces CYT-P450 (Fig. 3). Moreover the presence in this area of compounds with genotoxic activity was also confirmed by the results of agarose gel electrophoresis. This test revealed more strand breaks in DNA molecules of Mar del Plata samples than in the samples of Punta Bermeja. In the stranded sea lion we were also able to investigate the relationship between the destructive biomarker (BPMO in liver) and the nondestructive biomarker (BPMO in skin biopsy samples). Surprisingly, the MFO activity detected in the nondestructive samples was only one fifth that in the liver (Fig. 4). This means that the skin of sea lions has in this species a high metabolic rate and is suitable for nondestructive studies. Moreover the presence of Cyt.P450 in the skin sample was also confirmed by SDS PAGE, with the same two isoforms between 66 and 45 KD in liver and skin (Fig. 4).

Cetaceans: The BPMO activities and organochlorine concentrations (DDTs and PCBs) in the skin biopsies of striped dolphins and fin whales sampled in the Ligurian and northern Tyrrhenian Seas in the summers 1991 and 1992-1993 are reported in Figs. 5A and 5A. In 1991, seven biopsies from striped dolphins and nine from fin whales were analysed. In 1992-93, 18 biopsies from striped dolphins and 14 from fin whales were analysed. The trend of xenobiotics and BPMO activities was similar in the two periods.

In the samples of 1991, the concentrations of total DDT and PCBs were 21.96 µg/g d.w. (S.D.=16.5) and 45.96 µg/g d.w. (S.D.=29.3) respectively for striped dolphin, and 2.67 µg/g d.w. (S.D.=8.1) and 3.99 µg/g d.w. (S.D.=12.3) respectively for fin whale; in the samples of 1992-1993, they were 22.82 µg/g d.w. (S.D.=11.6) and 37.06 µg/g d.w. (S.D.=28.9) respectively for striped dolphin, and 4.02 µg/g d.w. (S.D.=3.5) and 5.16 µg/g d.w. (S.D.=3.5) respectively for fin whale. The BPMO activity differed significantly ($p< 0.001$) from one period to the other in striped dolphins and fin whales. In 1991, BPMO activity was 19.96 AUF/h/g tissue (S.D.=130.6) in striped dolphins and 5.44 AUF/h/g tissue (S.D.=25.4) in fin whales; in 1992-1993, it was 80.61 AUF/h/g tissue (S.D.=50.5) in striped dolphins and 37.80 AUF/h/g tissue (S.D.=21.1) in fin whales. BPMO activity was four and two times higher in striped dolphins than in fin whales ($p<0.020$) in 1991 and 1992-1993 respectively.

The two species also differed dramatically in levels of organochlorines in subcutaneous blubber. For the specimens in Fig. 5A the levels of PCBs and DDTs were twelve times ($p<0.001$) and nine times ($p<0.001$) higher respectively in striped dolphin than in fin whale; for the samples in Fig. 5B the levels of PCBs and DDTs were seven times ($p<0.001$) and six times ($p<0.001$) higher respectively in striped dolphin than in fin whale. The significant difference in organochlorine accumulation between these species seems principally due to their different positions in the food chain, the dolphin having a fish diet and the whale feeding on macroplankton. The different content of PCBs and other chlorinated xenobiotics in their prey is reflected by the different levels of xenobiotics detected. The most plausible explanation for this interspecies difference in MFO activity is related to the capacity of these contaminants, especially PCBs, to induce this enzyme response in the liver of birds, fish and mammals.

CONCLUSIONS These preliminary results on BPMO activities and lipophilic contaminants (OCs and PAHs) in skin biopsy samples of two populations of the pinniped *Otaria flavescens* and of two species of cetaceans (*Stenella coeruleoalba* and *Balaenoptera physalus*) allow us to draw several general conclusions.

The biomarker tests together with the results of chemical residue analysis in nondestructive skin samples can be used as a combined approach for evaluating the toxic risk to endangered populations of marine mammals.

The induction of BPMO activity in pinniped and cetaceans skin biopsy material is an useful nondestructive biomarker of exposure and the potential effects of organic lipophilic contaminants such as organochlorines and polycyclic aromatic hydrocarbons.

The dramatic induction of BPMO activity in the skin biopsy samples of the Mar del Plata sea lions combined with higher levels of OCs and PAHs revealed the high toxicological risk to which this population is exposed in this polluted environment. This data is a warning sign for the Regional Authorities in Argentina that better control of the environment in which this population of sea lions lives is necessary.

In conclusion, the preliminary results of the validation of this methodology in pinnipeds and cetaceans demonstrate that a nondestructive approach can be used instead destructive approaches, for the hazard assessment, protection and conservation of populations of marine mammals.

REFERENCES

Bickers, D.R., Dutta-Choudhury, T. and Mukhtar, H. 1982. Epidermis: a site of drug metabolism in neonatal rat skin. *Mol. Pharmacol.*, 21: 239-247.

Bickers, D.R., Mukhtar, H., Dutta-Choudhury, T., Marcello, M.S.C. and Voorkees, M.D. 1984. Aryl hydrocarbon hydroxylase, epoxide hydrolase, and benzo(a)-pyrene metabolism in human epidermis: comparative studies in normal subjects and patients with psoriasis. *J. Invest. Dermatol.*, 83: 51-56.

Fossi, M.C., Marsili, L., Leonzio, C., Notarbartolo di Sciara, G., Zanardelli, M. and Focardi, S. 1992. The use of non-destructive biomarker in Mediterranean cetaceans: preliminary data on MFO activity in skin biopsy. *Mar. Poll. Bull.*, 24(9): 459-461.

Griest, W.H. and Caton, J.E. 1983. Extraction of polycyclic aromatic hydrocarbons for quantitative analysis. Pp. 95-148. In: *Handbook of Polycyclic Aromatic Hydrocarbons.* (Eds: A. Biørseth and M. Dekker). INC.

Houlobek, I., Paasivirta, J., Maatela, P., Lahtiperä, M., Holoubková, I., Korínek, P., Bohácek, Z. and Cáslavsky, J. 1990. Comparison of extraction methods for polycyclic aromatic hydrocarbon determination in sediments. *Toxicol. Environ. Chem.*, 25: 137-154.

Marsili, L. and Focardi, S. 1996. Organochlorine levels in subcutaneous blubber biopsies of fin whales (*Balaenoptera physalus*) and striped dolphins (*Stenella coeruleoalba*) from the Mediterranean Sea. *Envir. Poll.*, 91(1): 1-9.

Marsili, L., Fossi, M.C., Notarbartolo di Sciara, G., Zanardelli, M. and Focardi, S. 1996. Organochlorine levels and mixed function oxidase activity in skin biopsy specimens from Mediterranean cetaceans. *Fresenius Envir. Bull.*, 5: 723-728.

Marsili, L., Fossi, M.C., Casini, S., Savelli, C., Jimenez, B., Junin, M. and Castello, H. 1997. Fingerprint of polycyclic aromatic hydrocarbons in two populations of southern sea lions (*Otaria flavescens*). *Chemosphere*, 34(4): 759-770.

Mukhtar, H. and Khan, W.A. 1989. Cutaneous cytochrome P-450. *Drug. Metab. Rev.*, 20(2-4): 657-673.

NRCC (1983). Polycyclic aromatic hydrocarbons in the aquatic environment: formation, sources, fate and effects on aquatic biota. *National Research Council Canada*, 18981: 1-209.

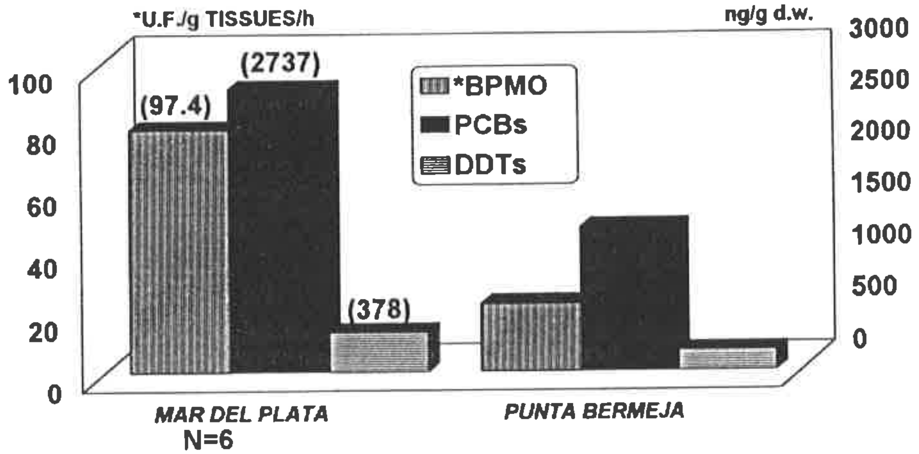

Fig. 1 - MFO activities (BPMO) and organochlorines in sea lion skin biopsy (June/September '95). S.D. in brackets.

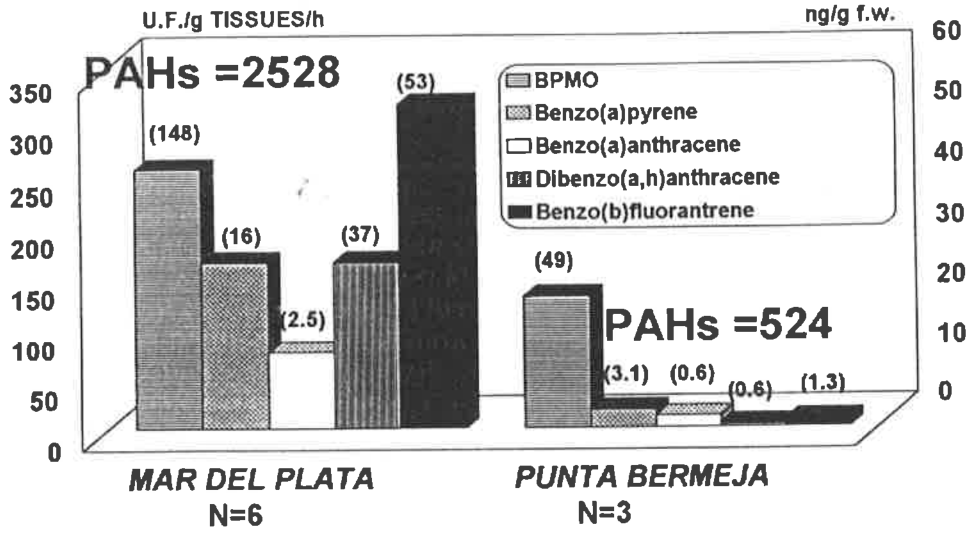

Fig. 2 - MFO activities (BPMO) and PAHs in sea lion skin biopsy (November '95). S.D. in brackets.

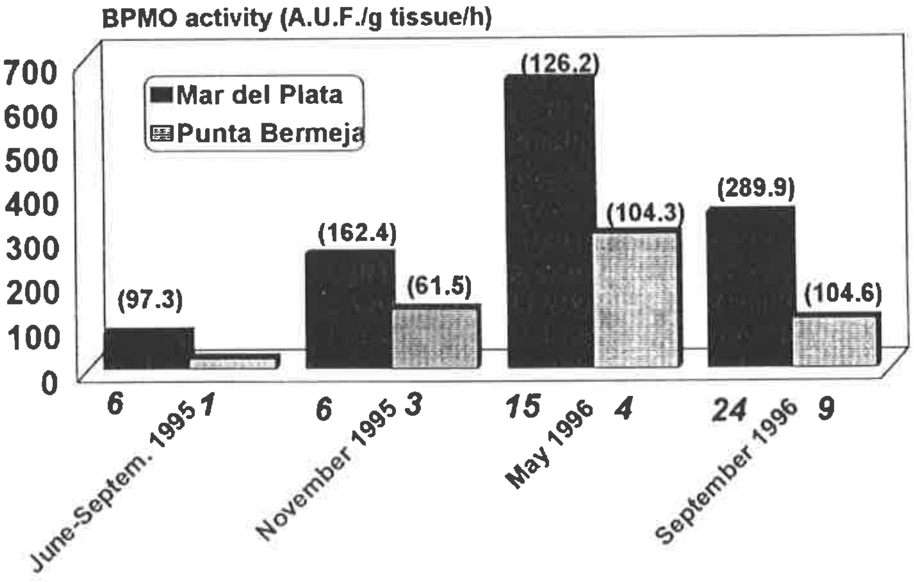

Fig. 3- Skin biopsyBPMO activities in different sampling periods. S.D. in brackets.

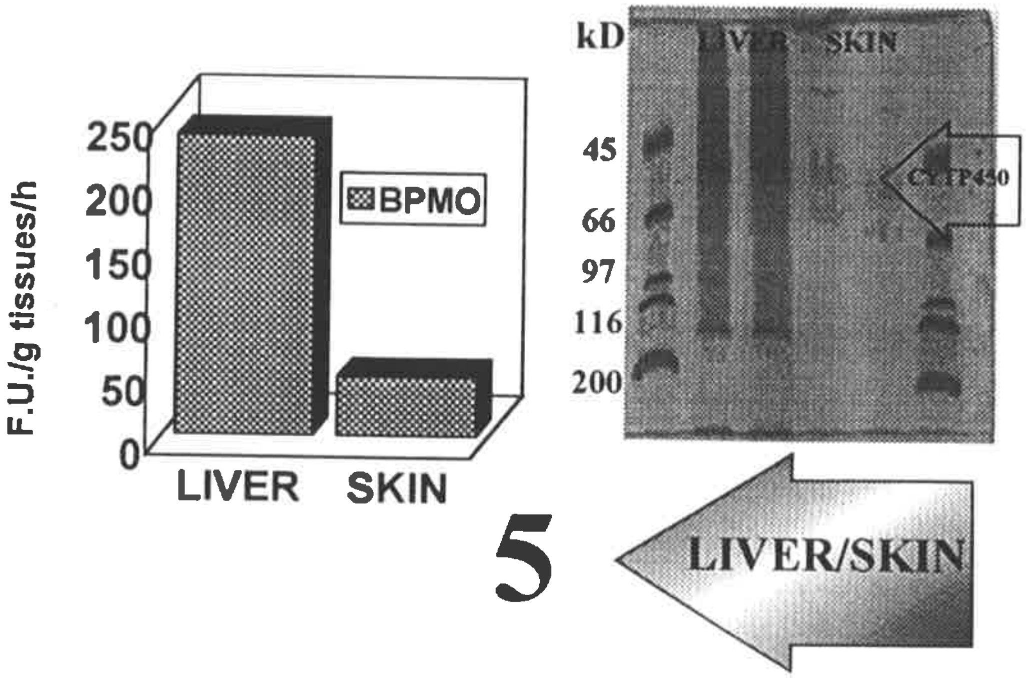

Fig. 4- MFO activities in liver and skin of a stranded sea lion

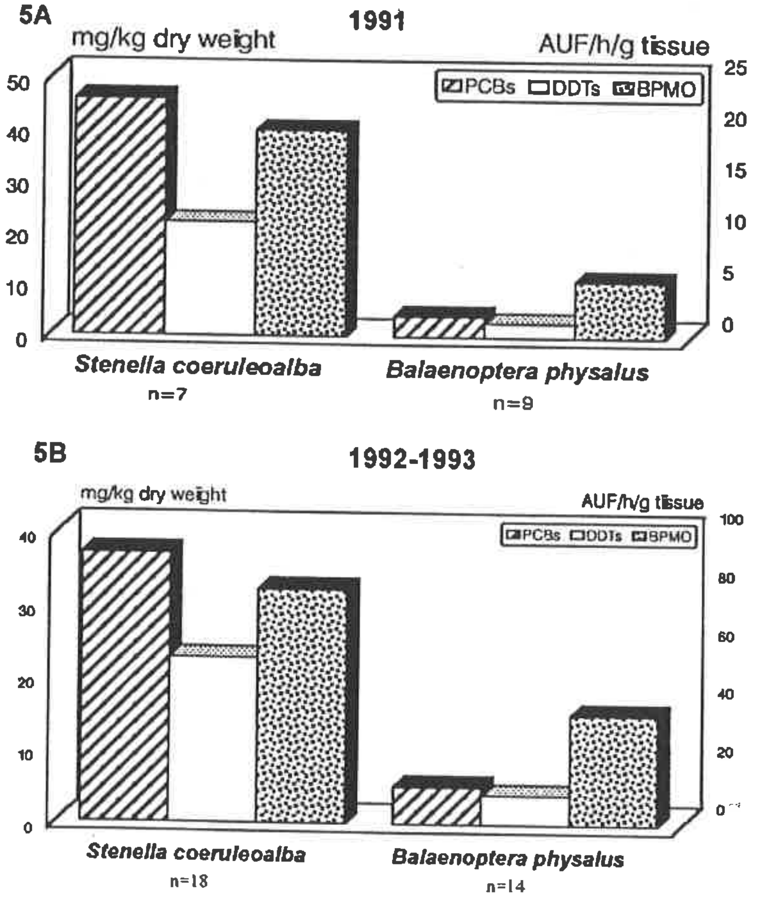

Fig. 5 - BPMO activity and organochlorines in skin biopsy specimens of cetaceans

MEASURING BODY VOLUME OF MARINE MAMMALS FROM A DISTANCE: A NEW METHOD BASED ON IMAGE ANALYSIS

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INTRODUCTION The assessment of body condition of animals is central to many ecological and physiological studies. Amongst marine mammals, seals display huge variations in body condition related to reproduction and moult on land, that must be compensated by periods of intense fat storage at sea (e.g. Kovacs et al., 1991; Fedak et al., 1994). Similarly, baleen whales are known to undergo impressive seasonal variations in blubber thickness (Lockyer, 1981). In dolphins and porpoises, variations in body condition can also be expected as a result of variable food availability (Lockyer, 1993; Liret *et al.*, 1996).To date, body weight of marine mammals have mostly been measured from direct weighing of dead or immobilised animals (e.g. Nordoy et al., 1993), or from morphometric measurements (Haley *et al.*, 1991). The aim of this study was to develop a new photogrammetric method for assessing body condition of marine mammals without handling them.

MATERIALS AND METHODS **Principle**: Body volume has been chosen as a measurement of the body condition of the animal. This volume can be extrapolated to an absolute weight, provided the body density is close to one kg/l. For assessing the body volume of marine mammals underwater, we have assumed that their body is elliptical in cross-section, i.e. it can be assimilated to a succession of elliptical truncated cones. The fin, flippers and tail fluke - or fore and hind flippers in case of seals ñ are dismissed for the estimation. The volume of each cone can then be calculated provided that the length of the two axes of the ellipses and the distance between them are known. Thanks to the bilateral symmetry of the body, vertical axes of the elliptical cross-sections can be measured on a lateral view of the body, whereas horizontal axes are measured from a dorsal or ventral view. Therefore, a single pair of pictures of the same individual is necessary for the photogrammetric measurement of the body volume : one fully lateral and one fully dorsal or ventral photograph.

These two pictures are analysed using a specific software developed under Windows format (de La Bernardie *et al.*, in press), along the following procedure. First, the two extremities of the animal and the outline of the body are manually traced by the operator using the mouse of the PC, fins, flippers and tail fluke being dismissed. Then, the cross-sections of the body are obtained by an iterative process which cuts the body along its length into 2^n slices (Fig. 1). A set of 32 (25) slices has been kept, giving the best results while the use of more slices (64 or 128) did not improve the accuracy of the measurements.

Every body height drawn on the lateral image is divided by the corresponding body width from the dorsal or ventral picture, in order to calculate the flattening ratios of the successive ellipses along the body. This set of 32 ratios constitutes the volumetric model of the animal. Then, a lateral picture alone can be used for the body volume assessment. The volume Vi of the truncated conical slice between cross-sections i and i-1 is given by formula (1):

$$V_i = (\pi/6\ [2(D_i/2)^2\alpha i\ + 2(Di\text{-}1\ /2)^2\ \alpha_{i-1} + (D_i\ /2)(D_{i-1}/2)\ (\alpha_i + \alpha_{i-1})]\ L/32 \qquad (1)$$

With: D_i: length of cross-section i; α_i: ellipse flattening ratio; L: total body length

The total body volume is: $\sum^{1 \longrightarrow 32} V_i$ (2)

If the total body length (L) of the animal is known, an absolute volume is obtained. This length can also be calculated by the software provided that a scaling object is set alongside the animal. If it is not available, the body length is arbitrarily set at 1 metre: consequently a relative volume, that can be used as a body condition index, is obtained.

Validation: The method has been tested on the images of six well-preserved stranded cetaceans. Because their weight is distorting their shape when they lie on the floor, the carcasses were hung by the flukes when filmed. Their mean body volume was estimated from image analysis, and converted into absolute weight according to a body density set at 1 kg/l. Estimated weights were compared to real weight of the carcasses.

In addition, a real size application has been attempted on a captive female harbour seal, Phoca vitulina, for investigating seasonal variations in her body condition. Underwater images were filmed during a 2.5-year period, so that varying body conditions could be detected ñ including a pregnancy period. The relative volumes V_i (1) of all slices constituting the body were detailed in order to assess the precise location of variations in body volume.

RESULTS Table 1 shows the comparison between estimated and real weights of the six stranded cetaceans. All estimations ±S.D. were within the real weight (reading accuracy of the weighing scale. The error in estimated body weights ranged from 0.1 to 2.6% of real weights.

Variations in body volume of the female harbour seal are shown on Fig. 2. The relative body volume varied from 47.7 litres (for an hypothetical length of one metre) at the end of pregnancy to within 30.3-38.1 litres when she was not pregnant. Except during gestation, variations of body volume were quite equally distributed along the body length, head and base of hind flippers displaying, however, only slight variations of volume, if any. This observation is in accordance with girth measurements made by Rosen & Renouf (1997) on Atlantic harbour seals.

DISCUSSION Image analyses conducted on stranded animals has shown a low error rate, ranging from 0.1 to 2.6%. This is lower than obtained in previous methods of marine mammal body weight assessment ; additionally it is within the same magnitude of error as most field balance readings. These results validate the method of image processing by the software.

The study of the female harbour seal showed that it is also possible to assess variations in body condition, even on a captive animal which does not undergo as dramatic variations as wild individuals. Similar measurements could be combined efficiently with other techniques such as Bioelectrical Impedance Analysis (BIA) for experiments on marine mammal energetics and thermal insulation. Figure 2 also shows that the ratio of slices 18 to slices 6 can provide a good indication of late lactation.

In addition to such physiological studies, the potential of this photogrammetric method is mostly for studies in the wild, where the use of conventional weighing methods is generally precluded. Photo-identified marine mammal populations are very interesting candidates, since one could parallel variations in body condition with individual life histories. Populations as a whole can also be studied following this method†: average body condition variations would be compared to productivity at sea for example. Photo-ID programs conducted on baleen whale populations by aerial surveys should provide numerous dorsal pictures of identified individuals that could be analysed for body volume assessments. Therefore, variations in body condition would be paralleled with biological and behavioural observations such as migrating or calving. Furthermore, several studies have already tested the possibility of measuring real body length of baleen whales from aerial photographs, giving helpfull data for the assessment of the real body weight of the animal by the present method (Angliss *et al.*, 1995).

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REFERENCES

Angliss, R.P., Rugh, D.J., Withrow, D.E. and Hobbs, R.C. 1995. Evaluations of aerial photogrammetric length measurements of the Bering-Chukchi-Beaufort seas stock of bowhead whales (*Balaena mysticetus*). *Rep. Int. Whal. Commn.*, 45: 313-324.

Fedak, M.A., Arnbom, T.A., McConnell, B.J., Chambers,C., Boyd, I.L., Harwood, J. and McCann, T.S. 1994. Expenditure, investment, and acquisition of energy in southern elephant seals. Pp. 354-373. In: *Elephant Seals*. (Eds. B. J. Le Bœuf and R. M. Laws) University of California Press, London, England. 414pp.

Haley, M. P., Deutsch, C. J., Le Bœuf, B. J. 1991. A method for estimating mass of large pinnipeds. *Marine Mammal Science*, 7: 157-164.

Kovacs, K. M., Lavigne, D. M., Innes, S. 1991. Mass transfer efficiency between harp seal (Phoca groenlandica) mothers and their pups during lactation. *J. Zool.*, Lond., 223: 213-221.

De La Bernardie, X., Vincent, C., Liret, C. and Ridoux, V. (in press). Assessing variations in marine mammal body condition by using video image analysis: preliminary tests. *Wildlife Telemetry*.

Liret, C., Creton, P. and Ridoux, V. 1996. Seasonal variations in habitat use and activity budget of resident bottlenose dolphins at Île de Sein, France. Pp. 146-149. *European Research Cetaceans - 9*: Proc. 9th Ann. Conf. ECS, Lugano, Switzerland, 9-11 Feb 1995. (Ed. P.G.H. Evans). European Cetacean Society, Kiel, Germany. 302pp.

Lockyer, C. 1981. Estimation of the energy costs of growth, maintenance and reproduction in the female minke whale, *Balaenoptera acutorostrata*, from the southern hemisphere. *Rep. Int. Whal. Commn.*, 31: 337-343.

Lockyer, C. 1993. Seasonal changes in body fat condition of northeast atlantic pilot whales, and their biological significance. Pp. 325-350. In: *Biology of northern Hemisphere pilot whales*. (Eds. G.P. Donovan, C.H. Lockyer and A.R. Martin). *Rep. Int. Whal. Commn.* (Special issue 14). 479pp.

Nordoy, E. S., Aakvaag, A. and Larsen, T.S. 1993. Metabolic adaptations to fasting in harp seal pups. *Physiol. Zool.*, 66: 926-945.

Rosen, D.A.S. and Renouf, D. 1997. Seasonal changes in blubber distribution in Atlantic harbor seals: indications of thermodynamic considerations. *Marine Mammal Science*, 13: 229-240.

Table 1. Comparison between estimated and real body masses of stranded dolphins. Appendages are dismissed in both mass measurements

Dolphins	Real body mass in kg. ± reading accuracy	Estimated body mass in kg. ± S.D.	Accuracy in % real weight
Common d. #1	75.0 ± 0.1	75.1 ± 1.5	0.1%
Common d. #2	23.3 ± 0.1	23.5 ± 1.2	0.9%
Common d. #3	7.8 ± 0.1	8,0 ± 0.2	2.6%
Bottlenose d. #1	280 ± 5	275 ± 15	1.8%
Bottlenose d. #2	352 ± 5	356 ± 7	1.10%
Harbour porpoise	58.5 ± 0.1	57.9 ± 1.9	1.0%

THE ACCURACY OF SATELLITE POSITIONING IN MARINE MAMMALS: AN EXPERIMENT WITH CAPTIVE GREY SEALS

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During the last decade, the development of satellite tracking technology using the Argos system has led to an increase in the number of investigations in marine mammal movements and activities at sea. However, because marine mammals spend most of their time underwater, the number of signals received and, therefore, the quality of the positioning are lower than in terrestrial or aerial applications. Consequently the accuracy of the location fixes is of greater concern in marine studies. Few experiments, however, have so far been undertaken to assess this accuracy.

The aim of this study was to measure the difference between estimated and real positions of seals held in captivity and to investigate possible relationships between signal quality and the seals' activities. Four grey seals (*Halichoerus grypus*) were fitted with Satellite Relay Data Loggers from the Sea Mammal Research Unit and kept in a tank for 2 to 4 weeks prior to their release into the sea. During the experiment, the main activities of the seals, their positions in the tank and their surfacing behaviour were recorded when the site was ´ visible ª to the satellites. The average errors in location fixes ranged from 3 to 12 km for the worst Location Quality (LQ 0, -1, -2) whereas the best results were for Location Quality 1 to 3 with average errors of 0.9, 0.5 and 0.3 km. Although few location fixes of level 3 were obtained, these high quality signals were received primarily when the seals were out of the water.

Further data are needed to document the relationships between seals' activities and the Location Quality. However, it is believed that calibration studies using captive animals should provide invaluable information that will eventually help in interpreting satellite tracking data.

MULTIPLE SPERM WHALES TRACKED BY COMBINING A TOWED DIPOLE HYDROPHONE AND FREE-DRIFTING SPAR-BUOY ARRAYS

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The feasibility of tracking individual large cetaceans acoustically while monitoring distribution and acoustic behaviour of other cetaceans within the same area or group was tested in the Ligurian Sea during April 1997. A towed dipole hydrophone array (4 hydrophones switchable to pairs, Casio DA-7 DAT recorder, COLMAR amplifier - system response 500 Hz to 17 kHz) and two semi-submersible free-drifting spar buoys (each equipped with a Garmin 45 GPS data logger, Sony D-8 DAT recorder and HTI SSQ-41B hydrophone - system response 10 Hz to 22 kHz, and a VHF radio for time synchronisation) were deployed in the presence of sperm whales (*Physeter macrocephalus*). While the buoys drifted free the dipole array was towed under sail on a track parallel to the drifting front of the buoys; vessel speed and heading were kept constant and its position logged automatically. One sperm whale was chosen as the reference bearing and tracked throughout the recording session (100 mins. of four channel digital recording were obtained). Six other whales could be discriminated and located in space by computing arrival time differences of clicks at the sensors and calculating bearings of the sources during post-processing. Two-dimensional locations were obtained for one-min. samples throughout the recording session, three-dimensional locations were obtained when the depths of several hydrophones were known.

Advantages of this combination are: (1) the freedom of the towing vessel to pursue other objectives after buoy deployment (an individual female sperm whale was tracked to obtain a fluke-ID); (2) the active variation of the array aperture to provide virtually infinite spacing combinations required for locating different cetacean species; (3) the use of the spar buoys to eliminate the right/left ambiguity of towed arrays while maintaining real-time tracking abilities; (4) the enhanced recording quality of buoys unaffected by towing noise; and (5) the extension of detection ranges by the cross-correlation of sounds from different sensors to extract masked signals. The result is a system that permits the simultaneous tracking of focal animals while conducting acoustic surveys of cetaceans over large geographic areas.

DEVELOPMENT OF A SOFTWARE RECEIVER FOR MARINE MAMMAL TELEMETRY

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Marine mammal telemetry logging systems are often of fixed frequency and designed for specific transmitters and applications. Their high cost reflects this tailored individuality often taking them beyond the budget of small research groups wanting to carry out a variety of telemetry studies. The aim of this project was to produce a low-cost multi-purpose telemetry data receiver for detecting and decoding transmitters of varying frequency and modulation using off-the-shelf system components.

Using digital signal processing many of the functions of a telemetry receiver can be carried out more cost effectively in software, thus removing the need for dedicated electronics. Using a low-cost laptop computer equipped with a sound card and a commercially available scanner with interface, it is possible to create a sophisticated software telemetry receiver. The audio output of the scanner is sampled using the laptop soundcard, and fast Fourier transforms (FFT's) are performed on the data in real time.

The system has excellent signal detection capability, and the FFT information allows the transmitter frequency to be measured accurately and therefore it can compensate for oscillator drift. It also has adaptive thresholding, providing the user with accurate probability of detection and false alarm statistics, even in constantly varying noise environments. Data transmitters encoded by different modulation schemes can be decoded in software, either providing a high capacity data link for sensors providing physiological and environmental information, or for enabling the application of matched filtering techniques for optimum signal detection. Using an off-the-shelf digitally controlled antenna switch, a variety of antennas or direction finding arrays can be connected to the system, making multi-frequency telemetry studies a simple task. A compact phased array direction finder has been developed that can be simply 'plugged in', however, cheaper direction finding can be achieved, at the expense of multi-frequency operation, by the application of 4 3-element Yagi antennas.

Our results indicate that cost effective marine mammal telemetry studies can be carried out with a high level of sophistication using off the shelf components and dedicated 'Windows 95' based software. System requirements are easily programmed providing a versatile receiver capable of adapting to new transmitter technologies.

THE USE OF THE MAMVIS SOFTWARE AND THE INTERNET IN COLLABORATIVE SATELLITE TRACKING PROJECTS

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A number of marine mammal satellite tracking projects have been set up on a collaboration basis between distant research groups. The access to both raw data and synthetic imaging should be made available to all participating laboratories. This paper presents how the MAMmal Visualisation System (MAMVIS) designed at the Sea Mammal Research Unit (SMRU) to display satellite tracking information, can accommodate the INTERNET format to share raw data, 2D graphs, 3D maps and animated sequences of the tracks in real time. In June 1997, four young grey seals, *Halichoerus grypus*, from the Océanopolis rescue centre were fitted with Satellite Relay Data Loggers (SRDLs) in order to monitor the final step of their rehabilitation at-sea. Location and dive data were relayed by CLS Argos to SMRU for analysis.

2D maps with location quality and 3D tracks were produced daily by using the MAMVIS software, dive profiles were analysed on a weekly basis. A password-protected page dedicated to the project was opened at the SMRU web site to deliver the list of transmissions together with analysed data ; the content of the page was updated on a daily basis. Consequently, track and dive data were available to OcÈanopolis research group in almost real time. The main advantage of this organisation is that equipment and working costs for data analysis can be shared. Additionally, animated 3D maps were displayed at the Océanopolis exhibition centre, allowing visitors to be informed in real time of the project being carried out. Ongoing projects on public display concerning marine mammals are more and more appreciated by sponsoring governmental agencies.

ARTEFACTS, ALIASES AND ARGOS: GAPS BETWEEN PERCEPTION AND REALITY

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Marine mammals behaviour and interaction with the environment range from scales of seconds and metres to years and thousands of kilometres. To understand such behaviour we must measure and relay data over a similar range of scales. The use of Argos-based satellite telemetry in marine mammology is now widespread. However the limitations imposed by Argos, and the underwater habit of marine mammals, severely limit the rate at which data may be relayed. Thus the content and scheduling of transmissions must be optimised to allow an unbiased and broad-scale view of the animal's life to be reconstructed.

Raw sensor data may be collected at a far higher rates (and smaller scales) than may be uplinked to Argos satellites. Thus, data compression techniques are required. One approach is to evaluate, at sea, key behavioural statistics that minimise loss of information while maintaining temporal resolution. For example, we may select and store a subset of points (and associated data) within a dive that best represent dive shape. However, the random nature of communication to Argos results in only a subset of these behavioural statistics being relayed. Therefore, data should be re-transmitted at a rate that is scaled to 1) their rate of change, and 2) to the importance of a complete series of behavioural events. Frequently, over 90% of Argos locations from marine mammals are of unguaranteed accuracy (LQ=0). However filtering methods that use objective criteria may be used to reject outliers.

The spatial resolution and temporal distribution of location data may be used to infer the minimum scale of movement and behaviour that can be reliably resolved. Battery energy limits the amount of information relayed. Therefore, a compromise, based on the scale of the behaviour being studied, must be made between short and intensive small-scale studies and longer, large-scale studies. However tracking duration is frequently foreshortened by chance events. The effect of variable duration may be investigated used Monte Carlo simulation.

To interpret marine mammal behaviour in an environmental context, external data (for example oceanographic, ecological and fishery data) must be available at the appropriate spatial and temporal scales. The full potential of marine mammal data may be limited by the difficulty in collecting or obtaining, and assimilating such data sets.

REPORT OF WORKSHOP ON MARINE MAMMAL REPRODUCTION: MORPHOLOGY & PHYSIOLOGY

REPORT OF THE WORKSHOP ON MARINE MAMMAL REPRODUCTION: MORPHOLOGY AND PHYSIOLOGY

Edited by T.B. Sørensen[1, 2] and C. Lockyer[2]

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INTRODUCTION Most information about reproduction in marine mammals has been based on post-mortem examination of gonads and reproductive tracts , and more recently data have been gathered on blood hormone levels, reproduction in relation to social structure of groups, and reproductive behaviour in free-ranging animals. The 1981 workshop on reproduction in cetaceans (Perrin *et al.*, 1984) provided the first large forum for discussion on various aspects of the reproductive biology in cetaceans. The workshop provided a foundation for future research, and by addressing many important key issues in reproductive morphology and physiology and it is still a very important source of information for anybody working in the field of cetacean reproductive biology.

In more recent years, a growing body of evidence suggests that environmental factors that resemble female sex hormones may be having an adverse effect on the reproductive capacity and well-being of diverse species (Toppari, 1995). The growing number of reports demonstrating that common environmental contaminants and natural factors possess estrogenic activity present the working hypothesis that the adverse trends in human male reproductive health may be, at least in part, associated with exposure to estrogenic environmental chemicals during fetal and childhood development. It is also suggested that a decline in the fecundity of many wild animal populations may be associated with exposure to oestrogenic chemicals.

Bearing in mind that there is a continued need for sharing information on these important issues, and because there has not been a major forum since the 1981 workshop, addressing these issues, we decided to organise the Workshop on Marine Mammal Reproduction: Morphology and Physiology, in connection with the World Marine Mammal Science Conference, Monaco 18th - 19th January 1998.

The following report is a collection of abstracts presented at the workshop. Many of the presentations were of a very high standard, and some of them will be published in international journals in the near future.

We would like to thank all participants in the workshop for making it a very interesting and rewarding event; and give many thanks to the whole organising committee of the WMMSC for giving us the opportunity to hold the workshop in connection with the conference.

Workshop agenda and schedule, 18-19 January 1998

18 January

12:00 - 13:00 Registration at Hotel Loews .

13:00 Introduction and welcome by convenors - Christina Lockyer and Thomas Buus Sørensen.

13:15 **Agenda 1 - New trends in methodology - Chair: Randy Wells - short introduction**

1.1 Live animals

1) Randy Wells - Dolphin population studies in Sarasota, Florida.

2) Motoi Yoshioka - Sperm collection and cryo-preservation in dolphins (paper for discussion, presented by Christina Lockyer for M.Yoshioka).

3) Michael Moore - Ultra-sound of blubber thickness in Eubalaena will it predict reproductive sucess?

14:15 **1.2 Autopsied animals**

1) Marie-Francoise van Bressem - Genital pathologies in dusky dolphins off Peru.

2) Bettina Bandomir - Reproduction in harbour porpoises in German waters.

3) Marjan Addink - Reproduction in harbour porpoises in Dutch waters.

15:30 - 15:45 **Refreshment break**

15:45 **Agenda 2 - Morphology and physiology in females and males -Chair: Aleta Hohn - short introduction**

2.1 Females

1) Aleta Hohn - general introduction and discussion on reproduction in Vacquita.

2) Thomas Buus Sørensen - Dynamics of follicular development

3) Jamie Bacon - Estradiol and progesterone levels in harbour seals in Bermuda.

17:10 **2.2 Males**

1) Genevieve Desportes - hormonal physiology of reproduction in cetaceans.

2) Stephanie Ploen - Sperm morphology and other aspects of reproduction in Kogia

17:45 **Summary of session - Chair: James Mead** - general discussion agenda 2.

18:00 **Break for the day and time for placing posters**

19 January

08:00 - 09:00 **Poster placement and informal reviews**

09:00 **Agenda 3 - Changes in fecundity associated with toxicology and pathology -Chair: Christina Lockyer**

3.1 Oestrogen levels in the environment and mechanisms of reproductive interference

1) Ailsa Hall - endocrine disruptors - review of symposium held during 1997.

09:25 **3.2 Contaminant levels in the environment and mechanisms of reproductive interference**

1) Gera Troisi - Biomarkers for monitoring organochlorine exposure to endocrine disrupting environmental pollutants.
2) Madeleine Mattson - Reproduction, health and contaminant burden in the Baltic seals - PART 1.

10:20 **3.3 Pathological changes in reproductive organs related to contaminant levels**
1) Eero Helle - Reproduction, health and contaminant burden in the Baltic seals -PART 2.

10:45 - 11:00 **Break**

11:00 **3.4 Pathology and pathology of infectious diseases related to fecundity**
1) Paul Jepson - Pathological findings of the reproductive tracts of cetaceans stranded in England and Wales.
2) Ursula Siebert - Pathology of harbour porpoises in relation to reproduction with special reference to German North and Baltic Seas and waters around Greenland.
3) Ailsa Hall - Pathology of infectious diseases in relation to reproduction.

12:30 - 14:00 **Break for lunch - and posters**

14:00 **Agenda 4 - Breeding in wild populations - Chair: Debbie Duffield - short introduction**
1) Kimberley Krusell - Maternal investment in Hawaaian monk seals.
2) Paddy Pomeroy - Determination of mating patterns in grey seals.
3) Jamie Bacon - The effectiveness of Lupron in controlling reproduction in harbour seals.
15:00 **Agenda 5 - Captive breeding - Chair: Jim McBain**
5.1 Feasibility and success to date in breeding programmes
1) Jim McBain - introductory review and examples as above.
2) Shannon Atkinson - Reproductive physiology and the road to captive breeding.
3) Debbie Duffield - Status of captive breeding in cetaceans and pinnipeds.
16:00 - 16:30 Refreshment break and posters
16:30 **5.2 Issues encountered in captive hybridisation**
1) Debbie Duffield - Examples in captivity and a genetic viewpoint.
5.3 Potential usefulness of captive breeding programmes
1) Mats Amundin - Mother-calf behaviour in captive breeding of bottlenose dolphins: lactation/suckling and bonding.

18:00 **Agenda 6 - Conclusion and summary - Christina Lockyer and Thomas Buus Sørensen**

18:30 - 20:00 Open forum and poster session.

20:00 **End of workshop**

POSTERS:
1) Age at reproduction in Norwegian minke whales by Erik Olsen,
e-mail: erik.olsen@imr.no
2) Reproduction in common dolphin from Portugal by Monica Silva,
e-mail: c/o msequeira@mail.telepac.pt

1. NEW TRENDS IN METHODOLOGY

LONG-TERM PERSPECTIVES FROM RESEARCH WITH FREE-RANGING BOTTLENOSE DOLPHINS, TURSIOPS TRUNCATUS

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Long-term observational and hands-on research with individually identifiable animals in an environment where they can be handled safely offers tremendous opportunities to learn about their reproductive patterns. Research initiated in 1970 in Sarasota, Florida, identified a year-round resident community of about 100 bottlenose dolphins (Wells et al., 1980; Irvine et al., 1981; Scott et al., 1990; Wells, 1991). The community consists of at least four generations of dolphins, inhabiting a home range that has remained stable for more than two decades, as documented by more than 14,000 group sightings involving more than 2,500 identifiable dolphins from Sarasota and adjacent waters. Some of the resident dolphins have been observed more than 600 times each. The long-term stability of this community in sheltered waters has facilitated observational and hands-on research providing unique information on reproduction (Wells, 1991). Observations allow the construction of reproductive histories for individual females. Capture-release efforts including such techniques as blood sampling and ultrasonic examinations provide data on gender, age (Hohn *et al.*, 1989), health, growth (Read *et al.*, 1993; Tolley et al., 1995), body condition, reproductive status, and genetic relationships (Duffield and Wells, 1991, in press).

We have found that reproduction is seasonal (Wells et al., 1987; Urian *et al.*, 1996), primarily during spring-summer, with about six calves born annually, on average. Females reach sexual maturity at 5-10 years; males at 8-12 years (Wells *et al.*, 1987). Females have an extended reproductive life span, with some giving birth every 3-6 years into their mid-forties. Parental investment is mostly limited to the mothers, and they often raise their calves in nursery groups with other mothers with young of similar age (Wells, 1991a,b). Nursery groups may change specific composition from day to day, but associates tend to be found together repeatedly (Wells, 1991a). The timing of weaning is difficult to define; lactation has been observed for females with calves up to seven years of age, but calves orphaned at one year of age have survived on their own (unpubl. data). Calves remain with their mothers typically until the birth of the next calf (Wells, 1993).

Reproductive success varies with mother age, calf age, and social patterns, among other factors. Females have been observed with as many as seven calves over the course of the study. Typically, the first-born calf is lost prior to the normal age of separation (3-6 years), and subsequent calves enjoy increased success (Wells, 1993). Calves raised in larger, more stable groups have a significantly higher probability of survival (unpubl. data). Human activities such as boating (Wells and Scott, 1997) and commercial and recreational fishing activities appear to take a disproportionate toll on young dolphins (Wells and Scot,t 1994; Wells et al., in press). The role of environmental contaminants on calf survivorship is currently being explored (Vedder, 1996).

Coastal bottlenose dolphins are not monogamous (Wells et al., 1987). Genetic studies indicate that 1) a given female may use different males to sire subsequent calves, 2) reproductive exchange occurs between communities, and 3) males typically are more than 20 years old when they begin to sire offspring (Duffield and Wells, 1991, in press). Strongly pair-bonded adult males may work together to guard mates, but female choice may play an important role in the dolphins' mating system (Moors, 1997).

REFERENCES

Duffield, D.A. and Wells, R.S. 1991. The combined application of chromosome, protein and molecular data for the investigation of social unit structure and dynamics in *Tursiops truncatus*. Pp. 155-169 In *Genetic Ecology of Whales and Dolphins. Rep. Intl. Whaling Commn*, Sp. Iss. 13 (Ed. A.R. Hoelzel). International Whaling Commission, Cambridge, U.K.

Duffield, D.A. and Wells, R.S. in press. The molecular profile of a resident community of bottlenose dolphins, Tursiops truncatus. In *Cell and Molecular Biology of Marine Mammals* (Ed. C.J. Pfeiffer).

Hohn, A.A., Scott, M.D., Wells, R.S., Sweeney, J.C. and Irvine, A.B. 1989. Growth layers in teeth from known-age, free-ranging bottlenose dolphins. *Mar. Mamm. Sci.*, 5:315-342.

Irvine, A.B., Scott, M.D., Wells, R.S. and Kaufmann, J.H. 1981. Movements and activities of the Atlantic bottlenose dolphin, Tursiops truncatus, near Sarasota, Florida. *Fish. Bull.* U.S., 79:671-688.

Moors, T.L. 1997. *Is 'menage a trois' important in dolphin mating systems? Behavioral patterns of breeding female bottlenose dolphins.* M.Sc. thesis, University of California, Santa Cruz. 95pp.

Read, A.J., Wells, R.S., Hohn, A.A. and Scott, M.D. 1993. Patterns of growth in wild bottlenose dolphins, *Tursiops truncatus. J. Zool.*, 231:107-123.

Scott, M.D., Wells, R.S. and Irvine, A.B. 1990. A long-term study of bottlenose dolphins on the west coast of Florida. Pp. 235-244. In *The Bottlenose Dolphin* (Eds. S. Leatherwood and R.R. Reeves). Academic Press, San Diego. 653pp.

Tolley, K.A., Read, A.J., Wells, R.S., Urian, K.W., Scott, M.D., Irvine, A.B., and Hohn, A.A. 1995. Sexual dimorphism in wild bottlenose dolphins (Tursiops truncatus) from Sarasota, Florida. *J. Mammal.*, 76:1190-1198.

Urian, K.W., Duffield, D.A., Read, A.J., Wells, R.S. and Shell, D.D. 1996. Seasonality of reproduction in bottlenose dolphins, *Tursiops truncatus. J. Mammal.*, 77:394-403.

Vedder, J. 1996. *Levels of organochlorine contaminants in milk relative to health of bottlenose dolphins* (Tursiops truncatus) *from Sarasota, Florida.* M.Sc. thesis, University of California, Santa Cruz. 35pp.

Wells, R.S. 1991a. The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pp. 199-225. In *Dolphin Societies: Discoveries and Puzzles* (Eds. K. Pryor and K.S. Norris). University of California Press, Berkeley. 397pp.

Wells, R.S. 1991b. Bringing up baby. *Nat. Hist. Mag.*, August 1991: 56-62.

Wells, R.S. 1993. Parental investment patterns of wild bottlenose dolphins. Pp. 58-64. In Proceedings of the 18th International Marine Animal Trainers Association Conference, November 4-9, 1990, Chicago, IL. (Ed. N.F. Hecker). IMATA, Chicago, USA.

Wells, R.S. and Scott, M.D. 1990. Estimating bottlenose dolphin population parameters from individual identification and capture-release techniques. Pp. 407-415. In *Individual Recognition of Cetaceans: Use of Photo-Identification and Other Techniques to Estimate Population Parameters. Rep. Int. Whal. Commn*, Sp. Iss. 12 (Eds. P.S. Hammond, S.A. Mizroch and G.P. Donovan). International Whaling Commission, Cambridge, U.K.

Wells, R.S. and Scott, M.D. 1994. Incidence of gear entanglement for resident inshore bottlenose dolphins near Sarasota, Florida. P. 629. In *Gillnets and Cetaceans. Rep. Int. Whal. Comm.*, Sp. Iss. 15 (Eds. W.F. Perrin, G.P. Donovan, and J. Barlow). International Whaling Commission, Cambridge, U.K.

Wells, R.S. and Scott, M.D. 1997. Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. *Mar. Mamm. Sci.*, 13:475-480.

Wells, R.S., Hofmann, S. and Moors, T.L. in press. Entanglement and mortality of bottlenose dolphins, *Tursiops truncatus*, in recreational fishing gear in Florida. *Fish. Bull.*

Wells, R.S., Irvine, A.B. and Scott, M.D. 1980. The social ecology of inshore odontocetes. Pp. 263-317. In *Cetacean Behavior: Mechanisms and Functions* (Ed. L.M. Herman). J.Wiley & Sons, New York. 463pp.

Wells, R.S., Scott, M.D. and Irvine, A.B. 1987. The social structure of free-ranging bottlenose dolphins. Pp. 247-305. In *Current Mammalogy*, Vol. 1. (Ed. H. Genoways). Plenum Press, New York.

SPERM COLLECTION AND CRYOPRESERVATION IN DOLPHINS

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SUMMARY In order to understand dolphin seminal characteristics and to develop the method of cryopreservation of sperm, fresh semen samples were collected from a sexually mature bottlenose dolphin (*Tursiops truncatus*) and a Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) which were trained to ejaculate on command. A summary of methods and results is given below. For details of references, please contact authors.

1. Sperm Collection

- Electrical stimulation method
  Tursiops truncatus - Hill & Gilmartin (1977); Flemming et al. (1981)
- Hand manipulaton method (much more useful and less stressful)
  T. truncatus - Keller (1986); present study, *T. aduncus* - Wu-Naijiang (1996)
- *Lagenorhynchus obliquidens* - present study.

- Present Study -

- *T. truncatus*: Body Length 306cm , Body Weight 394kg (caught off Taiji, Pacific)
- *L. obliquidens*: Body Length 228cm, Body Weight 135kg (caught off Chiba, Pacific)
  In captiviy of Kamogawa Sea World, Chiba, Japan.
  Both dolphins routinely provided fresh semens after about one monthís training.

2. Semen Characteristics

T. truncatus - Schroeder & Keller (1989); present study
L. obliquidens - Present study

- Present Study -

- *T. truncatus* Semen could be collected throughout the year.
  Seminal volume per ejaculate: 0.15 to 60.0 ml (mean=13.3, SEM=0.81, n=305)
  Sperm concentration: 0 to 43.9x108/ml (mean=8.4x108, SEM=0.58x108)
  Total sperm output per ejaculate: 0-493.9x108 (mean=55.4x108, SEM=4.38x108)
- *L. obliquidens* Semen collected only in limited months.
  Seminal volume per ejaculate: 0.1 to 14.3 ml (mean=4.2, SEM=0.34, n=85)
  Sperm concentration: 0 to 19.3x108/ml (mean=3.8x108, SEM=0.65x108)
  Total sperm output per ejaculate: 0-209.0x108 (mean=26.3x108, SEM=5.60x108

3. Sperm Cryopreservation

- *T. truncatus* -Pellet method by Fleming *et al.* (1981; to 10days), and Schroeder (1990) and Schroeder and Keller (1990) (to 955 days) for canine sperm; present study
- *L. obliquidens* - present study
- *Balaenoptera acutorostrata* - Cryotube method by Fukui *et al.* (1996), (sperm from testicular duct; to 125 days).

- Present Study -

- *T. truncatus* and *L. obliquidens*
  by pellet method by Schroeder (1990) and Onuma (1991) with some modifications
  Semen extender: 2.9% (w/v) trisodium citrate dihydrate, 8% (v/v) glycerol, 20% (v/v) egg yolk and antibiotics of 100IU/ml of crystalline penicillin G potassium and 1mg/ml
  of streptomycin sulfate (Stored in liquid nitrogen)
  Post-thaw motility of frozen sperm: (as of Jan. 1997)
  50-80% after 25-1547 day storage in *T. truncatus*
  80-95% after 268-1314 day storage in *L. obliquidens*

4. Artificial Insemination (AI)

Some trials were done for *T. truncatus* by Schroeder and Keller (1990), but no newborn dolphin calf has been born with AI. In vitro fertilisation was experimentally succeeded for the Antarctic minke whales (*B. acutorostrata*) by Fukui *et al.* (1997).

CAN ULTRASONIC METHODS MEASURE BLUBBER THICKNESS IN RIGHT WHALES, *EUBALAENA GLACIALIS*

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The right whale population size in the North West Atlantic appears to be static at about 300 individuals, of which about half are sexually mature. Ship and fishing gear trauma are significant mortality factors. There is also depressed calving compared to southern right whales. Our aim is to establish a tool to test the hypothesis that this relative lack of reproductive success is induced at least in part by poor body condition. A method is described to assess body condition in live right whales, deploying an ultrasound transducer on a cantilevered 12m carbon fiber pole. The pole is rigged on a 8m open boat with an upper steering station. The cantilever consists of a hinged balance point mounted on the end of a rectangular section stainless steel bowsprit. The bowsprit rolls on a semicircular track to allow rotation of the bowsprit end to 70° from the midline of the boat. The inboard end of the pole has a solid handle that also serves as a counterweight. The outer end of the pole carries a hinged Lexan disc with the transducer face flush with the disc surface to ensure perpendicular contact with the animal. Two analogue mode ultrasound systems have been used. The most useful is the Epoch 111 Model 2300, Panametrics Inc, 221 Crescent St, Waltham MA 02154, USA (www.panametrics.com).

This system is marketed for a diverse range of non-destructive thickness testing in steel, power generation and livestock industries. It has a broad range of adjustable signal and recording parameters. Ping strength can be set at 100, 200 and 400V. The echo recording sensitivity can be adjusted from 0-100 dB. Damping can be set at 50, 150 and 400 ohms. Filtration can be standard or high pass. The display on the unit shows an x-y plot of waveform pattern, with depth (timebase) range being selectable in terms of range and transmission velocity, with adjustable zero offset. The waveform can be full, half, and unrectified. The unit has a bi-directional serial port and an unidirectional (data out) parallel port. A wide range of transducers are available with the lowest frequency transducer being 0.5 MHz. The instrument can be powered with an external 12v supply, or can be supplied with internal 6 or 12 V lead acid batteries.

In this study, three transducers are used: 0.5, 1.0 and 2.2 MHz (Panametrics Catalog #'s A301S, A303S, and A304S respectively). Real time data recording for this unit has been developed as a custom PC software package by Upper Cape Systems, 29 Prince Henry Drive, Falmouth MA 02536, USA (www.uppercape.com). This consists of two parts, one for recording data (A-cord) and the other for viewing data (A-play). The A-cord program uses a serial communications link with the Epoch 111. It sends commands and receives responses and data through the COM1 or COM2 port. It gives interactive control of parameters such as gain, velocity and timebase, with real time capture, display and recording of waveforms at 2Hz. Data files are date and time stamped. Records are then viewed using A-play. Waveforms can be exported into other applications. This software is used in a 200 MHz laptop with 2 GB hard-drive, and internal ZIP drive for data backup, using Windows NT as an operating system.

Studies in the laboratory show that 0.5 MHz is the optimum transducer frequency for right whale blubber depths. Higher frequencies would be better for smaller species such as small odontocetes. Repeat field measurements on individuals suggest data points are consistent. Data can then be normalised to position on the body and length of the animal, estimated by mensuration from stereo video images of the animal during probing. Concurrent photo-ID data allows correlation of blubber thickness measurements with catalogued reproductive history. In this way, given a long-term consistent database of blubber thickness measurements we plan on testing the above hypothesis.

GENITAL PATHOLOGIES IN PERUVIAN DUSKY DOLPHIN *LAGENORHYNCHUS OBSCURUS* AND POSSIBLE IMPLICATIONS FOR ITS REPRODUCTIVE SUCCESS

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Cysts and a tumour of the ovaries, uterine tumours, vaginal calculi, abscesses of the broad ligament and undetermined testicular lesions were observed in a sample of 502 female and male dusky dolphins (*Lagenorhynchus obscurus*) caught off Peru in 1985-87 and 1993-94. A tentative or definitive diagnostic for some of these pathologies is Graafian follicle cysts, luteinized cyst, dysgerminoma, leiomyoma, fibroleiomyoma and chronic fibrino-suppurative inflammation of the broad ligament. All pathologies represent first cases for *L. obscurus*. The dysgerminoma is the first ever described tumour of this type in cetaceans. It is also the first time that a vaginal calculus is encountered in a sexually immature cetacean. The finding of struvite as the major chemical component of two vaginal calculi suggests an infectious etiology of these.

Polycystic ovaries and a large vaginal calculus are believed to have precluded reproduction in three affected dolphins. Out of 11 mature females suffering ovarian and uterine tumours and cystic ovaries only one was pregnant (9.1%), very significantly different ((2, P =0.005) from a normal pregnancy rate in Peruvian dusky dolphins of 53.3%. Several females with ovarian or uterine pathologies, and males with aberrant testes were large animals. We suggest that these pathologies may have a negative impact on the reproductive success of this population if normal reproductive senescence could be excluded in further investigations.

REPRODUCTION IN HARBOUR PORPOISES (*PHOCOENA PHOCOENA*), FROM GERMAN WATERS

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INTRODUCTION Until 1990, information did not exist on reproduction of harbour porpoises in German waters. As a part of a national research project on the abundance, health status and migration of small cetaceans in German waters between 1990 and 1993 and another project started 1994 with the aim to establish base of a future monitoring of small cetaceans, the reproductive organs of the animals were examined.

The focus of the effort in the present study has been some reproductive parameters, like age at sexual maturity, reproductive seasonality and pregnancy rates.

MATERIAL AND METHODS Between August 1990 and December 1995, the reproductive organs of 139 out of 478 stranded and bycaught harbour porpoises could be examined. The animals originated from the North and the Baltic Seas. At necropsy the standard body length, weight and gender of each animal were recorded. Teeth were removed for age determination. In males, size and weight of testes with and without epididymis and samples for histology were taken. Diameters of seminiferous tubules and phases of spermatogenesis were recorded. In females, evidence of lactation was obtained, the uterus was measured and examined for the presence of a foetus. After measuring and weighing the ovaries, corpora lutea and albicantia were counted, measured and histologically analysed. The reproductive status of each porpoise was classified, following Perrin and Donovan (1984). The mean age at sexual maturation (ASM) was estimated by using the sum of fraction algorithm. Annual pregnancy rate was calculated as the proportion of pregnant females in the sample of mature animals.

RESULTS The highest proportion of carcasses were made up of yearlings and neonates. Males dominated this group. Most of them were found along the North Sea coast of Schleswig Holstein. Animals older than ten years were rare. The oldest harbour porpoise found on the German coast was a 22 year old female from the Baltic.

The female harbour porpoises of the North Sea sample seem to reach sexual maturity at the age of 4 to 5 years (ASM = 4.58) and at a body-length of about 140 cm. Males become mature between their second and fifth year of life.

In female harbour porpoises it is remarkable that only the left ovary almost becomes active (Gaskin *et al.*, 1984). The right one normally remains submature during life. However 2 out of 6 mature females from the Baltic Sea and 2 out of 22 female porpoises from the North Sea were found to have corpora on both ovaries. The number of corpora increases with the age. At the beginning of the maturation, younger females ovulate more than once each year. Older females seem to ovulate only once each year. A maximum of 13 corpora was found in the ovaries of a 17 year-old female from the North Sea.

The pregnancy rate for harbour porpoises from German waters was estimated to be 0.78. Therefore, the majority of females in this population give birth every year, which indicates an annual reproductive cycle.

Harbour porpoises in German waters show a strong reproductive seasonality, which can be seen in female reproduction, by the finding of carcasses of neonates only in a very limited period of the year (May - July), and especially in the weight and size of the testes in males. The largest and heaviest testes with the largest tubuli seminiferi filled with sperm were found in a male recovered in July. So parturition occurs during May and July and the mating season in German waters seems to be June - August.

DISCUSSION Studies of the reproductive rates of harbour porpoises from different areas have shown varying estimates of fecundity. For example, sexual maturity is attained at 14 months to 6 years depending on region and author. Comparing the results of this study with others, one could get the impression, that the fecundity in this population is lower than in the most other populations, for example pregnancy-rates of 0.84 for Danish waters (Møhl-Hansen, 1954), 0.91 for the North Atlantic (Gaskin *et al.*, 1984), 0.93 for the Gulf of Maine (Read and Hohn, 1995) and an ASM of 3-4 years for the Bay of Fundy (Gaskin et al., 1984), also for Danish waters (Sørensen and Kinze, 1990), 3.36 for the Gulf of Maine (Read, 1995) and 6 years for Dutch waters (Van Utrecht, 1978). Up to now the causes of these interpopulation differences in reproductive rates are not known. Different reasons would be likely.

Differences and mistakes in the method, for example the age determination, are thinkable. And the origin of the material is different. In some cases only bycatches are used for the examination, but in this study material from dead stranded animals was also used. It is possible, that fecundity was disturbed for animals, which were sick.

During the course of a one-year calving cycle, the female porpoise is pregnant during most of the year and probably lactating for some months. These animals respond to this release of energy by consuming more prey or changing to a diet richer in nutrient. In different regions there may exist a variation of prey resources, which could influence the fecundity. Another reason for the different fecundity may be based on effects of chemical pollution (IWC workshop, Bergen, 1995).

REFERENCES

Gaskin, D.E., Smith G.J.D., Watson A.P., Yasui W.Y. and Yurick D.B. 1984. Reproduction in the porpoises (Phocoenidae): Implications for managements. *Rep. int. Whal. Commn.* (Special Issue 6): 135-148.

IWC 1995. Report of the workshop on chemical pollution and cetaceans, 27-20 March, 1995 in Bergen, Norway. SC/47/Rep. 2, Pp1-34.

Møhl-Hansen, U. 1954. Investigations on reproduction and growth of the porpoise (*Phocoena phocoena* (L.)) from the Baltic. *Vidensk. Medd. Fra Dansk naturh. Foren.*, 116: 369-398.

Perrin, W.F. and Donovan, G.P. 1984. Report of the workshop. *Rep. int. Whal. Commn.* (Special Issue 6): 1-24.

Read, A.J. and Hohn, A.A. 1995. Life in the fast lane: The life history of harbor porpoises from the Gulf of Maine. *Mar. Mamm. Sci.*, 11(4): 423-440.

S(rensen, T.B. and Kinze, C.C. 1990. Reproduction and growth in Danish harbour porpoises (*Phocoena phocoena* (L.)). Paper SC/42/SM32 presented to the IWC Scientific Committee, June 1990 (unpublished): 5 pp.

Van Utrecht, W.L. 1978. Age and growth in Phocoena phocoena Linnaeus, 1758 (Cetacea, Odontoceti) from the North Sea. *Bijdr. Dierkd.*, 48(1): 16-28.

2. MORPHOLOGY AND PHYSIOLOGY IN FEMALES AND MALES

MORPHOLOGY AND PHYSIOLOGY IN FEMALES AND MALES: CURRENT STATUS AND FUTURE DIRECTIONS

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INTRODUCTION The 1981 workshop on reproduction in cetaceans (Perrin et al., 1984) provided the first large forum to address some longstanding issues and controversies on reproductive morphology and physiology. To enhance further progress, consensus on standardized terminology and methodology was achieved. A range of key topics were addressed, from interpreting ovarian scars to variation in ovulation rates to defining sexual maturity to reproductive pathologies. The workshop provided a foundation for future studies on cetaceans, with broader applicability for other marine mammals, and it still provides a framework by which we can chart our progress since that time. Research since then has expanded our approaches to reproductive morphology and physiology across taxonomic groups, increased our information base, and highlighted where significant gaps remain.

STRUCTURE AND FUNCTION In large part, studies of gonadal morphology stemmed from the need to estimate reproductive parameters for exploited populations of marine mammals. Research focused on interpreting ovarian scars, including debating their persistence and whether *corpora albicantia* from pregnancies could be differentiated from *c. albicanti*a from infertile ovulations, and estimating ovulation rates. Samples from exploited animals were instrumental for defining basic morphology. Physiological studies were not feasible under these conditions and were pursued only in more recent years with access to captive animals and advances in field techniques that permitted safe handling of free-ranging animals, cetaceans, pinnipeds, and sirenians for the collection of blood and other samples. Merging of physiological and morphological studies on the same individuals has been more difficult, requiring extensive sampling of dead animals very soon after death or for live animals using medical procedures such as ultrasound coupled with clinical analyses of blood. But it is from this approach that the field is most likely to make the most progress.

VITAL RATES The participants at the 1981 Workshop discussed the need to distinguish between age at first ovulation, age at first conception, and age at birth. In cetaceans, the parameter generally estimated has been age at first ovulation because the available samples were typically from dead animals. More recently, long-term field studies of free-ranging marine mammals have allowed us to estimate age at first birth. Using these two approaches, we can now explore how within and between population variation within these parameters might indicate density compensatory responses or adverse reproductive effects of disease, contaminants, and endocrine disruptors. Between-species differences might elucidate differences in life-history strategies or susceptibility to disease or human impacts.

REPRODUCTIVE PATHOLOGY We are just attempting to go beyond the purely descriptive phase in reproductive pathology of individuals to interpreting the significance of pathologies at the population level. For example, vaquita, Phocoena sinus, ovaries were found to contain unusual mineralized concretions not previously described (Hohn *et al.*, 1996). When examined by a specialist in reproductive pathology of endangered species (Dr. Linda Munsen), the source of these concretions remained uncertain, although it is possible are they are mineralized corpora. Fortunately, it was thought that they would not interfere with ovulation of normal follicles. In order to adequately evaluate the ovaries, Dr. Munsen was supplied with ovaries from congeners, *P. phocoena* and *P. spinipinnis*. That examination revealed that vaquita have relatively fewer primordial and developing follicles and *C. albicantia* at a given age than its congeners. The studied highlighted to us how poorly we understand natural variation within and among species in fundamental parameters such as relative abundance of primary follicles and their degeneration and atresia, making it difficult to interpret results.

To some, such questions may seem arcane. Yet, it may be that a reduction in the number of follicles or rates of degeneration or atresia are the first indication of adverse impacts of contaminants, disease, or environment estrogens on individuals. Before we can know if that is the case, we need to collect data on levels of these factors. Then, attempts to detect, quantify, and possibly parameterize these characteristics may provide useful management information as well as interesting science.

FUTURE DIRECTIONS Two approaches seem the most promising for the future. First, studies that integrate results from various types of tissues from each individual are needed so that morphological and physiological characteristics can be correlated. Generally these studies will require large sample sizes over a wide variety of age classes. Care needs to be given to not combine samples from various locations or stocks to prevent confounding of results. To remove confounding effects due to temporal variation, samples would best be collected over a relatively short period of time, such as 1-2 years. These studies provide the vertical profile of reproductive characteristics of a population that can be compared within that population over time or between other populations or species.

The second approach involves long-term studies of individuals. Although difficult with free-ranging cetaceans, the long-term study of bottlenose dolphins in Sarasota Bay illustrates the possibilities (Scott *et al.*, 1990). An alternative and complementary sample is from the captive community of marine mammals. Captive animals offer more frequent and regular sampling, such as for blood, morphometrics, and ultrasound, over the lifetime of the individual. With recent husbandry success, that may be from the birth of the animal to beyond the research life of the investigator. The large numbers of captive animals should allow accommodation due to variability in capture location, age, and other potential covariates of the parameters being measured. One drawback to interpretation of these results is the uncertainty of effects of captivity. Comparisons with free-ranging populations should help determine whether such effects exist. For both sources of longitudinal data, acquisition of reproductive tissues following death will be particularly beneficial. It will be in understanding variation over the lifetime of individuals that we will be able to interpret variability in populations and how various factors induce changes in population parameters.

What are some pressing areas of research on morphology and physiology of reproductive biology in marine mammals? Among others possibilities, I have four suggestions for future research: Characterization (morphology/histology/physiology) of reproductive tissues in individuals with known reproductive histories; quantification of the relative frequency of ovulations that result in pregnancy; comparative morphology/histology/physiology within and among taxonomic groups including documenting baseline data and natural variation; and expanding the contributions of this kind of research into a broader context, such as ecosystem health, stock structure, and social structure.

CONCLUSION I would like to conclude this brief overview with a quote from an enlightening paper on pilot whales paper presented at that workshop by Marsh and Kasuya who noted that "The ovaries of various cetaceans have been studied as indices of relative age and terminal reproductive status and as records of reproductive history. However, with few exceptions, scientists have had no direct information on the species reproductive physiology or life history. Thus, the interpretation of cetacean ovaries has been rather like running an experiment without a control" (Marsh and Kasuya, 1984, p. 311).

It is clear that, despite our new knowledge and despite our new tools, there remain basic questions to meet this challenge to uncover the basic mechanisms of reproductive biology. It is also clear from the breadth and quality of the papers presented at this Workshop that there is no lack of interest in meeting this challenge.

REFERENCES

Hohn, A.A., Read, A.J. Fernandez, S. Vidal, O. and Findley, F. 1996. Life history of the vaquita, *Phocoena sinus* (Phocoenidae,Cetacea). *J. Zool.*, 239:235-251.

Marsh, H. and Kasuya, T. 1984. Changes in the ovaries of the short-finned pilot whale, Globicephala macrorhynchus, with age and reproductive activity. In Reproduction in Whales, Dolphins and Porpoises, *Rep. int. Whal. Commn*, Sp. Iss. 6. (Eds. W.F.Perrin, D.P. DeMaster and R.L. Brownell, Jr.). International Whaling Commission, Cambridge. 495pp.

Perrin , W.F., D.P. DeMaster, and R.L. Brownell, Jr. (Eds.) 1984. Reproduction in Whales, Dolphins and Porpoises. R*ep. int. Whal. Commn*, Sp. Iss. 6. 1-495.

Scott, M.D., Wells, R.S. and Irvine, A.B. 1990. A long-term study of bottlenose dolphins on the west coast of Florida. Pp. 235-244. In *The Bottlenose Dolphin* (Eds. S. Leatherwood and R.R. Reeves). Academic Press. San Diego. 653pp.

DYNAMICS OF FOLLICULAR DEVELOPMENT IN THE HARBOUR PORPOISE (*PHOCOENA PHOCOENA* (L.))

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OESTRADIOL-17ß AND PROGESTERONE CONCENTRATIONS AND OESTRUS VARIABILITY IN A GROUP OF CAPTIVE HARBOURS SEALS (*PHOCA VITULINA CONCOLOR*) IN BERMUDA

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INTRODUCTION In 1993, the Bermuda Aquarium, Museum and Zoo (BAMZ) began investigating available methods to control reproduction in its harbour seal colony. While doing so, it became apparent that the female seals' breeding season at BAMZ occurs later and lasts longer than what has been observed for the same subspecies at other facilities or in the seals' wild parent population. Specifically, the Baltimore Aquarium in Maryland, USA, observes behavioural oestrus between June 18-25 (*pers. comm.*) while the Mystic Marinelife Aquarium in Hartford, Connecticut, USA and the New England Aquarium in Boston, Massachusetts, USA observe mating behaviour throughout the month of June (*pers. comm.*). Among wild harbour seals on Sable Island, where the BAMZ male seal was captured, it has been suggested that nulliparous and non postpartum females may ovulate by early June and that most postpartum females ovulate by mid-June (Boulva and McLaren, 1979).

Mating behaviour at BAMZ, however, has been observed from late June to early August. In addition, previous progesterone data for one seal indicated that she had not ovulated by early August but had ovulated by mid-November. Thus, the purpose of the present study was to use plasma oestradiol-17fl and progesterone profiles of the female seals to determine the precise timing and duration of their oestrous cycles. These data, in turn, would then be used to ensure that future reproduction was prevented and to ascertain if relocating harbour seals to Bermuda's latitude may affect the timing of oestrus.

Four female seals were used in this study which was conducted between February and November, 1997. The eldest (Charlotte) was born in captivity in 1983 at the Hunt Marine Laboratory of New Brunswick, Canada, and was relocated to Bermuda (32.20N) during the same year. Both her parents had been captured in the Gulf of Maine. The other three females were born at BAMZ. Calico (born 1989) and Ariel (born 1991) were both Charlotte's pups and Pebbles was born to Calico in 1993. All three pups were sired by the same male who was caught as a pup on Sable Island, Canada (43°56'N) in 1971 and relocated to Bermuda in 1973.

Between late spring and July 17th, the male and females were held in separate but adjoining pools that were divided by a slatted partition. A shallow channel separates the pools which allows for water flow between them and some visual and tactile contact can be made through the partition. On July 17th, the partition was removed and the seals were free to swim between the two pools. The male had received prior injections of the chemical contraceptive Lupronß and showed negligible plasma testosterone when he was allowed to rejoin the females.

Blood samples were collected from the females by venipuncture of the vessels in the metatarsal region of the seals' rear flippers. Samples were collected on a monthly basis until June, after which they were collected on a weekly basis from June to September. Blood was collected in heparinised vacutainers. The blood was kept chilled until it was centrifuged (within three hours after collection) and the resulting plasma was frozen at -10°C and transported overnight to the Central Diagnostic Laboratory, Cornell University. The plasma samples were tested for oestradiol-17ß and progesterone by radioimmunoassay with Diagnostic Products Coat-A-Count Kits.

As shown in Figure 1, there was a large amount of individual variability found in the oestrous cycles of the four female seals. Charlotte began pro-estrous in late June and her oestradiol level peaked on approximately July 9th. Although the male was reintroduced on July 17th, she did not exhibit behaviours associated with behavioural oestrus until July 23rd. Copulation was observed on July 26th with Charlotte seen initiating the courtship and mating behaviours. Her progesterone level rose markedly after copulation indicating that ovulation had occurred.

Calico exhibited two oestrous cycles with her first pro-estrus beginning in early June and peak oestradiol level occurring on approximately June 25th. Her first oestrous cycle did not result in ovulation as indicated by her progesterone profile. Her second pro-estrus coincided with the reintroduction of the male into the pool and copulation was observed on July 31st. Again, it was observed that courtship behaviour was initiated by the female and not the male. This was likely due to the male's negligible testosterone level. Ovulation did occur during her second cycle as indicated by the sharp rise in progesterone seen after copulation occurred.

The data suggest that Ariel also exhibited two oestrous cycles. Her first pro-estrus began in early July and her oestradiol then remained elevated for approximately five weeks. Ovulation apparently occurred around August 8th as seen in the sharp rise in progesterone. Although no mating behaviour was observed, Ariel was seen exhibiting courtship-type behaviours with two other females in late July. Her progesterone level fell as she entered her second pro-estrus in mid-August suggesting luteolysis had occurred. Her progesterone profile indicates that no ovulation occurred as a result of her second oestrus.

Pebbles exhibited one oestrous cycle with pro-estrus beginning in early July. Her oestradiol level remained elevated for seven to eight weeks until late August. No copulatory behaviour was observed. Although it may have occurred, it was felt that Pebbles' young age may have prevented her from being able to initiate courtship and mating behaviours with the male. Her oestrous cycle did not result in ovulation as shown by her progesterone profile.

In sum, the data indicate that the oestrous cycles of individual female harbour seals may vary significantly from each other. These data are quite different from those presented for harbour seals by Reijnders (1990). In his study, all the adult females exhibited a very similar and predictable pattern consisting of a single brief oestrus period that is followed by either a pregnancy or a three to four month long pseudopregnancy.

Data from the present study also show that individual females may be either monoestrous or polyoestrous. This finding is supported by observations made by Bigg (1973) while studying Pacific harbour seals (*Phoca vitulina richardsi*). He noted from cytological examinations of vaginal and uterine tissue that two out of the eleven seals displayed a second oestrus three to five weeks following the first. Furthermore, data from the present study suggest that the introduction of a male may possibly cause the extension of an oestrus period or the initiation of a second oestrous cycle. In addition, behaviour oestrus may not coincide with the attainment of peak oestradiol concentration as was seen in Charlotte's case.

The results also strongly suggest that some if not all of the female seals in this study exhibit induced rather than spontaneous ovulation. This conclusion is supported by the fact that Calico did not ovulate during her first estrus and by the observation that she and Charlotte both ovulated promptly after copulation. The extended length of oestrus observed for Ariel and Pebbles also supports the theory that they are induced rather than spontaneous ovulators. Bigg (1973) too observed that only about half of the seven animals he autopsied had ovulated following oestrus and suggested that some females may be induced ovulators. It has also been observed in other mammals known to be induced ovulators that females may ovulate spontaneously after a prolonged oestrus or after female-female interactions (Milligan, 1982). Further research is required to determine if this subspecies of harbour seal relies primarily on induced ovulation.

The data further suggest that relocating harbour seals to Bermuda may cause a delay of three weeks or more in the onset of their oestrous cycles. The data also show that having polyoestrous seals in a colony can considerably extend the duration of the breeding season. These results have implications for other facilities attempting to control reproduction in their harbour seal colonies, especially if the facility is located outside of the normal home range of their subspecies.

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REFERENCES

Bigg, M.A. 1973. Adaptations in the breeding of the harbour seal, *Phoca vitulina*. *J. Reprod. Fert.*, 19: 131-142.

Boulva, J. and McLaren, I.A. 1979. Biology of the harbour seal, *Phoca vitulina*, in eastern Canada. *Bull. Fish. Res. Bd. Can.*, 200: 24.

Milligan, S.R. 1982. Induced ovulation in mammals. *Oxford Rev. Reprod. Biol.*, 4:1-46.

Reijnders, P.J.H. 1990. Progesterone and oestradiol-17 concentration profiles throughout the reproductive cycle in harbour seals (*Phoca vitulina*). *J. Reprod. Fert.*, 90: 403-409.

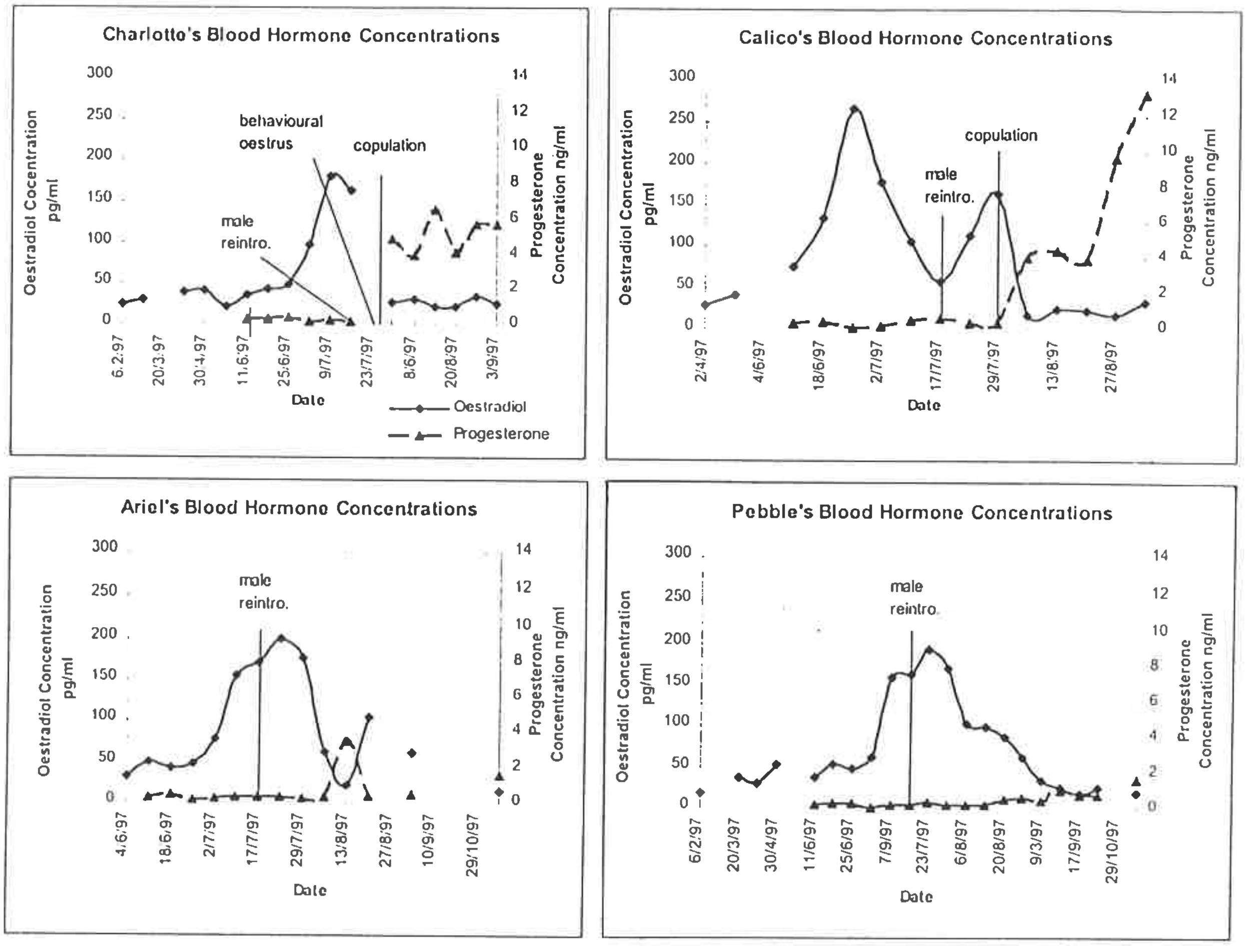

Fig. 1. Oestradiol-17ß and progesterone profiles for the four female harbour seals

REPRODUCTIVE BEHAVIOUR AND PHYSIOLOGY OF CAPTIVE HARBOUR PORPOISES (*PHOCOENA PHOCOENA*): A PROJECT DESCRIPTION

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THE FJORD AND BELT CENTRE-A new Danish Centre for research on harbour porpoises The Fjord and Belt Centre is a marine activity centre created to combine research, public exhibition, and education on marine issues which opened in March 1997 at Kerteminde, Fyn, Denmark. It combines a marine research laboratory (Odense University) with an active exhibition centre.

The Kerteminde Fjord and the Danish belts are the common denominator for all the activities. As such, the harbour porpoise in the Great Belt, which exhibits one of the highest density known in Europe, is the main topic of research and one of the main attractions. The purpose is to enhance research into behaviour and ways of reducing by-catch as well as creating more public awareness on these marine animals and their habitat.

The Fjord and Belt Centre has got permission from the Danish Ministry of the Environment and Energy to hold four porpoises in captivity for a period of three years for research purposes and public information and awareness. The permission may be renewed, depending on the success of the project.

Several research programmes are started, in co-operation with other Danish and foreign institutes, in particular the University of Odense and the Danish Fisheries Research Institute. Some are by-catch related, others cover more basic areas as acoustic, behaviour, physiology, growth and energetic.

The facilities The porpoises are kept in an outdoor pool of more than 500 m≤ and 1900 m≥, bordered on one side by a 25 m long underwater tunnel. The pool opens, through two wide opening spanned by nets, into a channel leading to the Great Belt and benefiting from a very strong water flow year round. The animals are thus exposed to natural conditions regarding water quality, flow and temperature, tidal currents, diurnal and seasonal variations in environmental conditions, flora and fauna.

The volume of water is suitable for different behaviour studies and reaction patterns to different fishing gear, while the tunnel allows scientists for observing the porpoises in their daily underwater activities and for a closer monitoring of their reaction to various kind of underwater devices.

The animals The two first harbour porpoises, a male and a female, arrived at the Centre in April 1997, after being by-caught in the same pound net. The male weighed 37.5 kg and was 130 cm long, the female 40.5 kg and 127 cm. They were estimated to be in very good health conditions and about three years of age. After 11 months of captivity, the male had gained more than 7 kg and 4 cm and the female 10 kg and 10 cm, and were still in excellent conditions.

Fjord and Belt Centre priorities The harbour porpoises held at the Fjord and Belt Centre have only been in captivity for a very limited amount of time. There is little experience and reference material on the capability of young harbour porpoises to cope with training. Very little is known on the natural body and health-related changes which might be expected from harbour porpoises in open captive conditions. The Fjord and Belt Centre decided then to give a high priority to health control and training of behaviours which may facilitate this control; 50% of the training time is devoted to the training of voluntary husbandry behaviour (VHB) and 50% to research-related training. After the phase of habituation to captivity, the training of the animals for medical behaviours and research purposes started progressively and is now progressing very well.

THE REPRODUCTION PROJECT The project on reproduction is led by the Fjord and Belt Centre, and is carried out in co-operation with KolmÂrden Djurpark, Sweden; Institute of Biology, Odense University, Denmark; Forschungs- und Technologiezentrum Westkueste, Kiel University, Germany; Veterinary clinic, Reinsbüttel, Germany.

Scientific background Several authors have studied different aspects of reproduction in harbour porpoises (e.g., Møhl-Hansen, 1954; Fisher and Harrison, 1970; Read, 1990ab, Read and Gaskin, 1990; Sørensen and Kinze, 1994; Addink *et al.*, 1995; Lockyer, 1995a,b). The scope of these studies is, however, mostly limited to morphological and histological investigations and resulting population parameters. The physiological cycle has not been investigated, and values of sex hormones have not been reported for harbour porpoises. Other techniques like vaginal cytology, sperm collection and ultrasound diagnostic have been very little used, if ever, on live harbour porpoises. The individuals kept at the Fjord and Belt Centre offer a unique opportunity to get a better understanding of harbour porpoises reproduction.

OBJECTIVES Characterising the reproductive activity and cycle of captive male and female harbour porpoises, both in terms of behaviour (visual and acoustic) and gonad activity.

> Find, among the methods used for studying the reproductive function in live cetaceans, the most suitable one to use for a longitudinal monitoring of captive harbour porpoises, in particular with regards to the small size of the animals.
> Insure a precise monitoring of the reproductive state of the captive harbour porpoises at the Fjord and Belt Centre
> Evaluate the best collection of methods to be used for a vertical monitoring of the reproductive state of wild harbour porpoises (live bycatch), knowing that sampling has to be quick, easily performed even from a small boat, not requiring a heavy machinery, and as little invasive as possible.

METHODOLOGY **Behavioural observations** A combination of different methods of sampling will be used. The behaviour of the porpoises will be recorded by surveillance cameras and on-line, as well as underwater cameras and camcorders placed in the underwater observatorium. Acoustic activity will be recorded with hydrophones after being transformed to audible range by means of envelope detectors (click detectors).

Hormonal titration Total oestrogen, progesterone and testosterone levels will be monitored regularly by radio immunoassay. Other hormones (e.g. prolactin) will also be monitored if possible. If feasible, daily fluctuations in hormonal secretion will be investigated for short period. The condition of the sampling site on the flukes and that of the animals in general will, however, limit the intensity of the blood sampling. .The possibility of using an alternative medium to obtain hormonal level will be tested.

Semen collection / Vaginal cytology / Body temperature
Semen production, images of vaginal cytology and body temperature will be collected and examined in relation to hormonal levels and behaviour.

Semen samples, collected by VHB, will be examined for different parameters such as volume, appearance, total sperm count, sperm density, motility, quality of motility, and percentage of clumping.

Ultrasound imaging If possible considering the size of the organs, ultrasound images will be taken from the ovaries and uterus to follow the ovarian and endometrium cycle and check for pregnancy, the testes and pelvic bones to follow growth and seasonal development.

Results expected An integrated approach to behavioural, morphological, histological and hormonal assessment of reproductive status is seldom possible in cetaceans, but offers the best tool for understanding and monitoring reproductive events. It is expected that the correlation of reproductive hormonal fluctuations with ultrasound ovarian and testicular imaging, semen production and vaginal cytology will lead to a better understanding of reproductive events in porpoises. It is hoped that this approach will also provide the necessary comparative basis to assess reproductive status of wild free-ranging animals, when only limited parameters are available, and only on a one-time basis.

Strong concerns have been expressed that toxins may cause reproductive failure in harbour porpoises, maybe contributing to the apparent decline of the population. However, the effect of toxins on reproductive capabilities is very difficult to investigate without a thorough understanding of the reproductive events, physiological, anatomical as well as behavioural. It is expected that this project will help providing the basis for this kind of studies.

This project is part of a wider study of reproductive events in harbour porpoises, based on data obtained from live and dead animals under the framework of ongoing projects: satellite telemetry, collection of dead porpoises under the EU-funded projects BY-CARE and EPIC.

REFERENCES

Addink, M.J., Sørensen, T.B. and Hartmann, G. 1995. Aspects of reproduction and seasonality in the harbour porpoise from Dutch waters. Pp: 459-64. In: *Whales, seals, fish and man.*, Development in marine Biology, 4. (Eds. A.S. Blix, L. Walloe, and Ø Ulltang). Elsevier. 720pp.

Fisher, H.D. and Harrison, R.J. 1970. Reproduction in the common porpoise (*Phocoena phocoena*) of the North atlantic. *J. Zool.*, Lond., 161: 471-486.

Lockyer, C. 1995a. Aspects of the biology of the harbour porpoise, *Phocoena phocoena*, from British waters. Pp. 443-58. In: *Whales, seals, fish and man.* Development in marine Biology, 4. (Eds. A.S. Blix, L. Walloe, and Ø. Ulltang). Elsevier. 720pp.

Lockyer, C. 1995b. Investigation of aspects of the life history the harbour porpoise, *Phocoena phocoena*, in British waters. *Rep. Int. Whal. Commn* (Special Issue 16): 189-197.

Møhl-Hansen, U. 1954. Investigation on reproduction and growth of the porpoise (*Phocoena phocoena* (L.)) from the Baltic. *Vidensk. Meddm fra Dansk naturh. foren.*, 116: 369-396.

Read, A.J. 1990a. Age at sexual maturity and pregnancy rates of harbour porpoises *Phocoena phocoena* from the Bay of Fundy. *Can. J. Fish. Aquat. Sci.*, 47: 561-565.

Read, A.J. 1990b. Reproductive seasonality in harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. *Can. J. Zool.*, 68: 284-8.

Read, A.J. and Gaskin, D.E. 1990. Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. *Can. J. Fish. Aquat. Sci.*, 47: 2158-2163.

Sørensen, T.B. and Kinze, C.C. 1994. Reproduction and reproductive seasonality in Danish harbour porpoises, *Phocoena phocoena* . *Ophelia*, 39(3):159-176.

SPERM MORPHOLOGY AND OTHER ASPECTS OF REPRODUCTION IN *KOGIA*

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INTRODUCTION South Africa has one of the highest stranding records in the world for both pygmy (*Kogia breviceps*) and dwarf (*Kogia simus*) sperm whales and as such offers a unique opportunity to study these poorly understood animals.

For the present study reproductive organs and teeth were collected from animals stranded along the South African coastline during the last 34 years. The samples were examined using standard histological techniques to establish reproductive status and age. Sperm were extracted from the testes of sexually mature males and examined with the scanning (SEM) as well as the transmission electron microscope (TEM).

SPERM MORPHOLOGY The sperm head of *K. breviceps* is round, while that of K. simus is more bullet-shaped. Furthermore the length of the midpiece in relation to the total length of the spermatozoon was almost half as long in *K. breviceps* than in K. simus. These results support the findings for species specifity of spermatozoa. In comparison with published data on other cetacean species sperm head shape seems to vary little within the cetacea. The spherical mitochondria found in *Kogia* sperm and that of other Cetacea seems to be unique within the Mammalia. The number of mitochondria ranges from 9 for *Delphinus delphis*, 12 for *Tursiops truncatus*, 12-16 for *Globicephala melas* to 16 for *Kogia breviceps* and 20 for *K. simus*. This low number of mitochondria is related to the relatively short midpiece found in cetacean sperm.

AGE AND REPRODUCTION The age of the animals was estimated by counting growth-layer-groups (GLG's) in the dentine and cementum of thin, transverse, longitudinal sections of teeth (Perrin and Myrick, 1980).

MALE REPRODUCTION The onset of sexual maturity in male *K. breviceps* occurred at a body length of around 230 cm, 4 GLG's and a combined testis weight of 396.2g. In male *K. simus*, the onset of sexual maturity occurred at around 201 cm, 3 GLG's and a combined testis weight of 420g.

Sighting and stranding data of *Kogia* suggest that these animals occur in small groups of 3-4 animals. The combined testis weight of stranded *Kogia* from South Africa makes up only 1.04% of the total body weight in *K. breviceps* and 2.05% in *K. simus*. Compared with data on combined testes weight from other odontocetes these data suggest that both *Kogia* species have relatively small testes. The relationship between testes size and the mating system of a species has been widely studied and small testes in relation to body size are generally associated with a polygynous mating system (Harcourt *et al.*, 1981). Furthermore sexual dimorphism is usually found to be great in species with a single-male breeding system. Since *Kogia* do not exhibit great sexual dimorphism in either weight or length, the small testes and group size suggest a promiscuous mating system with the males moving between the females in order to increase their reproductive opportunities rather than monopolising a number of females. A similar mating strategy has been suggested for bottlenose dolphins off Florida.

FEMALE REPRODUCTION In *K. breviceps* the number of ovarian corpora increased markedly around 260 cm body length and about 4 GLG's, which indicates the onset of sexual maturity. The corpora of ovulation persist throughout life in cetaceans and a count of ovarian corpora yielded an ovulation rate of 0.68 per GLG for all mature females. If it is assumed that 1 GLG is laid down over the period of one year this would mean that, on average, ovulation occurs approximately every 1.5 years (17.7 months).

In female *K. simus* sexual maturity occurred at a body length of about 215 cm and 5.6 GLG's. The ovulation rate was 0.41 per year, which means that ovulations occur every 2.4 years (29.3 months). We interpret these results as indicating that *K. breviceps* has the potential, and typically does, ovulate every year while in *K. simus* ovulation occurs every two years.

Although no reproductive seasonality was observed for male *Kogia* the occurrence of foetuses and calves up to and including the age of 2 GLG's suggests a prolonged calving season. In *K. breviceps* conceptions occur from April to September and births from March to August. This would suggest a gestation period of approximately 11 months.

In *K. simus* conceptions occur between January and March with births occurring between December and March. Thus the gestation period seems to last approximately 12 months. In both species lactation seems to last about 12 months. Furthermore 24.1% of all mature *K. breviceps* and 11.5% of all mature *K. simus* stranded along the South African coastline were found to be simultaneously pregnant and lactating. This in conjunction with the other reproductive parameters indicates that a post-partum oestrus may occur in these two species.

REFERENCES

Harcourt, A.H., Harvey, P.H., Larson, S.G. and Short, R.V. 1981. Testis weight, body weight and breeding system in primates. *Nature*, 293: 55-57.

Perrin, W.F and Myrick, A.C. (Eds.) 1980. Age determination of toothed whales and sirenians. *Rep. int. Whal. Commn*, Sp. Iss. 3. International Whaling Commission, Cambridge.

Ross, G.J.B. 1979. Records of pygmy and dwarf sperm whales, genus *Kogia*, from southern Africa, with biological notes and some comparisons. *Ann. Cape Prov. Mus. (Nat. Hist.)*, 11: 259-327.

Ross, G.J.B. (1984) The smaller cetaceans of the south east coast of southern Africa.. *Ann. Cape Prov. Mus. (Nat. Hist.)*, 15: 173-410.

3. CHANGES IN FECUNDITY ASSOCIATED WITH TOXICOLOGY AND PATHOLOGY

ORGANOCHLORINE-MEDIATED ENDOCRINE DISRUPTION IN MARINE MAMMALS: TOXIC MECHANISMS AND BIOMONITORING

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INTRODUCTION Organochlorines (OCs) can cause endocrine disruption via interference with steroid functioning at the receptor site or by altering cytochrome P450 isozyme activity. For example, Polychlorinated biphenyls (PCBs) and PCB metabolites (-OH and -MeSO2) can bind estrogen (ESTRO) (Patnode and Curtis, 1995; Fielden *et al.*, 1997) and progesterone (PROG) receptors (Gillner *et al.*, 1988) thereby reducing steroid binding and altering intra-uterine biological response. Steroids are synthesised from cholesterol and other pre-cursors in the adrenals and gonads (testis and ovary) via the specific activity of CYP450 isozymes (Griffin and Ojeda, 1996). PCB-mediated alteration of CYP450 isozyme activity can therefore affect steroid biosynthesis and biotransformation and ultimately, reproductive success. Chemicals with endocrine modulating potential typically affect endocrine and uterine functioning at the sensitive stages of gestation and development (Reijnders and Brasseur, 1992). For example, in laboratory animals OC-mediated endocrine disruption can cause implantation failure, reduction in number and weight of offspring (Aulerich *et al.*, 1995; Kihlstrøm *et al.*, 1992), disruption of hormone cycles (Örberg and Lundberg, 1974), embryotoxicity (Seiler *et al.*, 1994) and inhibition of steroid binding to uterine receptors (Patnode and Curtis, 1995; Gillner *et al.*, 1988).

There are published reviews identifying OCs as mediators of endocrine disruption in wildlife (IEH, 1998; Colborn and Smolden, 1996). In grey seals (*Halichoerus grypus*), A1254 has been shown to cause significant alteration in adrenal and testicular steroid biosynthesis in vitro via the inhibition of CYP4503(-HSD (hydroxysteroid dehydrogenase) activity (Freeman and Sangalang, 1979). Field and semi-field experiments have also linked OC exposure with endocrine-disruptive effects, including reduced circulating serum testosterone (TESTO) levels in North Pacific male Dallís porpoise (*Phocoenoides dalli*) (Subramanian *et al.*, 1987), reduced reproductive success & incidences of abnormal sexual development in the St. Lawrence Estuary beluga whale (*Delphinapterus leucas*) (DeGuise et al., 1994) and reduced TESTO and PROG hepatic metabolism (Troisi and Mason, in press) (Figs. 1 and 2) and reproductive failure in harbour seals (*Phoca vitulina*) (Reijnders, 1986a). Due to their potential to bind the steroid receptor protein uteroglobin (UG), PCB-MeSO2 (MSFs) selectively accumulate in the uteri of laboratory animals treated in vivo with PCBs (Gillner *et al.*, 1988). The binding affinity of these metabolites exceeds that of their parent molecules and also of endogenous ligands, ESTRO and PROG. It is plausible, that at the molecular level PCB-MeSO2 are responsible for mediating PCB-associated reproductive failure as observed in mink and seals (Aulerich *et al.*, 1985; Kihlstrom *et al.*, 1992; Reijnders, 1986a) by reducing steroid binding. This can interfere with hormonal signalling of endometrial preparation (thickening and vascularisation) for embryo implantation and maintenance of pregnancy, leading potentially to implantation failure (Reijnders, 1986b) or early embryonic mortality (Bäcklin and Bergman, 1992). However, this theory can only be confirmed by toxicity testing cultured seal uterine epithelium with MSFs in vitro and also the monitoring of uterine MSF concentrations to determine whether seals in the wild are exposed to toxicologically significant levels of MSF. Preliminary analyses of uterine tissue have indicated that MSFs are present in environmentally exposed seals (unpubl. data).

Reproductive failure attributable to the endocrine disrupting effects of OC exposure can reduce reproductive rates. Subsequently, the capacity of marine mammal populations to recover impacts of direct (e.g., whaling, epizootics, other mass stranding events) and indirect mortality (e.g., fisheries interactions) may be compromised, particularly in the case of populations exposed to high levels of endocrine modulating chemicals (including OCs) in the environment. Endocrine disruption is therefore of significant ecological and conservation importance. In order to identify marine mammal populations at risk from the endocrine disrupting effects of OCs, biomonitoring of OC exposure and endocrine disruptive effects is required. This can only be successfully accomplished by employing a suite of biomarkers for OC ìexposureî and endocrine disruptive ìeffectsî, conducting full complimentary contaminant analysis of tissues. Resultant biomarkers and contaminant concentration information, can subsequently be integrated with population dynamics data to predict the susceptibility of a population to endocrine disrupting effects. Hepatic and cutaneous cytochrome P450 isozymes and dependent monooxygenases have been successfully applied as biomarkers of OC exposure in seals (Troisi and Mason, 1997) and cetaceans (Fossi *et al.*, 1992; Moore *et al.*, 1995). Also, new research has demonstrated that provided specific reducing agents are used, CYP420 (degradation product of CYP450) can be accurately quantified and used as a biomarker of OC exposure in stranded animals where sampling at the time of death is rarely possible (Fig. 3) (Troisi and Mason, 1997).

There are, as yet, no reliable specific biomarkers of endocrine disruptive ‘effects’ for use in marine mammal monitoring. However, there is good laboratory evidence that the expression of the female-specific glycoprotein lactoferrin (LTF) can be used as a biomarker of “effects” specifically attributable to environmental oestrogenic exposure. LTF is found in the mammalian uterus and mammary glands. It is involved in stimulation of DNA synthesis, iron transport to the foetus, uterine proliferation and uterine tissue remodelling. Uterine LTF is highly responsive to oestrogen and oestrogenic chemicals. Exposure to oestrogenic compounds prenatally and during early post-natal development, has been shown to result in LTF expression in male rats and unnaturally elevated LTF in female rats (LeBlanc and Bain, 1997). The reliability of LTF as a biomarker of estrogenic exposure and effect in marine mammals needs to be established experimentally so that it can then be used to identify marine mammal populations ìat riskî from health effects associated with environmental estrogenic exposure. Another advantage of using LTF as a biomarker is that LTF quantification requires sampling of blood, and where possible, uterine fluid, both of which can be sampled non-destructively facilitating sampling of a reasonable number of free-ranging animals in the field.

Other possible biomarkers of endocrine disruptive effects are hepatic glutathione-S-transferase enzymes (GSTs) (LeBlanc and Bain, 1997). In certain species, these enzymes exhibit sexual dimorphism and function to inactivate steroids. For example, androgen sulphotransferase is induced by estrogen and the levels in females exceed those in males since they serve to inactivate androgens. As the expression of GSTs is controlled by steroids, exposure to xeno-oestrogens and/or androgen-agonists can increase androgen sulphotransferase expression. This causes an increase in androgen deactivation thereby depressing androgenic activity in males (LeBlanc and Bain, 1997). As GSTs are hepatic enzymes, sampling of animals cannot be non-destructive and occur within minutes of death before protein deactivation/degradation processes ensue. It is not known whether GSTs exhibit sexual dimporphism in marine mammals. Clearly, further research is needed to determine the reliability of GSTs as biomarkers of endocrine disruptive “effects” in marine mammals before their use can be warranted. Despite the difficulty in obtaining reasonable numbers of fresh liver samples, it is anticipated that GSTs may prove to be invaluable tool for biomonitoring endocrine disruptive effects in marine mammals in the future.

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REFERENCES

Aulerich, R.J., Bursian, S.J., Breslin, W.J., Olson, B.A. and Ringer, R.K. 1985. Toxicological manifestations of 2,4,5,2í,4í,5í-, 2,3,4,2í,3í,6í-, and 3,4,5,3í,4í,5í-hexachlorobiphenyl and Arochlor 1254 in mink. *J. Toxicol. Environ. Health*, 15: 63-79.

Bäcklin, B. and Bergman, Å. 1992. *Ambio*, 21: 596-601.

Colborn, T. and Smolen, M.J. 1996. *Rev. Environ. Contam. Toxicol.*, 146: 91-171.

DeGuise, S., Lagace, A. and P. Beland, P. 1994. True hermaphroditism in a St. Lawrence beluga whale (*Delphinapterus leucas*). *J. Wildl. Dis.*, 30: 287-290.

Fielden, M., Chen, I., Chittim, B., Safe, S. and Zacharewski, R. 1997. *Env. Health Persp.*, 105: 1238-1248.

Fossi, C., Marsili, L., Leonzio, C., Notarbartolo Di Sciara, G., Zanardelli, M. and Focardi, S. 1992.. *Mar. Pollut. Bull.*, 24: 459-461.

Freeman, H. and Sangalang, G. 1979. *Arch. Environ. Contam. Toxicol.*, 5: 369-383.

Gillner, M., Lund, J., Cambillau, C., Alexandersson, M., Hurtig, U., Bergman, Å., Klasson-Wehler, E. and Gustaffson, J. 1988. *J. Steroid Biochem.*, 31:27-33.

Griffin and Ojeda. 1996. *Textbook of Endocrine Physiology.*

IEH (Institute for Environment and Health) 1998. Ecological Significance of Endocrine Disruption: Effects on Reproductive Function and Consequences for Natural Populations. Institute for Environment and Health, University of Leicester.

Kihlstrøm, J.E., Olsson, M., Jensen, S., Johansson, Å., Ahlbom, J. and Bergman, Å. 1992. Effects of PCB on the reproduction of the Mink (*Mustela vison*). *Ambio*, 21: 563-569.

LeBlanc, G. and Bain, L. 1997. *Env. Health Perps.*, 105: 65-80.

Moore, M., Miller, C., Weisbrod, A., Shea, D. and Stegeman, J. 1995. *Abstracts* from the 11th Biennial Conference Marine Mammology. Society for Marine Mammalogy, Orlando, Florida.

Patnode, K. and Curtis, L. 1995. *Toxicol. Appl. Pharmacol.*, 127: 9-18.

÷rberg, J. and Lundberg, C. 1974. *Environ. Physiol. Biochem.*, 4:116-120.

Reijnders, P.J.H. 1986a. Reproductive failure of common seals feeding on fish from polluted waters. *Nature*, 324: 456-457.

Reijnders, P.J.H. 1986b. *Environ. Cons.*, 11 : 61-65.

Reijnders, P.J.H. and S. Brasseur, S. 1992. Pp. 159-174. In *Chemically-Induced Alterations in Sexual Development: The Wildlife/Human Connection.* (Eds. T. Colborn and C. Clement).

Seiler, P., Fischer, B., Lindenau, A. and Henning, M. 1994. *Human Reprod.*, 9:1920-1926.

Subramanian, A.N., Tanabe, S., Tatsukawa, R., Saito, S. and Miyazaki, N. 1987. Reduction in testosterone levels by PCBs and DDE in Dall's porpoises of the north-western North Pacific. *Mar. Poll. Bull.*,18: 643-646.

Troisi, G. and Mason, C. 1997. *Chemosphere*, 35: 1933-1946.

Troisi, G. and Mason C. (in press). *Mar. Env. Res.*

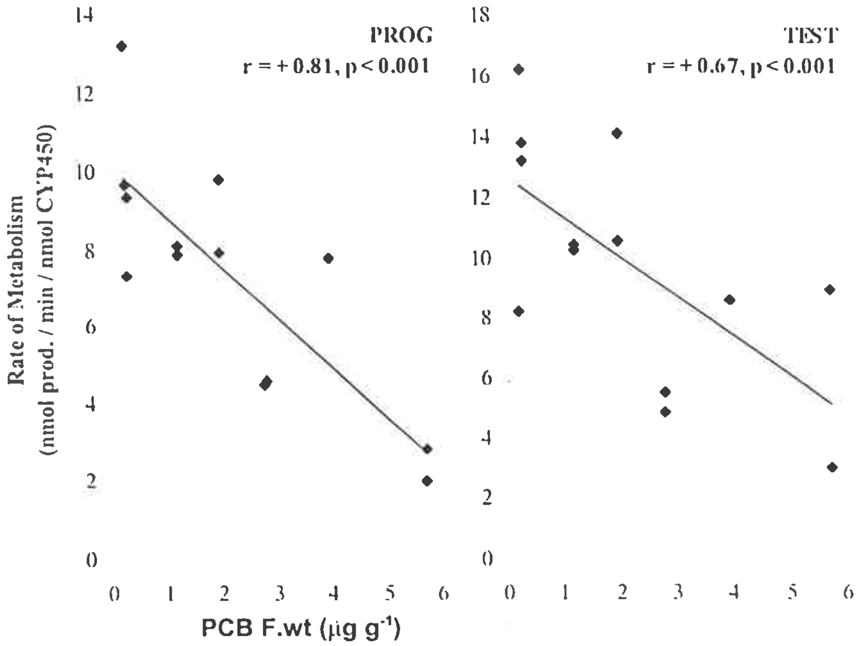
Figure 1

Relationship between liver PCB burden and rate of progesterone metabolism by harbour seal hepatic microsomes.

Figure 2

Relationship between liver PCB burden and rate of testosterone metabolism by harbour seals hepatic microsomes.

source:
Troisi & Mason (*in press*)[15]



Figs. 1 and 2. Hepatic Microsomal PROG & TESTO Metabolism Versus Liver PCB Concentration (Troisi & Mason, in press). Fig. 1 shows the relationship between liver PCB burden and rate of progesterone metabolism by harbour seal hepatic microsomes. Fig. 2. Shows the relationship between liver PCB burden and rate of testosterone metabolism by harbour seal hepatic microsomes.

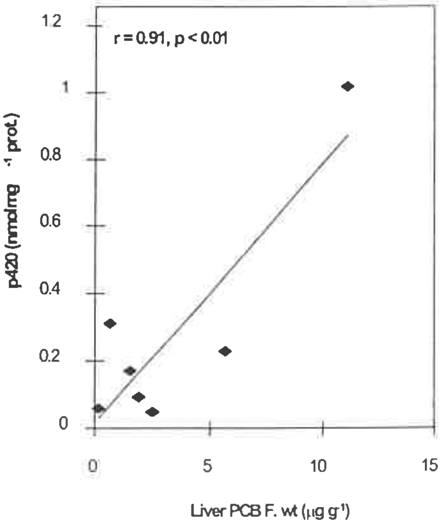


Fig. 3. Hepatic microsomal cyt. P420 concentration versus liver PCB concentration (Troisi and Mason, 1997).

REPRODUCTION, HEALTH AND CONTAMINANT BURDEN IN THE BALTIC SEALS

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INTRODUCTION The Baltic seal populations have decreased in our century from several tens of thousands or even a couple of hundreds of thousands to only a few thousand. The decreasing trend stopped in the early 1980s. Since then, the main part of the grey seal (*Halichoerus grypus*) stock has been increasing by a good 10% annually and that of the ringed seal (Phoca hispida) by 5-6 %. The present size of the countable haul-out population is close to 6,000 for the grey seal and 5,500 for the ringed seal. The Baltic seal populations have been affected by severe reproductive disorders from the late 1960s onwards. These failures, as well as other pathological findings, have been linked to high levels of environmental toxins, especially chlorinated hydrocarbons.

REPRODUCTIVE PERFORMANCE Pathological uterine occlusions, causing life-long sterility in females, emerged in the ringed seal population of the Bothnian Bay in the late 1960s. Its frequency peaked in 1977-79, when more that 50% of the mature females were affected by the failure. Since then, the frequency has decreased, affecting ca. one third of the mature females in the 1990s. The frequency of uterine occlusions has been positively dependent of the age of the female throughout its occurrence. Uterine occlusions have been found also in other parts of the Baltic ringed seal population, but time trends are not known.

In the Baltic grey seal, uterine disorders have been of a different type. Occlusions and stenoses, (narrowing of the uterine horns) are markedly less frequent than in the ringed seal, while the most frequently obsserved pathological changes are tumours (leiomyomas). In the Finnish material of 36 adult females from 1982-97, only specimens older than 30 years of age were diseased, in most cases by tumours.

In a species comparison, uterine pathology seems to affect ringed and grey seals differently: ringed seals are hit mostly by uterine occlusions throughout their mature age, with an increasing frequency with age, whereas grey seals are affected mostly by tumours and (almost entirely) at high ages.

OTHER HEALTH DISORDERS In addition to the uterine pathology, other disorders have been documented in high prevalence in the Baltic seals. Enlarged adrenals, claw deformations, skull lesions, chronic intestinal ulcers, arteriosclerosis and kidney failure are the most common changes. The disorders have been observed within all age groups, although their frequencies tend to increase with age. The time trend has been generally positive, and today the diseases occur most frequently in old individuals.

The above mentioned pathological disorders, including the reproductive ones, have been associated with the elevated contaminant burdens measured in the seal tissues. The contaminants are suggested to interfere with the immune and hormonal systems. The exact mechanisms by which the contaminants affect the Baltic seals has not been clarified as yet. A Dutch study was conducted on young harbour seals (phoca vitulina), in which the seals were fed Baltic herring during 2 years. In this study, a slightly decreased vitamin-A level and NK-activity were observed. This suggests that some foreign compounds in the Baltic herring affect at least the health of harbour seals.

DDT AND PCB BURDENS Levels of DDT and PCB compounds peaked in the Baltic ecosystem in the 1960-70s. The decreasing trends since then have been documented also in the seals. Monitoring of young Baltic grey and ringed seals shows that the PCB levels in grey seals has declined the least. Despite the overall decreased levels, the organochlorine concentrations are still rather high, averaging ca. 15 ppm (blubber, extractable fat) for DDT and 50 ppm for PCBs in young grey seals in the early 1990s.

RELEVANT QUESTIONS The Baltic seal research of to-day is looking for answers to several questions. What are the consequences for the sealís health after a life long exposure? What causes the observed pathological changes? Do the changes occur in the same patterns in an uncontaminated seal population? Can a part of the pathological changes be considered as the effects of ageing? If the contaminants have an effect on the seals, what are the mechanisms behind the interference? Can both seal species deal with, and get rid of, contaminants in the same manner and with equal efficiency?

AIMS AND SUGGESTIONS FOR FURTHER RESEARCH For this study, our aim is to find biomarkers to assess the exposure and effects of environmental contaminants on the Baltic seals. In addition, our goal is to work out non-invasive methods for monitoring this risk assessment. The biomarkers will be assessed for (a) the general health of the seal, (b) the contaminant exposure, (c) the toxic potency of the contaminants, and (d) possible immunological and reproductive disturbances.

REFERENCES

Baltic Seals 94. 1994. International Conference on Baltic Seals, Nyköping, Sweden, 28 Nov- 1 Dec, 1994.

Bergman, A. 1994. Organskador hos Östersjösälar: Jamförelse mellan resultat från obduktioner av gråsäl under perioderna 1977-1986 och 1987-1993. Wildlife Pathology meeting, Geta, Åland, 18-20 May, 1994.

Bergman, A. and Olsson, M. 1985. Pathology of Baltic grey seal and ringed seal females with special reference to adrenocortical hyperplasia: Is environmental pollution the cause of a widely distributed disease syndrome? *Finnish Game Res.*, 44: 47-62.

Bergman, A. and Olsson, M. 1986. Pathology of Baltic grey seal and ringed seal males: Report regarding animals sampled 1977-1985. Pp. 74-86. In Proceedings of the Soviet-Swedish symposium *Effects of toxic substances on dynamics of seal populations*. Moscow, USSR, 14-18 April, 1986.

De Swart, R., Ross, P., Vedder, L., Timmerman, H., Heisterkamp, S., van Loveren, H., Vos, J., Reijnders P. and Osterhaus A. 1994. Impairment of immune function in harbour seals (*Phoca vitulina*) feeding on fish from polluted waters. *Ambio*, 23: 155-159.

Helle, E. 1980 Lowered reproductive capacity in female ringed seals Pusa hispida (Schreber) in the Bothnian Bay, Northern Baltic Sea, with special reference to uterine occlusions. *Ann. Zool. Fennici*, 17: 147-158.

Helle. E. 1989. Game animals as indicators of environmental pollution, with special reference to Baltic seals. *Finnish Game Res.*, 46: 87-92.

Helle, E. 1998. Reproductive failures in the Baltic seals. Unpublished.

Olsson, M. 1992. Sälarna i Östersjön. *Naturvetenskapliga forskningsrådets Årsbok*. 110-123.

Ross, P., de Swart, R., Timmerman, H., Reijnders, P., Vos, J., van Loveren H. and Osterhaus, A. 1995. Suppression of natural killer cell activity in harbour seals (*Phoca vitulina*) fed Baltic Sea herring. *Aquatic Toxicol.*, 34: 71-84.

REPRODUCTIVE SYSTEM PATHOLOGY OF CETACEANS STRANDED IN ENGLAND AND WALES

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INTRODUCTION The health and reproductive function of marine mammals is a focus of increasing concern, particularly for those species that have been subjected to the greatest population declines. In recent years, pathological studies have identified novel pathogens such as Brucella sp. infecting marine mammals (Ewalt *et al.*, 1994; Foster *et al.*, 1996; Ross *et al.*, 1996). In terrestrial mammals, Brucella spp. are known to cause serious disease in reproductive and other tissues (Corbel and Morgan, 1975). Additionally, the possible effects of bioaccumulation of persistent environmental contaminants on reproductive function in marine mammals are an omnipresent concern (Reijnders, 1986). In 1990, a collaborative and systematic programme of research on stranded marine mammals was established in the UK, which was later sub-divided into two separately co-ordinated programmes for England/Wales and Scotland. A detailed analysis of the reproductive system data collected from the marine mammal strandings programme since 1990 has yet to be conducted. However, we take the opportunity here to report, in a qualitative manner, some of the pathological findings recorded in cetaceans stranded in England and Wales between 1990 and 1997.

MATERIALS AND METHODS Between August 1990 and December 1997, postmortem examinations of over 500 cetacean carcasses stranded in England and Wales were conducted according to standard postmortem protocols (Kuiken and Baker, 1993). The species most commonly examined were the harbour porpoise (*Phocoena phocoena*; n=342) and the common dolphin, (*Delphinus delphis*; n= 182) although 71 individuals from 12 other cetacean species were also examined. As part of the postmortem protocols, entire reproductive tracts were examined grossly, together with microbiological and histological examinations of any gross lesions, depending on their suspected aetiology.

RESULTS Infectious diseases of the reproductive tract were relatively uncommon. A *Brucella* sp. was isolated from a grossly and histologically normal testis in one harbour porpoise. Only one other *Brucella* sp. isolate was recovered from a chronically arthritic atlanto-occipital joint, also in a harbour porpoise. An organism typed as *Moraxella lacunata* was isolated from the testis of a harbour porpoise with chronic orchitis characterised by necrosis of seminiferous tubules with loss of normal tissue architecture, heavy neutrophil and plasma cell infiltration and peritubular fibrosis. Immunohistochemistry of formalin-fixed sections of this lesion using *Brucella abortus* antisera was inconclusive. Other bacterial diseases of the reproductive tract included necropurulent ulcerative balanitis in a harbour porpoise from which *Bacteroides stercoris* was isolated, purulent mastitis associated with *Streptococcus canis* septicaemia and purulent metritis in a harbour porpoise from which *Streptococcus* sp. and *Pseudomonas* sp. were isolated.

Papillomatous or fibropapillomatous warts or plaques were seen on the penile epithelium of a striped dolphin (*Stenella coeruleoalba*) and several harbour porpoises and common dolphins, and on the vaginal epithelium of two female harbour porpoises. All individuals apart from one male harbour porpoise were sexually mature. Mammary gland infections with Crassicauda sp. were rarely seen in harbour porpoises and common, striped and white-sided dolphins (*Lagenorhynchus acutus*). There were minimal pathological changes associated with the presence of these parasites.

Uterine leiomyomas were recorded in 2 harbour porpoises, vaginal calculi in three common dolphins and one harbour porpoise, and a twin pregnancy was reported in a common dolphin. Dystocia was recorded in a number of harbour porpoises which often resulted in the death of the pregnant individual and/or the calf. Complications of dystocia such as uterine rupture and the development of septic shock were also occasionally seen.

DISCUSSION There have been only two isolates of *Brucella* sp. from two harbour porpoises (both in 1997) in this study. Within England and Wales, serological evidence of exposure to *Brucella* sp. has been reported in common and grey seals (*Phoca vitulina* and *Halochoerus grypus*, respectively), harbour porpoises, common dolphins, a striped dolphin, a bottlenose dolphin (*Tursiops truncatus*), a killer whale (*Orcinus orca*) and a pilot whale (*Globicephala melas*) stranded in England and Wales (Jepson *et al.*, 1997). Increasing evidence is emerging of the widespread nature of Brucella sp. exposure in marine mammals (Ewalt, 1994; Nielsen *et al.*, 1996; Foster *et al.*, 1996) although the pathogenicity of *Brucella* sp. in marine mammals is still not fully understood.

The genital warts described here grossly and histologically resembled genital papillomas or fibropapillomas reported in other cetacean species (Van Bressem *et al.*, 1996) caused by papillomavirus infection (Cassonnet *et al.*, 1998). Papillomavirus is strongly suspected to have a role in the aetiology of genital papillomas in cetaceans in England and Wales. Further studies are needed to understand the effect of reproductive diseases like those described above on cetaceans populations in British waters.

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REFERENCES

Cassonnet, P., Van Bressem, M.F., Desaintes, C., Van Waerebeek, K., and Orth, G. 1998. Papillomaviruses cause genital warts in small cetaceans from Peru. In *Abstracts* the World Marine Mammal Science Conference, Monaco, 20-24 January 1998. Society of Marine Mammalogy and European Cetacean Society.

Corbel, M.J. and Morgan, W.J.B. 1975. *Intl. J. System. Bacteriol.*, 25: 83.

Ewalt, D.R., Payeur, J.B., Martin, B.M., Cummins, D.R. and Miller, W.G. 1994. Characteristics of a Brucella species from a bottle-nosed dolphin (Tursiops truncatus). *J. Vet. Diag. Invest.*, 6. 448-452.

Foster, G., Jahans, K.L., Reid, R.J. and Ross, H.M. 1996. Isolation of Brucella species from cetaceans, seals and an otter. *Vet. Rec.*, 138: 513-515.

Jepson, P.D., Brew, S., MacMillan, A.P., Baker, J.R., Barnett, J., Kirkwood, J.K., Kuiken, T., Robinson, I.R. and Simpson, V.R. 1997. Antibodies to *Brucella* in marine mammals around the coast of England and Wales. *Vet. Rec.*, 141: 513-515.

Kuiken, T. and Baker, J.R. 1993. *Guidelines for the postmortem and tissue sampling of cetaceans.* Zoological Society of London, London, 16pp.

Nielsen, O., Nielsen, K. and Stewart, R.E.A. 1996. Serological evidence of *Brucella* spp. exposure in Atlantic walruses (*Odobenus rosmarus rosmarus*) and ringed seals (*Phoca hispida*) of Arctic Canada. *Arctic*, 49: 383-386.

Reijnders, P.J.H. 1986. Reproductive failure in common seals feeding on fish from polluted coastal waters. *Nature*, 324: 456-457.

Ross, H.M., Jahans, K.L., MacMillan, A.P., Reid, R.J., Thompson, P.M. and Foster, G. 1996. *Brucella* species infection in North Sea seal and cetacean populations. *Vet. Rec.*, 138: 647-648.

Van Bressem, M.F., Van Waerebeek, K., Pierard, G.E. and Desaintes, C. 1996. Genital and lingual warts in cetaceans from coastal Peru. *Dis. Aquat. Org.*, 26: 1-10.

PATHOLOGY OF HARBOUR PORPOISES IN RELATION TO REPRODUCTION WITH SPECIAL REFERENCE TO THE GERMAN NORTH AND BALTIC SEAS AND WATERS AROUND GREENLAND

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INTRODUCTION The integrity of the reproductive system is a key factor for the equilibrium of a population. Post mortem investigation of individuums of the decreasing harbor porpoise population of the German North Sea and Baltic Sea focused therefore on the causes of death and the biology and pathology of the reproductive system. The possible influence of environmental pollutants on the reproductive capacity of these animals was of special interest. For comparison, carcasses of harbor porpoise of less polluted waters of Greenland were also examined.

MATERIALS AND METHODS Since 1990, all cetaceans stranded on German coasts and by-caught by German fishermen have been recorded and examined pathologically and zoologically. Between 1991 and 1997 necropsies were performed on 491 harbour porpoises (*Phocoena phocoena*) in various states of preservation. The animals were from the North and Baltic Seas and were strandings or bycatches. 154 animals were preserved well enough to allow complete sampling for histological, microbiological, parasitological, toxicological and genetic investigations. The 14 harbour porpoises from waters around Greenland were killed as part of Inuit hunting. For all animals detailed necropsies and complete further investigations were performed.

The carcasses were weighed and measured, and four teeth were removed for age determination. The nutritional state was judged based on blubber thickness, measured in four different locations, and based on the state of the muscles. Pathological examinations were carried out according to the Proceedings of the First ECS Workshop on Cetacean Pathology (Kuiken and Hartmann, 1993).

RESULTS Pathological findings of the female genital system were inflammation of the vagina, uterus and mammary gland, vaginal calculi, parasites of the mammary gland and perimammary tissue and dystocia. Whereas parasites of the mammary gland were only found in animals from Greenland, endometritis, dystocia, rupture of the uterus and vaginal calculi occurred only in animals from German waters.

Vaginal calculi were found in an immature bycaught harbour porpoise from the North Sea. In total a number of 10 stones were found ranging in size between 0.5 to 2.5 cm, located in the plica of the vagina in front of the external orifice of the cervical canal. The calculi consisted of 70% struvite and 30% calcium-oxalate, the same make-up that kidney stones in other species commonly have. Associated with the calculi, a mild suppurative vaginitis was found. The urinary system showed no lesions, and the etiology of the stones in this animal is unknown.

In the mammary gland of three harbour porpoises from waters around Greenland, eggs of nematodes were found, but no adult nematodes could be detected. These nematodes found in the subcutis, muscles and perimammary connective tissue were identified as *Crassicauda sp.* from the family Spiruridae.

In general the vaginitis was mild and thought to be of little importance to the health of the animals. There was one case of dystocia caused by a wrong position of the fetus in the uterus. The umbilical cord was twisted causing failure of the blood supply to the fetus. One harbour porpoise from the German North Sea showed a rupture of the uterus and associated suppurative-fibroplastic peritonitis most probably resulting from complication during birth.

Pathological findings of the male genital system were balanoposthitis and orchitis. No lesions were found in the six males originating from Greenland. Suppurative or suppurative necrotizing balanoposthitis was found in four harbour porpoises from German waters. In three of the four cases the balanoposthitis resulted in a septicemia with pyelonephritis, myocarditis and/or leptomeningitis caused by β-hemolytic streptococci. A granulomatous necrotising orchitis was detected as one organ manifestation of a systemic Rhizopusmycosis in a harbour porpoise from the German Baltic Sea with multinucleated giant cells and intra- and extracellular fungal hyphae and spores. The fungal hyphae were up to 40 µm in diameter, rarely septated, irregularly branched, and had a thick wall. One harbour porpoise showed a chronic suppurative orchitis. The inflamed testis was three times larger than the normal right one. The etiology could not be clarified.

DISCUSSION Lesions of the genital system are rare in harbour porpoises from German waters. Compared to the examined number of animals from Greenland lesions occured more often in those animals but were due to parasitic infection of the mammary gland. Whereas the lesions of the female genital system were in general mild the balanoposthitis were severe and in some cases balanoposthitis was the portal of entry for fatal septicemia mostly caused by β-hemolytic Streptococci (Siebert *et al.,* 1996, Swenshon *et al.*, 1998).

No macroscopical or histological lesions suspicious for effects of contaminants as tumors (1994a), hermaphorditism (De Guise *et al.*, 1994b) or stenosis and occlusions of the uterus (Helle, 1976; Olsson *et al.*, 1994) could be detected. Nevertheless, investigations on the possible effects of specially organic toxins with the potential to disrupt the endocrine system of animals need to be continued because porpoises from German waters show a lower fecundity compared to other populations (Bandomir *et al.*, in prep).

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REFERENCES

Bandomir, B., Siebert, U. and Chavez-Lisambert, L. (in prep.). The life history of harbour porpoises from German waters.

De Guise, S., Lagace, A. and Beland, P. 1994a. Tumors in St. Lawrence beluga whales (*Delphinapterus leucas*). *Vet. Pathol.*, 31 (4): 444-9.

De Guise, S., Lagace, A. and Beland, P. 1994b. True hermaphorditism in a St. Lawrence beluga whale (*Delphinapterus leucas*). *J. Wildl. Dis.*, 30 (2): 287-90.

Helle, E., Olsson, M. and Jensen, S. 1976. PCB levels correlated with pathological changes in seal uteri. *Ambio*, 5: 261-263,.

Kuiken, T. and Hartmann, M. G. 1993. Dissection techniques and tissue sampling. *Proc. ECS Workshop*, Leiden. 39pp.

Olsson, M, Karlsson, B. and Ahnland, E. 1994. Diseases and environmental contaminants in seals from the Baltic and the Swedish west coast. *Sci. Total Environ.*, 154: 217-27.

Siebert, U., Lick, R., Weiss, R., Frank, H., Benke, H. and Frese, K. 1996. Post-mortem findings in small cetaceans from German waters of the North and Baltic Sea. Proceedings of the First scientific meeting of the European Association of Zoo- and Wildlife Veterinarians, Rostock, Germany: 1-8.

Swenshon, M., Lämmler, Ch. and Siebert, U. 1998. Identification and molecular Characterization of β-hemolytic Streptococci isolated from harbour porpoises of the North and Baltic Seas. *J. Clin. Microbiol.*, 36(7): 1902-1906.

4. BREEDING IN WILD POPULATIONS

BREEDING BEHAVIOUR AND OESTRUS IN FREE-RANGING GREY SEALS, (*HALICHOERUS GRYPUS*)

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INTRODUCTION Marine mammals are typically long-lived and have low reproductive rates. Long term studies of known individuals can maximise information on reproductive parameters by using non-destructive approaches. The advantages and disadvantages of this approach applied to a longitudinal study of the factors which contribute to reproductive success in grey seals (*Halichoerus grypus*) are considered here, along with some apparently contradictory evidence on mating behaviour, genetics and physiology.

In the UK, grey seals breed on land, usually on remote islands and coastline. Females are primiparous at 3-5 years old, males may be physiologically mature at five but are thought to be socially mature only after they reach 8 years old. During this time mothers fast, and rely on stored reserves. Grey seals are sexually dimorphic: females may reach a postpartum body mass of 250kg, while males may exceed 400kg. Individual females come ashore in autumn for approximately 20 days to give birth and suckle a single pup and mate before returning to sea. The breeding season may last for 10 weeks depending on the colony, so there is turnover of individuals on the colony. Colonies have a very predictable geographic structure, and probably a very complex social structure.

The main breeding aggregation of grey seals on the stable colony of North Rona, Outer Hebrides, occurs in the same area each year, on open areas inland from the gullies which offer very limited access from the sea. Approximately 1,400 pups are born over a 10 week season. The typical operational sex ratio on the colony is 7:1 (F:M). Males that give every sign of polygynous behaviour in that (generally big) dominant males take up positions within groups of females and defend access to those females aggressively. Although most male:male interactions appear to be formalised and involve no physical contact, fights which do occur between males frequently result in injury (Twiss *et al.*, in press).

Breeding patterns in grey seals: apparent contradictions In the course of examining grey seal breeding patterns, results appeared which posed questions for traditional views of mating success and polygyny (Amos *et al.* 1993, 1995). Known males and females tend to return to breed in the same parts of the colony from year to year (Twiss *et al.*, 1994; Pomeroy *et al.*, 1994). However, fewer pups were sired by dominant males than would be expected by their behavioural dominance and apparent mating success (Amos *et al.*, 1993; Twiss *et al.*, 1994, in press). In addition, pups born to the same mother tended to have the same father more often than would be predicted by the observed temporal and spatial occurrence of the parents on the colony. Furthermore, many of the fathers of full sibs were not among the sampled (mainly dominant) group (Amos *et al.*, 1995). These results suggest that observed mating patterns and success may not be as straightforward as had been assumed.

Behavioural oestrus has been described typically as occurring around 14 days into the 18 day lactation period (Hewer, 1960; Anderson *et al.*, 1975). Hormonal studies supported this, but there was also equivocal histological evidence of a possible second ovulation occurring at the moult, (around Jan-Feb, either just before or around implantation; Boyd, 1991). However no evidence of sexual interactions between adults has been recorded at moult.

Female grey seals show aggression to males in nearly all interactions ashore and prior to day 12, males are usually chased off. Experienced males make tentative approaches to females and seem to be checking their condition. Female responses to attempted copulation seem dependent as much on male identity as stage of lactation. If a sub-dominant male tries to mate a female in the centre of the North Rona colony, the female (and often her neighbours) become animated and vocalise aggressively, usually with result that a dominant male chases off the intruder. Around day 14 or later, females succumb to attempts at copulations after an initial resistant phase, and the later in lactation, the more likely a female is to be compliant. Males may force copulations, but this usually results in injury to the male, female or both. Some females mate and then wean the pup within hours, but some mate and stay several more days.

Physiological, hormonal and behavioural indications of oestrus in grey seals in the UK The relative sizes of mother and pup and maternal condition are good indications of the likely oestrus stage of the mother. Hormonal profiles indicate timing of ovulation but require sequential samples which are difficult to obtain from free ranging animals and individual variation may obscure any cross-sectional trend. Vaginal cytology is successional and reflects hormone profiles directly. Females in late lactation show a vaginal dilation response to touch.

Individual seals lactate for similar periods between years and the duration of lactation is related to maternal postpartum masses. There were differences between the cytological stages recorded at the same day of lactation for females from North Rona and the Isle of May. Females at N. Rona were less advanced in the oestrus cycle on the same days of lactation, yet sperm was found on vaginal swabs on similar days of lactation. Observations of mating in the colony indicated that where paternities were assigned, the identified male was in the area of the mother in 89% of cases. Mothers at the Isle of May isolated from males beyond the normal full duration of their lactation periods still appeared pregnant the next year.

Areas for further investigation Male dominance relationships may change at night, but there is no evidence of this. Sperm from dominant males may be of lower quality than that from other males. Alternative mating patterns are possible, for example on the margins of the colony, but the full sibs finding requires explanation. Individual variation in female reproductive cycles may mean that spontaneous and induced ovulation may occur in females on the colony. Female breeding patterns may mean that males off the main colony may be successful.

REFERENCES

Amos, W.A., Twiss, S.D., Pomeroy, P.P. and Anderson, S.S. 1995. Evidence for mate fidelity in the gray seal. *Science*, 268: 1897-1899.

Amos, W., Twiss, S., Pomeroy, P.P. and Anderson, S.S. 1993. Male mating success and paternity in the grey seal (*Halichoerus grypus*): a study using DNA fingerprinting. *Proc. R. Soc. Lond. B.*, 252: 199-207.

Anderson, S.S., Burton, R.W., and Summers, C.F. 1975. Behaviour of grey seals *Halichoerus grypus* during a breeding season at North Rona. *J. Zool.*, 177: 179-195.

Boyd, I.L. 1985. Pregnancy and ovulation rates in grey seals (*Halichoerus grypus*) on the British coast. *J. Zool.*, 205: 265-272.

Boyd, I.L. 1991. Environmental and physiological factors controlling the reproductive cycles of pinnipeds. *Can. J. Zool.*, 69: 1135-1148.

Hewer, H.R. 1960. Behaviour of the grey seal (*Halichoerus grypus* Fab.) in the breeding season. *Mammalia*, 24: 400-421.

Pomeroy, P.P., Anderson, S.S., Twiss, S.D., and McConnell, B.J. 1994. Dispersion and site fidelity of breeding female grey seals (*Halichoerus grypus*) on North Rona, Scotland. *J. Zool.*, 233: 429-448.

Twiss, S.D., Pomeroy, P.P., and Anderson, S.S. 1994. Dispersion and site fidelity of breeding male grey seals (*Halichoerus grypus*) on North Rona, Scotland. *J. Zool.*, 233: 683-693.

Twiss, S.D. (in press). Determinants of individual male mating success in the grey seal (*Halichoerus grypus* Fabricius, 1791) on North Rona. *J. Zool.*

Twiss, S.D., Caudron, A., Pomeroy, P.P., Thomas, C.J., and Mills, J.P. (submitted). Fine scale topography influences the breeding behaviour of female grey seals. *Behav. Ecol. Soc.*

THE EFFECTIVENESS OF LUPRON^R IN CONTROLLING REPRODUCTION IN HARBOUR SEALS, *PHOCA VITULINA*

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INTRODUCTION In 1993, the Bermuda Aquarium, Museum and Zoo (BAMZ) initiated a programme to control reproduction in its harbour seal colony. After investigating various alternatives, it was decided that the chemical contraceptive leuprolide acetate in depot suspension (Lupron^R) would be used.

Lupron^R's success in controlling reproduction in captive harbour seals has been mixed. For example, the National Aquarium in Baltimore, Maryland, USA has experienced no pregnancies since they began using Lupron^R in 1992 even though matings have occurred (personal communication). The New England Aquarium in Boston, Massachusetts, USA, however, has tried Lupron^R three times, and each time resulted in a pregnancy. They concluded that their pregnancies were due to the protocol they used in administering Lupron^R however, and not because Lupron^R itself was ineffective (personal communication). The purpose of this paper is to summarise the data obtained on the effectiveness of Lupron^R at BAMZ and to present the protocol that BAMZ has found to be most successful.

LUPRON Lupron^R is a GnRH agonist which binds to receptors in the pituitary. While initially producing a surge in leutinizing hormone, and thus a spike in testosterone secretion by the testes, the continued presence of Lupron^R causes the plasma testosterone concentration to decrease to negligible levels. Sperm production is therefore discontinued due to the lack of circulating testosterone and the animal becomes sterile. Plasma testosterone concentration will continue to be negligible until the Lupron^R wears off or if Lupron^R injections are given at regular intervals (TAP Pharmaceuticals, 1990 and personal communications).

MATERIALS AND METHODS The male seal used in this study (Archie) was captured as a pup on Sable Island, Canada in 1971, and relocated to Bermuda in 1973. The initial phase of this study involved collecting Archie's baseline testosterone data for a year long period beginning in July 1993 and ending in July 1994. In the following years, injections of Lupron^R were given at different intervals as described later in this abstract. The dosage for each injection of Lupron^R was 0.075mg/kg which equaled an injection of 7.5 mg.

Testosterone concentrations were obtained from blood serum samples. Blood samples were collected by venipuncture of the vessels in the metatarsal region of the seal's hind flippers. Blood was collected in heparinised vacutainers and the blood was kept chilled until it was centrifuged (within three hours after it was collected). The resulting plasma was frozen at -10°C and transported overnight to the Central Diagnostic Laboratory at Cornell University. Plasma testosterone concentrations were then determined by radioimmunoassay.

RESULTS Figure 1 shows how Archie's baseline testosterone concentrations vary before, during and after a breeding season. Testosterone secretion normally begins in March and the serum testosterone concentration fluctuates but remains elevated until it begins to decline in August. A similar pattern was observed in the males at the National Aquarium except that their males did not begin to secrete testosterone until April (Hunter, 1996).

On July 14, 1994, Archie was given his first injection of Lupron^R. His testosterone concentration for that date was 1.56 ng/ml. By two weeks following the injection his testosterone concentration had dropped to 0.52 ng/ml, and by August 4th his testosterone concentration was undetectable.

During 1995, Archie's testosterone level rose in mid-March as it had in 1994. It was decided that spring to use the protocol followed by the National Aquarium. Their males are given one injection in mid-May which keeps their testosterone levels suppressed to negligible values during the entire breeding season (Hunter, 1996). Archie was given a Lupron^R injection on May 3rd and his testosterone concentration for that date was 1.43 ng/ml. His testosterone concentration showed an increase to 2.8 ng/ml on May 11th which was not unexpected and it was assumed that his testosterone concentration would reach undetectable levels within one to two weeks.

Although Archie displayed no courtship behaviours during June and early July, he began exhibiting such behaviours in mid-July and it was discovered that his testosterone concentrations were 1.01 ng/ml and 0.88 ng/ml on July 13th and 27th respectively. Mating behaviour was observed on the 27th and Archie was given a second injection of Lupron^R on that date. Subsequently, his testosterone concentration increased to 1.37 ng/ml on August 2nd, but then fell to undetectable levels by August 17th. No pregnancy resulted from the mating, but it was suggested that Archie could have possessed viable sperm cells at the time of the mating (Mike Briggs, personal communication).

For 1996, it was decided to follow the protocol recommended by Mike Briggs (personal communication) which had proven successful for *Tursiops truncatus*. This protocol uses monthly injections of Lupron^R and Archie was given monthly injections from March through September. Biweekly blood samples revealed that his testosterone concentrations remained at undetectable levels throughout this period once the initial spike in testosterone had subsided. In addition, no courtship or mating behaviours were observed.

During the spring of 1997 Archie's testosterone concentrations failed to increase normally and there was some concern that he was experiencing some permanent effect from the seven Lupron^R injections he received during the previous year. Once his testosterone rose above 1.0 ng/ml in May, however, he was given monthly Lupron^R injections from mid-May through mid-August. His testosterone concentration remained undetectable from late May through October when blood sampling was discontinued. Archie was observed to mate with two different females in late July, but in each case, courtship and mating behaviours had to be initiated by the females. No pregnancies resulted from these matings.

DISCUSSION In conclusion, our experience at BAMZ has shown that Lupron^R can wear off within ten weeks after it is injected. Because certain female seals at BAMZ are polyoestrous and the colony has an extended breeding season, it was determined that repeated monthly injections (or longer-duration injections) were necessary in order to ensure that reproduction did not occur.

It is believed that it takes approximately two months between the initiation of testosterone secretion and the production of mature sperm cells (Mike Briggs, personal communication). However, there are no clear data that detail the longevity of sperm in the vas deferens and epididymis after testosterone secretion is inhibited. It was concluded, therefore, that it was necessary to begin giving the Lupron^R injections to Archie early in the spring before viable sperm could be produced. In this way, even though mating could occur while Archie was on Lupron^R , there would be no possibility of a resulting pregnancy due to viable sperm remaining in the vas deferens. Such pregnancies have resulted from matings by recently gelded horses (Kent Allen, personal communication). It is also possible that a similar occurrence could have been responsible for the pregnancies observed at the New England Aquarium. In addition, it may be possible that the National Aquarium has observed no pregnancies because testosterone secretion is being suppressed before mature sperm cells are produced. Research on the longevity of sperm in seals after testosterone secretion is suppressed would be very useful to clarify if sperm viability is indeed a concern for facilities using Lupron^R to control reproduction in seals and other seasonally breeding animals.

ACKNOWLEDGEMENTS I would like to thank Ian Walker, Patrick Talbot, Jennifer Gray and all the other volunteers and staff members at BAMZ that have helped with this project over the years. In addition, I would like to thank TAP Pharmaceuticals, Inc. for supplying the LupronR used in this study. And finally I would like to thank the Bermuda College for the financial assistance they provided as part of their professional development programme.

REFERENCES

Hunter, S. 1996. The control of harbour seal reproduction at the National Aquarium in Baltimore. Draft in preparation.

TAP Pharmaceuticals, Inc. 1990. LUPRON DEPOT^R (leuprolide acetate for depot suspension). Product insert description. Deerfield, Il.

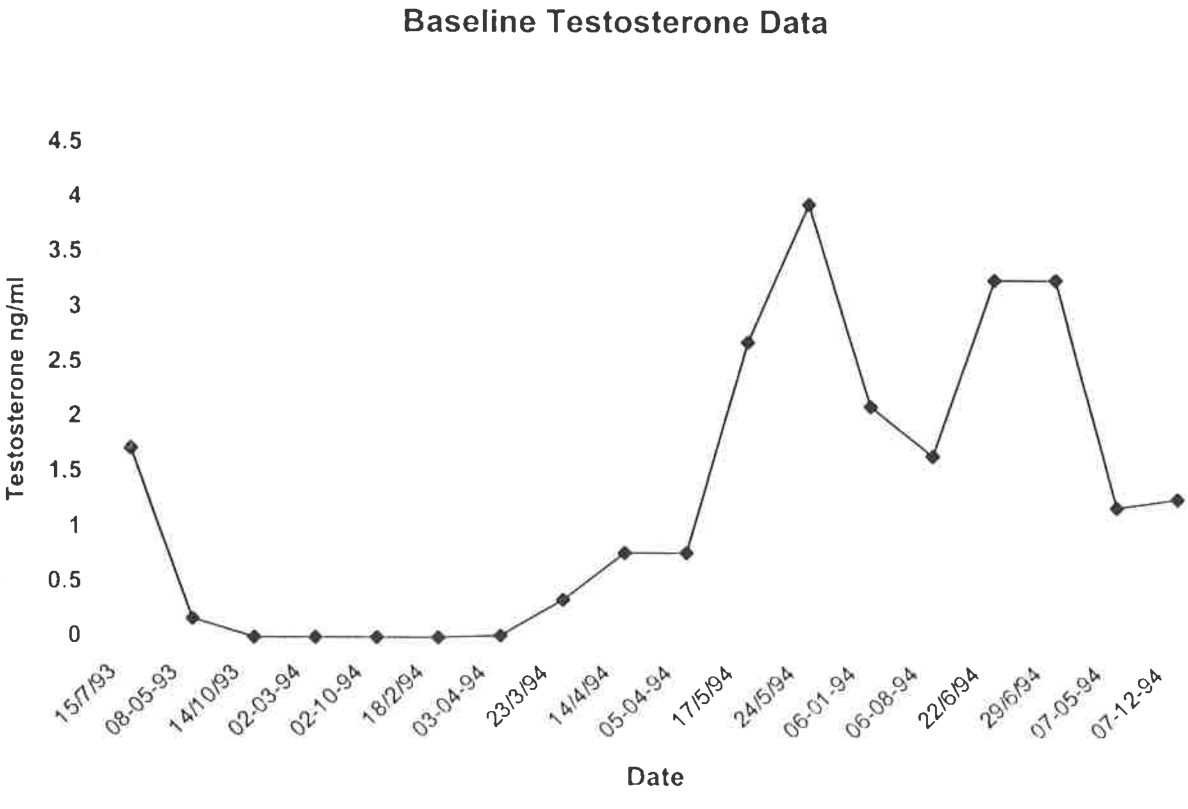

Fig. 1. Baseline Testosterone Data

5. CAPTIVE BREEDING

CAPTIVE BREEDING OF MARINE MAMMALS: FEASIBILITY AND SUCCESS

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The North American "Marine Mammal Census" database, which was first established in 1976, is a tool which allows us to assess the success of contemporary captive marine mammal breeding efforts. The marine park populations of California sea lions (*Zalophus californianus*), harbor seals (*Phoca vitulina*), and gray seals (*Halichoerus grypus*) are 68.3%, 59.1%, and 57.1% captive born respectively (Duffield and Shell, unpubl. data, 1996). In the author's opinion, this was achieved without significant human effort beyond housing sexually mature males and females together. Reproductive success has been more elusive in cetaceans. Serious attempts to enhance reproductive success of bottlenose dolphins (*Tursiops truncatus*), killer whales (*Orcinus orca*), and beluga whales (*Delphinapterus leucas*) have resulted in a captive born population of 45.1%, 51.6%, and 17.6% respectively (Duffield and Shell, unpublished data, 1996).

The available information has lead the author to conclude that successful captive reproduction of cetaceans is feasible. Numbers of animals, sex ratios, age, reproductive experience of the animals, facilities design, husbandry, nutrition, water quality, and the appropriate use of science and technology are all features which comprise the formula for reproductive success. Because of the large captive population, bottlenose dolphins appear to be an appropriate model for understanding the most important characteristics of a successful marine mammal breeding program. All dolphinaria with eight or more bottlenose dolphins, have experienced reproductive success. Mean age at birth of first calf in bottlenose dolphins is 13.2 years ±5.5. Percentage of births resulting in live offspring ranges from a first calf rate of 57.7% to a sixth calf rate of 80% (Duffield and Shell, unpublished data, 1993). This demonstrates the influence of numbers of animals, age, and reproductive experience. Most of the other features mentioned previously are related more to the art of successful dolphin reproduction than the science.

It is the author's belief that successful captive reproduction results from the understanding of the effects of the previously mentioned features as well as the artful application of that knowledge, combined with a spirit of co-operation between marine mammal institutions. A prototype for reproductive success with small populations of marine mammals has been achieved with Commerson's dolphins (*Cephalorhynchus commersoni*). They have been maintained at Sea World of California for the primary purpose of captive reproduction of the species for 14 years. The captive born members of this group make up 75% of the total population of twelve individuals (Duffield and Shell, unpubl. data, 1996).

REFERENCES

Duffield, D.A. and Shell, D. 1996. *Marine Mammal Census* (Unpublished data) Portland State University

Duffield, D.A. and Shell, D. 1993. *Marine Mammal Census* (Unpublished data) Portland State University

REPRODUCTIVE PHYSIOLOGY OF MONK SEALS: THE ROAD TO CAPTIVE BREEDING?

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It is essential to understand the reproductive physiology of endangered species to aid in their recovery. All of the world's monk seals are endangered or extinct, and the two surviving species are facing major declines in their populations. This presentation covers the aspects of reproduction that are needed when contemplating captive breeding. My research with Hawaiian monk seals is used as the model species.

The onset of puberty is of concern if young animals are to be used to initiate a captive breeding program. Body composition, endocrine changes and sociosexual behaviours are three aspects that can be monitored to determine whether or not animals are pubertal. Once animals are sexually mature, reproductive seasonality needs to be assessed. In female seals, this has been done using vaginal cytology, and endocrine monitoring. In male seals, ultrasound for testis size, endocrine monitoring and the evaluation of sperm production are useful techniques. Two aspects of the reproductive cycle of female seals are the length of the oestrus cycle and the duration of oestrus. These are perhaps the most important pieces of information for females in a breeding program. For the males, the methods of ejaculation and of cryopreservation are necessary to collect and store genetic information.

Once breeding has taken place, the management of seals can be facilitated by knowing the critical stages of gestation, and monitoring the body composition of the female seal. Research on the lactation cycle, milk composition, and postpartum oestrus, enables optimal management of seals during this phase. Working with surrogate species has the advantages of larger sample sizes and the ability of generating knowledge faster, however, if the species are not closely related, then these advantages may be minimised.

STATUS OF CAPTIVE BREEDING OF CETACEANS IN ZOOS, AQUARIA AND MARINE ZOOLOGICAL PARKS IN NORTH AMERICA

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These data were drawn from the Marine Mammal Census database for marine mammals on display in North America. This database was established in 1976, includes data on the inventories of all facilities maintaining marine mammals in the United States and Canada from their inception and has been periodically up-dated (Cornell and Asper, 1978; Cornell *et al.*, 1982; Asper *et al.*, 1988; Asper *et al.*, 1990; Duffield and Shell, 1998). As of 31st December 1996, there were 23 species of marine mammals being exhibited at 108 institutions. Of the total number (1,435) of marine mammals being maintained, 78.2% belonged to three species (*Zalophus californianus*, 525; *Tursiops truncatus*, 341; *Phoca vitulina*, 256). Ten species were represented by <50 individuals (12-46), ten species by <10 individuals. For a copy of the current inventory summary see Duffield and Shell (1998).

The emphasis of this presentation was on the status of captive breeding programs. The success of these programs was demonstrated by the change in composition of these managed populations from 1976 to 1996 (examples for pinniped and cetacean species are given in Table 1). For all species for which the numbers being maintained allow breeding, the proportion of individuals in these colonies which were captive-bred has significantly increased in this 20-year period. Many species have second and third generation offspring in their numbers.

The age distributions of the each of these species have continued to mature from 1976 to 1996, with more and more animals moving into the older age categories. The younger age categories are currently represented almost entirely by captive-born animals. The oldest *Tursiops truncatus* on display in 1996 was 43 yrs. old and captive-born; the oldest *Phoca vitulina* was 34 years of age and also captive-born; and the oldest *Zalophus californianus* was 34 years of age and wild-caught.

Captive reproduction has been a priority for the zoological community and has been especially successful with marine mammals. The availability of active breeding colonies for these species provides an immeasureably valuable resource for field biologists, where there is the need to investigate reproductive parameters not easily measured in the wild. Co-operative research opportunities exist and increased communication between the zoological community and the field biology is timely and strongly encouraged.

REFERENCES

Asper, E.D., Cornell, L.H., Duffield, D.A. and Dimeo-Ediger, N. 1988. Marine mammls in zoos, aquaria and marine zoological parks in the North America: 1983 census report. *Intl. Zoo Yb.*, 27: 287-294.

Asper, E.D., Duffield, D.A., Dimeo-Ediger, N. and Shell, D. 1990. Marine mammls in zoos, aquaria and marine zoological parks in the North America: 1990 census report. *Intl. Zoo Yb.*, 29:179-187.

Cornell, L.H. and Asper, E.D. 1978. A census of captive marine mammals in North America. *Intl. Zoo Yb.*, 18: 220-224.

Cornell, L.H., Asper, E.D. and Duffield, D.A. 1982. Census up-date: captive marine mammals in North America. *Intl. Zoo Yb.*, 22: 227-232.

Duffield, D.A. and Shell, E. D. 1998. 1996 Marine Mammal Census: Summary of Current Inventory. (Available on request from <duffieldd@pdx.edu>).

Table 1. Comparison of the composition of the North American captive populations, 1976 and 1996, for selected marine mammal species. Wc = wild-caught, cb = captive-born, st = stranded.

SPECIES	YEAR	n	% wc	% cb	% st
Pinnipeds					
Zalophus californianus	1976	456	87.3	2.9	9.8
Zalophus californianus	1996	525	19.0	68.8	12.2
Phoca vitulina	1976	205	39.5	3.9	56.6
Phoca vitulina	1996	256	8.6	58.2	33.2
Halichoerus grypus	1976	33	78.8	12.1	9.1
Halichoerus grypus	1996	35	25.8	57.1	17.1
Cetaceans					
Tursiops truncatus	1976	259	92.7	6.9	0.4
Tursiops truncatus	1996	341	52.2	46.3	1.5
Orcinus orca	1976	19	94.7		5.3
Orcinus orca	1996	31	48.4	51.6	
Cephalorhynshus commersonii	1976	8	100.0		
Cephalorhynshus commersonii	1996	12	25.0	75.0	
Delphinapterus leucus	1976	12	100.0		
Delphinapterus leucus	1996	34	82.4	17.6	

EXAMPLES OF CAPTIVE HYBRIDISATION AND A GENETIC POINT OF VIEW

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INTRODUCTION Marine mammals have been displayed in the United States throughout this century, but in sufficient numbers for a concentrated breeding emphasis within the past twenty years (see Duffield and Shell, this volume). Where there are multi-species exhibits, the opportunity for hybridisation exists. This presentation is not intended to be an exhaustive list of the pinniped and cetacean hybrids which have been reported to-date, but to serve as examples of the types of hybridisation which have been seen in captive breeding programs, with observations on the reproductive potential of these hybrids.

EXAMPLE 1: dam (*Callorhinus ursinus*) x sire (*Zalophus californianus*). This female was wild-born on San Miguel Island, California and was determined to be a northern fur seal: California sea lion hybrid by morphological, biochemical and chromosomal investigation (Jameyson *et al.*, 1981). She was resighted on San Miguel Island as a yearling and brought into captivity in order to evaluate her reproductive capabilities. She had a live-born, full term pup when bred back to a *Zalophus californianus* male. The pup appeared normal and healthy, but she did not rear this pup and it did not survive. She has not been bred again. The question of fertility, however, was answered - Northern fur seal: California sea lion hybrids are viable and fertile. Occasional "hybrid" pups have been subsequently been sighted on the California Island rookeries where fur seal and California sea lions both have breeding colonies.

EXAMPLE 2: dam (*Globicephala macrorhynchus*) x sire (*Tursiops truncatus*). Two hybrid offspring from crosses between these two species have been recorded (Marine Mammal Census Database, Duffield and Shell, 1998). In both cases, the dams were pilot whales and the sires, bottlenose dolphins. At least one of the offspring was live-born. Both appeared to be full-term and well developed. Neither survived past one day.

EXAMPLE 3: dam (*Tursiops truncatus* or *gilli*) x sire (*Pseudorca crassidens*). There have been at least 6 hybrid offspring to crosses between these two species. In all cases, the dams were bottlenose dolphins and the sires, false killer whales. One hybrid offspring, born at Kamogawa Seaworld in Japan (Nishiwaki and Tobayama, 1982), lived for over one year, dying of a respiratory infection. Another hybrid offspring is currently living and has had two calves from back-crosses to a bottlenose dolphin (Marine Mammal Census Database, Duffield and Shell, 1998). One of these second generation calves is also currently alive. Bottlenose dolphin:false killer whale crosses are, therefore, viable and fertile. Their offspring are viable and, in time, breeding will establish whether they are also fertile.

EXAMPLE 4: dam (*Tursiops truncatus*) x sire (*Delphinus delphis*). There are two hydrid offspring currently living from crosses between these two species. In both cases, the dams were bottlenose dolphins and the sire a common dolphin (Marine Mammal Census Database, Duffield and Shell, 1998). As these offspring mature they have the potential to demonstrate whether or not they are fertile.

It has now been amply demonstrated by captive breeding that hybridisation can occur between cetacean (and pinniped) species being maintained together and that the offspring can be viable and fertile. This is of significance for populations in the wild where there is proximity or interaction between different species at times of reproductive receptivity. There do not appear to be the typical genetic barriers to cross-fertilisation in these marine mammals - hybrids can be carried to term and are both viable and fertile. How much inter-species crossing actually goes on in the wild and whether this has any real impact on the genetic distinctness of species has yet to be determined. However, it is not inconceivable that some degree of exchange does occur, at least between some of these species, naturally.

REFERENCES

Duffield, D.A. and Shell, E.D. 1998. *Marine Mammal Census Database.* (For further information contact <duffieldd@pdx.edu>).

Jameyson, E. D., Duffield, D.A., Cornell, L.H., Antonellis, G. and DeLong, R.L. 1981. Discovery of a *Callorhinus ursinus* x ? hybrid within the San Miguel Island population. *Abstracts*, Fourth Biennial Conference on the Biology of Marine Mammals. San Francisco, CA.

Nishiwaki, M. and Tobayama,T. 1982. Report on the hydrid between Tursiops and Pseudorca. *Sci. Rep. Whales Res. Inst., Tokyo*, 34: 109-121.

OBSERVATIONS OF REPRODUCTION IN CAPTIVE BOTTLENOSE DOLPHIN, (*TURSIOPS TRUNCATUS*): DELIVERY, NURSING, MOTHER-CALF INTERACTIONS, SOCIAL DYNAMICS, AND CALF SURVIVAL/MORTALITY

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INTRODUCTION Most bottlenose dolphin (*Tursiops truncatus*) neonatal deaths in European dolphinaria occur within the first two weeks after birth (Amundin, 1994). The present, ongoing study aims at finding possible, observable precursors to these deaths. It is a part of the European Endangered Species Programme (EEP) for the bottlenose dolphin. This report presents preliminary findings and case histories.

MATERIALS AND METHODS The study was carried out at the KolmÂrden Dolphinarium, where pregnant dolphins are kept in a 900 m^2, irregularly shaped breeding pool, with a water depth of 3-6 m. It has a closed circuit water filtration system with chlorinated, artificial sea water. The endo-bacterial counts are kept at zero per 1,000 ml of pool water. The temperature is 19-20°C.

The behaviour observations were carried out through underwater acrylic panels, with video cameras and monitors allowing the observers to see all parts of the pool. Some of the observations were facilitated by means of air filled plexiglass cupolas mounted on the panels, providing a wide angle view.

The dolphins were observed continuously, 16 -24 hrs/day for up to 14 days post partum. The behaviour observations were entered on line into two PC's, using The Observer 2.0 and 3.0 behaviour study software (Noldus Information Technology). The position of the calf in relation to its mother, and the identity of other adults swimming with the mother-calf pair (within one body length and swimming in the same direction), were entered as instantaneous samples every 2.5 minutes. The time stamp of three consecutive surfacings in both mother and calf was entered every five minutes. In addition to this, the suckling duration and a number of behaviour in the mother that facilitated the calfís suckling attempts, were recorded *ad libitum*, as were the occurrence of a number of other behaviours in the calf, its mother and other adults.

A total of nine dolphin calves, born between November 1994 and October 1997, have so far been included in the study (Table 1):

RESULTS AND DISCUSSION In all but one case, the female stayed away from and/or was avoided by the other females during labour. But as soon as the calf was expelled, all other adults closed in tightly around the mother and calf. The whole group seemed to be very excited and curious about the calf. The mother tried to escape from their attention by swimming at fast speed and making evasive turns. On several occasions another female tried to steal the calf from the mother, and in some cases this caused fights, with the calf in the midst of this fight. One calf (5687) was taken by an allomother, the alfa-female in the herd, immediately after birth, without any visible protests from the biological mother. Calf 5683 was killed by another, late term pregnant female, although this was not in connection with the birth (Table 1).

When the first post partum turmoil had ceased after a couple of hours, the mother and calf pair kept away from the immediate vicinity of the other adults. This was normally achieved by means of subtle changes of swimming direction, breaking away from the other animals if they happened to come too close.

These observations indicate that dolphins may have a similar pattern to those seen in terrestrial social mammals, *e.g.* the lion *Panthera leo*, the wolf *Canis lupus*, the wild boar *Sus scrofa scrofa*, and several antelope and deer species. In these animals the female leaves the herd shortly prior to delivery, in order to give birth in privacy, and then keeps her neonates isolated for several days to several weeks (Estes, 1991; Jensen, 1986; MacDonald and Barret, 1993). This allows an undisturbed bonding between her and her young, and also the undisturbed transfer of the necessary amount of colostrum. The case with the allomother (calf no 5687; see Fripp *et al.*, 1998; and below) shows that a calfís bonds may be transferred from one adult to another at least within a period of two weeks. The adult was responsible for maintaining the proximity with the calf, indicating that privacy might facilitate the bonding process.

Immediately after birth, all mothers placed their calves in the so called echelon position, i.e. along the mother's back, besides her dorsal fin, and kept it there all the time. There was no preferred side, nor did the females systematically place themselves between their calves and the pool walls. All but one female preferred to stay in the 6 m deep section of the pool.

It was not possible to distinguish between successful and unsuccessful suckles. Therefore only the total number of suckling attempts are considered here. In clear cases, when the calf was "hooked on the nipple", this was revealed by a typical tail beat pattern in the calf, but it was not possible to always see if the calf actually received any milk. The average duration of the calf being "hooked on the nipple" was around five seconds. The total number of suckling attempts in the first 24 hours was 15-20 per hour. On day 3-6 it usually had dropped to below 5 per hour. The distribution of suckles over time was even around the clock, with a tendency for increasing pauses in between bouts of several suckling attempts in a row.

An increased frequency of nursing during the first couple of days after birth indicates that the calf did not get enough milk at each suckling. If the increased frequency did not compensate for this, too little colostrum would be transferred. This should then be reflected in a low level of immuno-globulins in the calf's serum, leaving it more vulnerable to infections. However, in the cases where a γ-globulin value could be obtained, the correlation between this value, the frequency of total suckling attempts, and the calfs' survival was not clear (Table 1).

Calf 5687 did not receive any colostrum from his mother, since the alfa-female took possession of him right after birth (see Fripp et al., 1998). This female had given her colostrum to her own calf (5684) two weeks before, a calf that died 5 days prior to the birth of calf 5687. As a consequence the γ-globulin level in the blood of calf 5687 was only 2 g/l (Table 1). This would leave him more vulnerable to infections.

Calf 5687 was captured on day 5, after having shown signs of deteriorating health. He was transferred to and kept isolated in a small pool for 24 hours, and was treated with a total of 350 ml of serum from his father, injected peritoneally. In this way the immunoglobulins from the father could enter the blood of the calf. The calf was also given two i.m. injections of trimethoprim sulphur (Borgal® vet, Hoechst Roussel Vet, 240 mg/ml). Every two hours he was tube fed a milk formula (ref. F. Townsend, Bayside Hospital for Animals, Florida), resulting in him gaining 800 grams during the treatment. When returned to the breeding pool, he was first attended by the allomother. However, after nine hours she suddenly appeared to loose interest in him, whereupon the biological mother was re-introduced. The calf was then nursed by both females, but by two weeks after the birth the allomother's contributions were completely phased out.

A total of 576-864 surfacings per day and mother/calf pair were recorded. The average breathing interval was 18-33 secs during week one. It appeared that the mother was mainly responsible for setting this interval, but the calf also appeared to be able to initiate a surfacing by means of subtle body signals, *e.g.* small upward jerks with the head.

Usually the calf surfaced within seconds of the mother. However, with increasing play and other activities within the first two weeks, the calf more and more often surfaced alone or made double breaths within the same surfacing. According to a preliminary analysis there was no clear correlation between an increased number of separate surfacings or double breaths and the survival of the calf. It was thus not possible to distinguish an increased breathing frequency due to *e.g.* a possible lung disorder from that caused by increased activity.

Due to a suspected lung problem, calf 6232 was treated on day 9 and 10 post partum with 2 ml enrofloxacin (Baytril® vet, Bayer, 100 mg/ml), injected i.m. in the back muscles lateral to the dorsal fin. The injections were given by means of a blow pipe dart projected from 3-4 m distance by means of a Dan Inject CO_2 dart pistol. The dart was attached to a thin nylon fishing line, allowing it to be retrieved after the drug was injected. The calf did not react significantly to being hit by the dart.

CONCLUSIONS So far, these preliminary analyses have not allowed us to identify any specific parameters which could be used in the diagnosis of potentially lethal problems in the neonates. The analyses are continuing, and hopefully will resolve this. However, the aggression seen in connection with the births, and the persistent efforts of the females with neonates to avoid close contact with their tank mates, indicate that it may be preferrable to allow females to deliver in privacy and to be separated at least for the first couple of days post partum.

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REFERENCES

Amundin, M. 1994. Monitoring survey of the human-attended bottlenose dolphin population in Europe. Oral presentation at the 11th European Endangered Species Programme Conference in Alphen a/d Rijn, Holland, June 15-17, 1994.

Estes, R.D. 1991. *Behavior Guide to African Mammals.* University of California Press, London. 611pp.

Fripp, D.M.R., Tyack, P.L. and. Amundin, M. 1998. A case of prolonged alloparenting helps define relationships between adult and infant captive bottlenose dolphins, *Tursiops truncatus.* Poster presentation at the World Marine Mammal Science Conference, Monaco, January 20-24, 1998.

Jensen, P. 1986. Observations on the maternal behaviour of free-ranging domestic pigs. *Appl. Anim. Beh. Sci.*, 17:69-76.

MacDonald, D. and Barret, P. 1993. *Mammals of Britain and Europe.* Collins Field Guide. Harper Collins Publishers, London. 312pp.

Table 1 Data on calf birth and survival

Calf ID no	Sex	Birth date	Surviving days	γ-globul. level 1)	Suckling rate	Mother experience (2)	Social setting 3)
5685	F	01.11.94	alive		n	Multiparous (1)	3 females
5683	M	25.04.95	6 4)	4 g/l	n	Multiparous (1)	4 females
5684	M	22.05.95	8		n	Multiparous (4)	3 females
5686	M	29.05.95	9	7 g/l	i	Primiparous	3 females
5687	M	04.06.95	alive	2 g/l	n 5)	Multi-/primiparous	2 females
5993	M	14.02.96	7	3 g/l	i	Multiparous (1)	1 female
6232	M	11.09.96	alive		n	Multiparous (1)	1 female
6233	F	06.10.96	alive		n	Multiparous (5)	2 females
6549	M	27.10.97	13	5 g/l	n	Multiparous (2)	2 females

n=normal suckling rate; i= increased suckling rate. 1) post mortem in serum, except in 5687. The normal (-globulin level in our adults is 7-13 g/l; 2) number of calves delivered before the present one; 3) number of females in the pool, including the mother; 4) killed by another female; 5) a multiparous allomother at first

ELEVENTH ANNUAL REPORT OF THE EUROPEAN CETACEAN SOCIETY: 1997

Paid-up members of the European Cetacean Society for the year 1997 numbered 362 plus 3 institutional members, from 25 European and 5 non-European countries. The highest representation came from Germany (119), Italy (50), United Kingdom (48), France (19), Spain (16) the Netherlands (15), Denmark (14) Portugal (11), the United States (11) and Switzerland (11). Other member countries include Austria, Belgium, Croatia, Finland, Greece, Hungary, Iceland, Ireland, Israel, Monaco, Poland, Sweden, the Czech Republic, Turkey and Ukraine within Europe, and Algeria, Australia, Canada, Japan, and South Africa elsewhere.

The conference held in Stralsund between March 10th and 12th on the theme "Behavioural Aspects of Cetacean Bycatch" was very successful, with 250 participants from 27 different nations. Five invited speakers addressed the society: Scott Kraus and Andy Read from the United States, Steve Dawson from New Zealand, and David Goodson and Jonathan Gordon from UK. The Society is very grateful to Harald Benke, the staff of the Stralsund Museum particularly Gerhard Schulze and Ines Westphal, and the team from the University of Kiel headed by Roland Lick and Ursula Siebert, for organising this enjoyable conference.

Three newsletters were produced during the year, reviewing recent research and news items in Europe and elsewhere in the world, conservation issues, cetacean meetings and publications, and Society business. The organisers of the Stralsund conference also made it possible to print the Proceedings of Lugano (1995) and Lisbon (1996), which were distributed to the membership. The editor, Peter Evans, would like to thank also Chris Parsons and Sarah Clark for their invaluable help in typing and editing, Costanze Blödner for the help in the final production, and Roland Lick for organising the printing of the Stralsund Proceedings.

The Membership list of the Society has found a new home at the German Museum for Marine Research and Fishery in Stralsund, which is also taking care of the mailing of material from the Society. We are very grateful to its director Harald Benke, and to Mrs. Wesphal who is now in charge of these tasks.

The organisation of the Conference in Monaco held between January 20th and 24th, 1998, continued under the supervision of Anne Collet, in collaboration with the Society for Marine Mammalogy (SMM). Registration material was sent to the members and posted on the respective web pages.

Finally, the European Cetacean Society has continued to provide advice to government departments and non-governmental organisations in European countries, and specialist information for various public enquiries, with representation at both ASCOBANS and ACCOBAMS.

Beatrice Jann
(Hon. Secretary)

FINANCIAL REPORT FOR THE YEAR UP TO 15 JAN 1998

	DM	£
Balance as of 7 March 1997	**1,809.44**	**1,558.98**

Income	**German account DM**	**British account £**
ECS account savings from 1996	**1,809.44**	**1,558.98**
Membership fee for 1997 (Conference in Lisbon)	6,235.00	
Membership fee during the year 1997	11,963.35	
Profit Conference in Stralsund	25,813.87	
Other payments to the German account	513.00	
Interest on Savings account		18.40
Total Income	**46,334.66**	**1,577.38**

Expenses	**German account DM**	**British account £**
Travel expenses: board meetings Stralsund 1996 & Monaco 1997	3,480.84	205.00
ECS-Newsletters (printing)	1,119.49	
ECS Proceedings Stralsund (typing and production)		200.00
Editorial expenses (duplication, postage, faxes, etc)		150.00
Secretarial expenses (Address List)	628.00	
Postage (Newsletters, Proceedings, Student Award, etc)	5,439.02	57.16
Bank account expenses	356.16	
Computer Support Group (Internet costs, 1996)	501.21	
E-mail subscription		150.00
Total Expenditure	**11,524.72**	**762.16**

DM **Balance as of 24 October 1997** **Total 36,644**	**DM**	**£**
	34,809.94	**815.22**

ROLAND LICK
(Hon. Treasurer)

EUROPEAN CETACEAN SOCIETY - 1998

The **European Cetacean Society** was formed in January 1987 at a meeting of eighty cetologists from ten European countries. A need was felt for a society that brought together people from European countries studying cetaceans in the wild, allowing collaborative projects with international funding.

AIMS (1) to promote and co-ordinate the scientific study and conservation of cetaceans;
(2) to gather and disseminate information to members of the society and the general public.

ACTIVITIES The Society set up seven international working groups concerned with the following subject areas: sightings schemes; strandings schemes; cetacean pathology; bycatches of cetaceans in fishing gear; computer data bases that are compatible between countries; the harbour porpoise (a species in apparent decline in Europe, and at present causing serious concern); and a regional agreement for the protection of small cetaceans in Europe (in co-operation with the United Nations Environment Program/Convention on the Conservation of Migratory Species of Wild Animals, Secretariat in Bonn, Germany). Some of these have been disbanded now, having served their purpose, and other groups (such as one covering the Mediterranean Sea) have been established. The names and addresses of contact persons for all working groups are given at the end.

Contact persons have been set up in each European member country, where appropriate, to facilitate the dissemination of ECS material to members, sometimes carrying out translations into the language of that country. Their names & addresses are given below.

A newsletter is produced three times a year for members, reporting current research in Europe, recent publications & abstracts, reports of working groups, conservation issues, legislation & regional agreements, local news, and cetacean news from around the world.

There is an annual conference with talks and posters, and at which the annual general meeting is held. The results are published as annual proceedings, under the title *European Research on Cetaceans*. Besides the present volume, ten others have been published for conferences held in Hirtshals (Denmark) in 1987, Tróia (Portugal) in 1988, La Rochelle (France) in 1989, Palma de Mallorca (Spain) in 1990, Sandefjord (Norway) in 1991; San Remo (Italy) in 1992, Inverness (Scotland) in 1993, Montpellier (France) in 1994; Lugano (Switzerland) in 1995, Lisbon (Portugal) in 1996, and Stralsund (Germany) in 1997. In January 1998, the ECS joined with the Society of Marine Mammalogy (SMM) to hold the first World Marine Mammal Science Conference, held in Monaco.

At intervals, workshops are held on particular topics, and the results published as special issues of the newsletter: no. 6 - a workshop on the harbour porpoise, held in Cambridge (England), 1988; no. 10 - a sightings workshop held in Palma de Mallorca (Spain), 1990; no. 17 - a workshop to standardise techniques used in pathology of cetaceans held in Leiden (Netherlands), 1991; no. 23 - a workshop to review methods for the field study of bottlenose dolphins held in Montpellier (France), 1994; and no. 26 - a workshop for the diagnosis of by-catches in cetaceans held in Lugano (Switzerland), 1995.

Membership is open to *anyone* with an interest in cetaceans. The annual subscription is **DM 60** for full and institutional members, or **DM 35** for those who are 25 years of age or younger, full-time students or unwaged. Payment may be made at the Annual Conference in German Marks or the currency of the host country. During the year, payment must be in German Marks by **Eurocheque** or any other cheque drawn to a German bank, payable to the *European Cetacean Society* (you are advised not to send cash). Send cheques together with membership details to:

European Cetacean Society, Mrs Ines Westphal, Deutsches Museum für Meereskunde und Fischerei, Katharinenberg 14-20, D-18439 Stralsund, Germany.

Membership fees can also be paid by **credit card** or **transferred directly** to the following ECS-account: Dr Roland Lick, Treasurer, ECS, Postbank Hamburg (FRG), Account No. 789584-205, Bank Code 200 100 20 (giving your name and calendar year for membership fee.) Payment in excess of the membership fee will be gratefully received as a donation to the Society.

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Please use the format given below. If you depart substantially from this, your contribution may be rejected.

(1) Keep the text, references, and figures/tables to a total of no more than five pages (single-spaced). For those to whom English is not their native language, please ask an English speaker to check the entire text.

(2) Prepare all tables and figures in their final form (in black and white NOT colour), and provide the originals for camera-ready printing. Number every table and figure for cross-reference to the text. Place tables, then figures, in chronological order, and on separate pages to the text. DO NOT INCLUDE THEM WITHIN THE MAIN BODY OF THE TEXT. Figure captions should be placed underneath each one and Table captions above, with Fig. 1, Table 1, etc. in bold type, lower case, and the caption itself in ordinary type, lower case and centred. Use Times font throughout.

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Stewart, B. S. and Leatherwood, S. 1985. Minke whale *Balaenoptera acutorostrata* Lacépède, 1804. Pp. 91-136. In *Handbook of marine mammals*, vol. 3. (Eds. S. H. Ridgway and R. J. Harrison). Academic Press, London. 430pp.

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