

PROCEEDINGS OF THE ECS BEST PRACTICE WORKSHOP

Flying Forward: Innovations, Ethics, and Best Practices for Unmanned Aerial Vehicles in Marine Mammal Research

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CONTENTS

1. Dolman, S.J., Hague, E. and Stainfield, C. Overview and workshop recommendations	X
2. Hague, E., Stainfield, C. and Dolman, S.J. UAV survey results.....	X
3. Stainfield, C. Conducting routine drone surveys of grey seals (<i>Halichoerus grypus</i>) at Forvie National Nature Reserve.....	X
4. Folmer, E. & Aarts, G. Using UAVs to monitor body condition of seals?.....	X
5. Vivier, F. <i>et al.</i> Drone-based monitoring of marine mammals: applications, workflows, and best practices from dolphin and monk seal studies.....	X
6. Veys, M-L. <i>et al.</i> Shore-based drone operations for killer whale behavioural research in a Norwegian Fjord System.....	X
7. Hewitt, R.C., Rapson, K. & Cheney, B.J. Integrating UAVs into Marine Mammal Research – harbour seals and bottlenose dolphins	X
8. Manthorpe, S. <i>et al.</i> Higher predators UAV monitoring in Ireland.....	X
9. Ceolotto, L. & Fiore, E. Collecting blow from bottlenose dolphins.....	X
10. Castro, J. <i>et al.</i> Integrating Drones into Marine Mammal Research: Practices and Insights from AIMM	X
11. Stainfield, C. Global examples of drone guidance and legislation.....	X
12. Hall, K. Drones and conservation legislation in Scotland	X
13. Discussion, key points and recommendations.....	X
14. List of Participants	X
15. Agenda	X

1. OVERVIEW & WORKSHOP RECOMMENDATIONS

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BACKGROUND AND INTRODUCTION

Unmanned Aerial Vehicles (UAVs) or drones are increasingly being used in marine mammal studies on a wide range of species in all the world's oceans. UAVs are used for a variety of applications including aerial surveys, species monitoring, abundance estimates, biological sampling and health monitoring, understanding habitat use, population dynamics and social structure, as well as biometrical thermology.

One of the main benefits of using UAVs to research and observe marine mammals is the new perspective provided by the aerial vantage point. Their use for research purposes can provide a potentially cost-effective and non-invasive tool to reduce the use of boats for close proximity approaches thus reducing risk and noise disturbance, can improve viewing limitations related to terrestrial/vessel-based vantage points and overall can increase the detail of observations while simultaneously potentially reducing the potential for observers' presence to influence behaviour.

However, there are still disturbance risks associated with UAV use, and these must be carefully assessed. The workshop covered the objectives of studies using UAVs, types of UAVs, scientific strengths and weaknesses with respect to meeting objectives for different species, age classes and study areas. Levels of actual and potential disturbance to animals were discussed and consideration was given of trade-offs when deciding study methods (including flight height and duration) and UAV types to use.

This is a fast-moving area of field research. Researchers with experience of operating UAVs around marine mammals were invited to present their results in this one-day workshop. Case studies presented included data from research projects that integrate UAVs to understand population assessment, habitat use, human pressures, body condition and behavioural studies. The workshop also covered examples of current UAV legislation and guidance.

In addition, prior to the workshop an online questionnaire was distributed globally via marine mammal forums and networks. The results of this survey, summarised from 95 responses, are identified in this report (Section 2) and inform us about the current use of UAVs for marine mammal research globally. A goal of the questionnaire was to highlight emerging approaches, share lessons learned and to help inform future projects and best practice, as well as capturing the diversity of applications, species, project goals and researcher experiences associated with drone use in marine mammal science.

Discussions with the audience followed the presentations (see section 2). Key recommendations resulting from the workshop are listed below.

KEY WORKSHOP RECOMMENDATIONS

Human and wildlife safety

- Human and wildlife safety procedures and safety practices are paramount and should be considered at all times. Drone operators should be familiar with the data protection and safety aspects in CAA guidance, and follow the latest CAA guidelines at all times.

Marine mammal drone-specific guidance

- There is a need for development of marine mammal drone specific guidance and/or training.

- The development of such guidance should include consideration of existing global UAV legislation and any marine mammal measures that are available already. Any guidance or certification related to the use of drones within marine mammal research should be considered by any relevant organisations, as part of their ethical approval process, where and when relevant.
- Monitoring, understanding and importantly, reporting details of observed disturbance is necessary, particularly as species and activity specific differences in behaviour, including thresholds for disturbance, are likely.
- It is important that the drone operator and/or field team are familiar with ‘normal’ behaviour and are therefore receptive enough to be responsive to behavioural change(s) and then act accordingly.
- The development of standard operating procedures might act as a baseline and be adjusted accordingly and will also allow for comparative analysis across the field.

Recreational drone use

- It is important to create public awareness around the differentiating scientific use of drones and its benefits for conservation and research.
- Recreational drone use requires management because of observed disturbance impacts associated with the poor use of drones around marine mammals. Advice is required to be developed in relation to recommended flight heights, distances and approach recommendations for recreational users.

This workshop was held as one of a series of ‘Best Practice’ workshops organised by the European Cetacean Society (ECS) Scientific Advisory Committee. The workshop took place on Sunday 21st April at the Malmaison Hotel, Dundee, Scotland before the start of the 37th Annual European Cetacean Society conference. It was attended by more than 100 people. A list of participants is provided at the end of the workshop report.

The workshop organisers / chairs are grateful to all the workshop presenters and participants for their role in making the workshop an interesting and successful day. We are very grateful to the ECS Scientific Advisory Committee for covering the costs of the workshop so that there was no attendance fee.

2. Using drones for marine mammal research and monitoring

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A questionnaire survey was designed by the workshop organisers and distributed, via the MARMAM list-serve, social media and our own networks, to capture how drones are being used for marine mammal research. The survey consisted of several tick-box or open-ended questions and took 5-15 minutes to complete. Ethics approval for the questionnaire was received from the University of the Highlands and Islands (UHI) under Application ID: ETH2526-0829.

Prior to the workshop, 95 responses were received. The results were presented to the workshop participants in two short sessions and are summarised below.

1) How drones are being used for marine mammal research and monitoring

Participants responded that drones were being used in 42 countries (the top 10 countries were the USA, Australia, Mexico, Canada, Brazil, Ireland, Portugal, Scotland (UK), Denmark and Spain) and for over 60 species of marine mammals (the top 10 species were bottlenose dolphin, *Tursiops truncatus*, humpback whale, *Megaptera novaeangliae*, fin whale, *Balaenoptera physalus*, common dolphin, *Delphinus delphis*, grey seal, *Halichoerus grypus*, killer whale, *Orcinus orca*, Bottlenose dolphin (Indo-Pacific), *Tursiops aduncus*, southern right whale, *Eubalaena australis*, sperm whale, *Physeter macrocephalus* and harbour seal, *Phoca vitulina*).

The primary aims of drone use listed in survey responses are listed in Table 1.

Table 1. The primary aims of drone use, according to responses to the questionnaire

Primary aim of drone use	Number of respondents
Behavioural observations	72
Photogrammetry (size/condition)	71
Abundance/counts	47
Habitat use	22
Blow/respiratory sampling	21
Photo-identification	7
Health assessment (e.g. entanglement, scarring, informing rescue)	6
Tagging	3
Acoustics	2
Biopsy	1
Detection of mother-pup pairs	1

The main considerations or limitations of using UAVs with marine mammals were considered to be weather limitations (36%), regulatory constraints (e.g. flight distances or height) (23%), technical limitations (16%), potential disturbance (12%), data processing time (11%) and others (2%).

Almost half of the responders (48%) added additional equipment to their UAVs, including LiDAR/laser altimeter/rangefinder, petri dishes, tagging equipment, handles for hand catching, additional lens (i.e. zoom, no distortion lens), thermal camera, hydrophone, water landing equipment and air quality monitoring kit.

The majority (68%) of researchers collect drone data themselves, 51% of whom have obtained UAV pilot certification and 36% had completed another form of training (e.g. research-specific, organisational/internal).

Many (39%) collect data using drones just occasionally (every few months), 20% collect data monthly, 15% weekly and 7% daily.

Most (68%) conduct flights using fully manual control. Almost half (45%) operate UAVs from land and from a boat, 36% from a boat and 14% from land only.

2) *Best practises and available guidance*

Almost half of respondents (48%) have specific drone take off/landing procedures related to marine mammal operations.

In response to a question about whether the researcher had observed potential disturbance from UAV operations, 58% responded that they had not, 36% *had* observed potential disturbance and 6% were unsure. Many examples of disturbance were provided.

When asked if a minimum UAV flight height was applied when operating over marine mammals, 82% said yes. The questionnaires provided a range of preferred flight height which varied according to the research objective, and the marine mammal species surveyed listed in Table 2.

Table 2. Preferred flight height, depending on research objective, according to responses to the questionnaire.

Note, results are displayed for illustrative purposes to display survey results, the workshop, authors and organisers do not necessarily recommend these heights as best practice.

Preferred flight height (m)	Research objective	Species
80	Availability estimate	Australian humpback dolphin, Indo-pacific bottlenose dolphin
5-100	Behaviour (including focal follows, pod overview, and tracking)	Antilean manatee, dugong, bottlenose dolphin, sperm whale, common dolphin, spotted dolphin, spinner dolphin, minke whale, Australian humpback dolphin, Indo-pacific bottlenose dolphin, North Atlantic right whale, blue whale, fin whale, humpback whale, California sea lion, pilot whale, southern right whale, northern bottlenose whale, mediterranean monk seal
1-5	Blow Sampling	Common dolphin, bottlenose dolphin, Spotted dolphin, spinner dolphin, minke whale, sperm whale, fin whale, blue whale, humpback whale, orca, Northern Atlantic right whale, Short-finned pilot whale, beluga whale, goose-beaked whale, sei whale, northern bottlenose whale, Southern right whale
15-50	Body Condition (including health assessment, and scarring analysis)	Southern right whale, grey seal, beaked whales, killer

		whales, mediterranean monk seal
40-100	Counts	Grey seal, Antilean manatee, dugong, fur seal, elephant seal, spotted seal
15-50	Photo ID	Bottlenose dolphin, sperm whale, spinner dolphin, orcas, porpoises, humpback whale, southern right whale, mediterranean monk seal
3-5	Tagging	Blue whale, sei whale, humpback whale, killer whale, northern bottlenose whale, sowerbys beaked whale, sperm whale, North Atlantic right whale, fin whale, minke whale, short-finned pilot whale, beluga, goose-beaked whale
90	Thermal signature	Humpback whale
0	Underwater acoustic recordings	Grey whale
15-55	Photogrammetry	Antilean manatee, dugong, bottlenose dolphin, spinner dolphin, Orca, harbour porpoise, fin whale, grey seal, humpback whale, North Atlantic right whale, fin whale, minke whale, short-finned pilot whale, beluga whale, harbour seal, goose-beaked whale, sei whale, Blue whale, common dolphin, northern bottlenose dolphin, Southern right whale, spotted seal, mediterranean monk seal
10-120	Aim not specified	Beluga whale, Atlantic humpback dolphin, bottlenose dolphin, long-finned pilot whale, fin whale, dugong, franciscana dolphin, grey seal, harbour seal, Guiana dolphin, harbour porpoise, elephant seal, ringed seal, humpback whale, Southern right whale, Bryde's whale, sei whale, minke whale, hector's dolphin, maui dolphin, common dolphin, orca, sperm whale, manatee, mediterranean monk seal

When asked about legislation and guidance, 84% and 78% responded that there is drone-specific legislation and mandatory guidance respectively in the country they operate in. In addition, 44% stated there is mandatory guidance specific to operating drones specifically around marine mammals in their country, 12% identified voluntary guidance, 29% responded none is available and 27% were unsure.

3. Conducting routine drone surveys of grey seals (*Halichoerus grypus*) at Forvie National Nature Reserve

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This study presents an example for the use of drones for monitoring grey seals (*Halichoerus grypus*) within a highly dynamic coastal system at the Forvie National Nature Reserve, Aberdeenshire. The research aims to quantify seal abundance, age structure, and spatial habitat use through non-invasive aerial surveys, while also evaluating interactions between wildlife and human recreation in a seal protected area.

Data collection was conducted using small, commercially available drones (Parrot Anafi <500 g and DJI Mavic 2 Enterprise <1 kg), selected for their low noise output and minimal visual disturbance. Surveys utilised pre-programmed automated flight transects (*Pix4Dcapture v2.3.0* and *DJI GS Pro v2.0.17*), flown at consistent altitudes of 50 m with nadir imagery and 80% overlap to enable photogrammetric outputs. Flights were restricted to <18 minutes, conducted within Visual Line of Sight, and launched >100 m from seal aggregations and >30m from uninvolved people, with take-off and landing procedures designed to minimise disturbance. Surveys were carried out weekly for two years, where weather permitted, during daylight hours and within ± 2 hours of low tide.

Drone imagery was processed (*Pix4Dmapper v4.10.1* and *Agisoft Metashape v2.3.0*) to generate orthomosaic images, which were analysed (*QGIS v3.44.8*) for manual digitisation of individual seals and spatial distribution mapping. Kernel density estimation and temporal analyses were used to identify patterns in seal abundance and habitat use. These datasets were further integrated with human activity data to assess spatial overlap and potential disturbance risk. The data revealed seasonal patterns in resting location choice and therefore proportion of seals at disturbance risk. Single drone images were also compiled as an extensive training set for use in producing a machine-learned algorithm (*Rootpainter*) for seal detection and automated abundance counts.

All fieldwork was undertaken under NatureScot research permit approval and in compliance with UK Civil Aviation Authority (2026) regulations. The research aligns with national legislation under the Marine (Scotland) Act 2010 and guidance such as the Scottish Marine Wildlife Watching Code (2016). The researcher holds a drone pilot licence with A2 Certificate of Competency (A2 CofC), supported by 10+ years field-specific experience in seal behaviour observation, monitoring and disturbance mitigation. Paid observers (student interns), who maintained records of interactions, bird species, human presence and flight hazards, were utilised throughout the study.

The use of drones provided significant benefits, including high-resolution spatial data, a repeatable survey method, increased accuracy compared to ground counts, contribution to improved efficiency in data processing and, quantified recording and reporting of disturbance events. This work demonstrates how low-impact drone methodologies can support evidence-based conservation management. At this site this includes informing mitigation strategies such as signage and visitor guidance, while contributing to broader understanding of sustainable wildlife tourism in a protected coastal environment.

Key lessons learned and recommendations from this work emphasise that:

- (1) **Platform choice** – no disturbance was recorded from research flights using small, low-noise drones;
- (2) **Flight design** – reaching altitude (50 m) before approaching survey area, maintaining consistent altitudes, minimising time over animals, and avoiding complex manoeuvres near wildlife all mitigated disturbance risk to birds and seals during our research at the site;
- (3) **Launch site selection is often more important than flight path** – traverse to launch site and distance

between operator activity and wildlife was important to align with reserve conservation aims and site protection legislation (schedule 1 breeding birds access);

(4) **Environmental conditions drive survey effort** – aligning flights with optimal conditions was essential for surveying, weather had an influence on data collection with 413 (58%) no-fly days out of a total of 709 days related to wind and precipitation;

(5) **Data-processing time is substantial** – high-resolution outputs require significant post-processing, both as manual digitisation and input into training algorithms with machine learning;

(6) **Early Engagement with reserve management team produced greater impact of science** –providing research outputs with quantifiable data to provide actionable insights for management, including informing signage and visitor guidance;

(7) **Clear disturbance thresholds and abort protocols** – pre-defined behavioural indicators and emergency flight plan responses were critical components to pre-survey planning for reassurance of new technology in the area.

The study demonstrates that low-cost UAV systems can provide high-quality ecological data while maintaining low disturbance when guided by robust protocols. Importantly, it highlights that best practice extends beyond flight parameters alone, requiring integration of training, legislation, site-specific knowledge, and adaptive management. These findings contribute directly to the development of practical guidelines for responsible drone use in marine mammal research and conservation.

References:

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4. Using UAVs to monitor body condition of seals?

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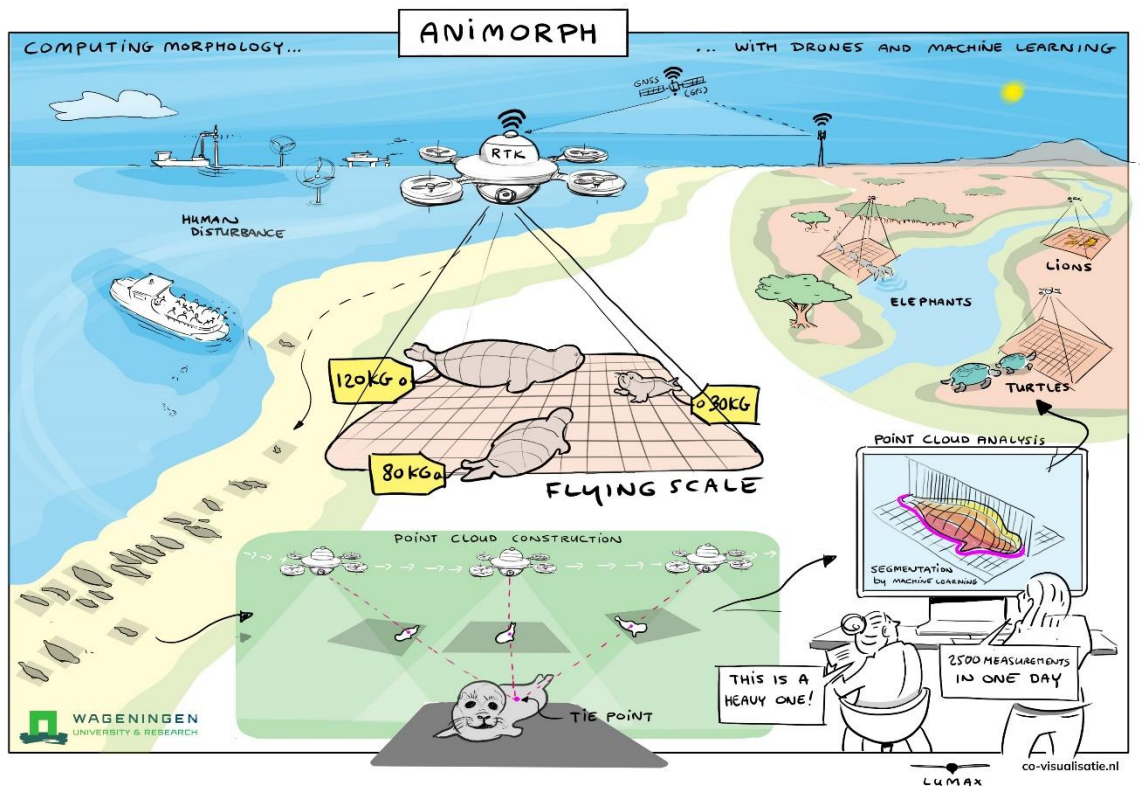
Increasing human activities in the North Sea may compromise the foraging success of marine mammals, potentially causing nutritional stress with downstream consequences for reproduction, survival, and population dynamics. Identifying the periods during which marine mammals are most vulnerable to disturbance is therefore of conservation importance, and seasonal variability in body condition may serve as a key indicator of such vulnerability. Yet seasonal fluctuations in body condition in wild marine mammal populations remain poorly understood.

This project investigates the applicability of drone-based photogrammetry for assessing the body condition and nutritional status of harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in the Dutch Wadden Sea. Recent advances in drone technology offer a non-invasive means of estimating body condition through morphometric measurements derived from aerial imagery, enabling sampling across entire haul-out and breeding areas (including locations inaccessible to ground-based observers), while minimising disturbance.

The study comprises four interconnected phases: (1) flight planning and data acquisition through repeated drone surveys; (2) development of automated analytical workflows incorporating photogrammetry, object detection, image segmentation, and point-cloud analysis; (3) data analysis and validation to assess methodological reliability and address ecological questions; and (4) reporting and recommendations for long-term monitoring applications.

Initial surveys have been conducted using Autel Robotics EVO II RTK and DJI M4E-RTK platforms (20 MP, 4/3-inch CMOS sensor) at altitudes of 25–120 m, yielding ground sampling distances of 0.4–3.2 cm/pixel. Observations confirmed minimal disturbance responses. Image processing utilises Agisoft Metashape for orthomosaic and point-cloud generation, YOLO for seal detection, and the Segment Anything Model (SAM) for body outline segmentation.

Ultimately, this project aims to deliver a standardised, drone-derived body-condition index suitable for ecological modelling, while generating scientific evidence to support management measures that protect seals during periods of peak nutritional vulnerability.



5. Drone-based monitoring of marine mammals: applications, workflows, and best practices from dolphin and monk seal studies

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Unoccupied aerial systems (UASs) are increasingly used in marine mammal research as non-invasive tools to collect high-resolution data on individuals and populations. This presentation provides a practical overview of drone applications across multiple species, with a focus on workflows, best practices, and operational considerations. We present case studies from bottlenose dolphins (*Tursiops truncatus*), spinner dolphins (*Stenella longirostris longirostris*), and Mediterranean monk seals (*Monachus monachus*), where UASs were used for photogrammetry, population assessments, photo-identification, body condition estimation, and behavioural observations. Drone platforms included DJI Inspire 2 and Mavic 3 Pro systems, with custom-fit laser altimeters and Lidar systems used to improve measurement accuracy. Data collection protocols are described for vessel-based operations, including take-off and landing procedures, flight altitudes, and communication between team members. We also touch on surveys conducted across multiple field seasons, with repeated flights enabling the collection of individual-level and population-level data. We outline analytical workflows using tools such as MorphometriX and Whalength, including image selection, altitude correction, measurement extraction, and data management. Training requirements and certification processes (e.g. Australia RePL, USA Part 107) are discussed, alongside key regulatory frameworks governing UAS operations and research permits in marine environments. Briefly, these approaches have enabled, in the study systems discussed here, the quantification of dolphin age-structure as an indicator of population status, as well as the assessment of body condition and behaviour in monk seals, demonstrating the versatility of UAS-based methods. Finally, we highlight the main benefits of UASs (e.g. access to remote areas, improved data quality, reduced disturbance), as well as important considerations, including weather constraints, battery limitations, potential disturbance to animals, and the importance of robust field protocols and team communication. Based on these experiences, we provide practical recommendations for the effective and responsible use of drones in marine mammal research.

6. Flying in the fjord: lessons from shore-based drone surveys of killer whales in Hardangerfjord, Norway Veys, M-L.

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Background

Unmanned aerial vehicles (UAVs) have become a widely adopted tool for non-invasive observation of cetacean behaviour, enabling fine-scale data collection that would otherwise be unattainable from surface level. However, the practical and logistical challenges of deploying drones in complex coastal environments, particularly fjord systems with limited road access, unpredictable weather, and increasingly frequent use of recreational drones by bystanders, remain underreported. This contribution presents field experience from one season of shore-based drone surveys targeting killer whales (*Orcinus orca*) in Hardangerfjord, Vestland county, Norway.

Methods

Data were collected between February and April 2025, targeting three killer whale groups known to seasonally enter Hardangerfjord. We conducted aerial video surveys using a DJI Mavic 3 Enterprise equipped with a wide-angle and 56x hybrid zoom camera at 4K resolution. All flights were shore-based as the primary approach, with one session conducted from a 4.6m fibreglass motorboat (Yamarin 4730, 50 hp). A minimum flight altitude of 25m above the sea surface was maintained throughout, with camera angles ranging from 45° to nadir. All operations complied with Norwegian Civil Aviation Authority (CAA) drone regulations, and the operator holds an A1/A3 EASA drone pilot licence. Across 7 sighting days, we completed 68 group follows totalling 594 minutes of flight time. A second team member maintained visual contact with the animals at all times and operated a DSLR camera (Nikon D7000, 70 200mm lens) for complementary photo-identification. Killer whale sightings were located in real time via the citizen science Facebook group 'Spekkhoggara i Hardanger'. Aerial footage was subsequently analysed using BORIS (v8.27) for behavioural event coding, and statistical analyses were performed in R (v4.3.3).

Results

We recorded 45 collective deep dives and 274 social interactions across three groups. Adult females initiated 82% of group dives, significantly more than males or juveniles, supporting the presence of unshared decision-making linked to age-sex class. Social interactions, synchronised surfacing and physical contact, were most frequent in adult female-calf dyads and were context-dependent, occurring rarely during foraging. These findings are reported in a manuscript accepted for publication in *Animal Behaviour* (Veys et al., in press).

Field challenges and key lessons

Operating in a fjord system presents specific logistical constraints that are rarely addressed in published drone protocols. Fjord road networks do not continuously follow the coastline, meaning that when killer whales moved through the fjord, vehicle repositioning could require detours of up to one hour, while the animals simply continued swimming. Shore-based operations were therefore planned around pre-identified launch locations, and the two person setup (pilot and observer) was essential for maintaining animal contact during transitions. A rigid boat was used as a supplement on one occasion, providing greater mobility at the cost of increased operational complexity. A critical incident during the 2025 field season highlighted an underestimated risk: concurrent recreational drone use by bystanders. On one occasion, a third-party operator flew a drone over the study animals at an altitude below 25 m, the minimum recommended height for cetacean drone surveys. Despite our request to maintain altitude, the operator did not comply. Visible behavioural responses in the killer whales were recorded

on video and are presented as part of this talk. This incident rendered the concurrent footage unsuitable for inclusion in our study of natural behaviour, directly compromising data integrity. This experience underscores the urgent need for clearer national guidelines and, where possible, site-specific coordination protocols to manage concurrent drone use in areas where cetacean research is conducted. Currently, no specific national guidelines exist in Norway for the use of drones over marine mammals.

Recommendations

Based on one field season in this system, we suggest the following practical recommendations for researchers planning drone-based cetacean surveys in fjord or complex coastal environments: (1) conduct pre-season location scouting to identify and test shore-based launch sites and map road access constraints; (2) always operate with a minimum of two people, i.e. one pilot and one dedicated observer; (3) invest in a drone equipped with a zoom camera to maintain large observation distances while preserving individual-level detail; (4) account for cold temperature effects on battery performance, particularly at temperatures below -10°C ; (5) consider a boat as a valuable fallback in areas where road access is consistently limiting, but avoid relying on it as the primary data collection platform. Boat operations increase logistical complexity and, even when minimum approach distances are respected, carry a greater risk of animal disturbance compared to land-based alternatives; and (6) develop a protocol for managing or communicating with recreational drone operators in shared airspace.

7. Integrating UAVs into Marine Mammal Research – harbour seals and bottlenose dolphins

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Accurate individual-level data underpins effective conservation and management of marine mammals. Unoccupied aerial vehicles (UAVs) offer an effective means of collecting such data, especially morphometric and health information, that can be difficult to obtain by traditional methods. When integrated with long-term, individual-based studies, UAV data can enhance our understanding of population dynamics and inform management decisions. The University of Aberdeen Lighthouse Field Station has incorporated UAV surveys into two long-term research programmes in Scotland: bottlenose dolphins in the Moray Firth Special Area of Conservation and harbour seals at Loch Fleet National Nature Reserve. For bottlenose dolphins, boat-based UAV surveys provide aerial images and video for photogrammetry. We extract body morphometrics, including length and width, and link these to life-history data such as age, sex, and reproductive status. This allows us to monitor reproductive success and track changes in growth and body condition over time. We discuss the challenges of matching individuals in UAV images to our existing photo-ID catalogue. Works are also underway to extract information from UAV footage on the fine-scale movement and behaviour of dolphins under different social and behavioural contexts. Linking this information with life history data of known individuals (age, sex and relatedness), will provide powerful insight to the social dynamics of these group living animals. The use of AI models is being explored to allow automated detection and tracking of dolphins in aerial videos, and observations will also be paired with synchronous 4-channel acoustic recordings to further investigate acoustic communication. For harbour seals, UAV surveys have replaced land-based techniques to monitor this population. UAV imagery enables accurate counts of different age classes and species, photo identification of individuals across the haul-out and spatial mapping of seal distribution. Ongoing work is exploring the use of UAV photogrammetry to assess morphometrics, body condition, and reproductive status, as well as the potential for AI matching of individual seals. Using these two case studies we outline practical insights of UAVs in marine mammal research, including survey design, flight operations, image processing, data management, insurance and regulatory and licencing requirements. We also discuss the benefits and limitations of UAV surveys including repeatability, cost effectiveness, weather constraints, communication, image quality, and knowing when not to fly.

8. Higher predators UAV monitoring in Ireland

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Unmanned aerial vehicles (UAV) are increasingly used to survey marine mammals and higher predators, providing insight into population dynamics, spatial ecology, animal health, as well as many other ecological research questions. Ireland hosts many important marine mammal species, such as grey seals (*Halichoerus grypus*), that can benefit from the growing use of drones to monitor their ecology. As part of Ireland's first national marine park, Páirc Náisiúnta na Mara, Ciarraí, drones are being used to monitor grey seals haul-out dynamics, pupping, spatial distribution and body condition. A variety of drones are used to monitor grey seals across the marine park, namely the DJI Mavic 3TA, DJI Mavic 3T and DJI Air 2S. Flights are carried out monthly from both boats and land to collect visual and thermal imagery, with standardised protocols for deployment, data and metadata collection, disturbance monitoring and recovery. All flights are subject to EU regulations and Irish Wildlife Act permits. Imagery is stitched using Drone2Map with corrections done using ground control points. Annotations and further analyses are carried out in ArcGIS, QGIS and R.

9. Collecting blow from bottlenose dolphins

Ceolotto, L. & Fiore, E.

Non-invasive genetic sampling can improve cetacean conservation by reducing disturbance while providing information on population structure and connectivity. In this study, we evaluated the feasibility of UAV-assisted blow sampling for obtaining host DNA from free-ranging common bottlenose dolphins (*Tursiops truncatus*) in two Mediterranean areas: The Gulf of Ambracia (Greece) and the Gulf of Trieste (off Piran, Slovenia). Blow samples were linked to photo-identified individuals and assessed through UAV video review. Mitochondrial DNA amplification was successful in 78% of Greek and 100% of Slovenian samples, whereas a nuclear marker amplified only in the positive under human care control, indicating that mtDNA is currently the most reliable target for blow-derived low-template DNA. Fifteen individuals were sequenced for up to six mitochondrial loci, and 13 were retained in the final concatenated dataset. Phylogenetic, haplotype network, and multivariate analyses indicated partial but incomplete differentiation between the two study areas, with significant but moderate mitochondrial structuring. Video-confirmed sampling events were strongly associated with molecular success, showing that UAV footage can predict sample quality and improve workflow efficiency. Overall, our results support UAV-assisted blow sampling integrated with photo-ID as a promising, scalable, and ethically robust tool for individual based monitoring and conservation genetics of small cetaceans.

10. Integrating Drones into Marine Mammal Research: Practices and Insights from AIMM

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In recent years unoccupied aerial vehicles (UAVs) have become powerful tools, enabling researchers to observe marine mammals from aerial perspectives and obtain new insights into their behaviour and social complexity. Over the past decade, AIMM has extensively integrated the use of UAVs into its research. While primarily applied to analyses of cetacean behaviour and social structure, we have used UAVs across a variety of research objectives (e.g. blow sampling and impact assessments), demonstrating the versatility and broad applicability of this methodological tool. When first implemented into our research in 2016, UAVs represented a novel approach within both the organisation and the broader scientific field. This raised important concerns regarding their potential impact on the animals, particularly given the objective of observing natural, undisturbed behaviour. Addressing these uncertainties became a necessary first step, and initial efforts therefore focussed on assessing the effects of UAV presence on the behaviour of two small delphinids (bottlenose dolphins - *Tursiops truncatus*, common dolphins - *Delphinus delphis*) prior to their broader application. The results showed that UAVs had a minimal impact on the immediate behavioural responses of the animals when flown at altitudes >5 m. Using a precautionary approach, this pilot study helped us to establish key operational guidelines, restricting the minimum UAV altitude to 20 m, with a typical working altitude around 25 m. This laid the foundation for multiple scientific outputs, ranging from fine-scale analyses of behavioural and movement patterns to efforts progressing toward the integration of artificial intelligence to enhance observational methodologies. As drone technology has advanced, we have employed a wide range of UAV platforms, from early quadcopter models such as the DJI Phantom 2 equipped with external GoPro systems to more advanced platforms like the DJI Matrice M30T equipped with two cameras, a laser rangefinder and thermal imagery, as well as a vertical take-off and landing (VTOL) fixed-wing system, the Autel Dragonfish Standard. By applying different UAV types across projects with varying objectives, we have identified key practical features, allowing us to determine which models are best suited for specific research goals. In recent years, the DJI Mavic 3 Pro has become our primary model for studies based from small vessels. This is due to its compact design, three high-quality Hasselblad cameras with different optical zoom capabilities, and compatibility with attachable polarised filters which provide an optimal setup for achieving most research objectives. In southern Portugal, where our research is conducted from a 7 m rigid-hulled inflatable boat (RHIB), high portability and ease of deployment and recovery from a moving platform are essential. This model's design meets these requirements and allows for seamless integration into daily field gear, enabling not only focal follows of target species such as the common dolphin and bottlenose dolphin but also opportunistic recordings of non-target species, including killer whales (*Orcinus orca*), harbour porpoises (*Phocoena phocoena*), and other cetaceans. However, the planning and integration of UAVs must be carefully tailored to specific research aims, encompassing both the selection of appropriate drone models and the optimisation of flight strategies. During AIMM's collaboration with Ocean Alliance's 2021 SnotBot expedition, the collection of blow samples required the deployment of a modified DJI Inspire 2 incorporating Petri dish attachments, alongside specific flight operations such as low-altitude flybys and backward flight to minimise sample loss to meet objective goals. Building on our research in the northeast Atlantic, we conducted three drone-based studies aboard tuna purse-seine vessels to assess potential impacts of the Eastern Tropical Pacific tuna purse-seine fishery on spinner dolphins (*Stenella longirostris*) and pantropical spotted dolphins (*Stenella attenuata*). This research required long flight endurance and the ability to image complex, fine-scale behavioural events, as well as co-navigating with a fishery-associated helicopter in the air. To meet these requirements, multiple UAV types were deployed, including the DJI Mavic 3 Pro, DJI Matrice M30T, and the Autel Dragonfish, each exhibiting specific strengths and limitations. The DJI Mavic 3 Pro offered strong overall performance, especially regarding image quality and ease of deployment. However, it was limited by relatively short battery life, the lack of simultaneous recording with

multiple cameras and its comparatively higher susceptibility to adverse weather conditions (wind and rain). The DJI Matrice M30T provided well balanced technological capabilities and strong weather resistance; however, vertical take-off and landing from a moving platform proved challenging. The Autel Dragonfish enabled automated flight paths that allowed the pilot to focus on camera operation, supported by powerful optical zoom (180x times) capabilities. Nevertheless, it also presented limitations, including interruptions in continuous video due to camera rotation and reduced portability resulting from its bulky, multi-component setup. Further, since this model is a prototype, we encountered a variety of technical issues associated with this novel technology. While the first two UAV models generally operated at altitudes of 20–100 m, the latter platform was capable of consistently flying at heights of >100 m while still capturing high-quality, analysable imagery. As altitude restrictions vary by country, UAVs equipped with high resolution zoom cameras and powerful gimbals can facilitate flying at/near the maximum allowable altitudes without sacrificing data quality while simultaneously reducing UAVs' already minimal impacts on cetaceans. In sum, deployment of UAVs at sea has been a routine and essential component of our research during the past 10 years. By understanding the strengths and weaknesses of different UAV types, we can select the optimal UAV for each research question. This has greatly advanced our research programme and generated new insights into cetacean behaviour. ¹This was only done in international waters where we are not aware of legal restrictions regarding UAV operation. Here we were sharing the air space with a fishery-associated helicopter, needing to fly above it to avoid collision risk. In all other study areas respective national and international legislation was followed.

11. GLOBAL EXAMPLES OF DRONE GUIDANCE AND LEGISLATION

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The use of unmanned aerial vehicles (UAVs) has expanded rapidly in marine mammal research, providing new opportunities for population monitoring, photogrammetry, behavioural observations, health assessments, and sample collection. However, the rapid adoption of this technology has overtaken the development of consistent guidance on ethical operation, disturbance mitigation, and regulatory compliance. To inform the European Cetacean Best Practice Workshop, we reviewed existing legislation and guidance governing UAV operations around marine mammals and conducted an international survey of UAV practitioners to capture current operational practices, perceived risks, and recommendations for best practice.

The survey received 95 responses from researchers and practitioners representing 27 countries, including 13 European countries and a further 14 from elsewhere worldwide. Respondents reported UAV operations across 60 marine mammal species and 253 research applications. Considerable variation was identified in methodology and training, reflecting differences in species, research objectives, and institutional experience. Most operators (58%, 55 responses) reported no observable disturbance during routine research flights. However, behavioural responses were reported when drones were flown at low altitudes, descended rapidly, or involved larger, noisier platforms. Overall, 36% (34 responses) observed responses such as increased vigilance, changes in swimming direction, altered dive behaviour, and flushing of hauled-out seals. These findings highlight the need for species-specific and context-dependent operating procedures, particularly given that intentional disturbance of marine mammals is prohibited.

Our review identified a high degree of consistency in aviation regulations worldwide, with common requirements for pilot competency and registration, operation within visual line of sight (VLOS), maximum flight altitudes of 120 m, and restrictions on operations near people, buildings or within controlled airspaces. Regulations also commonly categorise drone operations according to factors such as aircraft weight and intended use. In contrast, legislation and guidance relating specifically to marine mammals remained fragmented, although they are evolving. While some countries including Spain, the Netherlands (Wadden Sea), Australia, Canada, the United States, and Brazil, as identified through our survey, have explicit drone-specific marine mammal legislation with mandatory permitting requirements for research or operations around marine mammals, many others rely on broader wildlife disturbance legislation or voluntary best-practice guidance.

These findings demonstrate the need for co-ordinated, evidence-based best practice guidance for UAV operations around cetaceans and other marine mammals. Developing recognised scientific recommendations on species, flight heights, approaches, disturbance protocols, and permitting will help maximise the value of UAV research while ensuring high standards of animal welfare and regulatory compliance. This is particularly important considering the increasing use and accessibility of drones by recreational operators and would help clearly differentiate scientifically justified, ethically conducted UAV operations from recreational use, thereby supporting both effective scientific rigor and public understanding.

12. Drones and conservation legislation in Scotland

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Relevant articles of the EU Habitats Directive 1992 and transposed Habitats Regulation 1994 (as amended in Scotland) require strict protection for Annex IV species, including all cetaceans. This protection includes from capture, injury, killing, harassment, disturbance in specific circumstances, obstructing access to or deny use of breeding site or resting place and taking or destroying eggs. Protection applies to all life stages. In addition, Reg (39) gives additional protection to cetaceans making it an offence to disturb any whale, dolphin or porpoise.

Researchers planning to fly a drone closer than 30 m vertically from a cetacean as part of a research programme in Scotland must apply for an EPS licence for disturbance from NatureScot. The three strict tests of licencing for disturbance are: 1) Licensable purpose; 2) No satisfactory alternative; and, 3) No detrimental impact on the maintenance of favourable conservation status.

Relevant legislation for protection of seals, under the Marine (Scotland) Act 2010 and Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014 and of basking sharks, under the Wildlife and Countryside Act 1981, from offences were discussed.

Animal welfare is not exclusive to the target species and consideration must be made for all species that could be disturbed by an operational drone, including colonies of breeding birds and seals at haul out sites.

Drone specific Standard Operating Procedures have been developed as part of the ECOPredS (Ecological Consequences of Orca Predation on Scottish seals) project. These are available online at <https://ecopreds.com/wp-content/uploads/2023/05/ecopreds-prospective-flights-2023.pdf>

The Scottish Marine Wildlife Watching Code (SMWWC) (available online at www.nature.scot/marinecode) was developed to provide guidance, advice and information, minimise disturbance to wildlife, help you enjoy watching marine wildlife, to provide a standard for the industry and to help everyone stay within the law. Review and update of the SMWWC is planned to include the use of drones.

Everyone should follow the Scottish Outdoor Access Code (available online at <https://www.outdooraccess-scotland.scot/>) at all times.

13. Discussion, key points and recommendations

A number of considerations related to using UAVs for marine mammal research were discussed during the workshop. It was broadly acknowledged that the use of drones might be less invasive or disturbing than traditional methods, if operated correctly and responsibly. The following topics were considered key.

Human safety

Human safety procedures and safety practices are paramount and should be considered at all times. Drone operators should be familiar with the safety and data protection aspects in CAA guidance, as above.

Marine mammal drone-specific guidance

In response to a question to the group about whether there is a need for development of marine mammal drone specific guidance and/or training, the majority of researchers agreed that there is a need, and none said no guidance was necessary.

It was agreed that the development of any such guidance should include consideration of existing global UAV legislation and any marine mammal measures that are available already.

Any general guidance or certification should be adhered to by all, and consideration is particularly important for those within research institutions as part of ethical agreement.

The development of formal marine mammal-specific training day and/or online course were seen to be beneficial. It was acknowledged that this is often happening informally with collaboration between experienced drone operators and new operators in many field projects. Consideration might be given to funding requirements for adequate training.

Guidance and training might vary according to a number of factors that include species, research focus, field objectives, type and angle of UAV as well as the region of operation. The basic principles are likely to be similar, but any guidance and training should be flexible to accommodate these differing factors.

Monitoring, understanding and importantly, reporting details of observed disturbance is necessary, particularly as species and activity specific differences in behaviour are likely. Recognising that disturbance behaviour has a spectrum. Certain levels may have short-term consequences that may have negligible/very minimal detriment to individuals. Whereas cumulative or other disturbances may have long-term energetic consequences and negatively impact individuals. Justifiable strong rationale for requirements of low-level disturbance accompanied by an appropriate response protocol should be considered especially if this disturbance level is lower than current or traditional monitoring techniques. It is important to be responsive to any behavioural changes; however, overly restrictive legislation or zero tolerance of any behaviour change could potentially limit the adoption of technologies that may reduce disturbance associated with existing monitoring approaches. Behaviours that are recognised as disturbance, such as vigilance, movement, diving, belly-up, mother and calf separation, flushing, are important to recognise and respond to, as appropriate (while noting these may be species specific).

The development of standard operating procedures might act as a baseline and could be adapted accordingly (e.g. to species, research aim) and may allow for comparative analysis across the field.

Workshop attendees suggested that best practice guidance might include the following considerations:

- Full awareness of existing regulations and best practise guidance (locally, nationally and internationally);
- Population status and the number of other threats a species is already facing;
- Species specific requirements;
- Consideration of more stringent measures in protected areas, sensitive areas or during sensitive seasons;
- Gradient for harassment: for example, a traffic light system as a form of risk assessment;
- Cumulative effects (repeated behaviours, disturbance) and avoidance of cumulative drone exposure (Including how to know if different groups/people are working in same/similar area or same population);

- Point of approach: for example, seals might be less disturbed by a UAV that approaches from the seaward side rather than land;
- Awareness and consideration of other non-target species;
- Data sharing and collaborative working with other researchers;
- Type and size of drone: ensuring the correct drone is used for the specific purpose of research;
- Awareness of the mammals' life cycle during project planning;
- Noise penetration and shadow of drone on the surface may cause behavioural changes in animals. Workshop attendees highlighted this has been noted in bottlenose dolphins;
- Best boat practice for UAV operations;
- Site variation: For example, seals reactions to drones appears to vary according to site.

Recreational drone use

Recreational drone use amongst the general public is extremely accessible. Differentiation between research and recreational drone use is important. It can be useful to highlight to recreational users that often researchers have licences or permission to fly drones over marine mammals.

Concern was raised by a number of presenters and participants about the potential disturbance impacts associated with the poor use of recreational drones. The public have often been observed using drones at heights over marine mammals that can cause disturbance.

Several incidences of recreational drone pilots interfering with drones deployed for research purposes (e.g. by flying near or under them during flights) were reported by participants.

Participants agreed that height regulations should be in place for recreational users, and more generally, that recreational drone use requires management.

Participants highlighted that public outreach is essential. It is important to create public awareness and to reach out to recreational drone users, highlighting the basic need for responsible behaviour around marine wildlife. Promotion of images or videos that show disturbance might be a powerful educational learning tool.

Other applications or examples of emerging uses of drones in relation to marine mammals (for example, industry, rescue, disturbance response)

In response to a question posed to the room, the following areas of emerging uses of UAVs in relation to marine mammals were identified.

- Monitoring diving behaviour
- Morphometrics: size, body condition, energetic requirements
- Prey distribution
- Detecting cetacean vocalisations
- Combination with acoustic recordings, hydrophones
- To ground-truth satellite data
- Distance sampling dive times
- Documenting habitat change over time
- Capturing poor wildlife watching behaviour to be used as evidence to enforce regulations
- Support Marine Mammal Observers to communicate with industry, for example, during pile driving or to managing vessel traffic
- To contribute towards prediction of high-risk bycatch areas
- Recording mechanisms of fishing interactions, e.g. bottom trawlers and static gear
- In exceptional events (e.g., whale giving birth): creating safe area to create border

14. List of Participants

Geert Aarts, Wageningen Marine Research
Sophia Adamson
Simon Allen, University of Zurich
Natalie Amigo, SUBMON
Rebecca Bakker, Waardenburg Ecology
Zakaria Barmakran
João Bernardo Barreiros, iSEA - Environmental Organisation for the Preservation of the Aquatic Ecosystems
Elise Beauchemin, UiT - Arctic University of Norway
Juliette Biacchi, Association AL LARK
Pierre Bomio
Bertrand Bouchard, Centre d'Ecologie Fonctionnelle et Evolutive
Jason Brook, Aberystwyth University
Helena Busch, CIIMAR - Interdisciplinary Centre of Marine and Environmental Research of University of Porto
Julia Cable, BDMLR
Joana Castro, AIMM
Luca Ceolotto, Department of Comparative Biomedicine and Food Science, University of Padova
Barbara Cheney, University of Aberdeen Lighthouse Field Station
Mara Company, CIRCE
Ann-Kristin Craul, University of Rostock
Manuela Cristaldi, Marecamp
Bárbara Diogo, Universidade de Aveiro
Sarah Dolman, Environmental Investigation Agency (organiser)
Eda Dönmez, University of Hamburg
Bradley England, Institute for Terrestrial and Aquatic Wildlife, University of Veterinary Medicine Hannover
Pia Eriksson, Swedish Museum of Natural History
Elia Fiore, Department of Comparative Biomedicine and Food Science, University of Padova
Luis Freitas, Madeira Whale Museum
Anxo Gende Seoane
Tilen Genov, Morigenos - Slovenian Marine Mammal Society
Joan Gonzalvo, Tethys Research Institute
Sadie Gorvett, Hebridean Whale and Dolphin Trust
Miguel Grilo, Institute for Terrestrial and Aquatic Wildlife Research, TiHo
Emily Hague, University of the Highlands and Islands – Shetland (Organiser)
Karen Hall, NatureScot
Rebecca Hewitt, University of Aberdeen Lighthouse Field Station
Valerie Idárraga Garcés, Futurismo Azores Adventures
Dan Jarvis, British Divers Marine Life Rescue
Matt Oscar Juris, Universidad de La Laguna
Urška Kajtna
Monica-Grace Kelly
Alan Knight, British Divers Marine Life Rescue
Magdalena Kolenc, Faculty of Veterinary Medicine, University of Zagreb
Edita Magileviciute, ECOCV
Sarah Jana Manthorpe
Sarah Matthews, Dolphin Zone CIC
Nina Maurer
Suzanne McCarthy, NatureScot
David McDonald
Cameron Molland Mem.MBA, AK Wildlife Cruises
Phoebe Moss
Maksymilian Nabzdyk
Emma Neave-Webb, Orkney Marine Mammal Research Initiative

Joyce Neves, Bottlenose Research Institute
Eilidh O'Brien, Icelandic Orca Project
Gareth Pierce, University of Cambridge
Antony Pieters, AIMM Portugal - Marine Environment Research Association
Rémi Pigeault, Institut für Terrestrische und Aquatische Wildtierforschung (ITAW)
Martim Quinta
Alicia Quirin, AIMM - Associação para a Investigação do Meio Marinho
Claire Raffaelli, MARE - Marine and Environmental Sciences Centre/ARNET- Aquatic Research Network,
Regional Agency for the Development of Research
Florence Rappin, Astrolabe Expeditions
Katie Rapson, University of Plymouth
Jonas Rasim, Deutsches Meeresmuseum
Leon Rostock
Alexander Nicolas Rychwalski, University of Hamburg
Rocio Sánchez, La Laguna University
Jessica Schop
David Silgado, CIRCE
Iolande Silva, CIIMAR - Interdisciplinary Centre of Marine and Environmental Research
Raquel Soley, Projecte Guaita
Claire Stainfield, SRUC (Organiser)
Johanna Stedt, Lund University
Anikó Szegedi
Sally Tapp, Sea Watch Foundation
Tim Taugnitz, Deutsches Meeresmuseum
Marie-Laure Veys, Institute of Marine Research, Norway
Fabien Vivier, Observatoire Pelagis UAR 3462 CNRS-La Rochelle Université
Alice Walters, Whale and Dolphin Conservation (WDC)
Keara Windels, Wageningen University & Research
Maisie Kirkland, Montenegro Dolphin Research
Sarah Randall, JNbp
Lena Szyzmanyek, National Marine Fisheries Research Institute

15. Agenda

Welcome and introduction

Survey responses (Emily Hague)

Examples of marine mammal research (short talks)

Tea break 10:45-11:15 (group photo)

Examples of marine mammal research (short talks)

Lunch 12:45 – 14:00

Other drone applications (e.g. Using drones to inform rescues (videos from Anthony Rigell and Daniel Manchester (Proform Group New Zealand)); using drones to observe disturbance)

Best Practices - inc. Survey responses (Emily Hague)

Guidance, discussion (Global examples of drone guidance and legislation (Claire Stainfield); Drones and conservation legislation in Scotland (Karen Hall, NatureScot)

Tea break 15:45-16:15

Discussions, conclusions, next steps