PROCEEDINGS OF THE ECS WORKSHOP

BEAKED WHALES AND ACTIVE SONAR: TRANSITIONING FROM RESEARCH TO MITIGATION

Held at the
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1. INTRODUCTION

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The European Cetacean Society (ECS) workshop on Active Sonar and Cetaceans (Evans and Miller 2005) helped to document the association between atypical mass strandings of beaked whales and naval sonar exercises. The exact mechanism by which sonar leads to the death of beaked whales remains unknown, but since the 2004 workshop there has been considerable progress on scientific knowledge on beaked whales and in mitigation techniques, including acoustic and visual detection, distribution mapping and modelling, discussed at a further ECS workshop on Beaked Whale Research (Dolman *et al.*, 2007). Ongoing research is mainly focused on the responses of individual beaked whales to naval active sonar, while a clear protocol on how to use these results for designing mitigation guidelines is currently lacking. Therefore an urgent requirement remains to design an effective monitoring and mitigation protocol to reduce the risks of intense sound sources damaging beaked whales.

This workshop provided a background to the current field research investigating mitigation techniques, as well as a legal and official perspective about the feasibility of promoting a standardised mitigation protocol. In addition to researchers, the workshop included representatives from international forums dealing with marine management and conservation, and those using sonar, such as ACCOBAMS, ASCOBANS, OSPAR, NGOs, NATO, etc, to participate in an open table dialogue with opportunity for questions and discussion.

As a result of the workshop, an ECS Resolution on the need to regulate sonar mitigation was adopted at the Conference (this issue). A subsequent Technical Report on effective mitigation for active sonar and beaked whales was presented to ASCOBANS (this issue).

The workshop was convened on Sunday 1st March 2009 in Istanbul, Turkey, in association with the 23rd Annual Conference of the European Cetacean Society. The workshop ran from 10 am to 4.30 pm. It consisted of thirteen invited talks and submitted presentations, with time for questions and some discussion. Over 70 people attended.

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Evans, P.G.H. and Miller, L. (Eds.) 2004. *Active sonar and cetaceans*. Proceedings of workshop held at the ECS 17th Annual Conference, Las Palmas, Gran Canaria, 8th March 2003. European Cetacean Society, Kiel, Germany. 84pp.

2. ECS RESOLUTION ON THE NEED TO REGULATE SONAR MITIGATION

Adopted at ECS Annual General Meeting (AGM) in Istanbul, Turkey on 4th March 2009

There is sufficient evidence that active sonar exposure even at relatively low levels can have significant impacts on some cetacean species.

Beaked whales in particular are vulnerable to serious impacts including mortality from exposure to mid-frequency active sonar (1-10 kHz). Here we reaffirm the ECS 2003 Statement of Concern on Marine Mammals and Sound.

The development of knowledge since this ECS 2003 resolution was adopted underscores the need for urgent action on sonar mitigation. Current mitigation efforts are generally untested and insufficient for beaked whales. Recently available data includes further evidence on the causal link between sonar and beaked whale mass-strandings. This includes spatio-temporal coincidence between naval exercises and mortalities and a consistent pathology on necropsied whales, pointing to an acoustic source as primary cause of death/stranding. In addition, abundance estimations of local populations of beaked whales indicate that populations are small and that the reproductive rate of some beaked whales may be low. Small, sometimes isolated, populations with reduced recruitment rate are vulnerable to human impacts as they may have a limited capability to recover after trauma.

This means that there is the potential for unsustainable impacts on beaked whales to occur in relatively short time periods. The advances in our understanding of behavioural reactions of beaked whales to sonar indicate that required mitigation ranges are larger than practical mitigation ranges in many cases.

In consequence, regulation of standardised mitigation protocols, including practical measures recently available, becomes a priority. Mitigation should be applied by all countries using military sonar in the three stages of sonar exercises: before (the planning phase), during and after sonar use. As sonar may have transboundary effects, mitigation procedures need regulatory support at both international and national levels.

Thus, the European Cetacean Society requests competent authorities to urgently adopt and enforce regulations for effective mitigation.

3. TECHNICAL REPORT ON EFFECTIVE MITIGATION FOR ACTIVE SONAR AND BEAKED WHALES

Presented to ASCOBANS Scientific Committee, March 2009

Working Group: Sarah Dolman, Natacha Aguilar de Soto, Giuseppe Notarbartolo di Sciara, Michel Andre, Peter Evans, Heidrun Frisch, Alexandre Gannier, Jonathan Gordon, Michael Jasny, Mark Johnson, Irini Papanicolopulu, Simone Panigada, Peter Tyack, Andrew Wright

THE NEED FOR EFFECTIVE MITIGATION AND REGULATION OF SONAR

There is evidence that active sonar exposure can have significant impacts on some cetacean species at relatively low levels (Evans and England, 2001; Evans and Miller, 2004). Beaked whales in particular are vulnerable to serious impacts including mortality from exposure to mid-frequency active sonar (1-10 kHz) (Jepson *et al.*, 2003; Fernández *et al.*, 2004, 2005, 2006; Jaber *et al.*, 2005; Cox *et al.*, 2006; Fernández, 2006). This year, the ECS reaffirmed its 2003 Statement of Concern on Marine Mammals and Noise, noting further that the development of scientific knowledge since 2003 underscores the need for taking urgent action on sonar mitigation. Current mitigation efforts are generally untested and insufficient for beaked whales.[1]

Continuing evidence on the causal link between sonar and beaked whale mass strandings includes spatio-temporal association between naval exercises and mortalities and consistent symptoms on necropsied whales pointing to an acoustic source as the most likely primary cause of death/stranding (Evans and England, 2001; Jepson *et al.*, 2003; Fernández *et al.*, 2004, 2005; Jaber *et al.*, 2005; Fernández, 2006). In addition, abundance estimates of local populations of beaked whales all indicate that populations are small (Aparicio *et al.*, 2009; Baird *et al.*, 2009; Marques *et al.*, 2009) and that the reproductive rates of some beaked whales may be low (Aguilar Soto, 2009; Aparicio *et al.*, 2009). Small, sometimes genetically isolated populations (Dalebout *et al.*, 2005) with reduced recruitment rates are particularly vulnerable to human impacts as they may have a limited capability to recover after trauma. This means that there is the potential for unsustainable losses of beaked whales to occur within relatively short time periods. The advances in our understanding of behavioural reactions of beaked whales to sonar (Moretti *et al.*, 2008; Tyack, 2009), in particular indicate that the ranges required for successful mitigation are in many cases going to be larger than feasible with current practices. This is compounded by the growing realisation of the potential for cumulative impacts arising from multiple exposures to sonar and/or in conjunction with other threats (e.g. Wright *et al.*, 2007a, b; Wright, 2009). The adoption of effective mitigation protocols, based on standardised guidelines and including technical measures only recently developed (Andre *et al.* this volume; Gordon and Gillespie this volume; Johnson and Aguilar Soto this volume), is therefore a priority.

Mitigation should be applied by all countries using military sonar in the three stages of sonar exercises: before (in the exercise planning phase), during, and after (i.e. reporting on effectiveness and adapting mitigation for future exercises) sonar use. Since sonar may have

[1] While this workshop focused on the particular impacts of active sonar on beaked whales, we recognise that impacts from other sources, and on other marine species, may be significant and require appropriate mitigation.

transboundary effects (Fernández *et al.*, 2006), mitigation procedures need support at both international and national levels.

THE IMPORTANCE OF MITIGATION IN EXERCISE PLANNING

Current real-time mitigation efforts, whilst better than none at all, are either untested or known to be of extremely limited effectiveness, particularly for beaked whales. For example, the ship-board visual monitoring currently conducted by naval vessels during sonar exercises is considered to have vanishingly low probabilities of beaked whale detection, even in optimal sighting conditions (Barlow and Gisiner, 2006). This applies even with the most experienced observers and most suitable platforms, simply because beaked whales spend so much time below the surface and are almost impossible to spot except in calm conditions. Effective mitigation at the planning stage is therefore essential. Of these measures, a properly implemented system of spatio-temporal avoidance is, at present, the most effective way to reduce the impacts of active sonar on beaked whales and many other species (Agardy *et al.*, 2007; Dolman, 2007; Parsons *et al.*, 2008). Recent regional developments in real-time detection and habitat modelling for beaked whale have improved our ability to identify important habitat (Cañadas *et al.*, 2005; Kaschner *et al.*, 2007; Zimmer *et al.*, 2008; Andre *et al.*, 2009; Gordon and Gillespie, this volume; Johnson and Aguilar Soto, this volume). However, these models are often based on a limited dataset of the distribution of beaked whales. Models need to be considered with care to avoid interpreting lack of data as lack of beaked whale presence in little studied areas, and there is an important need to conduct detailed studies in a range of habitats and locations before extrapolating too readily from simple models.

Navies using active sonar should commit without delay to the following minimum procedures in exercise planning to reduce uncertainty to an acceptable level:

1) Navies should use field surveys and modelling to determine areas with low densities of animals, and without other risk factors (such as the presence of small resident populations), where exercises might be more suitably placed, as well as identifying ‘hot spots,’ where exercises should be avoided year-round or seasonally. Boundaries of such ‘hotspots’ should be regularly verified and adapted as necessary. The location of exercises needs to be planned allowing time to collect necessary information on absolute abundance and density of beaked whales and other populations in the area. It needs to be recognised that vast unsurveyed areas far from shore may be suitable beaked whale habitat (Barlow *et al.*, 2006; Gannier, 2009). Within areas under consideration for sonar exercises, scientists and government authorities should collaborate on the following research and analysis:

- a) ongoing collection of field survey data on the habitat use, abundance, distribution and density estimates of marine mammals in the area, including beaked whales, as well as on other biological and oceanographic variables. This includes a review of previous scientific knowledge and adequate new data gathered in any areas under consideration for siting exercises;
- b) use of these data in a modelling context to make predictions of current marine mammal densities. Uncertainties in the detection function, environmental and correction factors for species with low detection availability (acoustic and visual), such as beaked whales, need to be incorporated into the models;
- c) use of these data in tandem with models of acoustic exposure, bearing in mind the effects of certain oceanographic conditions (including the probability of surface-

ducting conditions) on sound propagation, to make informed estimates of the numbers of impacts associated with each potential location and mode of operation. At the same time, the data should be used to identify risk factors other than density, such as the presence of small resident populations, that may be associated with certain locations; and

d) collecting additional field data and confirming conditions for sound propagation closer to the time of operations, for purposes of model verification and adaptive management.

2) Navies should identify a limited number of locations to which such exercises can be confined, with suitable monitoring, including passive acoustic monitoring (PAM) and mitigation measures in place. Until such time as reliable extensive surveys and models are available for a given region, navies should avoid important oceanographic features, such as canyons, steep walls, and seamounts, persistent upwellings, and bays, as well as Marine Protected Areas (MPAs), such as those created under EU Natura 2000 and the SPAMI protocol, and known high biodiversity or biologically relevant habitat.[2]

3) Navies should widely implement (and further develop) PAM, as an effective tool for identifying low-density areas in exercise planning and for real time monitoring of exercise areas. This acknowledges that whilst beaked whales are detectable for only 8% of the time when they are theoretically 'visible' at the surface – assuming suitable environmental conditions (where the encounter rate of beaked whales decreases by more than an order of magnitude as survey conditions deteriorate from Beaufort 1 sea state to sea state 5) and appropriate level of observation (Barlow *et al.*, 2001; Barlow and Gisiner, 2006) – they are vocally active for some 25% of the time when they are foraging at depth (Aguilar Soto, 2006). For towed hydrophones consideration should be given to the fact that acoustic detection range is only c. 1 to 5 km, depending on ambient noise and whale orientation with respect to the receiver (Zimmer *et al.*, 2008). Thus, passive acoustic surveys have to account for the limited proportion of time – typically less than 25% – during which beaked whales are potentially audible with suitable equipment. Protocols for use of PAM detectors, including required actions when species are detected and how to deal with false alarms in different ambient noise environments (Johnson and Aguilar Soto, this volume), should be specified.

4) Navies should identify avoidance areas or environmentally preferred exercise sites within a transparent process that affords opportunity for public participation, as, for example, through an independently conducted Environmental Impact Assessment or Strategic Environmental Assessment framework.

5) Avoidance restrictions should apply to all types of exercises, including both strike-group level exercises, which involve multiple sonar arrays, and unit-level exercises, which involve single platforms; and should be defined in clear, unambiguous terms.

This strategic mitigation process, during the exercise's planning phase, will enable governments to make informed, transparent decisions about the comparative risks of exposure and determine the best locations for siting exercises. In general, during joint exercises between two or more navies, the more stringent mitigation measures should apply, even if these are not those of the host nation.

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[2] To avoid potentially damaging ensonification within MPA borders, we recommend avoiding operating within an appropriate distance of MPA boundaries.

TOWARDS EFFECTIVE REAL-TIME MITIGATION

Standards should be developed that define an appropriate level of cetacean monitoring, depending on the species. To improve the effectiveness of real-time mitigation, such measures must reflect the challenges involved in detecting some of the most sonar-sensitive species, particularly beaked whales, as noted above.

In addition to a recent comparative review of current measures (Dolman *et al.*, 2009), we recommend that navies adopt the following measures for real-time mitigation:

1) Effective detection of cetaceans present in the exercise area:

- Monitoring with an appropriately designed array of visual and passive acoustic sensors in the exercise area during operation. Where available, on-range hydrophone networks should be utilised for real-time mitigation: otherwise, temporary hydrophone arrays of adequate size and sensitivity to reliably detect beaked whales should be used;
- Acoustic monitoring using transparent protocols for detection and classification of cetacean vocalisations. For beaked whales, on-range hydrophone networks and networks of temporary hydrophone arrays (including gliders, drifters, vessel based and bottom mounted platforms) are potentially useful methods upon which efforts should continue to be focused (Andre *et al.*, 2009; Johnson and Aguilar Soto, this volume);
- Pre-sonar watch of a predetermined period (at least 2 hours for beaked whale detection) in which to provide the best chance to detect all available cetaceans visually (on board and where possible from aerial surveys) and acoustically;
- Use of dedicated and experienced and, where possible, independent marine mammal observers, trained to a minimum standard on visual and acoustic detection of beaked whales; and
- Assuming visual monitoring is maintained for the protection of other species, restriction of operation, to the greatest extent possible, to observable visual conditions, such as during good light (during the daytime) and appropriate environmental conditions (including a sea state <3). Such restrictions should be prescribed for some types of sonar use (e.g. brief tracking exercises and sonar research, development and evaluation) even if they are not easily applicable to others (e.g. multi-day free play exercises).

2) Mitigation requirements once cetaceans are detected:

- Sonar power reduction and shut-down within conservatively defined radii to the greatest extent practicable around the sonar array, based on models of sound transmission (verified in local conditions) and of effects of sonar on sensitive species. For beaked whales (and likely for other species and situations), a conservatively defined radius would extend to the isopleth where the risk of significant behavioural effects becomes more than negligible (acknowledging that this might be beyond the radius of visibility in some cases); and,
- Suspension or relocation of activities where detections of potentially affected species are higher than predicted in pre-exercise planning. Suspension, relocation, or other restrictions are also warranted where detections of potentially affected species are

higher than predicted in pre-exercise planning, or where unexpected oceanographic conditions such as surface-ducting would result in higher numbers of impacts than predicted.[3]

In short, as existing measures have very poor detection rates for beaked whales, measures that stand a greater chance of success for both detection and mitigation need to be identified.

TOWARDS EFFECTIVE POST-EXERCISE MONITORING

To improve the effectiveness of future mitigation efforts while also producing less disruption of operational activities, we recommend the following:

1) Post-exercise monitoring should include visual and acoustic cetacean surveys in the exercise area to compare with pre-exercise densities;
2) Transparent reporting to national authorities should occur within a predetermined time-frame, so that effectiveness and compliance to guidance can be monitored and appropriate adaptive management can be applied. The probability of detection at different ranges and the probability of false alarm should be considered and reported both for visual and acoustic monitoring. Other information provided should include visual sea conditions, experience and number of observers and type of binoculars or other visual aids used; background noise levels and number/spacing of hydrophones for acoustic monitoring; and types of detectors for classifying cetacean vocalisations; and, cetacean observations during post-exercise monitoring. It is also important that navies develop protocols for providing information on the tracks of vessels and specific areas of operations, which are necessary for a meaningful evaluation of effort relative to sighting rates; and,
3) Ongoing monitoring of populations (including of identified individuals), especially in areas of repeat exercises.

GLOBAL IMPLEMENTATION OF EFFECTIVE MITIGATION FOR SONAR

Recognising that sonar is used in all maritime areas, that many cetacean species are migratory or have large ranges, and that sonar pulses can propagate across boundaries (including those of protected areas),[4] countries have a responsibility to limit the impacts of their active sonar systems regardless of their location (including on the high seas) and preventing impact on fauna inhabiting waters of neighbouring countries. To this end:

- We are convinced that States must adopt and implement, via legal regulations, the measures indicated above as a matter of urgency;
- We welcome the work already done by international bodies such as CMS, ACCOBAMS, ASCOBANS, OSPAR and the European Community towards the adoption of mitigation measures, assure them of the support of the European scientific community, and encourage them to continue pursuing the issue;
- We believe that this issue must also be addressed by all relevant bodies engaged in the protection of the marine environment;

[3] In regions where certain broad, dynamic conditions (such as surface-ducting) are unavoidable through planning, navies should adopt other mitigation (such as power-downs) to the greatest extent possible.
[4] For example, exercises in international waters in 2004 resulted in stranding of beaked whales in two countries (Spain and Morocco) (Fernández *et al.*, 2006).

- We believe that there remains a need for international bodies to compile information on the mitigation protocols used by navies, including information on areas excluded from sonar use, and to make such information publicly available; and, to this end,
- We request all navies to publish their current active sonar mitigation programs and to inform the public on their ongoing effort to test and to improve their effectiveness.

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4. MASS STRANDINGS AS FOCAL EVENTS FOR UNDERWATER NOISE REGULATION, CHALLENGES AND NEED OF SONAR MITIGATION FOR BEAKED WHALES

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Mass strandings as focal events

Focusing events have been described as key events that influence the policy making process, catalyzing the transitioning of a conservation problem from "event status" to "agenda status" (McCarthy, 2004). This means that a conservation problem becomes noticed when events attract enough attention for it to be integrated into the priority lists of regulating bodies. In the best scenario, this results in the development of legal measures that prevent or reduce further impacts. The process by which one or a series of discrete environmental impacts become a focusing event is reviewed by McCarthy (*op. cit.*). To become a focusing event, an impact needs to be clearly identified, acknowledged by the public and interested parties, and prioritized in the scientific and political agenda. Mass strandings of beaked whales in coincidence with naval exercises fulfil, at least partly, all these requirements:

<u>Identification</u>

Beaked whales are the most common species in mortalities related to naval exercises and, in contrast with other cetacean species, beaked whales do not tend to strand collectively (> 2 whales together) under natural circumstances[5]. Since the first recorded atypical stranding of beaked whales in the sixties (Tortonese, 1963), coinciding with the onset of widespread use of sonar, evidence continues to accumulate for a causal link between naval exercises using high intensity sound sources such as sonar, and beaked whale mass strandings involving from two to more than twenty whales. This evidence includes contextual spatio-temporal association between naval exercises and mortalities, and consistent lesions on necropsied whales pointing to an acoustic source as the most conservative primary cause of death/stranding (Simmonds and Lopez Jurado, 1991; Frantzis, 1998; Balcom and Claridge, 2001; Evans and England, 2001; Martin *et al.*, 2004; Jepson *et al.*, 2003; Fernández *et al.*, 2005; Jaber *et al.*, 2005; Yang *et al.*, 2008). A focusing event needs to reach the public to be decisive. Mass strandings and other potential impacts of sonar on beaked whales have received much attention from the media, including news items in scientific journals, e.g. Nature[6] or Science[7], and in the lay media [e.g.8,9,10,11]. The issue has been taken up by several conservation NGOs groups and their activities in building awareness of the issue have also received considerable media attention (e.g. NRDC court cases[12,13], demonstration after a mass stranding in Canary islands[14], etc).

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[5] http://www.acousticecology.org/docs/IWC56-hildebrandnoise.doc
[6] http://www.nature.com/news/2008/080801/full/news.2008.997.html
[7] http://sciencenow.sciencemag.org/cgi/content/citation/2007/1214/2
[8] http://news.bbc.co.uk/2/hi/science/nature/3173942.stm
[9] http://www.independent.co.uk/environment/nature/navy-sonar-blamed-for-death-of-beaked-whales-found-washed-up-in-the-hebrides-805399.html
[10] http://www.zifios.com/noticias-internet/noticias-cetaceos-grandes/1-CNN-noticias.gif
[11] http://news.nationalgeographic.com/news/2003/10/1008_031008_whalebends.html
[12] http://www.nrdc.org/media/pressreleases/030826.asp

Acknowledgement:

For a conservation problem to be recognized, it needs to both be accepted by the relevant scientific community and taken up by governmental and non-governmental entities. Scientific bodies such as the European Cetacean Society[15] and the scientific committee of the International Whaling Commission (e.g. Brownell *et al.*, 2004; Hildebrand, 2004[1]; Dolman *et al.*, 2008) have produced reports and resolutions asserting the relation between naval sonar and mortalities of beaked whales. Many NGOs dedicated to nature conservation have expressed their concern on the impact of naval activities on cetacean (e.g. NRDC, WDCS, IFAW, Greenpeace, Ecologistas en Acción, Oceana, etc). Within governmental bodies, an acknowledgement that naval exercises may have an impact on marine fauna is evident in the Resolution on Active Sonar of the European Parliament (B6#8209;0089/2004), asking the Parties for the adoption of a moratoria and restrictive measures in the use of active sonar in naval exercises and to develop alternative technologies. The apparent particular vulnerability of beaked whales to sonar is recognized by the US Navy, e.g. stating "since the exact causes of the stranding events are unknown (...), all predicted Level B harassment of beaked whales is therefore counted as Level A harassment" (2005 OEIS/EIA Undersea warfare training range EIA) Level B harassment is defined in that document as any disruption of natural behavioural patterns while level A harassment is defined as having the potential for permanent damage or mortality.

Prioritization:

Mass strandings have already functioned as focusing events by leading the prioritization of research on beaked whales. Until recently most information on the Ziphiidae family (more than 20 species of beaked whales inhabiting all oceans) was gathered from stranded animals. Cuvier´s beaked whales (*Ziphius cavirostris*) is by far the most common species in mass strandings related to acoustic sources, but little was known about its population, behaviour, hearing capabilities or acoustic ecology prior to the galvanizing stranding events in the eighties (Canary Islands, Simmonds and Lopez Jurado, 1991), 1996 (Greece, Frantzis, 1998), 2000 (Bahamas, Balcom and Claridge, 2001) and 2002 (Canary Islands, Martin *et al.*, 2004). In the last decade there has been a significant increase in scientific knowledge on beaked whales, mainly on their ecology, acoustic and diving behaviour, habitat selection, diet, physiology and population genetics (e.g. Hooker *et al.*, 1999; Gowans *et al.* 2001; Santos *et al.*, 2001; Johnson *et al.* 2004, 2006; Claridge, 2005; Dalebout *et al.*, 2005, 2006; MacLeod, 2005; Madsen *et al.*, 2005; Zimmer *et al.*, 2005; Aguilar Soto, 2006; Baird *et al.*, 2006; Barlow *et al.*, 2006; Tyack *et al.*, 2006; Cranford *et al.*, 2008) and even on the potential effects of sound on *Ziphius* (Aguilar Soto *et al.*, 2006; Tyack this, volume). There has been an effort to standardise necropsy protocols in mass strandings of beaked whales to allow investigation of potentially common pathological lesions with reliability (Rommel *et al.*, 2006). However, these measures have not always been applied and information on the timing and location of naval and other noise making activities concurrent with mass strandings has been often difficult to gather, despite public right to environmental information being included in many national regulations.

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[13] http://www.supremecourtus.gov/opinions/08pdf/07-1239.pdf
[14] http://www.zifios.com/noticias-prensa-2002/noticias-cetaceos-grandes/22-concentracion-contra-maniobras-militares.gif
[15] http://www.europeancetaceansociety.eu/ecs-news.php.

Research of the kind described above is essential in order to base conservation actions on solid scientific data. However it is widely acknowledged by modern conservation management schemes that some uncertainty must be accepted if conservation actions are to be taken in time to not exceed acceptable risks (Taylor, 2000; National Research Council, 2005; Parsons *et al.*, 2008). The lack of knowledge on basic population and life history parameters of beaked whales makes it difficult to assess their conservation status and the impact of mass mortalities at a population level. However, the scientific data recently available suggest that local populations of beaked whales might be small (Baird *et al.*, 2007; Aparicio *et al.*, 2009), genetically isolated (Dalebout *et al.*, 2005, 2006) and have territorial fidelity (Aguilar Soto, 2006; McSweeny *et al.*, 2007), affecting their capability to recover if depleted. The difficulties in studying these elusive species render the time necessary to detect potential significant declines in local populations too long to prevent impacts effectively (NRC *op. cit.*). Thus, mitigation regulations needs to be put in place now and updated as new data are acquired.

Guidelines to reduce the risks to marine fauna during naval exercises have been developed by NATO[16] and in several countries such as USA, UK, Spain, Netherlands, Norway[17], Australia, Italy or Germany (e.g. Carron, 2004; Cerutti, 2005). Guidelines include a variety of mitigation measures, from keeping watches for marine fauna in the vicinity of boats to spatial exclusions of naval exercises using sonar in areas identified as likely beaked whale habitat (see Jasny, this volume, for a review on mitigation measures). Since 2004, the Spanish Ministry of Defence has maintained a moratorium on the use of sonar within 50 nautical miles from the Canary Islands. During this time, no atypical strandings of beaked whales have been reported in the Archipelago (A. Fernández pers. comm.) compared with two mortalities coincident with naval exercises in Canaries during the previous three years. Another regulatory approach has involved the recognition of sound as a form of, potentially trans-boundary, marine pollution. As such, it falls within the domain of existing regulatory bodies both at national and international levels (McCarthy, 2004). With some exceptions, mitigation of sonar use in naval exercises has taken the form of guidelines instead of regulations. This limitation is due, in part, to the lack of information on the effectiveness of some of the mitigation measures adopted. In the following we discuss the biological reasons behind the difficulties in mitigating potential impacts on beaked whales and in evaluating the performance of mitigation measures.

Challenges and need of sonar mitigation for beaked whales

Although a number of local populations have been identified, the distribution of all species of beaked whales is still largely unknown. Models of habitat selection predict higher densities in deep waters and in areas with steep bathymetric slopes but these models are based on a limited dataset of surveys performed with different methodologies and effort. Most importantly, there are enormous areas of the world oceans that have simply not been surveyed for beaked whales. Barlow and Sexton (1996) and Barlow *et al.* (2006) explain the difficulties involved in surveying for deep divers that spend a large proportion of their time underwater and predict a visual detection probability of just 0.23, within the transect line, for Cuvier's beaked whales. Aguilar Soto (2006) analysed DTag (Johnson and Tyack, 2003) data to show that Blainville´s and Cuvier´s beaked whales spend only 8% of their time at the surface, "available" to be seen by a visual observer, and less than 25% of their time vocally

[16] http://enterprise.spawar.navy.mil/nepa/whales/pressrel.cfm
[17] http://rapporter.ffi.no/rapporter/2008/01414.pdf

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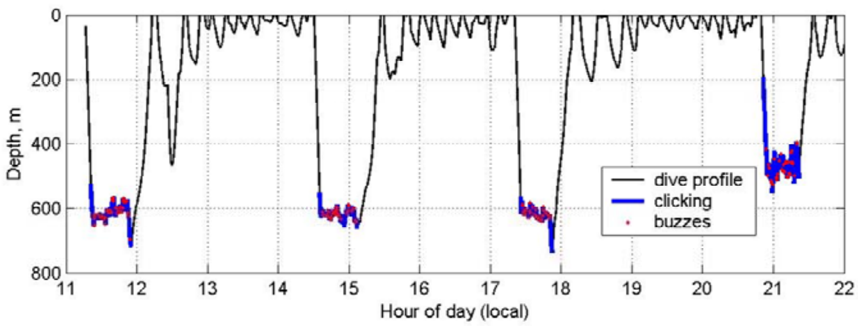
active, i.e., available for acoustic detection during day and night time (Figure 1). This cryptic behaviour makes it difficult to distinguish lack of detection and absence of beaked whales in an area. However, this distinction is crucial for the effectiveness of any mitigation protocol, both in real-time or to gather distribution data for mitigation during the planning phase of potentially impacting activities.

Figure 1: Example dive profile of a Blainville´s beaked whale gathered with a suction-cup attached DTAG. The blue line indicates the time when the whale is vocally active and the red dots mark the occurrence of buzzes marking prey capture attempts in the echolocation process.



The picture in Figure 1 exemplifies the importance of combining acoustic monitoring with visual surveys in order to increase the probability of detecting beaked whales. While some cetacean species, such as sperm whales, produce powerful clicks that may be detected at large distances (Møhl, 2003), the range for reliable acoustic detection of beaked whales appears to be shorter but is still not well defined (Ward *et al.*, 2008; Zimmer *et al.*, 2008; see Johnson and Aguilar Soto, this volume). The figure above illustrates that beaked whales are vocal mainly when deeper than 200-500m depth. In summer and autumn the sea is noticeably warmer near the surface, forming what is coined the "seasonal thermocline". The change of temperature between the deep waters where the sound source (i.e., the whale) is located and the shallow depth of towed hydrophones used in many survey and mitigation efforts tends to refract sound away from the surface, limiting the detection range of clicks near the surface. This effect will be variable in different seasons and areas and needs to be accounted for when evaluating the probability of acoustic detection. The visual detection range is also quite limited, even when whales are at the surface, on account of the small surface profile and cryptic behaviour of beaked whales (Barlow *et al.*, 2006). This means that real-time mitigation will be detection range limited while the question of at what range should we mitigate is still open. Contextual and anecdotal evidence suggest large impact ranges based on the spatial distribution of dead beaked whales during mass strandings[1]. In general, discrete lethal effects are considered indicative of more widespread sublethal impacts. If impacts may occur at ranges further than those for which mitigation is possible, the responsible action is to mitigate as far as practical now. There is a need for continued research on beaked whales and on the effects of sonar on marine fauna, and to acknowledge that the time necessary to get complete certainty on elusive species such as beaked whales may be too long to prevent biologically significant effects on local populations, rendering an immediate need for regulating mitigation.

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5. BEHAVIOURAL RESPONSES OF BEAKED WHALES TO SOUND

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There has been growing recognition that atypical mass strandings of beaked whales may coincide with naval exercises that use mid-frequency sonar (Frantzis, 1998; Cox *et al.*, 2006), but the causal chain of events from sound exposure to stranding has not been elucidated. The classic way to reduce risk of a hazard to a vulnerable species is to understand the distribution of the risk and the distribution of the species, to understand what exposures create the risk, and to use this information to reduce the odds that the species will get a hazardous exposure (Harwood, 2000). This approach is particularly difficult for beaked whales and sonar. Beaked whales are extremely difficult to sight, and visual monitoring has low probability of detecting whales at sea (Barlow, 1999). It is similarly difficult to obtain either historical data or current information on exactly when and where navies transmit military sonar. These problems interfere with normal epidemiological analyses of risks for the beaked whale sonar issue. Even in the few cases where it is known where and when sonar was transmitting during an exercise, is impossible to know where the whales were when they heard the sonar that started the chain of events leading to stranding, so it is not possible to estimate from the stranding record, the exposure that poses risk.

Even less is known about potential risks for other signals or for other odontocete species. There are at least two reports of beaked whale strandings coinciding with seismic survey, another of the most intense sound sources humans use in the ocean (Malakoff, 2002), and species other than beaked whales have stranded along with beaked whales during naval exercises (Evans and England, 2001; Cox *et al.*, 2006; Hohn, 2006; Southall *et al.*, 2006). While the link between these strandings and exposure to intense anthropogenic sounds is less strong than that between atypical strandings of beaked whales and sonar exercises, we do not have enough data to rule out these risks.

Here we describe preliminary results from a research program that uses several different approaches to answer the following issues:

- To suggest new approaches for more effective monitoring of vulnerable species
- To validate these approaches
- To better understand the cause of strandings
- To quantify what exposures of what stimuli are safe for which species

This program uses passive acoustic monitoring and tags to monitor responses of beaked whales to mid-frequency sonar exercises and to experiments using carefully controlled exposures of sound to compare responses of beaked whales vs other odontocetes to playbacks of mid-frequency sonar sounds vs other anthropogenic signals.

Data on the sounds produced by beaked whales have become available thanks to acoustic recording tags called Dtags (Johnson and Tyack, 2003) placed on Cuvier's beaked whales, *Ziphius cavirostris* (Zimmer *et al.*, 2005), and Blainville's beaked whales, *Mesoplodon densirostris* (Johnson *et al.*, 2006). These whales make high frequency (>24 kHz, centre frequency 40 kHz) frequency modulated upsweeps with source levels of about 200-210 dB re 1µPa. Once the sounds produced by beaked whales were defined, this opened the opportunity for passive acoustic monitoring for these animals. Each beaked whale in a group makes a deep foraging dive every few hours, and makes thousands of echolocation clicks for about half an hour during each dive. When these whales are pointing at a sensor, their clicks can be detected up to about 4-6.5 km and when they are not pointing at the sensor, the off-axis clicks still should be detectable at a range of about 0.7-1 km (Ward *et al.*, 2008, Zimmer *et al.*, 2008). This provides a much better opportunity for detecting the whale than the fleeting opportunities to sight them (Zimmer *et al.*, 2008), and the sounds can be monitored day or night in all weather conditions.

A variety of different modalities can adapt beaked whale PAM for different applications. An array of hydrophones can be towed for surveys, where acoustic detections can be particularly useful for deep divers (Barlow and Taylor, 2005; Gordon and Gillespie, this volume). When it is possible to record sound continuously or to detect taxon-specific signals automatically (Johnson and Aguilar Soto this volume), acoustic detectors can be added to autonomous platforms for efficient storage of high-frequency data. Mobile autonomous platforms such as gliders may be useful for surveying areas. The cost of this kind of survey may be significantly reduced compared to ship-based surveys. Similar detectors can be deployed on buoys or drifters for applications that do not demand moving through an area. New statistical techniques are being developed to use such acoustic data from either mobile or stationary platforms to estimate density and abundance of marine mammals (www.creem.st-and.ac.uk/decaf). Such platforms may be promising for testing for the presence of animals either before a sound producing activity as part of the planning process, or just before and during an activity for real-time mitigation monitoring.

An exceptional opportunity for passive acoustic monitoring of beaked whales is presented by a sophisticated array of hydrophones covering about 1500 km^2 on a US Navy underwater range in the Tongue of the Ocean in the Bahamas. When a beaked whale makes a foraging dive, it produces several thousand echolocation clicks that can be heard up to 6.5 km away on this range (Ward *et al.*, 2008). With hydrophones separated by 1.2-4 km, whales can be detected and located reliably on the range. The M3R (Marine Mammal Monitoring on navy Ranges) project, led by David Moretti of NUWC-Newport (Rhode Island), developed hardware and software to record audio data from these arrays, to monitor for cetacean sounds, and to plot spectrograms of selected hydrophones. This system detects beaked whales most of the time on the range and allows rough localization of beaked whales (Moretti *et al.*, 2006). Collaborating with Diane Claridge of the Bahamas Marine Mammal Research Organisation, they have been able to sight beaked whales surfacing soon after clicks in that location stopped being heard. Validation of this capability opened the opportunity to conduct controlled exposure experiments to beaked whales Dtagged on this range.

A series of experiments were conducted during 2007 and 2008 in the Tongue of the Ocean. The design of these experiments called for a whale to be tagged with the Dtag, for pre-exposure data to be collected, then for a pre-selected stimulus to be started at a source level of 160 dB re 1 µPa, likely inaudible to a whale about 1 km away, and then slowly increased by 3 dB every 25 seconds until either the sound reached a source level of 211 dB re 1 µPa (received level (RL) = ~150 dBrms re 1 µPa at the animal) or until a response was noted from the animal. For beaked whales, exposure was only started after clicks were detected after the start of a foraging dive, and the sound playback was stopped once the whales were heard to stop clicking. The maximum duration of exposure if no response was detected was 12 minutes, comprising the ramp up interval and then 13 pings or 25 second intervals of sound.

Four sets of baseline tag data from unexposed Blainville's beaked whales, *Mesoplodon densirostris* and nine playback sequences (including measurements during control and exposure intervals) were conducted on four species of odontocete cetacean [Blainville's beaked whale, *Mesoplodon densirostris* (n=2); Melon-headed whale, *Peponocephala electra* (n=1); short-finned pilot whale, *Globicephala macrorhynchus* (n=4); false killer whale, *Pseudorca crassidens* (n=2)] to measure the behavioural responses of beaked whales and other odontocete cetaceans. Observations were also made of odontocete vocalizations at a coarser (group) level using the hydrophone array during playbacks and sonar exercises. One of the tagged Blainville's beaked whales responded to playbacks of simulated mid-frequency (3-4 kHz) naval sonar at a received level of 138 dBrms re 1µPa and killer whale sounds at RL = 98 dBrms re 1µPa by interrupting foraging dives, prematurely ceasing vocalizations, making an unusually slow and long ascent. After exposure to the killer whale sounds during the next deep foraging dive, the same whale showed the same kind of response followed by sustained avoidance of the playback area for more than ten hours. A second tagged whale was exposed to a noise stimulus with the same timing and overall bandwidth as the sonar signal, but which sounded very different. This beaked whale playback evoked cessation of vocalizations and premature ascent after exposure to RL = 141 dBrms dB re 1 µPa. The responses to anthropogenic stimuli observed in these experiments were similar to the 136 dB broadband rms level previously reported for ship propulsion noise that caused a Cuvier's beaked whale to cease clicking and break off a foraging dive in the Mediterranean Sea (Aguilar Soto *et al.*, 2006).

The other species tested appear to be less sensitive to the sonar and control sounds than beaked whales, demonstrating some changes in vocal and movement behaviour but nothing like the clear silencing and avoidance responses seen in the beaked whales. During several of these playbacks, the other species showed increased calling rates and increased social cohesion with little avoidance, indicative of a social defence against predation very different from the silent avoidance response of the beaked whales. Our results demonstrate that useful scientific information can be obtained through controlled exposure experiments on beaked whales and a range of other species without causing serious negative effects on the target or non-target species. These results are particularly useful for comparing differential sensitivity of different species to different stimuli.

Observational studies of responses of whales to actual sonar exercises are an important complement to low-level experimental studies (Tyack *et al.*, 2004). Acoustic monitoring of beaked whales during sonar exercises on the naval range in TOTO suggests sustained avoidance similar to that observed in the experiments described above. During sonar exercises, fewer beaked whales were detected on the range, and if they were detected, they were more likely to be on the periphery, 10-20 km from the centre where the sonar exercise was concentrated. It took several days after the exercise was over for the calling rates to return to normal throughout the range. These results are consistent with the silencing and avoidance responses observed during the playback experiments.

All of the studies cited here have been carefully designed not to pose a risk to the animals, so they do not provide data on the whole causal chain of events leading from sonar exposure to stranding. They only provide information on the exposure levels that provoke initial disruption of behaviour. Taken together these results indicate that beaked whales respond to the anthropogenic signals tested at received levels of about 140 dBrms dB re 1 µPa, with little evidence that beaked whales respond to sonar more intensely or at a lower level than to other anthropogenic sounds. These results suggest that beaked whales, like the Phocoenidae (porpoises) are particularly sensitive, in the sense that they respond more strongly to lower exposures than most other toothed whale species (Southall *et al.*, 2008). An important point about what kinds of responses may pose a risk for stranding is that beaked whales live in deep water, which in most places is far from shore. This means that whatever else happens, they must swim far from their normal habitat to be at risk of stranding. These results therefore suggest that a species' defence from predation may be a risk factor for stranding, with flight responses being higher risk and social defences against predation potentially reducing risk.

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6. CURRENT MITIGATION MEASURES FOR MID-FREQUENCY ACTIVE (MFA) SONAR EXERCISES

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ABSTRACT

A growing body of evidence indicates that mid-frequency active (MFA) sonar can lead to marine mammal strandings, mortalities at sea, and other impacts. These environmental risks have highlighted the need for effective mitigation measures, but relatively little is known about which measures are being utilized world-wide. At present, the numbers of states known to possess ship-based MFA sonar substantially exceeds those known to have adopted measures, of any kind, to mitigate the impacts of their sonar training on marine mammals. In general, the environmental community has focused most on sonar use by the U.S. Navy since, with over 150 surface ships and submarines equipped with MFA sonar (in addition to aircraft and other platforms), the U.S. is widely assumed to be the world's most intensive user of the technology. At least one regional seas agreement, ACCOBAMS (the Agreement on the Conservation of Cetaceans of the Blacks Sea, Mediterranean Sea and Contiguous Atlantic Area), has requested member states to submit information on the mitigation they undertake, if any (ACCOBAMS 2004); thus far, however, only a small minority have done so. The widespread use of MFA sonar suggests that a body with broader geographic competence, such as the U.N. Division for Ocean Affairs and the Law of the Sea (DOALOS), is needed to solicit and compile this information.

Mitigation measures can be classified into three categories, depending on when they are undertaken relative to sonar use: in advance of an exercise during the planning process, during the exercise itself, or after the exercise is concluded. Under each category a variety of measures are available, including placing buffer zones around exclusion areas, reducing power in certain oceanographic or operational conditions, and implementing post-exercise surveys of the exercise area (Dolman *et al.*, 2009). In practice, however, most forms of sonar mitigation reduce to one of three principal devices: spatial-temporal constraints on the siting of exercises; maintenance of a "safety zone" to reduce species exposures in the near vicinity of a sonar array; and monitoring for purposes of exercise planning, real-time mitigation, and adaptive management. This paper will focus primarily on the first two measures: geographic mitigation and safety zones.

Geographic mitigation: Avoiding high-value habitat is recognized to be the most effective measure presently available to mitigate the biological impacts of MFA sonar (Agardy *et al.*, 2007; Parsons *et al.*, 2008). Most of the navies that have adopted mitigation measures (Australia, France, the NATO Undersea Research Centre, Spain, and the U.S.) engage in some form of habitat protection, further suggesting the importance of the method.

Several nations have established protection areas in the vicinity of previous sonar-related stranding events. For example, Spain, at the behest of the regional government, established an exclusion zone running 50 nm around the Canary Islands, the site of multiple mortality events; similarly, the U.S. Navy agreed to avoid the Northeast and Northwest Providence

Channels in the Bahamas in the wake of the March 2000 multi-species mass stranding event. Some states extend this concept by avoiding areas with features similar to those present in certain stranding events; in the case of the U.S. Navy, these features are defined narrowly such that only a few locations in the whole of North America qualify for protection. A more precautionary approach – used by Australia, France, Italy, the NATO Undersea Research Centre, and, from 2002 through early 2006, the U.S. Atlantic Fleet – defines protected areas to include known habitat for certain species of concern; areas with particular oceanographic features, such as canyons, steep topography, ocean fronts, and seamounts; and existing marine protected areas. Some authorities, such as ACCOBAMS and the U.S. Navy, are developing predictive habitat models for beaked whales and other species that, in combination with other exclusions, with validation, and with effective implementing language, could become the basis for best practice mitigation.

To maximize the effectiveness of geographic protection areas, it is critical that the legal language used to implement them is meaningful. Several states qualify their avoidance requirements with undefined practicability or feasibility clauses (e.g., "where possible," or "to the extent feasible") and without providing any mandates for reporting derogations. Such vague or subjective standards, especially when coupled with a lack of accountability, are known in other contexts to produce arbitrary decisions and result in low rates of adoption. Several mechanisms exist to improve implementation. For example, states can set higher substantive standards (e.g. no exception or exception only in case of "extraordinary need"), procedural requirements (e.g. planners must first obtain permission from fleet commanders in order to use an identified area), and reporting mandates (e.g. any derogation must be reported to the regulatory authority and publicly noticed in advance of the exercise).

Safety zones: Safety zones have been criticized as having limited value as mitigation measures, particularly for beaked whales, given the extremely low probability of detecting cryptic species (Barlow and Gisiner, 2006) and the insufficient coverage that safety zones provide of the expected impact area, either to eliminate the risk of serious injury in beaked whales or to significantly reduce the risk of sub-lethal behavioural harm (Parsons *et al.*, 2008). For more readily sightable species, however, safety zones are useful as a last-chance mitigation practice, preventing exposure of some animals to levels associated with hearing loss and direct tissue damage.

Safety zone distances vary significantly by navy, ranging from Norway at the short end (100 m) to Canada (1 km for odontocetes), Italy (1500 m), and Australia (4000 yd), within which sonar is temporarily shut down on the sighting of an animal. The U.S. Navy maintains a tripartite safety zone, securing its sonar on sighting marine mammals within 200 yd of the sonar dome, powering down by 10 dB at 500 yd, and powering down by 6 dB at 1000 yd.

In general, maintaining safety zones of 2 km or larger is appropriate even if the navy intends only to reduce the risk of direct tissue damage and hearing loss within the close vicinity of a vessel, given (1) that it is often very difficult, even for experienced observers, to predict the directionality of sighted animals at sea, (2) that marine mammal groups are often spread out over a wide area, and animals may go undetected within the safety zone even if group members are spotted outside, and (3) that substantial uncertainty remains over the thresholds and distances needed to cause hearing loss (Gedamke, 2009; Lucke *et al.*, 2009). In the past, U.S. Navy vessels, both voluntarily and under court order, have regularly secured their sonar well beyond their standard 200 yd zone, apparently shutting down whenever marine mammals were sighted except during critical points of an exercise. Allowing such limited exceptions may be an effective way of extending safety zones to sighting distances where strict mandates would not be practicable.

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7. HIGH OCCURRENCE OF CUVIER'S BEAKED WHALES IN THE TYRRHENIAN SEA AS EVIDENCED BY SMALL AND SLOW BOAT SURVEYS

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INTRODUCTION

The Cuvier's beaked whale (*Ziphius cavirostris*) is listed among the common cetacean species of the Mediterranean Sea (Duguy *et al.*, 1983). This species is not frequently observed during general cetaceans surveys (Barlow *et al.*, 2006), because of an often inconspicuous surface behaviour, low group size, and long lasting dives (Tyack *et al.*, 2006). MacLeod and Mitchell (2006) identified three regions in the Mediterranean Sea as key areas for Cuvier's beaked whales (CBW): the Alboran Sea, the gulf of Genoa and the Hellenic Trench in the Ionian Sea. CBW are supposed to occur in other regions, as suggested by the stranding distribution (Podesta *et al.*, 2006) and past survey reports. It is of crucial importance to discover regions of high occurrence, as CBW have been severely impacted during accidents related to the deployment of mid-frequency active sonars (Frantzis, 1998; Arbelo *et al.*, 2007). Marini *et al.* (1996) and Gannier and Epinat (2008) remarked the regular occurrence of CBW in the northern and central Tyrrhenian Sea.

Medium-sized ziphiid dive cycles are quite unusual because they often include series of shallower dives after one deep prolonged foraging dive: for CBW in the Ligurian Sea Tyack *et al.* (2006) reported such "shallow" dives to last 15.2 minutes in average, when deep foraging dives were 50.3 minutes long in average. During a standard large vessel survey, with a 10 knots cruising speed, such durations are equivalent respectively to 4,500m and 15,000m of survey track. These distances exceed the usual effective search width estimated during the surveys (Barlow *et al.*, 2006). This partly explains why the probability of detection on the line –g(0)- is often below 0.5 for medium-sized ziphiids. Survey boats cruising at low speed, for example five knots, cover half the above distances during successive surfacing events of CBW: therefore, with suitable sea and wind conditions they may be effective detection platform for ziphiid species.

During 2007 and 2008, we carried out two summer surveys aimed specifically at the determination of the distribution and relative abundance of CBW in the central Tyrrhenian Sea. This region is currently listed as a possible exercise area for different navies. Another survey goal was to gain preliminary data on group structure and surface activity patterns.

MATERIALS AND METHODS

The area of study is located between 40°30N and 42°N, offshore of the 500m isobath in the northern-central Tyrrhenian Sea. It is characterised by a variable topography, with submarine valleys and ridges, seamounts and a bottom depth generally increasing from north to south (Fig.1). This part of the Tyrrhenian Sea is located east of the straits of Bonifacio: there is a local upwelling-like enriched area, as evidenced by remote-sensed chlorophyll pigment concentration (http://oceancolor.gsfc.nasa.gov).

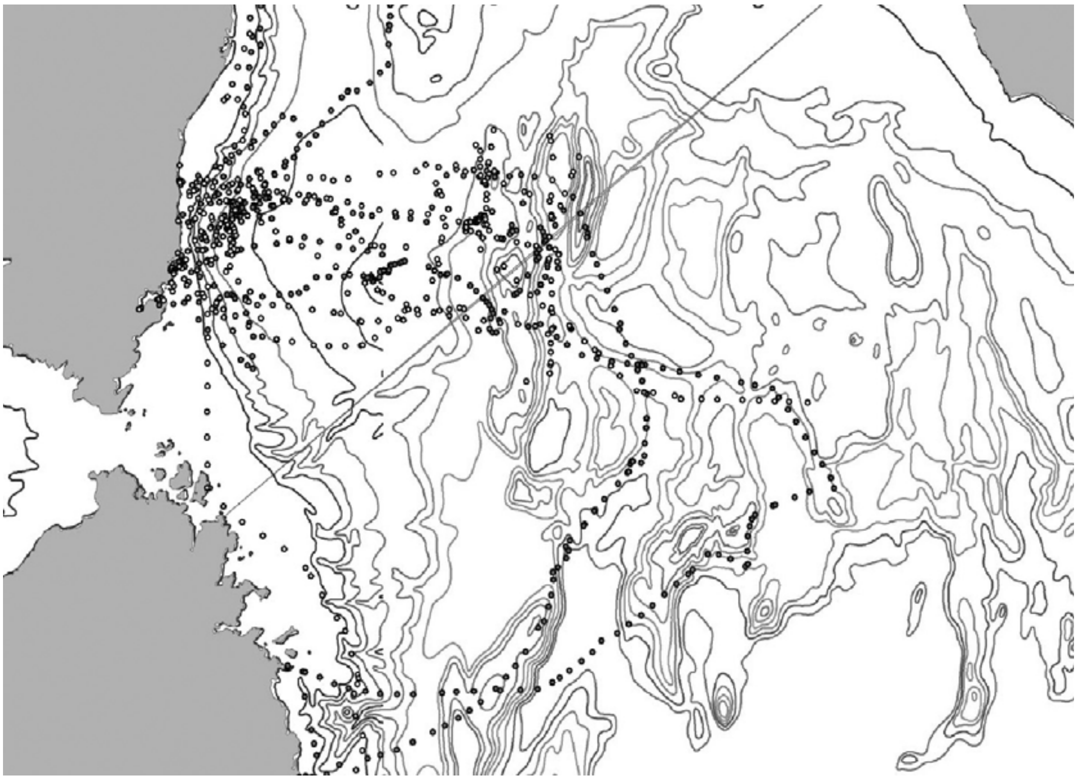

Figure 1. Area of study and total survey effort (2007-2008). The straight line is the southeast boundary of Pelagos marine mammal sanctuary. Drawn isobaths include 100m, 200m, 400m, 600m, etc.

Surveys were conducted in July 2007 and July-August 2008 with a 12m motor-sailing boat, using a consistent three-observer visual search protocol combined to systematic acoustic sampling. Individual observers rotated on a hourly basis. An 80hp diesel engine allowed the boat to cruise at a mean speed of 5 knots (2.5 m/sec). The visual survey technique consisted of naked eye observation and was adapted in an attempt to detect whales surfacing after a shallow 10-20 minute dive: one observer stood in front of the mast searching the +/-45° sector ahead, two other observers scanned the 30°-120° sectors both sides of the boat, thus allowing the detection of CBW surfacing rear of abeam. Visual searching took place from half-an-hour after sunrise to half-an-hour before sunset, whenever the wind speed was lower than or equal to Beaufort 2. The sampling strategy was not random, but our effort was widely distributed in order to cover different CBW possible habitats. On station recording with a mono dipping hydrophone was possible whenever the boat was close to a visually detected CBW school, although the recording equipment bandwidth was limited to 24 kHz.

When CBW were detected various sighting parameters were recorded, e.g. distance and bearing to the boat and school size. Further data on behaviour and school structure were collected by closing whales (whenever possible) and included calf presence, blow counts, surface and dive durations, photographs and recordings. The detection of clicks was our criterion to assume that whales engaged into a deep foraging dive, a signal to discontinue a sighting and resume our sampling route.

Data were exported to a GIS software, which was used for mapping the survey track and processing distribution variables, for which we used the IBCM depth contours provided by GEBCO Atlas (IOC-IHO-BODC, 2003). The physiographic variables presented here are the bottom depth and the slope. Sighting rates, sighting rates for individuals, mean school sizes and effective search width were computed with Distance 5.0 (Thomas *et al.*, 2006). Daily survey tracks were taken as sample units to estimate variances empirically.

RESULTS

The effective sampling effort amounted to a total of 512 nautical miles with Beaufort 0-2 conditions (947 km), 207 in 2007 and 305 in 2008 (table 1). A total of 22 CBW sightings were obtained during survey tracks, among which two were secondary sightings, i.e. whales detected while we were already studying one group (table 2). Five other sightings were made while on transit, or in standby while awaiting proper light or sea conditions (figure 2).

Table 1: Cuvier's beaked whale sampling effort in the northern-central Tyrrhenian Sea (2007, 2008)

Date	Beaufort conditions	Survey time	Effort nm	Sightings CBW
14-07-07	0-1	8h55-21h00	38	5
15-07-07	1	7h59-20h22	53	2
16-07-07	1-2	6h25-11h58	20	1
19-07-07	1-2	8h43-19h22	48	1
20-07-07	1	9h12-19h48	45	0
16-07-08	0-1	9h39-20h20	41	1
17-07-08	1	9h22-12h53	16	0
24-07-08	0.1	7h07-19h51	35	2
26-07-08	0.1	10h50-19h53	39	0
28-07-08	0-1	11h08-18h35	22	0
29-07-08	0-1	12h15-20h09	34	0
30-07-08	1	6h58-18h38	32	1
31-07-08	1	7h30-18h50	37	5
19-08-08	0-1	8h33-20h19	51	4

Table 2 : Cuvier's beaked whale sightings 2007-2008 (on-effort and secondary).

Sighting number	Date	Time	School size	Detection radial distance	Bottom depth	Remarks
1 7054	14/07/07	1150	1	500	800	
2 7056	14/07/07	1317	2	600	760	w. juvenile
3 7057	14/07/07	1726	1	1200	800	
4 7058	14/07/07	1759	2	1000	720	Secondary
5 7060	14/07/07	1935	5	1100	800	w. juvenile
6 7066	15/07/07	759	3	800	1190	w.calf
7 7072	15/07/07	1416	3	800	750	
8 7074	16/07/07	625	1	500	1600	
9 7088	19/07/07	1405	3	1000	1100	
10 8038	16/07/08	1558	1	150	1100	
11 8053	24/07/08	1305	1	1500	1190	
12 8054	24/07/08	1444	2	600	1100	w. juvenile
13 8090	30/07/08	1509	3	500	1507	
14 8095	31/07/08	840	1	2000	1094	
15 8098	31/07/08	950	3	2000	1114	
16 8099	31/07/08	1052	3	400	1132	
17 8100	31/07/08	1332	1	1500	987	
18 8101	31/07/08	1402	1	1500	876	Secondary
19 8121	19/08/08	1227	2	100	1536	w. calf
20 8122	19/08/08	1402	2	3000	1577	
21 8126	19/08/08	1700	3	250	1487	w. juvenile
22 8127	19/08/08	1819	2	1200	1517	

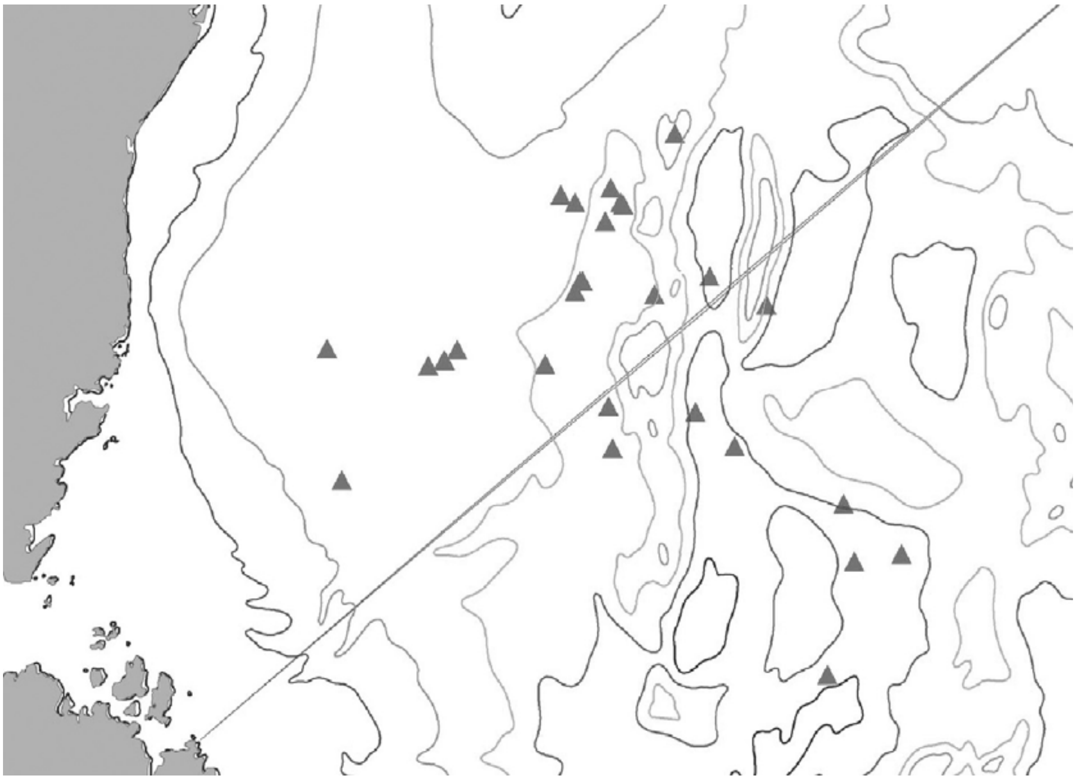

Figure 2. Cuvier's beaked whale sightings (2007-2008), including secondary sightings and observations obtained during transit legs or in stand-by status. The straight line is the southeast boundary of Pelagos marine mammal sanctuary.

School sizes ranging from 1 to 5, including 8 solitary whales and 14 sightings of 2-3 individuals. The mean school size was 2.09 (SD= 1.06). Among the 22 CBW schools sighted with good weather, six included either a calf, estimated to be less than one year old from its relative size, or a juvenile, making a proportion of 27.2%. Schools with a calf numbered 2 or 3 individuals in total. Gannier and Epinat (2008) obtained a mean school size of 1.8 in their results from various regions in the Mediterranean Sea, and Moulins *et al.* (2007) reported a mean group size of 2.3 in the Ligurian Sea.

We obtained an average sighting rate of 2.2 sighting/100 km (CV= 31%), and a relative abundance index of 4.6 individual/100 km (CV=35%). The effective search half-width was estimated at 755m (CV= 17%), with initial radial detection ranges varying from 150m to 3000m. This relative abundance index was similar to estimates obtained with the same survey boat in the Alboran and Tyrrhenian Sea (Gannier and Epinat, 2008).

CBW were encountered over bottom depth of 700 to 1577m (average 1094m), in an area restricted to a latitude range of 41°14 to 41°53 N and a longitude range of 9°48 to 10°51 E. Most of the sightings (15 out of 22) were recorded in the depth range 700-1200m. CBW were observed over moderate slopes (61 m/km in average), although the slope range was extended, with 5 sightings on slopes less than 25 m/km and 3 sightings on slopes over 100 m/km, and a maximal value of 260 m/km. A majority of sightings were obtained on bottom slopes of 25-

75 m/km. The habitat of CBW reported during our survey did not seem different from the habitat sampled in average, although this needs to be confirmed by a suitable analysis.

With calm sea, the stationary dipping hydrophone enabled to consistently record the CBW clicking activity during part of their deep dives, although this was only possible less than 500m from whales.

CONCLUSION

The Mediterranean Sea is still a major exercise area for many military vessels. Real-time mitigation is currently inefficient for beaked whales, and strategic mitigation must include the localization of hot and cold spots. In spite of initial research effort, there are still Cuvier's beaked whale favourable habitats which remain undiscovered. The present study showed that small scale regional effort can be used successfully to document regions which have been earmarked from previous results or suitable physiography.

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8. SIZE MATTERS: STRESS RESPONSES IN BEAKED WHALES AND WHY BIGGER SONAR EXCLUSIONS MAY BE NEEDED

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The management of marine mammals traditionally focuses on lethal takes, such as in bycatch, vessel collisions and strandings. To this extent, it is now clear that beaked whales require special consideration with regards to exposure to military mid-frequency sonar, as it is thought that their behavioural reactions at sound levels well below those thought to cause 'injury' (Hildebrand, 2005) ultimately cause the mass strandings that have been highly publicised (Cox *et al.*, 2006; Rommel *et al.*, 2006; Tyack *et al.*, 2006). This hypothesis appears to be supported by the limited and preliminary, but direct, data obtain in recent studies (Moretti *et al.*, 2008; Tyack, 2008). However, we are also beginning to realise that non-lethal impacts of human disturbance can also have serious conservation implications, indicating that the mortality counts (which are themselves likely to be substantial underestimates: see Parsons *et al.*, 2008) only reveal a fraction of the picture.

Possibly the most important of non-lethal (at least, not immediately lethal) impacts arise from the prolonged or repeated activation of the stress response. The physiological stress response, which highly conserved across all the species studied to date, is a life-saving combination of systems and events that essentially maximise the ability of an animal to kill or avoid being killed (for detailed reviews and further information see Deak, 2007, and Romero and Butler, 2007). The principle systems involved are the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis – both of which are activated immediately upon the *perception* of a threat by the animal. Within seconds, the release of adrenalin and noradrenalin (AKA epinephrine and norepinephrine) by the SNS produces numerous changes, including increases in heart rate, gas exchange and visual acuity, and a redistribution of blood to the brain and muscles and away from the stomach and other non-essential organs. Behavioural changes also result, most famously the fight or flight response. Meanwhile, a chain of hormones released through the HPA axis leads to the release of glucocorticoids (GCs) from adrenal cortex (e.g., cortisol, corticosterone, cortisone), usually within 3-5 minutes. These induce similar changes: an increase in blood glucose and suppression of non-essential activities, such as digestion, immune activity, growth, and reproduction, although the reproductive system can, in some reproductive contexts, become resistant to inhibition by GCs. GCs can also alter behaviour in context-specific ways (e.g. hiding or abandonment of an area; reproductive behaviour may also be suppressed). This suite of effects is thought to allow the animal to recover from a stressor delaying functions that can be postponed until the danger has passed, as well as to prepare the animal for any possible subsequent stressors.

However, this response can become maladaptive when initiated too often or for prolonged periods. This state of "chronic stress" is linked to numerous conditions in humans, including coronary disease, immune suppression, anxiety and depression, cognitive and learning difficulties, and infertility (see Clark and Stansfeld, 2007; Romero and Butler, 2007). In addition, *in utero* exposure to GCs via the mother and/or through mothers' milk to newborns has been shown to alter the stress response itself in these neurologically vulnerable young, leading to life-long health and psychological problems (e.g. Kapoor *et al.*, 2006).

Given that beaked whales appear to engage in a flight reaction to sonar exposure, we can deduce that they may indeed undergo a stress response, although this response, in and of itself, is not responsible for the stranding (see Wright *et al.*, 2007). It should also be noted that noise can trigger a stress response at levels of exposure below those that induce observable behavioural reactions in other species (e.g., rats: Baldwin, 2007). Furthermore, beaked whales, which are thought to be diving right at their physiological limits (Tyack *et al.*, 2006), are likely to be subject to additional stressors as a consequence of their reactions. Consider the problem of an increased rate of gas exchange for an animal holding its breath, or the fact that beaked whales are essentially being forced out of a particular area for some time as a consequence of sonar exposure. Either of these may lead to anxiety in an animal, as would separation of a mother/calf pair, which can act as a stressor in itself. Furthermore, an increase in heart rate with prolonged or frequent exposures alone can seriously impact the energy budget of animals (e.g. Beale, 2004), which could lead to additional anxiety if food is scarce or unavailable (e.g., within the area exposed to sonar pulses). Remaining closer to the surface will also bring the animals into closer contact with other sources of anthropogenic noise.

It is thus quite possible that exposure to sonar, especially frequent or for prolonged periods, has the potential to induce at least some aspects of chronic stress in beaked whales, with immune and reproductive suppression being of particular concern. This situation is further complicated by the fact that the beaked whales may already be undergoing stress responses as a consequence of exposure to one or more of the many other potential threats to cetaceans, such as persistent pollutants, habitat degradation, reduction in food availability, other noise sources, etc. (Reeves and Ragen, 2004).

But what does all this mean for the mitigation of impacts from sonar exposure in beaked whales? Well, growing human activity in aggregate in the marine environment is increasing the frequency with which human disturbance triggers stress responses in cetaceans and other marine mammals and thus also the likelihood of inducing chronic stress. Exposure to noise in the marine environment, especially at the levels below which behavioural reactions are observed, is a particular problem for marine life, as noise travels further in water than air. This means that beaked whales, like other marine fauna, will be acoustically exposed to human activity at much greater distances than terrestrial animals and may thus be particularly sensitive to chronic stress.

This has very obvious implications for area-based mitigation efforts, such as marine protected areas (MPAs), which are not usually large enough to provide effective shelter from anthropogenic noise for marine mammals (Agardy *et al.*, 2007). Without such effective protection, beaked whales, which are already living at their physiological limits, may be additionally sensitive to chronic stress resulting from exposure to sonar alone, or cumulatively with other threats. The possibility that these marine mammals, whose population structure and abundances remain largely unknown, might express the various conditions linked with chronic stress in humans has more troubling implications for conservation efforts, as the potential thus exists for an unobserved decline in abundance without observable fatal impacts. Much uncertainty exists, but the potential for serious and possibly multi-generational impacts in beaked whales merits immediate and appropriate management action.

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9. REAL-TIME DETECTION OF BEAKED WHALE SONAR SIGNALS OVER BACKGROUND NOISE AND OTHER ACOUSTIC EVENTS

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Beaked whales are often found in noisy areas heavily overloaded with several sound sources, whether natural or biological or associated to human activities. The challenge is then to identify and classify the different sources to reduce the detection ambiguity of the target signals, i.e. beaked whales. The Laboratory of Applied Bioacoustics of the Technical University of Catalonia has developed a code that analyses in real-time the acoustic flow of data coming from a four-hydrophone channel underwater observatory site in Sicily. The system consists in 8 detectors that first discard audio segments that do not contain acoustic information of interest, e.g. sea noise, and further classify the remaining signals in broad categories (pulse sounds, tonal, FM, etc.) before assigning them to more specific classifiers that enhance the detection and identification of beaked whale signals. The results of the real-time analysis are displayed on a website where the users can listen to the acoustic events on site and track beaked whales in the area through the statistical analysis of their presence over time.

10. PASSIVE ACOUSTIC DETECTION OF BEAKED WHALES USING NEAR SURFACE TOWED HYDROPHONES: PRACTICAL EXPERIENCE AND PROSPECTS FOR MITIGATION

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Beaked whales remain amongst the most poorly studied mammals. Mass strandings linked to military sonar exercises have increased the need to better understand this group and to devise improved mitigation procedures. Beaked whales are extremely difficult to sight at sea, which hampers attempts to study them, and makes operational mitigation difficult. Passive acoustic monitoring could improve detection efficiency. Beaked whales are readily detected on bottom-mounted hydrophones arrays and this fits recent research on their acoustic behaviour. However, the extent to which they can be detected using near-surface towed is unknown and is the focus of this work. Continuous recordings were made at a sampling rate of 192 kHz from 2 or 4 element towed hydrophone arrays during joint visual/acoustic surveys in the Bahamas, Canaries and Azores, and in conjunction with monitoring of bottom-mounted hydrophones at the AUTEC range and shore based visual tracking in the Canaries and Azores. A beaked whale click detector and classifier was developed within Rainbow Click and PAMGUARD. This was run in real time and on recordings to detect beaked whale click trains. Three species of beaked whale were encountered visually and detected acoustically: *Mesoplodon densirostris*, *Ziphius cavirostris* and *Mesoplodon europaeus*. Acoustic detections correlated well with sightings and with detection on bottom-mounted hydrophones. Target motion analysis of bearings to sequences of clicks suggests a maximum detection range of approximately three kilometres and preliminary results indicate that clicks can be identified to species. Fieldwork in the Canaries and Azores through the spring and summer of 2008 has focused on determining the effect of distance and hydrophone depth on the probability of detection. These early results suggest that passive acoustic monitoring could play an important role in improving the detection of these animals and thus facilitate population surveys, photo-id studies and, potentially, real time detection for mitigation.

11. PERFORMANCE EVALUATION OF PASSIVE ACOUSTIC DETECTORS FOR BEAKED WHALES

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Beaked whales are a family of mid-sized toothed whales best known for their presence in numerous mass strandings coincident with the use of navy sonar and possibly other high-powered sound sources. Although the causal link between human-sourced sound and strandings has yet to be explained (Cox *et al.*, 2006), there is a need to incorporate prediction and real-time detection capabilities in the planning and execution phases of sound producing activities to mitigate harm to these apparently sensitive species. To achieve this, efficient and reliable methods to detect beaked whales, whether in abundance surveys or as part of a real-time mitigation protocol, are required.

The probability of visual detection of beaked whales, at least during ship-based surveys, has been estimated to be extremely low, and active detection methods such as radar and sonar have yet to be demonstrated satisfactorily (Barlow and Gisiner, 2006). However, the discovery that two species of beaked whales produce a large number of distinctive echolocation clicks every few hours during deep foraging dives (Johnson *et al.*, 2004, Zimmer *et al.*, 2005, Johnson *et al.*, 2006, Tyack *et al.*, 2006) has opened the possibility for passive acoustic detection of these cryptic species. The clicks are relatively strong (source level of about 200 dB re 1µPa RMS at 1m), long in duration, and have a frequency modulated up-sweep characteristic with little energy below 25 kHz (Fig. 1). Clicks are produced at a rate of between 2.5 and 5 per second meaning that some 3800 clicks are produced in the vocal interval of a deep dive. Similar clicks have now been detected in a number of acoustic surveys and from other beaked whale species (Gillespie et al, 2009, McDonald et al, 2009), but there is still little information available about the distances over which detection is possible or about how to design a detector for these signals. This information is crucial both for mitigation applications (i.e., presence/absence decisions) and for deducing abundance from acoustic surveys (Marques *et al.*, 2008).

The narrow beamwidth of an echolocation sound such as beaked whale clicks (Zimmer *et al.*, 2005) means that movements of an animal during foraging will determine how many signals arrive at a remote hydrophone. Thus, detectability will be a function not only of the source strength and ambient noise conditions but also of the behaviour of the animal. A recent theoretical analysis suggested that the clicks from Cuvier's beaked whales, one of the species present in mass strandings, should be detectable at some point in a foraging dive in quiet conditions at ranges up to 4 km (Zimmer *et al.*, 2008). The analysis included a statistical model for movement of the whales based on data from sound and orientation recording tags (DTAGs, Johnson and Tyack, 2003). Detectability was deduced from derived source characteristics rather than from actual signals leaving unexplored how detector design might influence performance. Nonetheless, the detection radius of 4 km provided a starting point for designing mitigation and survey protocols for this species.

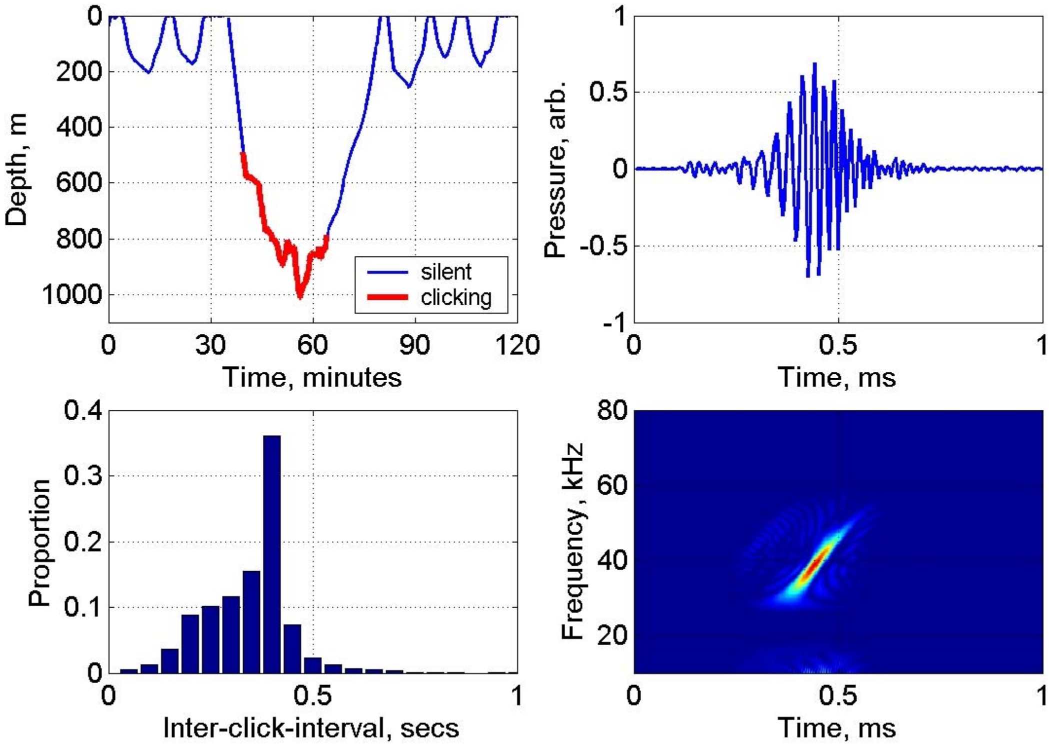

Figure 1: Summary of Blainville's beaked whale click characteristics. (A) Clicks are only made during the base of deep (500-1300 m) foraging dives. (B) The on-axis click waveform has a long duration and a Gaussian pulse shape, unlike most other odontocete clicks. (C) The inter-click-interval falls between about 0.2 and 0.45 s with a mean of 0.4 s. (D) The on-axis click has a distinctive frequency modulated (FM) up-sweep characteristic covering a frequency range of about one octave.

Another approach was taken by Ward *et al.* (2008) who used field recordings from a tagged Blainville's beaked whale in a naval underwater test range, instrumented with an array of bottom-mounted hydrophones, to explore detectability. The distance and bearing of the whale were derived by combining the tag sensor data with passive tracking from the hydrophone array. Detection at distances of up to 6.5 km was demonstrated with a matched filter detector. However, given the low ambient noise in this isolated field site, and the hydrophone depths of 1000-2000m, it is unclear to what extent these results can be used to predict performance in other locations or with other hydrophone arrangements.

A great variety of factors potentially influence the performance of a passive acoustic detector (Zimmer *et al.*, 2008) but these can be grouped into four broad categories: source characteristics, environmental factors, receiver design, and animal behaviour:

- Sound source characteristics include the on-axis source level (SL), beamwidth, frequency range and waveform of individual vocalizations as well as the variability of these characteristics across individuals.
- Environmental factors include the transmission loss of sound by spreading and

absorption, the ambient noise level, and the presence of interfering sounds e.g., from other animals or vessels.

- Receiver characteristics include the number, depth and distribution of hydrophones, the system noise floor, the processing bandwidth and sampling-rate, and the detection and classification algorithms deployed.
- Relevant aspects of animal behaviour include individual vocalization rates as a function of behavioural mode, time of day, season, habitat etc., and movement patterns, both short term (e.g., turning rate during foraging), and longer term (i.e., residence time in an area).

Given the many factors influencing detector performance it is essential to evaluate acoustic detectors in realistic conditions. However, field evaluation is complicated by the need for a ground-truth, i.e., independent and reliable information about the location of the target animals with respect to the receiver as a function of time, information which is difficult to obtain without hydrophone arrays for acoustic tracking. Moreover, detection successes and failures must be averaged over many trials to derive reliable performance statistics making the validation process time consuming. Finally, the conditions and animal sub-populations in the locations chosen for detector evaluation may differ in subtle ways from the conditions where the detector will ultimately be used. A promising approach is to simulate the operation of detectors using real waveforms taken from field recordings at known distances (Ward *et al.*, 2008). The level, spectrum, and noise floor of the recorded signals can then be modified to mimic the signals that would be available in different environments. Ultimately, Monte Carlo simulations using sets of real target, noise, and interference waveforms would provide repeatable and efficient performance comparisons of detectors, with the possibility of continual improvement as more test data become available. The main difficulty with this approach is the need for a large number of waveforms at known distances from animals of the target species, preferably from a variety of locations, seasons and behavioural conditions. Statistical information about how often a particular waveform might be received is also needed. Thus, both calibrated recordings and movement data are required, collected in a standardized form that can be shared with other field studies to produce an expansive database.

In an initial effort to explore how this kind of data might be obtained and used, we conducted a field study of Blainville's beaked whales in El Hierro in the Canary Islands where there is a resident coastal population (Aguilar de Soto, 2006). The study used low-cost rapidly-deployed drifting receivers at depths of 200 and 300 m in combination with acoustic tags attached with suction cups to the study species. Given the complexity of locating and tagging this cryptic species, we have only so far collected data from one tag deployment in which three deep foraging dives overlapped in time with deployment of the acoustic receiver. In this 7 hour interval, the whale produced 13400 clicks, all at depths below 500 m. Some 3500 of these clicks were detectable at the receiver with an in-band (27-48 kHz) RMS signal-to-noise (SNR) ratio greater than 10 dB. The distance to the whale was estimated using the time-difference-of-arrival of the surface-bounce at the receiver combined with the depth of the whale as recorded by the tag. The whale was between 310 m and 3700 m of the receiver during the three dives and tended to move gradually towards the receiver over the interval. As expected, the percentage of clicks received (SNR>10dB) decreased with distance with only about 2% of clicks being received at distances beyond 2.5 km (Fig. 2) with these coinciding presumably with moments in which the whale was pointing its sonar beam towards the receiver.

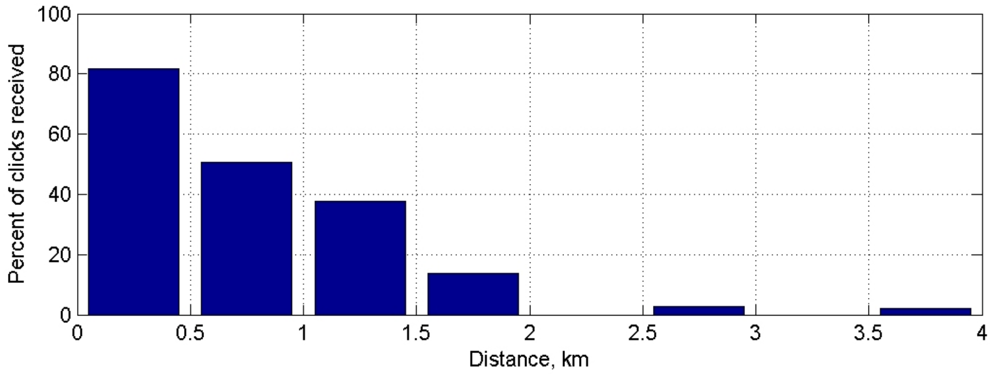

Figure 2: Percentage of clicks produced by the tagged whale within 500 m distance bins that were received at a two-element drifting receiver (hydrophone depths 200 and 300 m) with an RMS SNR > 10 dB. Distance bins with no bars were not sampled.

A set of 1300 click waveforms with RMS SNR better than 26 dB were selected for the simulation study. The high SNR is needed to ensure that detection performance is controlled by the noise added during the simulation rather than the noise already in the sample. A downside of selecting only high SNR clicks is that we do not sample the full variety of signals from the whale. However, this is only a significant issue at short simulated ranges; at long ranges, only nearly-on-axis clicks will be received and these are well-represented in the data set. The selected waveforms were corrected for absorption and spreading to produce an estimate of the waveform that would be measured at 1 m from the whale. These waveforms were then modified to simulate different propagation distances and combined with ambient noise samples to simulate the waveforms likely to be received in a variety of conditions.

Several different detector designs were compared, each configured for an average false alarm rate of 1 per 21 minutes. This might be an appropriate false alarm rate for an autonomous detector; in a survey application in which the detector will be closely supervised, a higher false alarm rate may be tolerable and the method used here can be repeated easily to study other operating points. Detector performance as a function of simulated range and noise level is shown in Fig. 3. Synthetic Gaussian random noise was used with a level corresponding to sea-state 1, 3, and 6 from the Wenz curves (Kinsler *et al.*, 1982). The best performance at all ranges was obtained with a matched filter detector (Kay, 1998) with the filter selected from the trial waveforms (MF1). In comparison, a matched filter based on a waveform previously recorded from the same species (MF2) performed less well. A simple band-pass energy detector performed as well or better than MF2 suggesting that an energy detector may be a more robust solution if it is found that there are substantial differences in the click waveforms produced by different individuals or in different locations. Overall, there is surprisingly little difference in the performance of the detectors at moderate and high noise levels. The benefit of using a matched filter is most apparent at long ranges and low noise: in sea-state 1, the MF1 detector detected about 25% of the trial waveforms at a simulated range of 6 km while the energy detector detected only half as many. These results confirm the conclusion of Ward *et al.* (2008) that a matched filter detector is suitable for beaked whale clicks despite the variability of the click waveform with aspect and the loss of high frequency components in the click at long ranges due to absorption. Nonetheless, the choice of matched filter has a strong influence on performance and a clear short-coming of the current data-set is that only one individual is represented. The use of synthetic noise is another short-coming that can be addressed in the future by using real ambient noise waveforms. The probability distribution of underwater noise may often have a heavier tail than the Gaussian distribution used here meaning that the detection functions in Fig. 3 will be left-shifted to maintain the same false alarm rate.

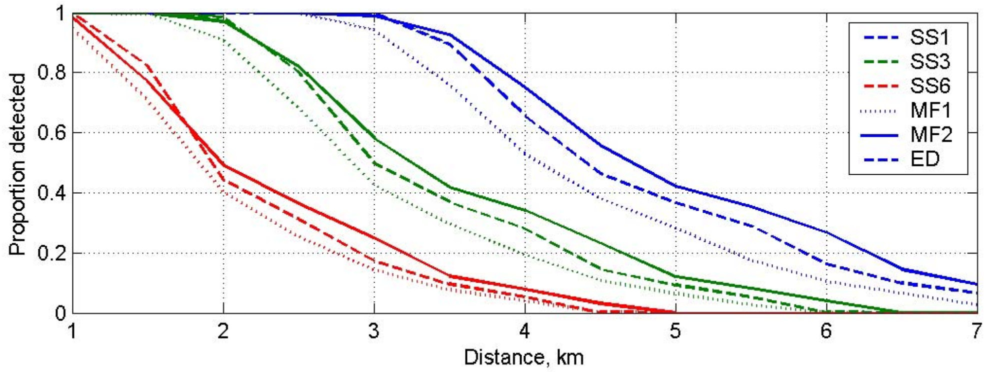

Figure 3: Proportion of clicks in a set of 1300 clicks that were detected in different simulated ambient noise conditions corresponding to sea-state 1, 3, and 6 (in blue, green and red, respectively) as a function of distance. The average false alarm rate was 1 per 21 minutes. Detector designs were: matched filters based on two different click waveforms (MF1 and MF2, dotted and continuous line, respectively), and a 27-46 kHz band-pass energy detector with window length of 220 µs (ED).

Each detector tended to detect clicks when the input SNR was above a roughly range-independent threshold. For the MF1 and ED detectors, this threshold was about 8 dB and 10 dB, respectively (SNR calculated as RMS level of the click over the 95% energy window vs. 27-46 kHz RMS noise level). Extrapolating from Fig. 2, some 2-3% of the clicks made by a whale at 4 km range might then be actually detectable, giving some 70-110 detections per dive. However, this depends critically on the movement of the whale during the dive: a whale moving away from the receiver will clearly provide less detectable clicks than one approaching.

Converting per-click to per-minute detection functions

Ultimately, what may be required in survey and mitigation applications is the probability of detecting a beaked whale given it is within a certain distance of the receiver during a listening interval of N minutes (Zimmer *et al.*, 2008). This performance metric combines both per-click detector performance information like that presented above, and information about the behaviour of the whale. At least three types of behavioural information are involved: (i) the dive cycle - how often does a whale perform a foraging dive and for how long does it vocalize during a dive, (ii) movement patterns during foraging - how often is the sound source likely to be directed close enough to a randomly-placed receiver to achieve detection, (iii) residence time - how long might a whale be available for detection from a system with a limited detection range. As beaked whales tend to swim in small groups and coordinate their foraging dives, the group acoustic and movement behaviour may be yet another influencing factor (Zimmer *et al.*, 2008).

Residence patterns can be derived from visual observations (Aguilar de Soto, 2006), acoustic tracking (e.g., Ward *et al.*, 2008) or from GPS-equipped tags. Arguably, the most direct way to obtain data on dive cycle, vocalization rates and movements during foraging is with multi-sensor acoustic recording tags. However combining these behavioural data with detector performance measures to predict detectability is not trivial. A key intermediate parameter is the effective beam-width of the detector, defined as the range of angles with respect to the animal's acoustic axis in which the receiver must lie for detection at a given distance and in given noise conditions. This summary parameter combines both the detector SNR threshold introduced above and the beam-pattern of the animal. The benefit of describing performance in terms of the effective beamwidth is that orientation measurements from tags can be analyzed to predict how often and for how long in a dive might the animal be pointing towards the receiver with an angle within the effective beamwidth. The effective beamwidth then provides a way of connecting per-click detector performance with animal behaviour as in the example of Fig. 4.

Unfortunately, the beam-pattern of beaked whales is currently uncertain making it difficult to predict the effective beamwidth. The two reports of beaked whale beamwidth available (Zimmer *et al.*, 2005; Ward *et al.*, 2008) differ markedly despite using similar methods suggesting that behavioural factors influence the apparent beamwidth. Both methods used orientation-sensing tags attached to the back of a beaked whale to determine its aspect with respect to a remote receiver. This method suffers from errors due to the relative movement of the head and body of the whale (Zimmer *et al.*, 2005). Beaked whales appear to be able to turn their heads to direct their sonar beam over a wide range of angles in a possible adaptation to echolocation foraging in a cluttered habitat (Madsen *et al.*, 2005). Alternative methods for measuring the beam-pattern (e.g., using multiple distributed hydrophones recording the same click *sensu* Mohl *et al.*, 2003) have yet to be reported. However, what is really required is a statistical description of the beam-pattern with respect to the body axes, i.e., the probability that the beam will be directed in a certain way given the current body orientation and behaviour. These data can be obtained using field methods like those described here and in Ward *et al.* (2008) but multiple trials are required to establish the beam density function with fidelity. In all cases, acquiring more click waveforms from animals at known distances and, to the extent possible, known body aspects, will result in more robust performance predictions.

CONCLUSIONS

For acoustic detection to be widely accepted as a component in survey and mitigation, reliable estimates of detection probability versus false alarm rate as a function of observation time are required that take into account the particular detector configuration as well as the prevailing ambient noise and sound propagation conditions. Ideally, a figure of merit, 'acoustic effort', that describes compactly the likelihood of detecting an animal over a fixed interval, would help normalize surveys and facilitate comparison of results. Although it is not yet clear how acoustic effort should be defined, we can work towards this objective by openly sharing field data and performance evaluation results in a standardized way. Here we describe a method for predicting the performance of acoustic detectors using field-acquired waveforms from beaked whales.

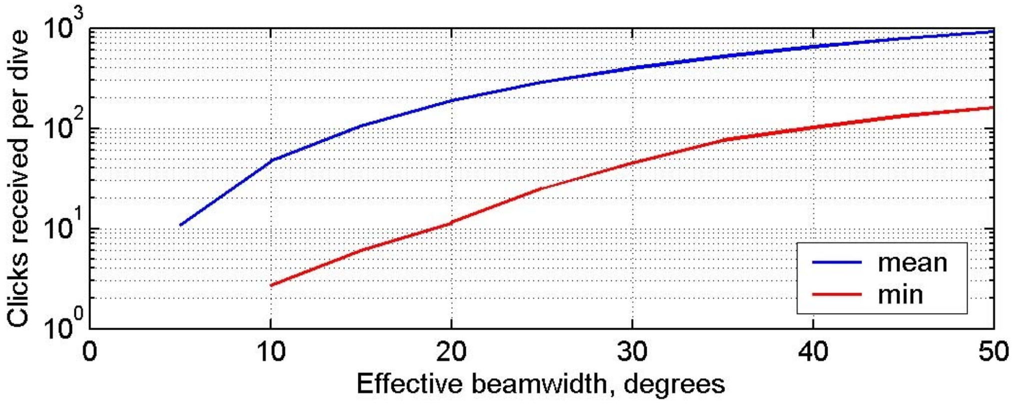

Figure 4: Estimated number of clicks received per foraging dive by a detector with a given effective beamwidth (i.e., range of aspects about the animal's acoustic axis for which detection is possible). This result was obtained by re-playing the orientation at each click, recorded by a tag on a Blainville's beaked whale, for receivers at random bearings from the whale.

The technique involves a low-cost rapidly deployed hydrophone array in tandem with an acoustic recording tag and so is portable to other locations. We show detection of Blainville's beaked whale clicks at ranges of 4 km directly from hydrophone recordings and predict detection of on-axis clicks at up to 6 km by simulation. However, conversion of per-click detection probabilities to detection rates over arbitrary observation intervals is complicated by a lack of reliable information about the sound radiation pattern of beaked whales. As this information becomes available, the realism of the simulation can be improved by incorporating real movement patterns, acquired from tags, and by using real ambient noise waveforms from the target location.

ACKNOWLEDGEMENTS

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12. THE ACCOBAMS PERSPECTIVE ON UNDERWATER NOISE

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ACCOBAMS, the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area, is a special agreement which was created within the framework of CMS (Convention on Migratory Species). The main goal of the Agreement, enounced in its Art. 2.1, is to ensure that "Parties shall take co-ordinated measures to achieve and maintain a favourable conservation status for cetaceans". At the current time (March 2009) ACCOBAMS is ratified by 21 parties. The Agreement's decisions are taken by parties through the adoption of resolutions during their ordinary meetings (roughly every three years). Decisions may be based on recommendations by the ACCOBAMS Scientific Committee.

The issue of anthropogenic noise has been addressed extensively by ACCOBAMS. It was first raised by the Scientific Committee during its second meeting (Istanbul, November 2003), with the adoption of recommendation 2.7, "*with a view inter alia to refine and test existing guidelines on the use of noise in the context of cetaceans (…) and where appropriate, develop new guidelines*". On that occasion a specific management recommendation was made, that "*the ACCOBAMS Parties consult with any profession using … acoustic devices, including military authorities, and urge that extreme caution be exercised in their use in the ACCOBAMS area, with the ideal being no further use until satisfactory guidelines are developed"*.

The noise issue was subsequently addressed by the parties during their second meeting (Palma de Majorca, November 2004), where they adopted a resolution (2.16) urging parties and non-parties to "*take a special care and, if appropriate, to avoid any use of man made noise in habitat of vulnerable species*", "*facilitate national and international research*", and charging the Scientific Committee to "*review the technical bases of this Resolution and to develop by the next Meeting of Parties a common set of guidelines on conducting activities known to produce underwater sound with the potential to cause adverse effects on cetaceans*".

As a result the Scientific Committee endeavoured to develop "*Guidelines to address the issue of the impact of anthropogenic noise on marine mammals in the ACCOBAMS area*", which were adopted during its 4th meeting (Monaco, November 2006) together with a recommendation to parties and non-parties to carefully consider the guidelines in order to regulate and mitigate underwater anthropogenic noise in the ACCOBAMS area. The SC guidelines explicitly addressed military sonar and civil high power sonar, seismic surveys and airgun uses, coastal and offshore construction works, offshore platforms, research (playback and controlled exposure experiments), and mitigation needs.

However, parties at their third meeting (Dubrovnik, October 2007) were unable to reach consensus on the guidelines that they had requested from the Scientific Committee. As a consequence, instead of the guidelines a resolution (3.10) was adopted, urging parties to act in accordance with a series of conservation-oriented principles "as soon as possible", encouraging parties to sponsor research in the ACCOBAMS area to detect and localize beaked whales by passive methods, and deciding, amongst other things, to "*establish a Correspondence Working Group by the Secretariat (…) to address anthropogenic noise deriving from activities such as seismic surveys and airgun uses, coastal and offshore construction works, the construction, the operation and the decommissioning of offshore platforms, playback and controlled exposure experiments, whale watching, blasting of residual war weapons, underwater acoustic devices, military sonar, civil high power sonar operations and shipping activities, in order to develop appropriate tools to assess the impact of anthropogenic noise on cetaceans and to further elaborate measures to mitigate such impacts*".

13. ASCOBANS RESOLUTION ON UNDERWATER NOISE

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INTRODUCTION

The international Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) was concluded in 1991 under the auspices of the Convention on Migratory Species (CMS or Bonn Convention), and entered into force in 1994. In February 2008, an extension of the Agreement area came into force, which changed the name to "Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas". The Secretary General of the United Nations has assumed the functions of Depository of the Agreement. ASCOBANS is open for accession by all Range States (i.e. any state that exercises jurisdiction over any part of the range of a species covered by the Agreement or whose flag vessels engage in operations adversely affecting small cetaceans in the Agreement area) and by regional economic integration organizations.

Originally only covering the North and Baltic Sea, as of 3 February 2008, the ASCOBANS Area has been extended (Figure 1) as follows:

"… the marine environment of the Baltic and North Seas and contiguous area of the North East Atlantic, as delimited by the shores of the Gulfs of Bothnia and Finland; to the south-east by latitude 36°N, where this line of latitude meets the line joining the lighthouses of Cape St. Vincent (Portugal) and Casablanca (Morocco); to the south-west by latitude 36°N and longitude 15°W; to the north-west by longitude 15° and a line drawn through the following points: latitude 59°N/longitude 15°W, latitude 60°N/longitude 05°W, latitude, 61°N/longitude 4W; latitude 62N/ longitude 3W; to the north by latitude 62°N; and including the Kattegat and the Sound and Belt passages."

Any State that becomes a Party to the Agreement after the entry into force of the Amendment shall, unless a different intention is expressed by that State, be considered as a Party to the Agreement as amended.

Ten countries have so far become Parties to the Agreement: Belgium, Denmark, Finland, France, Germany, Lithuania, The Netherlands, Poland, Sweden, and the United Kingdom.

All non-Party Range States are encouraged to join the ASCOBANS Parties in their efforts to conserve the small cetacean species which they share with other countries in the ASCOBANS Area, conscious that the management of threats to their existence, such as by-catch, habitat deterioration and other anthropogenic disturbance, requires concerted and coordinated responses.

One of the conservation management implications of this Agreement Area extension is that it now encompasses deeper waters of the eastern North Atlantic beyond the continental shelf edge. These include important habitats for beaked whale species of the family Ziphiidae.

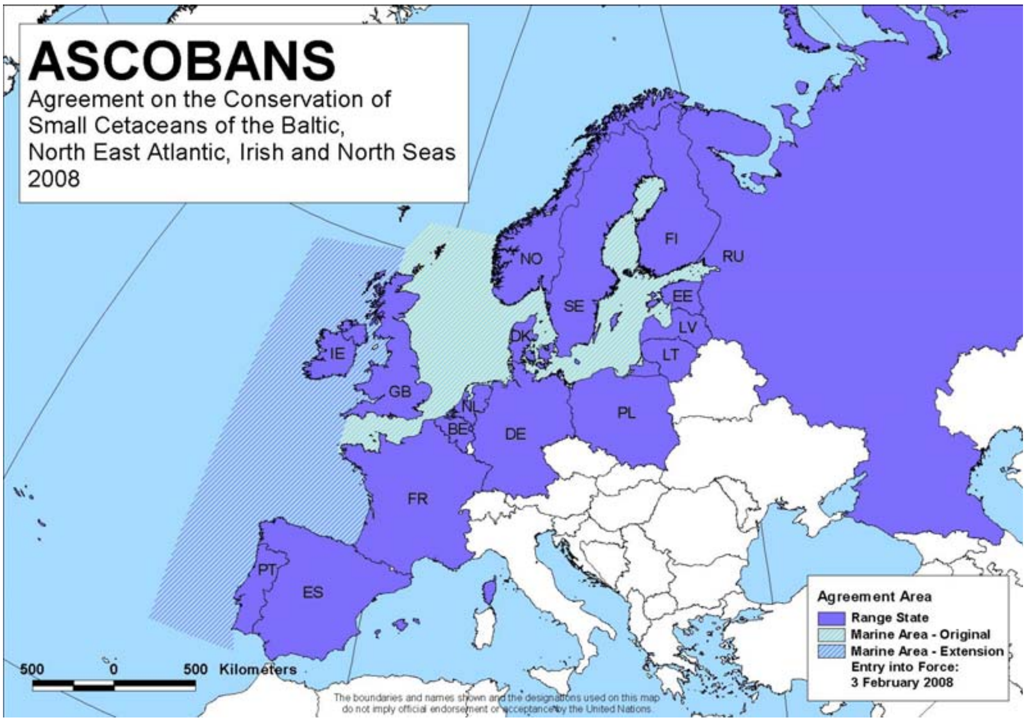

Figure 1. Extension of ASCOBANS Agreement Area, proposed in 2006 and adopted in 2008

STATUS AND DISTRIBUTION OF NORTH ATLANTIC BEAKED WHALES

Six species of beaked whale from three genera within the family Ziphiidae have been recorded within the ASCOBANS Area. These are northern bottlenose whale (*Hyperoodon ampullatus*), Cuvier's beaked whale (*Ziphius cavirostris*), Sowerby's beaked whale (*Mesoplodon bidens*), True's beaked whale (*M. mirus*), Gervais' beaked whale (*M. europaeus*), and Blainville's beaked whale (*M. densirostris*). Of these, only the first four are thought to be resident in the region.

The northern bottlenose whale is found in the temperate and arctic North Atlantic, from the ice-edge to the Azores, particularly in deep waters. Its main areas of concentration, identified from former whaling activities, appear to be west of Norway, west of Spitsbergen, north of Iceland, around the Faroes, and in the western North Atlantic in the Davis Strait off Labrador and The Gully off Eastern Canada (Mead, 1989a; Reeves *et al.*, 1993; Hooker *et al.*, 2008).

The Cuvier's beaked whale is the most widespread of beaked whales, occurring probably world-wide in warm and warm-temperate seas. It has an apparent preference for warmer waters**,** rarely recorded as far north as the British Isles (but with one record from Iceland). Further south it is the most common ziphiid off the Iberian Peninsula, in the Bay of Biscay and it is the only species known to occur regularly in the Mediterranean (Evans *et al.*, 2008e). It is seen year-round in the Canaries.

Within the genus *Mesoplodon*, the most common species in the ASCOBANS Agreement Area is the Sowerby's beaked whale. It is known only from the temperate N Atlantic, mainly in European waters; its distribution is presumably centred upon deep waters of the mid- and eastern North Atlantic, mostly north of other *Mesoplodon* species (Mead, 1989b; MacLeod, 2000; Evans *et al.*, 2003; Reid *et al.*, 2003; Evans *et al.*, 2008a).

The range of True's beaked whale is poorly known. It may be widespread in deep waters of the temperate Atlantic extending to the SW Indian Ocean, since there have been records from eastern North America, NW Europe, NW Africa and South Africa (Mead, 1989b; MacLeod, 2000; Evans *et al.*, 2008b). The great majority of European strandings have been from Western Ireland, with putative sightings of this species in the Bay of Biscay, Azores and Canaries (Evans *et al.*, 2008b).

Gervais' beaked whale is known only from the Atlantic where it apparently favours warm temperate and subtropical waters. The type specimen was found floating in the English Channel in 1848, but most records come from the western North Atlantic (Mead, 1989b, Jefferson and Schiro, 1997; Evans *et al.*, 2008c).

Blainville's beaked whale is one of the most widely distributed species of *Mesoplodon*, recorded from tropical and warm temperate seas of all oceans. In the eastern North Atlantic, there are records from Iceland, Wales, France, Portugal, Spain, and Madeira, but the species is found mainly around the Canaries and in the western North Atlantic (Mead, 1989b, Jefferson and Schiro, 1997, Evans *et al.*, 2008d).

ANTHROPOGENIC SOUND and BEAKED WHALES

Concerns over the negative effects of anthropogenic sound upon members of the family Ziphiidae have primarily related to the use of mid-frequency active sonar (1-10 kHz), as used particularly in military exercises, after a series of mass strandings involving ziphiids (Evans and England, 2001; Evans and Miller, 2004; Cox *et al.*, 2006). No localized mass strandings of beaked whales have been reported in the ASCOBANS region, although an unusually high number of Cuvier's beaked whale (at least eleven) and Sowerby's beaked whale (three), as well as ten long-finned pilot whale *Globicephala melas* strandings occurred at widely separated localities on the west coast of Britain in early 2008 (with further strandings in Ireland). It was not possible to identify cause of death for any of those strandings, since they were not in sufficiently fresh condition for post mortem analysis (Dolman *et al.*, 2010).

Military activities using active sonar take place particularly in four regions within the ASCOBANS Agreement Area: in deep waters off the west coast of Norway; in the North-west Approaches to the British Isles extending to the west coast of Scotland; in the South-west Approaches at the western end of the English Channel and south of Ireland; and in the Bay of Biscay. All those areas are frequented by beaked whales – northern bottlenose whale and Sowerby's beaked whale in the north, Cuvier's beaked whale and Sowerby's beaked whale in the south.

ASCOBANS RESOLUTIONS AND PROPOSED MITIGATION MEASURES

In 2003, the Advisory Committee of ASCOBANS reviewed the possible effects of shipping, recreational and military activities upon small cetaceans in the Agreement Area (Evans, 2003).

During the 5th Meeting of the Parties to ASCOBANS (2006), resolution 4 on *Adverse Effects of Sound, Vessels and Other Forms of Disturbance on Small Cetaceans* “requested Parties and Range States to:

- develop, with military and other relevant authorities, effective mitigation measures including environmental impact assessments and relevant standing orders to reduce disturbance of, and potential physical damage to small cetaceans

- conduct research and develop appropriate management measures, guidelines and technological adaptations to minimize any adverse effects on small cetaceans of the above sound sources

- develop and implement procedures to assess the effectiveness of any guidelines or management measures introduced.”

Resulting from this resolution, the ASCOBANS Triennium Work Plan for 2007-2009 requested that the Advisory Committee should “*continue to review the extent of negative effects upon small cetaceans of sound, vessels and other forms of disturbance on small cetaceans, and to review relevant technological developments with a view to providing recommendations to Parties, by the 6th Meeting of the Parties, on possible ways to mitigate those negative effects*”.

Alongside ASCOBANS resolutions, the European Commission recognised the importance of developing mitigation measures for the adverse effects upon cetaceans of anthropogenic sound. The *Marine Strategy Directive*, as adopted by the EU Parliament on 11 Dec 2007, defines in Article 3, Paragraph 5: “good environmental status” as meaning the “*environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations…… and that anthropogenic inputs of substances and energy, including noise, into the marine environment should not cause pollution effects*.”

EU Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 2010 (Article 26, Paragraph 1).

On behalf of the Advisory Committee of ASCOBANS, an inter-sessional Noise Working Group was established in 2008, with a view to developing guidelines for presentation in September 2009 at the Sixth Meeting of the Parties in Bonn, Germany.

Those draft guidelines contain a number of recommendations to improve monitoring and mitigation within the ASCOBANS Agreement Area. They have been developed alongside those established by Dr Gianni Pavan for the Scientific Committee of the sister Agreement, ACCOBAMS. The main recommendations from this Working Group (ASCOBANS, 2009) specific to military sonar and civil high power sonar are summarised below, under three main phases:

1) Planning Phase

- **a)** Exercise areas need to be well researched beforehand making the best use possible of data from past surveys and predictive models, introducing new surveys where necessary;
- **b)** Avoid important oceanographic features, such as canyons, steep walls, and seamounts, persistent upwellings, and bays, as well as Marine Protected Areas, and known habitat and other high-density areas; and
- **c)** Navies should widely implement (and further develop) passive acoustic monitoring (PAM), as an effective tool for identifying high-density areas in exercise planning, and for real time monitoring of exercise areas

2) Real-time Mitigation

Effective real-time measures include those that are source-based (technical and procedural modifications to reduce emitted level or other damaging noise characteristics such as rise time, wide beam pattern, long durations and duty cycles, activity reduction and sound containment); and those that are operational (establishment of exclusion zones, restrictions to certain times of day or to duration of emissions, improvements in monitoring and reporting, etc).

Specific measures include:

- **a)** Modelling of the generated sound field in relationship to oceanographic features (depth/temperature profile, sound channels, water depth, seafloor characteristics) and with existing background noise;
- **b)** Adopting a scientific and precautionary basis for an exclusion zone rather than an arbitrary and/or static designation, taking account of sound source and propagation characteristics;
- **c)** Mitigation procedures should be practical, using data that can be readily collected by fully trained marine mammal observers (visual and acoustic), accounting for operating conditions and constraints;
- **d)** Mitigation should include monitoring and reporting protocols to provide information on the implemented procedures and their effectiveness, and to provide datasets to be used for improving existing marine mammal databases;
- **e)** During operations, alert existing stranding networks in the area and, if necessary, introduce additional surveillance;
- **f)** Cease operating if any abnormal behaviour, stranding or death occurs that is thought to be related to the activity;
- **g)** If required, organise post-cruise surveys to verify if changes in population density/ distribution, or anomalous deaths have occurred;
- **h)** Restrict use of high power sources at night, during other periods of low visibility, and during significant surface-ducting conditions, since current mitigation techniques are generally inadequate to detect and localize marine mammals. Because of the impact of adverse weather conditions on the visual detection of mammals, emission during unfavourable conditions should be restricted;
- **i)** Passive acoustic monitoring (towed array technology for moving ships, radio-transmitting sonobuoys for stationary operations, or other suitable technologies with enough bandwidth to be sensitive to the whole frequency range of marine mammals expected in the area), should be used to improve detection capabilities. Real-time PAM should be mandatory for night operations or in poor visibility;

j) Before beginning any emission, there should be a dedicated watch of at least 30 mins to ensure that no animals are within the EZ, extended to 120 mins if prolonged divers such as beaked whales have been seen diving on the vessel track-line or if suitable habitats for them are approached;
k) On introducing a sound source, slowly increase acoustic power (ramp-up or soft start) to allow marine mammals sufficient opportunity to leave the ensonified area in the event that visual and passive searches are unsuccessful;
l) The beginning of emissions should be delayed or shut down, if marine mammal species are observed within the EZ or approaching it. Ramp-up should not start until 30 minutes after the animals are seen to leave the EZ, or 30 minutes after they are last seen (120 minutes in case of beaked whales); and
m) Avoid exposing animals to harmful acoustic levels, by changing the ship's course, if applicable, or by reducing (power-down), or ceasing (shut-down) the acoustic emissions.

Post-exercise Monitoring and Reporting

a) Post-exercise monitoring should include cetacean surveys within the exercise area;
b) Transparent reporting to national authorities should occur within a predetermined timeframe; and
c) Procedures for collecting observational data should be based on a standardised protocol

PROPOSALS FOR THE FUTURE

Progress to avoid potential conflict between activities that generate loud sounds and the well-being of cetaceans, particularly beaked whales, will only occur if a number of general actions take place. Probably the most important ones are:

1. Improve communication systems and cooperation between marine mammal scientists, conservation NGOs, national governmental and military authorities, and in liaison with the European Commission (for the ASCOBANS Agreement Area, this is best done through its Advisory Committee, with support from the recently formed Noise Working Group);
2. Develop a better understanding of the causes of mortality to beaked whales that are exposed to active sonar;
3. Promote acceleration of research into mitigation measures for active sonar; and
4. Consider establishing offshore protected areas in specific sensitive regions where routine military activities are restricted

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14. ACTIVE SONAR, BEAKED WHALES AND REGIONAL POLICY

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ABSTRACT

In recent years international and regional conventions, including CMS, ACCOBAMS, ASCOBANS and OSPAR, have shown an increasing interest and concern in marine noise pollution issues within Europe. This has resulted in various reviews, resolutions and guidance from the different fora (for example, ASCOBANS, 2006; ACCOBAMS, 2007; CMS, 2008; OSPAR, 2009). Objectives vary from improving understanding of impacts through increased and co-ordinated research; critically examining existing management measures; and development, implementation and reporting back on mitigation measures undertaken. All acknowledge the significance of marine noise pollution and the potential impacts on cetaceans in general and all highlight concerns surrounding the well-documented impacts of active sonar on beaked whales in particular.

As this political interest has blossomed, the science and science-based policy surrounding the issue has also developed (Boyd, 2008; Southall *et al.*, 2009). It is now widely acknowledged that effective mitigation measures for intense marine noise pollution sources are required for a variety of marine species. Further, it is acknowledged that beaked whale mass mortality events (strandings and mortalities at sea) that result from active sonar use (listed in Hildebrand, 2005) require special consideration (for example Cox *et al.*, 2006).

To determine population level impacts based on percentage 'takes' of individuals (of the sort which form the basis of US environmental legislation for the protection of cetaceans) requires knowledge of population range and size (Elith *et al.*, 2006) and trends over time (Austin, 2002; Cañadas *et al.*, 2005). Baseline population data are not available in Europe for any beaked whale species, and nor are they likely to be in the near future. The exception is some island groups, for example, the Canary Islands and Hawaii, where photo-identification studies for beaked whales are successful. However, traditional ship based survey techniques may not help monitor impacts even if data were available in Europe. Taylor *et al.* (2007) found in a review of US large-ship surveys that the percentage of precipitous declines that would *not* be detected for beaked whales was 90% (where a precipitous decline was determined as a 50% decrease in abundance in 15 yr).

Navy sonar guidance is developed by individual countries for use by their own Navy. On the whole, navies self-regulate and set their own mitigation strategies (Glassborow, 2006). The marine mammal mitigation guidance in use during naval exercises and operations in Europe and worldwide varies widely between regions (Table 1). This lack of consistency needs to be addressed so that a minimum 'best practice' with a scientific basis is adopted worldwide, offering adequate protection to all marine mammal species. Guidance is also needed for the management of naval exercises in waters where no guidance currently exists, perhaps starting with those countries that are members of NATO.

Table 1. Some marine mammal guidance implemented during naval exercises. Y=yes; N=no; N/R=not required (Caron, 2004; Cerutti, 2005; Kvadsheim, 2008; Kvadsheim *et al.*, 2004; Ministry of Defence, 2005; NATO, 2007).

MITIGATION	France	Italy	Norway	NURC	Canary Islands	UK
Selection of area	Y	Y	Y	Y	N	Y
Buffer zone	N	Y	N	N	N	N
Coastal exclusion	N	N	N	N	Y	N
Det sys/database	N	Y	Y	Y	N	Y
Pre/post ded. Survey	Y	Y	Y	Y	N/R	Y
Increased lookout	Y	Y	Y	Y	N/R	Y
Trained observers	N	N	N	N	N/R	Y
Weather/sightability	N	N	N	Y	N/R	Y
PAM	Y	Y	Y	Y	N/R	Y
Other monitoring	N	N	N	Y	N/R	N
Min source required	N	N	Y	Y	N/R	N
Prop. Conditions	N	N	N	Y	N/R	N
Soft start/ramp up	Y	Y	Y	Y	N/R	N
Delay if cet obs'd	N	N	Y	Y	N/R	N
Repeat rampup	N	Y	Y	Y	N/R	N
Pwr dn if cet det	Y	N	Y	Y	N/R	Y
Sonar off if cet det	Y	N	Y	Y	N/R	Y
Exclusion zone	Y	Y	Y	Y	Y	Y
All marine mammals	Y	Y	Y	N	N/R	Y
Cow/calf pairs	N	N	N	N	N/R	N
Other species	N	N	Y	N	N/R	Y
Stranding response	N	N	N	Y	N/R	N
Reporting	N	N	N	Y	N/R	Y
EIA	N	N	N	Y	N/R	Y
Excl. of spec. area	N	Y	N	N	Y	Y
Research	N	N	Y	N	N	N

Further, we are increasingly aware of the limitations of on-board mitigation measures to protect individual animals from injury when close to the sonar source, particularly for species such as beaked whales (see, for example, Parsons *et al.*, 2008; Dolman *et al.*, 2009). Not only are there probably undescribed beaked whale species in our deep open oceans (Pitman, 2002; Yamada, 2002), beaked whales are difficult to observe (Barlow and Gisiner, 2006) and they are already living at their physiological limits (Wright, this volume). Given the low received levels at which beaked whales are likely impacted by active sonar, short range on-board mitigation measures alone are not appropriate to protect individuals or populations (Parsons *et al.*, 2008).

Sonar-related strandings continue unabated. The most recent detailed pathological investigation was conducted on four Cuvier’s beaked whales that stranded in Almeriá, southern Spain in January 2006 (Fernández, 2006), coincident with a NATO naval exercise in the Cartegena Exercise Area (an important habitat for beaked whales). The pathological findings in the Almeria mass stranding were very similar to those in previous “atypical” beaked whale mass strandings associated spatially and temporally with military naval exercises in the Bahamas in 2000 and in the Canary Islands in 2002 and 2004 (Fernández, 2006).

How can we effectively protect beaked whales, species about which we know, from the negative impacts of naval sonar? To ensure protection of all marine wildlife, mitigation of naval sonar should remain inside regulatory frameworks (Dolman *et al.*, 2009). Generally, navy activities including active sonar may be exempt, yet many navies choose to apply environmental legislation.

Implementation of the EU Marine Strategy Framework Directive (EU MSFD), where transposition is to be undertaken by member states by July 2010, provides us with an opportunity. Article 2 of the EU MFSD states: "*This Directive shall not apply to activities the sole purpose of which is defence or national security. Member States shall, however, endeavour to ensure that such activities are conducted in a manner that is compatible, so far as reasonable and practicable, with the objectives of this Directive*." Article 3 defines "*'pollution' means the direct or indirect introduction into the marine environment, as a result of human activity, of substances or energy, including human-induced marine underwater noise, which results or is likely to result in deleterious effects such as harm to living resources and marine ecosystems…*". In Europe, all cetacean species are provided 'strict protection' under the EU Habitats Directive (92/43/EEC).

An appropriate precautionary step for the protection of populations of beaked whale species in European waters is required. As a matter of urgency, and at least until we can begin to understand the mechanisms that lead to deaths in beaked whale populations, effective measures for monitoring and mitigation surrounding the use of mid-frequency sonar SQS-53C should be standardised globally for the protection of populations of beaked whales and other vulnerable species. Available tools include promising passive acoustic monitoring techniques (André *et al.* this volume; Gordon and Gillespie this volume; Johnson and Aguilar Soto this volume) to protect beaked whales in real time as well as spatio-temporal measures for long term exercise planning (Agardy *et al.*, 2007; Dolman, 2007). Important cetacean habitats should be avoided by naval vessels during training and exercises involving either mid- or low-frequency sonar systems (Parsons *et al.*, 2008).

It is currently unclear how the recent US court decisions from California and Hawaii are likely to change the future of guidance in the US Navy, and in other navies operating in European waters and worldwide. However, the most significant environmental gains are achieved at the planning stage (MoD Sustainable Development and Environment Manual, 2005). It is clear that accountability and transparency are important and the production of Environmental Impact Assessments (EIAs), as the US Navy is currently undertaking for its exercise ranges, is a step in the right direction. Production of EIAs and Strategic Environmental Assessments (SEAs) can help with making the right decisions about when and where to operate active sonar. European navies should be undertaking full and transparent EIAs for their exercise activities, including active sonar use.

EIAs should consider behavioural responses in addition to injury in acknowledgement of what we understand from previous beaked whale mortality events (Parsons *et al.*, 2008; Weilgart, 2008). Behavioural responses at much lower sound levels have the potential to produce a range of detrimental effects (e.g. Wright *et al.*, 2007b), including those that may result in injury or death, and given the likelihood that population level impacts can arise from non-lethal exposures (Parsons *et al.*, 2008).

In the tradition of 'polluter pays', navies should continue to fund well-focused, independent research. A commitment from Nations to work with navies to mitigate, to monitor and to report back sonar activities and possible impacts to Conventions to which they are a Party should be observed. The transition from scientific research to policy implementation is a challenging one. The transition from regional policy development to implementation of effective mitigation measures at a national level is no less challenging, but it is urgent in the case of naval sonar and associated beaked whale mortalities. It is also required under European environmental legislation.

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15. THE INTERNATIONAL JURIDICAL FRAMEWORK: PRINCIPLES AND MECHANISMS

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Underwater noise is today considered as a form of pollution[18], to which the relevant international principles and rules apply. The basic principle is set by the 1982 United Nations Convention of the Law of the Sea, Art. 192: "States have the obligation to protect and preserve the marine environment". This obligation is spelled out in more detail in the following articles of the Convention, which make up Part XII, on the Protection of the Marine Environment. Further rules are contained in other international treaties dealing with the protection of specific seas or specific species.

Apart from these rules that apply to the protection of the marine environment generally, there are some instruments of soft law – such as declarations, non-binding resolutions, statements of intents, guidelines – dedicated specifically to the protection of marine species, and primarily marine mammals, from the harmful effects of acoustic pollution. Resolutions have been adopted in the framework, among others, of the International Whaling Commission, ACCOBAMS, ASCOBANS and the Convention on Migratory Species.

It is usually considered that rules on the protection of the marine environment do not apply to military vessels and other craft, as the latter enjoy complete immunity from the jurisdiction of other States. Nonetheless, immunity does not mean that nobody can regulate the construction and operation of military vessels and weapons: these vessels, in fact, are subject to the jurisdiction of the flag State. Immunity therefore means that only the flag State can adopt laws and regulations regarding its own vessels, and only this State can control and enforce these laws and regulations. The flag State, however, has a series of obligations, on the basis of a number of treaties and rules of customary international law, to take measures to ensure that such vessels respect the marine environment.

The first set of rules is contained in treaties applicable during peacetime, which aim at the protection of the environment. Art. 236 of the 1982 United Nations Convention on the Law of the Sea provides that:

"The provisions of this Convention regarding the protection and preservation of the marine environment do not apply to any warship, naval auxiliary, other vessels or aircraft owned or operated by a State and used, for the time being, only on government non-commercial

[18] According to Art. 3 (8) of the *Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)*, 'pollution' means "the direct or indirect introduction into the marine environment, as a result of human activity, of substances or energy, *including human-induced marine underwater noise*, which results or is likely to result in deleterious effects such as harm to living resources and marine ecosystems, including loss of biodiversity, hazards to human health, the hindering of marine activities, including fishing, tourism and recreation and other legitimate uses of the sea, impairment of the quality for use of sea water and reduction of amenities or, in general, impairment of the sustainable use of marine goods and services" (emphasis added).

service. However, each State shall ensure, by the adoption of appropriate measures not impairing operations or operational capabilities of such vessels or aircraft owned or operated by it, that such vessels or aircraft act in a manner consistent, so far as is reasonable and practicable, with this Convention."

This article imposes on the flag State of a military vessel the obligation to adopt appropriate measures to ensure that it does not harm the marine environment. This obligation, however, is limited by the possibility not to adopt measures that would impair operations or operational capabilities of such vessels and by the phrase "as far as reasonable and practicable", which leaves States certain discretion. It has to be remembered that Art. 236 applies only to vessels on non-commercial service. Consequently, military vessels and submarines which have been hired to private entities (such as research institutions or private companies) are obliged to respect the rules in Part XII of UNCLOS on the protection of the marine environment.

The same text is included in Art. 4 (3) of the 1992 Convention on the Protection of the Marine Environment of the Baltic Sea Area, according to which:

"This Convention shall not apply to any warship, naval auxiliary, military aircraft or other ship and aircraft owned or operated by a state and used, for the time being, only on government non-commercial service. However, each Contracting Party shall ensure, by the adoption of appropriate measures not impairing the operations or operational capabilities of such ships and aircraft owned or operated by it, that such ships and aircraft act in a manner consistent, so far as is reasonable and practicable, with this Convention." [19]

An even more environmental friendly provision, since it does not mention the need to preserve the operations and operational capabilities of such vessels, is contained in Art. 3 (5) of the 1995 Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention), providing that:

"Nothing in this Convention and its Protocols shall affect the sovereign immunity of warships or other ships owned or operated by a State while engaged in government non-commercial service. However, each Contracting Party shall ensure that its vessels and aircraft, entitled to sovereign immunity under international law, act in a manner consistent with this Protocol."

A second set of rules is to be found in international treaties that apply principally during wartime and which set the basic rules concerning the use of weapons. The 1977 Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts, contains two provisions particularly relevant. According to Art. 35 (1) and (3):

"1. In any armed conflict, the right of the Parties to the conflict to choose methods or means of warfare is not unlimited.

[19] A very similar provision is contained in Art. 4 of the Bucharest Convention: "This Convention does not apply to any warship, naval auxiliary or other vessels or aircraft owned or operated by a State and used, for the time being, only on government non-commercial service. However, each Contracting Party shall ensure, by the adoption of appropriate measures not impairing operations of such vessels or aircraft owned or operated by it, that such vessels or aircraft act in a manner consistent, so far as is practicable, with this Convention."

3. It is prohibited to employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment."

Furthermore, Art. 55 of the 1977 Protocol, which is devoted to the protection of the environment during conflicts, provides that:

"1. Care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby to prejudice the health or survival of the population.

2. Attacks against the natural environment by way of reprisals are prohibited."

It is to be stressed that these provisions apply during wartime, when States parties to the conflicts have a wider liberty in action and may disregard certain rules applicable during peacetime. Consequently, the protection of the environment is considered so important, that even during an armed conflict – that is, war – it cannot be seriously harmed.

If therefore States have such pressing limitations during wartime, it is evident that their possibility to have recourse to weapons that harm the environment will be even more limited during peace time. It is relevant to note that, so far, sonar linked with harmful effects for beaked whales has been used during military exercises, which are peacetime activities: the stricter standards should therefore apply. It is true that the negative effects of this type of weapon may have not been known when it was first used, but this does not exempt States from eventual responsibility. Art. 56 of the 1977 Protocol, in fact, provides that:

In the study, development, acquisition or adoption of a new weapon, means or method of warfare, a High Contracting Party is under an obligation to determine whether its employment would, in some or all circumstances, be prohibited by this Protocol or by any other rule of international law applicable to the High Contracting Party.

States have therefore to make sure that each weapon they intend to use is not contrary to any international law rule, including the obligation not to cause "widespread, long-term and severe damage to the natural environment".

In summary, under international law States have the obligation to protect the marine environment, to adopt all appropriate measures ensuring that military vessels flying their flag do not pollute, as far as possible, the marine environment and to test the weapons they intend to use in order to make sure that they will not cause widespread, long-term and severe damage to the natural environment. Until there are some generable acceptable standards, however, it will be very difficult to assess the compliance of a State with these requirements.

It is therefore particularly important to identify the best forum for the discussion of such issues and the adoption of the relevant regulations and standards. It is evident that international cooperation in this field is particularly important as military vessels sail through all the seas and as the effect of some weapons (like sonar) may cause transboundary effects. The choice of the competent body or organisation is therefore crucial in the discussion and adoption of any kind of measures.

Two paths can be chosen: the first is to work through the competent global international organisations, such as the United Nations, through the Division for Ocean Affairs and the Law of the Sea, or the UNEP; the second is to pursue action at the regional level. The international organisations that could have a role to play in Europe are principally regional organisations for the protection of the marine environment (Barcelona Convention, OSPAR, HELCOM) or, more specifically, for the protection of cetaceans (ASCOBANS and ACCOBAMS). In any event, it is evident that discussions will have to involve all interested parties and be based on the best available data, so as to arrive at a commonly agreed regulation.

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