OCEAN

Operator-Centred Enhancement of Awareness in Navigation

D4.1 – Workshop on Marine Mammal Ship Strike Mitigation Report

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Abbreviations and acronyms

Abbreviation or acronym used in this document	Explanation
4D-SAD	OCEAN 4D Situation Awareness Display
AIS	Automatic Identification System
APP	Software application (usually for handheld equipment)
AToN	Aids to Navigation
BAS	British Antarctic Survey
DE	Density Estimation
DMA	Dynamic Management Areas
DMON	Digital acoustic monitoring instrument
DOM	Dynamic Ocean Management
EC	European Commission
EMA	Escola do Mar dos Açores
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Reusable
IMO	International Maritime Organization
IWC	International Whaling Commission
IWC-SSWG	IWC Ship Strikes Working Group
IWDG	Irish Whale and Dolphin Group
JCP	Joint Cetacean Protocol
KER	Key Exploitable Results
km	Kilometre
kn	Knots
LFDCS	Low-frequency detection and classification system
MMO	Marine Mammal Observer
MPA	Marine Protected Area
NOAA	National Oceanic and Atmospheric Administration
Q/A	Questions and Answers
SMA	Seasonal management areas
SMS	Short Messaging Service
SOLAS	Safety Of Life At Sea
SOLAS-fleet	Cargo ships of 500 gross tonnage or more, and passenger ships on international voyages
SRZ	Speed restriction zones
STCW/STCW-F	International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel
TSS	Traffic Separation Scheme
US	United States of America
V-SRZ	Voluntary speed restriction zones
VVoIP	Video and Voice over Internet Protocol
WP	Work Package

Executive Summary

In accordance with the work-plan proposed for the project "OCEAN – Operator-Centred Enhancement of Awareness in Navigation", co-funded by the European Union (Grant Agreement 101076983), and running from 1st October, 2022, to the 31st September, 2025, a *Workshop on Marine Mammal Ship Strike Mitigation* was held in Horta (Azores, Portugal), in the installations of the Sea School of the Azores – EMA.

The workshop was organized as a series of presentations in four consecutive sessions over a period of two days, followed by four discussion sessions in the final day (see Annex 3: Workshop Program). A total of 17 presentations were delivered by speakers from 15 institutions, covering different aspects of the state of the art in the research on and mitigation methodologies for cetacean-ship collisions.

The workshop involved 49 participants, either *in-loco* or via video-conference, ranging from OCEAN Project partners, representatives of the Azores Regional Government – Regional Directorate for Maritime Policies, researchers and students at MSc and PhD level from the Institute of Marine Sciences – Okeanos; University of the Azores. The presence of four high-education level students is noteworthy as a unique opportunity to witness and actively participate in high-level meetings of this kind and directly interact with high-profile researchers and specialists.

A summary of each presentation is given in this report along with some relevant images taken from the presentations, with permission from the authors (see 2 Summary of the talks).

During the discussion sessions several different subjects were addressed covering the four main topics (animal detection; prediction of animal location; data fusion, interfaces, and flow; collaboration). A total of 24 recurrent discussion topics were identified and are highlighted in this report in BOLD CAPITALS (see 3 Discussion Sessions):

- AWARENESS.
- COLLABORATION.
- COMPLIANCE with risk reduction measures.
- DATA ASSIMILATION.
- DATA INTEGRATION.
- DATA MANAGEMENT.
- DATA QUALITY.
- DATA SCARCITY.
- DATA STANDARDIZATION.
- DEMONSTRATION.
- DISSEMINATION.
- END USERS.
- Appropriate [system] FRAMEWORK.
- MODEL PREDICTIVE POWER.
- MODEL VALIDATION.
- PRECISION.
- SCALE.
- SENSIVITY tuning.
- STAKEHOLDERS INVOLVEMENT.
- SYSTEM INTEGRITY.
- SYSTEM OPERATIONALITY.
- SYSTEM UTILITY.
- SYSTEM PERFORMANCE EVALUATION.
- TIME COHERENCE.

Some relevant conclusions and recommendations were also identified and are presented in **bold** along the text of the summaries of the discussion sessions (see 3 Discussion Sessions). Finally, the workshop also served to foster collaboration among all participating parts. Both at individual and at institutional levels, participants were invited to the *Maritime Stakeholders Forum*, and *the Technology Feedback Forum* created within the OCEAN Project (WP10[1]). Reciprocally, an invitation was extended by the representative of the International Whaling Commission (IWC) for specialists in the workshops, and specifically from the OCEAN Project Consortium, to apply to the IWC Ship Strike Working Group Expert Panel, which was received with satisfaction by the OCEAN Consortium that has subsequently nominated a representative for that body.

Several researchers present in the workshop indicated their intention to keep a close collaboration with the OCEAN Project. Specifically, two other projects with similar goals for reduction of cetacean-ship collisions, but anticipating the use of different and complementary methodologies to those of the OCEAN Project, and both funded through the EU-LIFE Programme. A close communication among all three projects was vowed to align goals and methods for efficient use of funding and human resources, and the creation of more powerful tools for whale-ship strike risk reduction.

During the Closing Session (see 3.6), many of the participants lauded the workshop organization and results, which was received as a qualitative measure of success. Overall, the *Workshop on Marine Mammal Ship Strike Mitigation* achieved the specific goals of providing the OCEAN Project partners with an overview of the state of the art in marine mammal ship strike mitigation, and fostering discussions with international specialists to enable aligning the work developed within the OCEAN Project with other similar efforts. The objective of forging new collaborations was also successfully accomplished and will undoubtedly be instrumental in fulfilling the goals of the OCEAN Project.

[1] Reference is made to OCEAN Deliverable D10.3, which outlines the formation of the OCEAN Maritime Stakeholders Forum as well as the OCEAN Technology Feedback Forum

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1 Introduction

1.1 Foreword

The OCEAN Project's *Work Package 4 – Detection and tracking of Marine Mammals in high-density areas* (WP4) has as overarching goal to create and use new technology for harnessing information from a variety of sources including hydrophone grids, software technology, crowd-sourced sightings (from a reporting app (OCEAN Task 4.4) and 4D-SAD (OCEAN WP7), animal distribution/niche models, and satellite imagery to provide mariners with warnings on ship strike risk with marine mammals (KER7). One of the specific objectives of WP4 is to align the OCEAN framework with existing initiatives and the state of the art in mitigation of vessel collisions with marine mammals. To fulfil that objective a multinational *Workshop on Marine Mammal Ship Strike Mitigation* was planned and organised for the second trimester of the project.

Prior to the organization stage of the *Workshop on Marine Mammal Ship Strike Mitigation*, a comprehensive scientific literature review was undertaken to obtain an inclusive assessment of the state of the art in marine mammal ship strike mitigation and to identify the key players in this subject.

That review was followed by direct contacts with key individuals and institutions to discuss their interest, and availability, to participate in the *Workshop on Marine Mammal Ship Strike Mitigation*, within the OCEAN Project timelines.

Following those preliminary contacts, a coherent workshop program was designed and final invitations were sent to 16 speakers (additionally to the OCEAN Project Coordinator who gave a presentation about the OCEAN Project and workshop objectives) from 14 different institutions.

The *Workshop on Marine Mammal Ship Strike Mitigation* took place in Horta, in the Azores archipelago (Portugal), from 24-26 January 2023 in the Sea School of the Azores – EMA. To guarantee a focused discussion, the workshop was closed to invited participants, and was run in a hybrid format, with on-site and remote participations via video-conferencing.

The *Workshop on Marine Mammal Ship Strike Mitigation* was attended by 49 participants, including speakers, OCEAN Project partners, representatives of the Azores Regional Government – Regional Directorate for Maritime Policies, researchers and students at MSc and PhD level from the Institute of Marine Sciences – Okeanos, University of the Azores.

1.2 Aim of the workshop

The declared goals of the *Workshop on Marine Mammal Ship Strike Mitigation* were: 1) to provide the OCEAN Project partners with an overview of the state of the art in marine mammal ship strike mitigation; and 2) foster discussions with international specialists to enable aligning the work developed within the OCEAN Project with other similar efforts.

A third, underlying goal of the workshop was to foster collaboration among players in this subject and to create synergies among other interrelated projects. Specifically, the workshop served as an opportunity to identify and invite individuals and institutions to participate in the *Maritime Stakeholders Forum*, and the *Technology Feedback Forum* created within the OCEAN Project (WP10[2]).

[2] Reference is made to OCEAN Deliverable D10.3, which outlines the formation of the OCEAN Maritime Stakeholders Forum as well as the OCEAN Technology Feedback Forum

1.3 Organisation and objectives

The workshop ran over three days. The first two days devoted to 20 minutes presentations from the invited specialists, followed by a short 10 minutes Q/A session (see 8). The final day was devoted to discussions focused on four topics:

- Animal Detection – Moderator: Guillaume Lapeyre.
- Prediction of Animal Location – Moderator: Jonathan Earthy.
- Data Fusion, Interfaces, Flow – Moderator: Francisco Rodero.
- Collaboration – Moderator: Erik Styhr Petersen.

All but two presentations were given by specialists with many years' (in some cases decades) worth of work in researching, designing, and applying measures for cetacean ship strikes mitigation. The first presentation was given by the OCEAN Project Coordinator, Erik Styhr Petersen, to introduce the goals of the project and the specific goals of the workshop. Since the OCEAN Project also includes designing a solution for tracking and recovery of lost containers (WP5) and, specifically, develop container forecast for vessels and salvage, a specialist in oceanic drift models was also invited and gave a presentation on models for tracking floating inanimate bodies in the ocean.

Five presentations were delivered remotely, and all other were given on site. A two-way video-conferencing system with multiple cameras was available during all sessions, enabling everyone to view and participate in real-time.

In the first day, a guided visit to the installations of the Sea School of the Azores – EMA, that included a visit to the various workshops and navigation training facilities, as well as one of the school's *campi* for firefighting, safety and survival at sea training.

1.4 Relationship with other deliverables

This document is related to all deliverables in WP4, WP6, and Tasks 5.2 and 5.3 of WP5. The final discussion on collaboration held in the last day of the workshop relates to WP10, specifically T10.2, T10.3, and T10.4.

2 Summary of the talks

2.1 Welcoming session

The head of the Sea School of the Azores – EMA, Ana Rodrigues, and Rui Prieto (Okeanos Institute of Marine Sciences; University of the Azores), opened the workshop by welcoming the participants and giving general information on the workshop structure and venue. This short introduction was followed by a visit to some of the facilities of the Sea School of the Azores, including a first-hand view of an ongoing class on basic safety STCW/STCW-F course.

2.2 Specialists talks – day 1

"The OCEAN Project"

Erik Styhr Petersen
Western Norway University of Applied Sciences

Erik Styhr Petersen, coordinator of project OCEAN, gave an overview of the goals and structure of the project and expectations of the workshop outcomes. It was emphasized that the focus of the project is on navigational safety, which is just one aspect of maritime safety, with the goal of improving navigational safety for every stakeholder at sea. Stakeholders were defined, including people on small human propelled crafts such as kayaks, other occasional users in recreational small boats, crews of small fishing vessels, on to larger vessels such as recreational and competition sailing boats, as well as the SOLAS fleet.

Figure 1: Expected outcomes of the Workshop on Marine Mammal Ship Strike Mitigation*. Reproduced from presentation slide; used with permission.*

Dr Petersen then identified another group of stakeholders under the project's definition, comprised by large marine animals, especially large whales. Differences in the conditions and equipment available for each type of vessel were highlighted, and how this can become a challenge when trying to deliver relevant safety information to the entire mariners' community. It was emphasized that different stakeholders have different navigational safety perspectives that are intertwined with diverse agendas. The OCEAN project's overarching goal of making hazards to navigation more obvious for mariners, and supporting successful evasion in time was stated. That was followed by an overview of the structure of the project. Finally, the expected outcomes of the workshop under the Ocean project's perspective were highlighted (Figure 1).

"Short summary on global ship strikes"

Christina Winkler
Atlantic Technological University, Galway, Ireland

Christina Winkler presented updated results of a study on collisions between vessels and cetaceans based on data available in the Global Ship Strikes Database created and maintained by the International Whaling Commission (IWC) [1]. It is worthwhile to stress that although representing the most extensive compilation on collisions between vessels and cetaceans worldwide. The Global Ship Strikes Database is populated with voluntary submissions of incidents, and it does not incorporate many records from other regional databases, providing incomplete characterization and most likely a gross underestimate of incidents [1]. The IWC Global Ship Strikes Database was created in 2007 but contains records dating back to 1820.

The study covered the period between 1820 to 2019, uncovering 1162 reported incidents, of which, after validation, 933 were used for analysis and categorized into 'Definite' (64.8%), 'Probable' (16.6%), and 'Possible' (18.5%). Of the 907 cases with recorded ocean basins, 64.3% occurred in the Atlantic Ocean, followed by 29,5% in Pacific Ocean, 3,7% in the Indian Ocean, 2,0% in the Southern Ocean, and 0,4% in the Arctic Ocean. Of the 818 cases with species or sub species assigned, 62.6% were mysticetes (baleen whales; 11 species detected) and 25.4% odontocetes (toothed whales; 24 species detected). Fin whales (*Balaenoptera physalus*; 20.2%), humpback whales (*Megaptera novaeangliae*; 17.5%) and sperm whales (*Physeter macrocephalus*; 10.9%) account for almost half of all incidents. The records contained 843 cases with year assigned, showing a clear increase of reports up to the mid-1990's, with a peak in the 2000's, followed by a recent decrease in reports. No interpretation was possible for these decadal trends and it is unclear if they relate to a recent decrease in the number of incidents or in reporting. Of the 402 cases with vessel type reported, 43 types of vessels were identified, that were grouped in 8 categories: ferries (12,9%), sailing yachts (12,2%), passenger vessels and cruise ships (11,2%), motor yachts (10,4%), whale watching vessels (8,4%), military vessels (8,2%), container ships (8,2%), general cargo vessels (6,2%). Only 101 cases had vessel speed assigned to the record, with 47% travelling at >15 knots, a speed which is considered to increase the chance of lethal injuries on struck animals. Finally, Ms Winkler highlighted that there are still several data gaps and that an effort to merge databases would be beneficial to gain further insight into the problem.

"IWC Ship Strike Working Group and database"

Lydia O'Loughlin
International Whaling Commission (IWC)

Lydia O'Loughlin represented the IWC, and presented the work and strategy of the IWC Ship Strikes Working Group (IWC-SSWG), including the "Global Ship Strikes Database". The IWC is the primary international body responsible for the conservation and stewardship of whales. The IWC-SSWG was established in 2005 at the IWC57 meeting of the parties, under the conservation group, with a mandate to raise awareness of the need for action on ship strikes at both a national and international level, and to promote the development and use of effective tools to tackle the issue. Recognizing that understanding when, where, how and why vessels collide with cetaceans is important in developing appropriate mitigation to reduce the occurrence of these events, the IWC set up to obtain data to allow a quantitative evaluation of the problem in order to target mitigation efforts. Collection of data is achieved through the Global Ship Strikes Database, currently assessable through a data portal[3]. The portal generates low-level data summaries[4] and high-level data assess can be requested directly to the IWC-SSWG.

Table I: At-risk whale populations identified under Objective 2 of the IWC strategic plan to mitigate the impacts of ship strikes on cetacean populations. Reproduced from presentation slide; used with permission. Please refer to the IWC strategic plan for further details[5].

Western North Atlantic right whale
Eastern North Pacific right whale
South Pacific right whale - Chile and Peru
Arabian Sea humpback whale
Western gray whale
Blue whale - Sri Lanka and Arabian Sea
Blue whale - Chile
Sperm whale - Mediterranean Sea
Fin whale - Mediterranean Sea
Bryde's whale - Gulf of Mexico
Omura's whale - Northwestern Madagascar
Sperm whale - Canary Islands region

Following, a brief description of the IWC strategic plan to mitigate the impacts of ship strikes on cetacean populations, 2022-2032[5], was given, namely the seven overarching objectives:

- Objective 1: Management of the Ship Strikes Database. Publication of routine summary statistics from the database. Establish the Ship Strikes Expert Panel.
- Objective 2: Identify at-risk populations and high-risk areas, update as necessary. Have data readily available to quantify scale of issue in areas of concern. Continued monitoring of measures implemented in identified High Risk areas.
- Objective 3: Support to IWC member countries putting in place re-routing and/or speed measures where necessary. Continue and expand developing specific guidance for vessels where there may be specific ship strike issues.
- Objective 4: Increased public and shipping industry awareness of reporting vessel collisions. Routine reporting of comprehensive and accurate ship strike data. Improve access to the database.
- Objective 5: Application of technology to avoid of overlap between whales and ships. Evaluate technological approaches for efficacy.
- Objective 6: Participation of Regional/International conferences, workshops, and meetings. Increase use of and contributions to the database. Outreach efforts to help implement IWC recommendations on mitigation measures.

[3] www.portal.iwc.int

[4] https://archive.iwc.int/?r=17562

[5] https://archive.iwc.int/pages/view.php?ref=19858&k=

- Objective 7: Promote training programmes, guidance, and APP-based technologies. Deliver specific advice to appropriate sectors. Develop outreach and educational resources to be available online.

Table II: High-risk areas identified under Objective 2 of the IWC strategic plan to mitigate the impacts of ship strikes on cetacean populations. Reproduced from presentation slide. Please refer to the IWC strategic plan for further details[5].

Stage	Definition	Location	Species of concern
Stage 1	High risk area of potential concern identified based on overlap of shipping and whale distribution or a high number of reported incidents	Port of Cape Town, South Africa	Southern right whales; Humpback whales
Stage 2	Survey data for whales, AIS data for shipping used to inform risk analysis and local vs. international jurisdiction.	NE Coast of Sakhalin Island, North Pacific	Western Grey Whales
Stage 3	Consideration of possible practical options based on risk analysis. Recommendations from IWC Scientific Committee. IWC approaches relevant states to offer information and advice.	Canary Islands	Sperm whales
		USA, West Coast, California	ENP blue whales
		SW Atlantic. Sub-Antarctic island at 54°15'S 36°45'W	Blue whales; Humpback whales
Stage 4	Stakeholder workshops to discuss possible mitigation measures and optimize risk reduction with stakeholder interests.	Sri Lanka	Blue whales
Stage 5	Relevant states consider proposals to IMO or other appropriate management bodies assisted by supporting information from IWC. Voluntary measures by vessel operators or shipping industry organizations may also be implemented.	Hellenic Trench, Mediterranean	Sperm whales
		Arabian Sea, Port of Duqm, Oman	Humpback whales
		Antarctic Peninsula	Humpback whales
		Pelagos Sanctuary, Mediterranean	Fin whales
		Balearic Islands, Mediterranean	Fin whales; Sperm whales
		Eastern Alboran Sea, Mediterranean	Fin whales; Sperm whales
Stage 6	Measures implemented through IMO or national authorities.	Panama	Humpback whales
		SW Atlantic Golfo Nuevo, Península Valdés, Argentina	Southern right whales
Stage 7	Continued monitoring to evaluate ongoing effectiveness of measures.	Hauraki Gulf, New Zealand	Bryde's whales
		USA, West Coast, California	ENP blue whales
		Straits of Gibraltar, Mediterranean	Fin whales; Sperm whales
		East coast of USA and Canada	North Atlantic right whale

Some information on work already made to identify at-risk populations (Table I) and high-risk areas (Table II) under Objective 2 above was presented. Finally, an invitation was extended by Dr O'Loughlin to specialists in the workshop to participate in the IWC-SSWG Expert Panel.

"Requirements of data systems to support effective ship strike reduction through routeing changes or targeted speed restrictions"

Russel Leaper
International Fund for Animal Welfare - UK

Russel Leaper from the International Fund for Animal Welfare – UK, participated remotely through a recorded presentation. The talk focused on data gaps required to reduce ship strikes on the great whales and current systems. Dr Leaper highlighted that most of the talk was based on discussions on the subject within the IWC Scientific Committee over the last 20 years. Dr Leaper agreed that the only effective ways to reduce risk are to keep ships and whales apart or reduce vessel speed, and produced a summary table of mitigation measures that have been used to reduce ship strike risks including where these measures have been implemented[6]. A framework was presented on how to utilize raw data in predicting whale distribution/density and then optimize mitigation responses to balance risk reduction against impacts on shipping (Figure 2).

Timescale is an important aspect to bear in mind when considering mitigation responses, and can vary in several orders of magnitude, from seconds to years. Avoidance manoeuvres in response to sightings from the vessel itself have to be implemented rapidly, normally within a few minutes. At the other end of the scale, permanent routeing measures through the International Maritime Organization (IMO) necessitate years of data on whale distribution to be certain that their presence is consistent and reliable overtime. Given the availability of predictions over periods of days to weeks, planning on optimal routeing or targeted speed reductions can be carried out at the planning stage of individual voyages. Changes to the voyage plan can be made when the vessel is already on route if messages with updated information can be received, just hours or few days in advance.

The presentation proceeded by stressing that quantifying the effect of risk reduction from any mitigation measures, has proven to be challenging. Estimating absolute risk must consider many variables that are, in most cases, unknown. Estimating relative risk, can be more achievable, for example by using indexes based on whale and ship density to identify high-risk areas. Examples of utilizing predictive models and validation to evaluate the effectiveness of enabling vessel responses for avoiding whale ship strikes for the Western and Eastern Mediterranean were presented. Finally, Dr Leaper highlighted recent discussions at the IMO for reducing ship speed in order to tackle distinct environmental problems simultaneously. The Blue Speed[7] project estimates that capping ship speeds at 75% maximum design speed, representing approximately 10% speed reduction for the global [SOLAS] fleet, would correspond to 40% less underwater noise pollution from ships, 50% ship strike risk reduction, and 13% less Green House Gases emissions from shipping.

[6] https://iwc.int/document_3616.download

[7] https://bluespeeds.org/blue-speeds-shipping

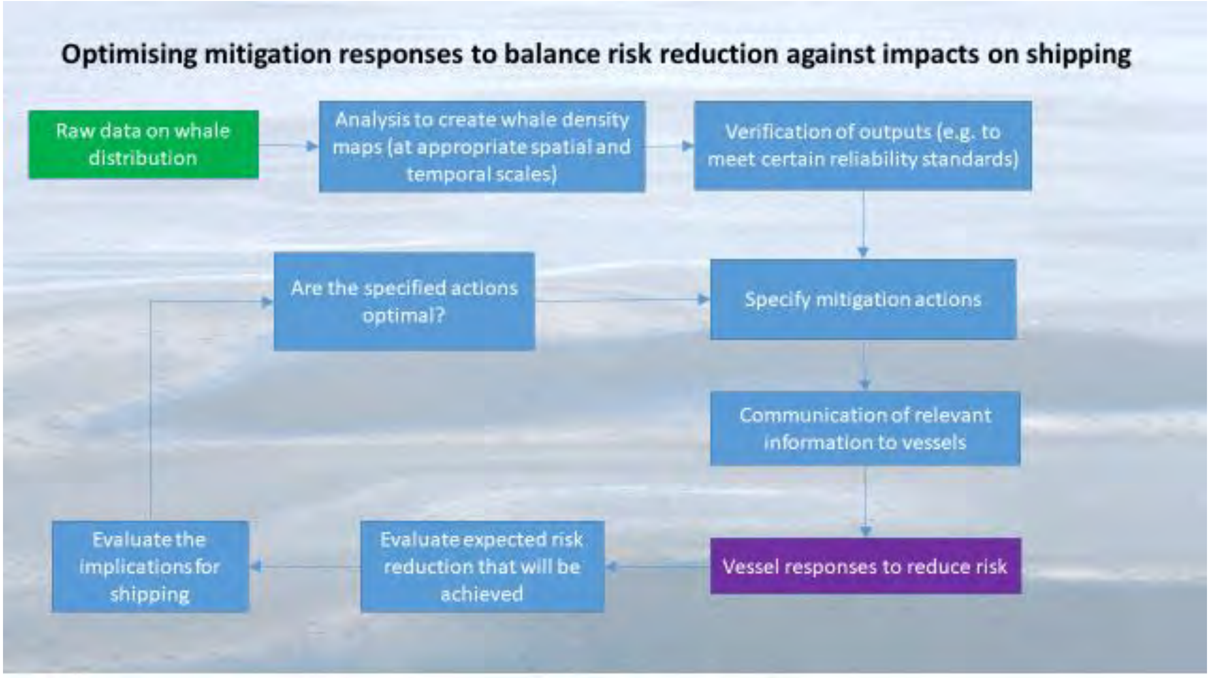

Figure 2: Framework to optimize mitigation responses to balance risk reduction against impacts on shipping. Reproduced from presentation slide; used with permission.

"Automating the process of finding whales in satellite imagery: current and future developments"

Peter Fretwell
British Antarctic Survey

Peter Fretwell from the British Antarctic Survey (BAS) presented the state of the art in whale detection utilizing remote sensing [satellite] images. The first study to utilize the technology was carried out in Península Valdez in 2014, using sub-meter resolution images from MAXAR's 50 cm resolution WorldView2 satellite to detect southern right whales (*Eubalaena australis*) [2]. With new higher resolution satellites, such as WorldView3 (30 cm resolution), detection and identification of other species became possible, leading to the development of automated detection and classification algorithms. Following this BAS, in collaboration with the IWC, identified several areas of global interest, to develop further studies and initiated many further collaborations. Data cases presented by Dr Fretwell highlight the need for good quality, high-resolution imagery, as well as automated processing to enable analysing thousands of images when the studies cover large areas. Since automation needs training data, a dataset was published and made available for developers.

However, more and new images from other areas, conditions, and species are still necessary for further advances/studies. Remote detection has the advantage of wide coverage, but there are limitations on the conditions in which images can be obtained and there are also species-specific variables such as behaviour, distribution, and chromatic patterns to be considered. In synthesis, whale detection automation on satellite imagery is dependent on: 1) the correct whale species with the correct behaviour; 2) the right environmental conditions; 3) a high enough conservation need [due to the high costs]; 4) correct automation techniques; 5) assess to imagery. In practicality, there are few places in the world where these conditions are all met, creating some limitations to the widespread utilization of the technology.

"Automated detection with buoys and gliders and tradeoffs in ship strike management"

Mark Baumgartner
Woods Hole Oceanographic Institution

Mark Baumgartner from the Woods Hole Oceanographic Institution (WHOI) participated remotely over videoconference. His presentation focused on two topics: 1) an automated near-real-time acoustic whale detection system on-board different platforms; and 2) the current ship strike management in the US, with focus on the East coast.

WHOI have developed technology for real-time acoustic recording and processing of audio from acoustically active whales, through the digital acoustic monitoring instrument, (DMON). The equipment was originally designed at WHOI by Mark Johnson, Alex Shorter and Tom Hurst, and redesigned at WHOI by Jim Partan, Tom Hurst, Keenan Ball and Mark Baumgartner. DMONs incorporate a low-frequency detection and classification system (LFDCS), which produces pitch tracks of sounds, which describe changes in the frequency (pitch) of a call over time [3]. The LFDCS extracts simple statistics of each pitch track (e.g., duration, average frequency, rate of change of frequency with time) and uses quadratic discriminant function analysis to classify each call. Classification is based on a known set of calls contained in a call library that is defined prior to deployment of the DMON/LFDCS. The system is integrated in a number of autonomous platforms, including Slocum gliders, profiling floats, wave gliders, and moored buoys. Information about detections by the LFDCS are transmitted to a shore station by Iridium satellite messages, reviewed by a trained analyst, and posted online[8]. The information is also re-distributed to a list of institutions, over email or SMS text message, including researchers, governmental agencies, industry members and an API to enable inclusion in applications by third parties.

DMON systems are deployed in several critical areas in the East and West coasts of the US, and sponsored by a wide range of actors that include governmental agencies, NGO, academia, and industry. Information is integrated in alert systems to prevent ship strikes on great whales. In the US West coast, the information is combined with other sources of information, including sightings and model predictions, in the WhaleSafe[9] tool, used to alert mariners about the presence of blue (*Balaenoptera musculus*), fin, and humpback whales in the approach areas of some large ports. WhaleSafe is also designed to monitor cooperation rates among shipping companies that are traversing voluntary speed restriction zones (V-SRZ). Cooperation rates off the Santa Barbara V-SRZ are currently below 62%, although the trend is positive since the inception of the program.

In the East coast of the US and Canada, the focus is only on one species, the North Atlantic right whale (*Eubalaena glacialis*). In the US East Coast, mandatory SRZ implemented through five static seasonal management areas (SMA), in which a 10 kt speed limit is mandatory for ships above 20 meters length. These areas are static both in time and space, and were based on historic whale density data from dedicated surveys. These SMAs are under revision, based on more recent data including exploring the expansion of their extent and periods of application. In In most mandatory SMAs, compliance is high (>80%). Outside those SMAs, acoustic (from DMON equipment) and visual observations trigger voluntary Dynamic Management Areas (DMA) and Slow Zones, to all vessels. These areas are managed by the

[8] http://robots4whales.whoi.edu

[9] https://whalesafe.com

National Oceanic and Atmospheric Administration (NOAA). Detections are reported online[10] and to a multi-platform application called 'WhaleAlert'[11]. Cooperation rates in the voluntary zones is poor, below 50%. In Canada, information obtained from equipment carrying the DMON system is used to implement mandatory SRZ shipping zones and call closures on fishing activities to reduce fishing entanglement risk. Dr Baumgartner stressed the importance of a robust monitoring network used for the success of any dynamic management system. In addition, dynamic systems produce uncertainties that are not welcomed by the shipping industry, and rely on a very good monitoring program to quantify and, if necessary, enforce compliance. The presentation finished with a summary of management options and trade-offs based on experience from managing North Atlantic right whales (Figure 3).

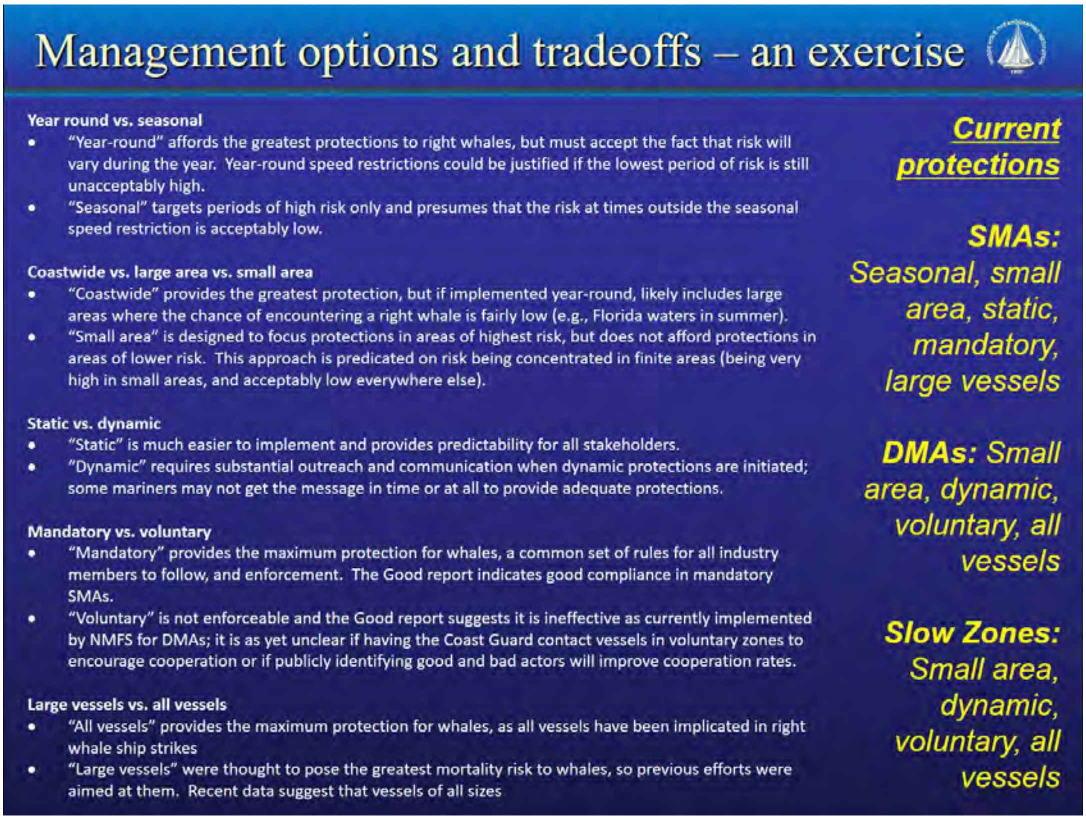

Figure 3: Whale ship strikes management options and trade-offs. Reproduced from presentation slide; used with permission.

[10] https://whalemap.org/whalemap.html

[11] https://www.whalealert.org

2.3 Specialists talks – day 2

"SEADETECT LIFE Project"

Simone Panigada
Tethys Research Institute

Simone Panigada from the Tethys Research Institute presented the goals and methodology of the ongoing SEADETECT LIFE Project, funded by the EU LIFE Program, for a development of an automated detection and anti-collision on-board system for vessels. To set the background, Dr Panigada presented statistics and results from scientific studies demonstrating the relevance of ship strikes as a non-natural mortality factor for diverse whale populations, and how that can affect their conservation in the long-term. For example, studies in the Pelagos Sanctuary showed that collisions with large ships are responsible for more than 20% of fin whale deaths in the Mediterranean. Additionally, ship strikes on large whales or floating objects such as lost containers can also cause damage to the vessels and endanger people on-board.

To tackle these problems, several on-board techniques are available and some have already been tested and even deployed (such as marine mammal observers, day and night vision systems) to try to reduce incidents by enabling evasive manoeuvres by the ships when danger is detected. However, some of the techniques are still experimental and there is also a need for automation in order to deliver information efficiently and in a timely manner. The SEADETECT LIFE Project proposes a new automated solution (REPCET) to prevent collisions. The ambition of the system is to be able to detect whales and unidentified floating objects in real time up to 1 km away from ships, in most weather conditions, 24 hours a day, both at the surface and underwater. SEADETECT will include three systems: 1) a system installed on the ships providing real-time alerts; 2) a network of passive acoustic monitoring (PAM) buoys to detect and triangulate cetaceans in real-time; and 3) detections will feed a data fusion and processing system, the REPCET sharing software, to inform vessels equipped with the system about the risk of collision, with at least an accuracy rate >80%. Throughout the talk, Dr Panigada mentioned the clear coincident points between the SEADETECT and OCEAN projects, and the potential for creation of synergies.

"AZORES NATURA LIFE IP Project"

Mónica A. Silva
Okeanos Institute of Marine Sciences; University of the Azores

Mónica Silva, from the Okeanos Institute of Marine Sciences, presented the goals and methodology of the section on cetaceans within the ongoing AZORES NATURA LIFE IP Project, funded by the EU LIFE Program. The AZORES NATURA Project is run by the Regional Government of the Azores and has as its overarching goal to significantly contribute to the conservation of species and habitats protected by the Habitats and Birds Directives in the Natura 2000 Network areas in the region. As all cetacean species are included in Annex IV of the Habitats Directive, all member states have an obligation to assess their conservation status and trends and report to the EU every six years. That calls for monitoring programs to enable assessment of status and trends regarding 1) natural range; 2) population size; 3) habitat extent and condition; and 4) future prospects.

The AZORES NATURA Project has four main objectives to enable compliance with these obligations: 1) provide updated estimates of cetacean abundance, distribution and habitat use; 2) develop cost-effective methods to address the Habitats Directive monitoring requirements; 3) assess intra- and inter-annual variability of ship strike risk and exposure to sound; and 4) compare efficacy of different risk management actions in reducing risk of ship strikes and noise exposure. Several techniques will be used, including a dedicated sighting survey for abundance estimation of several cetacean species. Simultaneously, automated routines to explore abundance, range and habitat use from fisheries observer data will be created and tested. A ship strike risk framework will be created using statistical methods integrating the density of ships and cetaceans, as well as functions to calculate lethality of ship strikes. Dr Silva also mentioned the complementary goals of AZORES NATURA, SEADETECT, and OCEAN projects and the opportunity for collaboration during and after the workshop.

"Importance of adapting the acoustic analysis process to the local calling repertoires"

Ana Širović
Norwegian University of Science and Technology

Ana Širović from the Norwegian University of Science and Technology discussed how variation in sound repertoires from cetaceans can influence detection rates by automated Passive Acoustic Monitoring (PAM) systems. Dr Širović presented a case study of the modifications that were necessary to apply the DMON system on-board moored buoys off the US West coast that was referred to by Dr Baumgartner in an earlier talk (refer to 0. The classification algorithm (LFDCS) relies on a large number of 'samples' to be 'trained' and thus, when applied to a new species or even a new area (because the same species of cetacean can have different repertoires in different regions) it needs to be 'trained' again, with an appropriate set of local acoustic samples. Following training, the validation process needs to be ran again, because the system may have different performances for distinct types of acoustic signals. Thus, the protocols to produce advisories [messages or reports] to ships about whale presence based on acoustic detections need to be adapted to species, species population, and regiont[8]. When relocating the DMON system from the US East coast to the West coast, there were changes to the detection of target species, as well as region, for a given species (in this case the fin whale).

One of the first challenges identified was that some species are more difficult to automatically detect, such as the humpback whale, since their vocal repertoire is complex and can evolve over time. In fact, for humpback whales, automatic classification is very difficult but visual classification by a trained human observer is relatively straight-forward. In this case, a simple protocol can be applied for visual verification of spectrograms to classify detections as positive, possible, or negative. The second case presented was for the fin whale. Although LFDCS was trained for signals from fin whales off the US East coast, the song dialect calls off the US West coast were distinct, presenting much more prolonged intervals between calls. This is an example of how changing the geographical context of a PAM system can influence the detection competence of the algorithm. The final case presented was for the blue whale. This species presents a further problem because the composing units of different dialects are completely distinct. Currently there are 11 known distinct song dialects for blue whales globally, with some overlapping geographically. That fact adds complexity for the classification protocol and again human intervention is fundamental to decide whether or not the automatic classification is correct. Overlap with ambient noise and other species is also an issue, not only due to masking but also through confusion due to similar song segments.

Dr Širović stressed that currently, fully automated classification is still not possible, and confirmation, or even full classification, from a human analyst may be necessary to guarantee the robustness of the system. One of the key aspects in order to have widespread acceptance of the system by the maritime community, is to have a credible system with very low levels of false positives. Having human analysts may delay issuing detections, but the amount of time will be context dependent, varying with season (because call rate varies seasonally), geographic context, and with each species. Thus, the temporal scale of advisories must be decided based on a case by case basis. Methods for assessing the rate of false and negative detections are necessary to test for robustness and should be implemented in each system.

"Effect of cue rates on acoustic detectability"

Tiago Marques
University of St Andrews; DBA/FCUL/CEAUL

Dr Tiago Marques, from the University of St Andrews and DBA/FCUL/CEAUL, made a presentation on how cue rates might affect detectability in passive acoustic monitoring (PAM) systems, and other aspects involving quantifying ship strike. For a number of reasons to evaluate the potential for ship strikes, it is important to be able to evaluate how many animals might be present in a given area. Some of the downsides of traditional visual based surveys are that individuals of some of the more elusive species can spend considerable time at depth, and surveys depend on favourable weather conditions and daylight to operate. They can also be expensive. This can make monitoring over long time periods very challenging. In particular for cetaceans, PAM approaches are increasingly being used, based on the fact that all cetaceans produce sounds which we can potentially detect with hydrophones. PAM has now become a method of choice to monitor many species of marine mammals, and different possible ways to estimate density or abundance from PAM data have been developed [4]. One possible approach to estimate animal abundance from PAM is a cue counting, which requires an assessment of cue production rates. In that context, cue rate is fundamental: all else being the same, a given number of detected sounds could correspond to a low animal density if the cue rate is high, but it might correspond to a high density if the cue rate is low. To convert an estimate of the number of sounds detected in a given area during a given period of time, we need to account for the number of sounds produced by an animal per unit time. A key aspect is that we need a cue rate that applies to the survey data, otherwise, bias might arise.

The ACCURATE[12] project is a large-scale multi-institution project, funded by the Living Marine Resources program of the US Navy, whose goals are to conduct research about everything that is related to cue production rate. Specifically regarding ship strikes, cue rate production is relevant because estimating density is essential for assessing high collision risk areas, and estimating acoustic availability as a potentially tool for avoidance or mitigation strategies. Datasets already available, such as that used in ACCURATE, can help in evaluating ship strike risk.

It is not only important to estimate cue rate, and its corresponding precision, but it is fundamental to understand what might drive variability in cue rates. Otherwise, it might be difficult to understand how one could use a given cue rate obtained at a given time or place for a survey conducted at another time and place. This is not because cue rates are dependent on seasonal patterns or regional differences per se but time and place might be easy to obtain overarching proxies to factors that affect cue rates, like behavioural state, diel patterns, group composition, ambient noise, sex, age, environmental covariates or even density itself. Of course if cue rate depends on density we must collect cue rate for the time and place we are interested in before making inferences, since by definition density will not be known for any particular specific species during passive acoustic density estimation (DE) exercises.

Acoustic availability can be calculated from data obtained from acoustic tags deployed on individuals, and can be used to estimate the time window necessary to detect individuals with some certainty. This can then be applied in, for example, calculating the time necessary to take pre-emptive action to avoid ship strike risk.

In the back of our minds we cannot forget that if some, or in fact any, of these factors affect cue rates (and sampling of animals for tagging [with tags that record sounds produced by animals] is not random with respect to those same factors), we might get confounding effects in the estimates of cue rates, induced by non-random sampling of animals. As an example, everything else being the same, if the sex ratio in an area is 1:1, but you tag more females than males and

[12] https://accurate.st-andrews.ac.uk

females produce more sounds than males, then you will overestimate cue rate, and underestimate animal density.

Not all sounds are appropriate for use in determining cue rate production. The sounds that are more appropriate for PAM DE have some general characteristics including: 1) wide propagation (for larger effective sampling areas); 2) easy to detect and classify automatically; 3) constant production over time. For these reasons, odontocete echolocation sounds might be far better than baleen songs for PAM DE.

From a statistical perspective, one of the challenges of estimating risk strike risk is that [ship strike] report rates and sampling effort are uneven, making comparisons across time, space, species, and ship time [spent in navigation] impossible. As an example, the striking decadal variation in ship strike reports (refer to 0) is difficult to interpret, and could be rooted in different causes, but shows the amount of uncertainty around the available data.

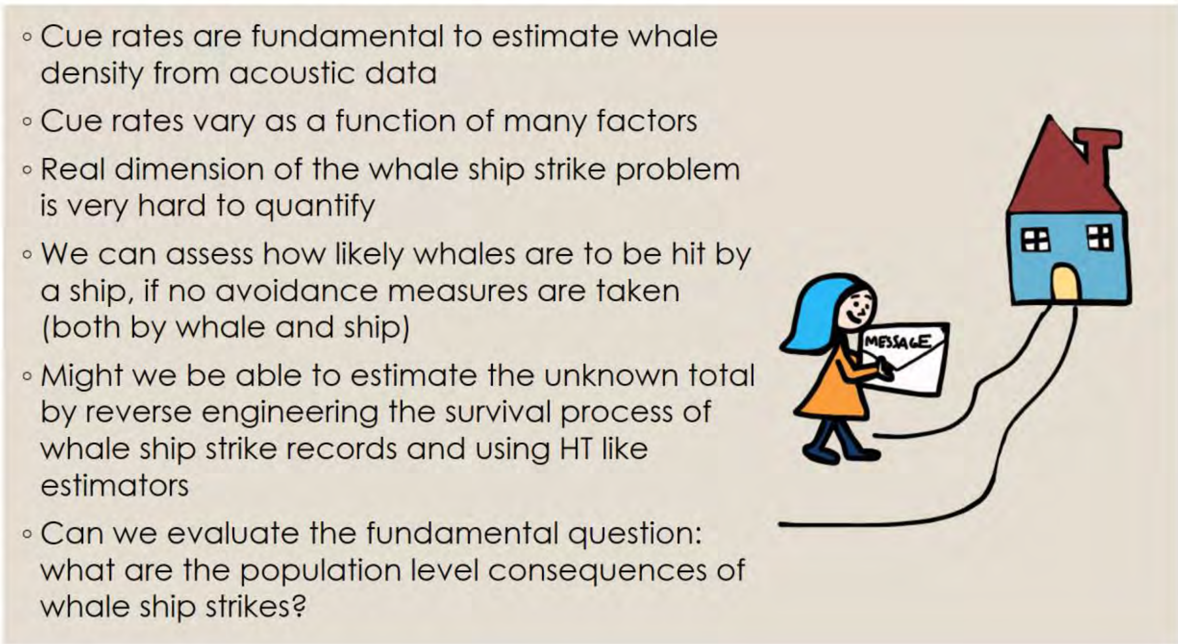

Figure 4: Highlights of the presentation ('Take Home Messages') by Tiago Marques. Reproduced from presentation slide; used with permission.

One of the objectives of any reasonable plan to tackle the issue must be able to identify which areas are of most concern, and these naturally occur at the overlap between whales and ships. However this is overcome by the fact we really only require relative surface density, not absolute densities, to address this question. However, other questions pose more challenges: 1) Can we quantify the impacts: from individual to population level consequences?; 2) Can we quantify the problem: how many whales are hit by ships per year in a given population?; 3) Can we assess the effectiveness of mitigation measures?. These questions are complex due to lack of data and consideration on how to tackle them is necessary and would benefit from experts in several fields from whale ecology to shipping. Dr Marques finished by presenting a list of 'take-home messages' (Error! Reference source not found.).

"An acoustic observatory for sperm whales in the Eastern Mediterranean Sea"

Emmanuel Skarsoulis
Institute of Applied & Computational Mathematics; Foundation for Research & Technology – Hellas

Dr Emmanuel Skarsoulis from the Institute of Applied & Computational Mathematics; Foundation for Research & Technology – Hellas presented results from a passive acoustic monitoring (PAM) system for detection and 3D localization of sperm whales that was developed and deployed in Greece. The SAVE Whales project[13] focuses of reducing ship strike risk for sperm whales in the Ionian Sea (Mediterranean), due to high rates or detected mortality attributed to ship-strike. The observatory was deployed in the southwestern sea off Crete and consists of three moored buoys equipped with hydrophones suspended at 100 meters depth, and a custom click detection and classification system that applies several filters and then applies a peak detection function to spectrograms to detect sperm whale clicks [5]. The main features of the system are:

- Real-time detection & localization of vocalizing sperm whales.
- 3D localization accounting for sound refraction effects (ray theory).
- Bayesian approach allowing for location uncertainty estimation.
- Autonomous acoustic buoys.
- Efficient, low-consumption on board processing.
- Real time data telemetry and 2-way communication.
- Synchronization through GPS.

In order to have a functional system several challenges had to be overcome:

- Arrival synchronization [of signals].
- Detection of regular click patterns.
- Identification of arrival pairs in each reception.
- Arrival association between receptions.
- Computational efficiency.
- Discerning multiple sources.

To tackle those challenges, the analysis is performed in two parallel lines of analysis, one for detection and another solving localization. The system was tested in 2020 (July – October) and 2021 (May – September) under controlled conditions (using artificial sources) and real conditions (tracking passing sperm whales geolocated visually from a boat). Results showed that localization of echolocating sperm whales was possible from up to 20 km, and 3D localization and tracking from up to 7 km. The system proved to be functional but there are challenges to be overcome, including: 1) Year-round operation, operation in remote areas; 2) power supply, communications, durability; 3) observatory cabled to shore for higher communication efficiency.

[13] https://sites.google.com/view/savewhales

"Smart Cables"

Sérgio M. Jesus
LARSys, SiPLAB, University of Algarve

Dr Sérgio Jesus presented a work by himself and Ricardo Duarte, both from the LARSys, SiPLAB, University of Algarve. The work is still theoretical, based on the principle of using communication submarine cables to detect and transmit acoustic signals from in the ocean. The work is being developed under the Knowledge and Data from Deep Space project[14]. The 'smart cable' concept was devised by You in 2010 [6], who called for multi-lateral cooperation to enable utilizing submarine telecom cables to obtain deep-ocean and seabed data by adding environmental sensors to the repeaters (deep nodes) installed in the cables approximately every sixty kilometres. Based on that concept, and among other goals, the Knowledge and Data from Deep Space project intends to install calibrated hydrophones in submarine cable repeaters to obtain sound data from the surrounding environment.

One problem with the concept, is that most existing passive acoustic monitoring systems (PAM) are deployed at or near the surface, while with the 'smart cables' concept, the PAM system would be deployed close to the bottom. This raises questions about the effect of water stratification and ambient noise in the detectability of signals.

By running mathematical simulations for acoustic sensors positioned at 10 meters above the bottom for different frequency bands and source distances, it was possible to show that marine mammal detection and localization can be sensed from deep nodes, but may be species and depth dependent. The potentiality and limitations of using 'smart cables' to detect and even localize marine mammals will be further studied within the project, which could be useful to extend PAM monitoring capabilities to remote areas.

"Use of circulation models to track drifting objects"

Manuela Juliano
Okeanos Institute of Marine Sciences; University of the Azores

Dr Manuela Juliano, from the Okeanos Institute of Marine Sciences; University of the Azores presented case studies in tracking drifting objects using a tri-dimensional hydrodynamic numerical model called MOHID. MOHID is a three-dimensional water modelling system, developed by MARETEC (Marine and Environmental Technology Research Center) at Instituto Superior Técnico (IST) which belongs to the University of Lisbon in Portugal[15].

The MOHID model was downscaled for the Azores region at two scale levels (with resolutions of 0.06° and 0.02°). As any modelling approach, circulation models of the initial sea conditions to be fed into the model, and validation is necessary to evaluate model robustness. The Azores MOHID model was validated for several variables, including temperature and salinity (in the water column) using Argo-buoys, and Sea Surface Temperature using remote sensing data. With the model calibrated, it is possible to use a Lagrangean model for backtracking and forecasting the trajectory of floating objects, such as containers, boats, drifting buoys, and other floating objects.

As a first study case, a small recreational fishing boat which disappeared in 2011 with its sole occupant from Terceira island, in the Azores on-board was, localized despite search and rescue missions by air and sea, and was assumed to have been sunk due to bad weather. After 11 days

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[14] https://www.mitportugal.org/research/flagship-projects/k2d-knowledge-and-data-from-the-deep-to-space

[15] http://www.mohid.com

the boat was finally found by a recreational fisherman, with its occupant dead on-board, in São Jorge island, some 30 nautical miles away from the departure port. In order to evaluate the utility of the drift models in cases such as this, Dr Juliano worked with the local authorities and ran two models with slightly different starting conditions (priors) to hind-cast the trajectory of the lost boat. One of the models did predict, although with low confidence, the arrival of the drifting object in São Jorge, but more importantly, the models enabled calculating the limits of a credible search area.

In a second study case, a lander (a platform moored to the bottom of the ocean with research equipment) prematurely released from its mooring and floated freely to the surface. Despite having a recovery system based on a satellite positioning beacon, bad weather conditions did not allow a rescue mission for two weeks, after which the battery of the recovery system was exhausted and stopped broadcasting the drifting lander position. Dr Juliano was contacted by the team responsible for the lander and forecasted the likely track for a period of five days after the last position received. The lander was indeed recovered just one nautical mile away from the predicted track[16]. One aspect that helped in this case was having the track from the previous days, to calibrate the model by hindcasting it.

The third study case refers to a sailing boat that disappeared in the Azores in 2018. No contact was made with the boat after 10 days and was declared missing. Even so an attempt to use drifting models were made to locate the boat. Predictions were made by two teams using slightly different models, that also had different resolutions. Although both models predicted very similar trajectories, the Azores MOHID model had a better resolution yielding a smaller search area. Unfortunately, the vessel was not found, presumably sunk.

These study cases illustrate the importance of knowing the detail of the velocity fields that, due to spatial and temporal variability and to its tridimensionality can only be known using mathematical models. The confidence of the predictions degrade rapidly overtime, but the models can also be used to create credible search areas. Finally, forecasting can be improved by calibration through hindcasting based on past known positions.

“Assessing trade-offs from static to dynamic management”

Elliott Hazen
University of California, Santa Cruz

Dr Elliott Hazen from the University of California Santa Cruz discussed the utilization of dynamic modelling to support management of maritime activities. Oceans are dynamic systems and therefore the animals that use those oceans are also dynamic in nature. Notwithstanding, many of the tools that we use to manage human activities in the oceans are static.

A case in point is the North Atlantic right whale. Management measures to reduce pressure from human activities such as fishing activities causing morbidity and mortality from entanglements, and ship strikes from increasing shipping traffic, were having some success until the early 2010’s leading to a positive recovery trend of the population. However, between2013-2014 environmental conditions in the areas used by the whales as feeding grounds moved their distribution further north, where management measures were not in place and whale mortality shot up drastically, leading to a loss of 15-20% of the population and a great part of the past conservation achievements were lost. The point is that even if management had the correct measures, if it is applied in the wrong place or time, it may not only be inefficient, but may actually cause more harm than good. A similar pattern also occurred in the US West coast with the humpback whale. Entanglements of whales, particularly humpback whales, off the US West coast increased sharply in the mid-2010’s,

[16] http://www.eu-midas.net/sites/default/files/newsletters/MIDAS_Newsletter_June2016_lowres.pdf

peaking in 2015-2016. The change in mortality rates could be tracked back, through a careful investigation, to a cascading effect of oceanographic changes on fisheries and on whale's prey availability and distribution. That led to an unusual time-space overlap of a large number of foraging humpback whales and crab pots/lines, leading to the increased number in entanglements and mortality. That particular case allowed for theoretically testing a new dynamic adaptive fisheries model that takes into account species protection with the maximum revenue [for the fisheries], by utilizing ecosystem models and data from revenues of the relevant human activities [fisheries]. By hind-casting the models and running them in a management program called 'Prioratizor' it was possible to show that by having smaller and more dynamic management areas, it would be possible to more efficiently minimize risk of whale entanglement while maximizing revenue for the fisheries.

This type of approach falls in the concept of 'dynamic ocean management' (DOM) that can be defined as "*Management that changes in space and time, at scales relevant for animal movement and human use*" (Figure 5). Most of the existing cases of DOM are voluntary schemes, but there are very good examples of mandatory systems as well.

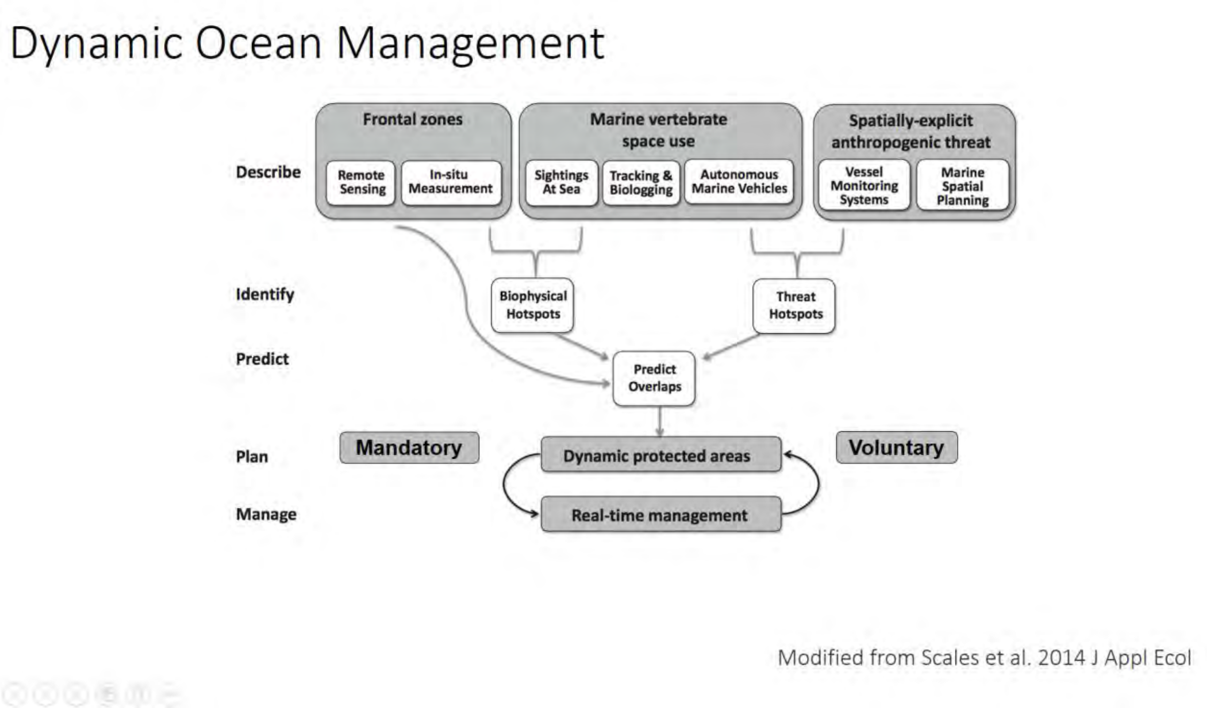

Figure 5: An example of a dynamic ocean management (DOM) framework. Reproduced from presentation slide; used with permission.

An example of a working tools for DOM is the EcoCast fisheries sustainability tool[17] [7], that is tailored to enable fishermen to target fisheries activities in high-yield areas/times but lowering the risk of accidentally capturing some marine predator species in the region covered by the tool. Results of the model are published through a dedicated app and updated daily.

A similar approach is being utilized to try to support ship traffic management in the US west coast by using ecosystem models to not only predict blue whale habitat but also whale density[18], which will be detailed by Briana Abrahms (see 0). The goal is to reduce ship strike risk for blue whales, which are experiencing high rates of whale morbidity and mortality in the region due

[17] https://coastwatch.pfeg.noaa.gov/ecocast

[18] https://coastwatch.pfeg.noaa.gov/projects/whalewatch2

to ship strikes. A model was built to predict whale habitat quality and then whale densities are predicted using contemporary environmental conditions.

One caveat with this type of approach is that the models predict the 'fundamental niche' while animals can only occupy the 'realized niche' that depends on factors such as accessibility (the area may have good conditions but is inaccessible) and population size (there are no animals available to occupy all the good areas). Thus, good data to check the robustness and transferability of model results is also necessary.

As a conclusion, Dr Hazen highlighted some of the main characteristics of DOM:

- We need a portfolio of integrated scales of management
- Dynamic ocean management can be a win - win and up to 10x more efficient than static management approaches.
- Dynamic ocean management offers a climate-ready management approach and a better match with ecological processes AND human activities in space and time.

Relevant literature, websites and software code are presented in Figure 6.

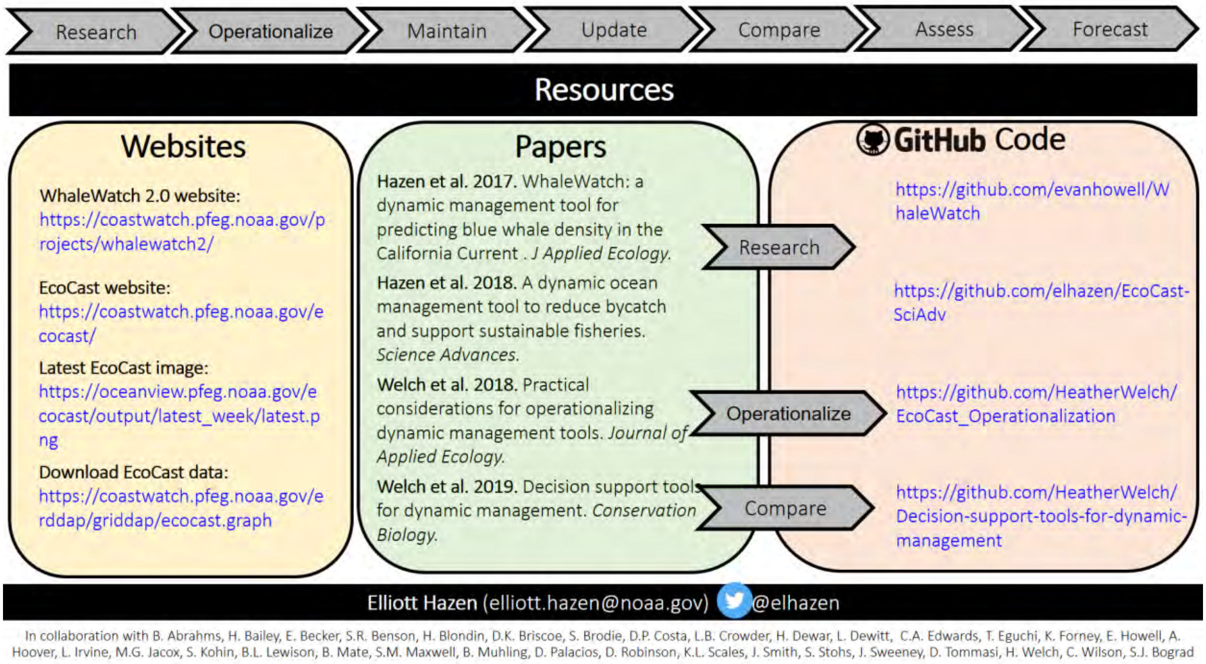

Figure 6: Relevant literature, websites and software code mentioned in Dr Hazen's presentation. Reproduced from presentation slide; used with permission.

"Matching scales of human and ecological data: Ship strike risk to blue whales (Balaenoptera musculus) in the Southern California Bight"

Hannah Blondin
NOAA Southeast Fisheries Science Center

Dr Hannah Blondin from NOAA Southeast Fisheries Science Center presented her work in characterizing ship strike risk for great whales, using whale and vessel distribution data. Dr Blondin started by presenting the study case of the blue whale in the Southern California Bight.

The Southern California Bight has a high seasonal concentration of blue whales and simultaneously intense shipping traffic, which has already been discussed (Harzen 2.3.8) are factors for enhanced ship-whale collisions risk. Although a Traffic Separation Scheme (TSS) is in place, passing through a Marine Protected Area (MPA), ships not always approach the area from the same direction, and have a dynamic distribution. On the other hand, the whale habitat is also dynamic in nature, which affects whale distribution and density. Notwithstanding, during last decade, most management policies in the region aimed at reducing ship strike risk have been static in nature, both seasonally and spatially, and have not accounted for variation in the overlap of whales and ships at a finer time-scale.

To investigate if a dynamic ocean management (DOM) could be more efficient in reducing blue whale ship strike risk in the area, Dr Blondin and colleagues undertook a study characterizing the ship strike risk by combining predicted daily whale distributions with continuous vessel movement data [8].

Models were run at different temporal resolutions to investigate the effect of using coarser resolution input data. For example, static models based on years of data will smooth the effects of interannual variability, such that from 'El Niño' years; by having higher temporal resolution these effects are captured.

Variability in risk was much greater when using higher resolutions of potential interactions, showing that coarser data mask this variability in risk arising from patchy conditions of blue whale habitat and/or variations in vessel traffic. In contrast, coarser temporal resolutions lead to the overestimations of risk. Additionally, the whales' short-term behaviour also affects the risk of ship strike. Dive data shows that the animals tend to stay at, or close to, the surface at night-time, which increases their exposure to ship strikes during those hours of the day. Thus, even if the model's resolution is 24 hours, some variation in risk will occur intra-daily and that should be taken into account.

In that sense, DOM accounting for dynamic patterns of human activity and species occurrences improves the assessment of human-wildlife conflict. Long-term environmental solutions depend on matching ecological data to human activity data at the most appropriate scale.

Dr Blondin continued by presenting preliminary results from a similar work towards assessing ship strike risk for North Atlantic right whales off the US East Coast. Simulations are being carried out to evaluate potential increase in right whale protection levels by enlarging areas of limited cruising speed. The preliminary results, not surprisingly, do indicate lower ship strike risk from that measure if implemented.

"Applying dynamic whale distribution models to mitigate ship strikes"

Briana Abrahms
University of Washington

Dr Briana Abrahms from the University of Washington presented work in utilizing a dynamic ocean management (DOM) approach to reduce ship strike risk in the US West Coast. The presentation builds on and complements those of Dr Hazen (see 0) and Dr Blondin (see 0).

Dr Brianna started by emphasizing that at current levels, blue whale ship strikes per year in the US West Coast is 10 times higher than the federal lethal limit. That fact is an important motivation to come up with realistic and efficient management tools that can significantly reduce incidents. Since it has been shown that a reduction of ship speeds below 10 kt can significantly reduce ship strike, a Whale Advisory Zone and Voluntary Vessel Speed Reduction Zone to reduce impact of ship strikes on whales is in place in the Santa Barbara Channel TSS. However, since it is not a mandatory rule, compliance levels are low. Consultation with shipping companies revealed that having 'blanket' advisories that do not change over time is too coarse and is not accepted well by the industry, as opposed to having concrete grounding of whale presence/absence in critical areas.

Thus, a multi-agency partnership was created to produce a tool to give shipping companies more realistic information about when are whales likely to be present in the area their ships are traversing and inform NOAA about compliance levels and areas/times to issue advisories. The goal was to develop a tool predicting blue whale habitat based on daily environmental conditions and 10 km resolution to offer finer scale approaches towards reducing ship strike risk.

The habitat model for blue whales was informed by whale telemetry data, and the Regional Ocean Modelling System[19]. Model validation was performed using extensive temporal and spatial cross-validation using independent sighting survey datasets [9]. After fitting and validating the model, it was transferred to a data-server to run and produce daily predictive maps [20,21].

To leverage the potential of this tool in reducing ship strike risk for blue whales in the US West Coast, the daily model predictions were integrated as an informative layer into the WhaleSafe[9] tool already described by Dr Baumgartner (see 0).

As mentioned earlier, WhaleSafe also implements a tool to measure compliance with the Voluntary Vessel Speed Reduction advisories issued by NOAA, utilizing the Automatic Identification System (AIS) call sign of ships and metadata to obtain ships cruising speed and trajectories. Compliance reports are public and provided to the shipping companies. Since the implementation of the WhaleSafe tool in 2020, the compliance levels have been steadily increasing, from 23% in 2017 to 59% in 2021, and although several confounding factors exist, the program seems to have played a role in that increase.

[19] https://oceanmodeling.ucsc.edu

[20] https://coastwatch.pfeg.noaa.gov/projects/whalewatch2/whalewatch2_map.html

[21] https://github.com/Brianaabrahms/DynamicEnsembleSDM

"An eco-informatics approach to map the risk of whale-ship collisions across the world's oceans"

Ana Nisi
University of Washington

The last presentation of the workshop was by Dr Ana Nisi, from the University of Washington. Dr Nisi presented the outline and preliminary results of an effort to quantify ship strike risk for great whale species, globally.

The preceding presentations illustrated some of the efforts that are currently in place to reduce ship strike risk to whales. One of the clear caveats of these efforts is that they are limited to relatively small areas and few species for which there are data available, both on whales and vessel traffic, as well the imminent threat to population/species viability in some cases. However, as also mentioned in a previous talk by Ms. Winkler (see 0) the issue is widespread and global. Having information on ship strike risk to whales is essential in deciding the prioritization of areas where directed interventions are necessary, as well as reducing overall ship strike risk by broader measures.

However, the greatest challenge to that goal is that great whale distributions globally have not yet been determined. That is in great part due to data deficiencies and challenges in modelling species distributions at large scales. To tackle that Dr Nisi and colleagues are developing global species distribution models for key great whale species, which will then be followed by creating maps of hotspots of ship strike risk by using ship traffic maps. The species distribution maps are being fitted using >1.4 million records from 600 private and public data sources. However, there are several challenges in modelling the distribution of wide-ranging, hard to observe species such as most of the whales.

One of the first issues is that data collected in different ways do not have the same statistical properties, and as such have traditionally had to be treated separately. Thus, this effort will rely on emerging models to leverage big data and more accurately infer habitat preferences and predict distribution; namely integrated species modelling that can process different types of data with distinct statistical properties, such as from dedicated sighting surveys, opportunistic sightings, and animal-borne biotelemetry tags.

Sampling bias is another problem. Not all areas have the same sampling effort, and thus inferences of habitat preferences can be skewed towards conditions present on the areas where more data are available. To try to counteract sampling bias, pseudo-absence data (data where whales are presumed not present) will be generated inside a 100 km buffer around presences and used to characterize the available environmental conditions to fit the models. Preliminary results for the blue whale in the North Pacific have good validation statistics, indicating that the model predictions are robust.

The next steps will include mapping shipping traffic using Automated Information System (AIS), finding ship strike risk by overlaying whale predicted distribution maps and AIS shipping density maps, and find 'blind-spots of ship strike risk' where information is scarce. Predictions of both whale distribution and ship strike risk, as well as uncertainty maps, will eventually be made public through a tool similar to WhaleSafe[9]. There are also predicted extensions to the project, including: 1) Finer-scale regional modelling; 2) Predict whale distribution shifts with climate change; and 3) Predict exposure to other threats.

3 Discussion Sessions

3.1 Discussion format overview

Discussion sessions were held on the final day of the workshop (26 January 2023). Discussions were undertaken in a round table format, with all workshop participants having equal opportunities to intervene. In the same manner as the presentations sessions, discussions were hybrid, with in-person and video conference participations. Participants over video conference could intervene in real-time via VVoIP.

Four discussion topics were proposed, with differing durations based on the perceived complexity of the topic. Each session was steered by a moderator from within the OCEAN Consortium to keep discussions within subject:

- 09:00 – 10:30: Animal Detection – Moderator: Guillaume Lapeyre.
- 11:00 – 12:00: Prediction of Animal Location – Moderator: Jonathan Earthy.
- 12:00 – 12:30: Data Fusion, Interfaces, Flow – Moderator: Francisco Rodero.
- 14:00 – 15:30: Collaboration – Moderator: Erik Styhr Petersen.

3.2 Session I: Animal Detection – Moderator: Guillaume Lapeyre

The moderator, Guillaume Lapeyre, kicked off the session by summarizing the questions that would be under discussion:

- How can marine mammals be detected?
- What are the actual cues for detection of marine mammals?
- After detection how should data processed?
- How to take all these data into a system that can provide near real time warnings to navigators?

Based on the questions raised by the moderator (above), the discussion evolved over the following recurrent subjects, that are highlighted along the text in BOLD CAPITALS:

- SYSTEM OPERATIONALITY.
- DATA SCARCITY and DATA QUALITY.
- Appropriate FRAMEWORK and SENSITIVITY.
- SYSTEM INTEGRITY.
- AWARENESS and COMPLIANCE with risk reduction measures.
- STAKEHOLDERS INVOLVEMENT.

It was suggested that one of the best platforms to have real time information are the vessels themselves. The example of WhaleAlert app mentioned during the presentations (see 0) utilized in the US for reporting whale sightings by mariners of all sectors in an attempt to reduce ship strikes. However, it was also noted that reporting rates by large ships can be negatively affected by the culture in the shipping industry. There may be a negative incentive not to report, especially under voluntary schemes, as reporting can affect other ships navigation and create delays. This is a COMPLIANCE issue and started a discussion about using independent Marine Mammal Observers (MMO) on the ships. The discussion on the utilization of MMO permeated the entire discussion of this session and became a recurrent subject.

On one side, one argument was that independent and trained MMO deployed throughout the SOLAS fleet would not only increase COMPLIANCE, as would enable collecting much needed data to tackle DATA SCARCITY and DATA QUALITY issues throughout the ocean. DATA SCARCITY hinder essential tasks as calculating population size, estimating risk, and fitting robust animal distribution models, testing model performance, and evaluating effectiveness of management policies to reduce ship strikes. On the other hand, it was argued that observers may be a burden to the industry and that training of mariners could in some sense be an alternative to dedicated MMO, given that they are already on-board. However, the consensus among the invited specialists was that mariners cannot replace MMO for data acquisition if the goal is to respond to questions about risk assessment and animal abundance, neither for *de-facto* or predicted distribution. One argument that was raised was that MMO are already systematically deployed in several sectors of the maritime industry, such as fisheries, marine seismic surveys, and marine wind farm construction sites, and that this experience could be applied in the transport sector.

However, the other dimension to the observers question is the efficacy of observers, trained or not, in giving information relevant to avoid imminent threats. After some discussion about the SYSTEM OPERATIONALITY aspects of making course or speed changes in response to an imminent collision risk from an on-board sighting, the consensus from the floor was that sudden changes in ship speed or course were not only inefficient but dangerous. Automated detection systems were discussed, not only to replace observers but to increase system efficiency by allowing detection at night, but the fundamental problem is that detections from the ship with current technologies will never be made at a far-away enough distance to enable safe pre-emptive manoeuvring. Shipborne acoustic systems were also discussed, in part because they would allow for detection at longer ranges, but also during night-time, of submerged animals and under adverse sea conditions. However, the acoustic specialists agreed that current systems are not useful for shipborne detection since the ships are a source of noise that masks all other sounds, especially in the low frequency ranges utilized by most of the whale species. According to the specialists, these systems work best when decoupled from the ships.

Thus, the consensus from the floor was that most of the value of shipborne observations is to alert other vessels, although it can also help avoiding ship strikes from the vessel reporting the sightings under certain circumstances. In that sense, it was argued by some in the floor that DATA QUALITY can be sacrificed in the name of efficiency. If the goal is to reduce ship strikes, knowing the species of whale that has been sighted is not as important as getting the information about the presence of whales know by other mariners in the area.

The discussion also brought up the issue of maximizing STAKEHOLDER INVOLVEMENT, closely tied to AWARENESS. STAKEHOLDER INVOLVEMENT has several dimensions, ranging from the involvement in contributing data to tackle DATA SCARCITY and DATA QUALITY issues, participate in discussions to try to reduce the risk of ship strikes and for creating policies, and guarantee COMPLIANCE with mitigation measures. It was emphasized that stakeholders must include all sectors of the maritime activity, and the floor agreed that an operational system would benefit from contributions from all types of stakeholders, and as such should be data agnostic, in the sense that it should be prepared to accept data from different sources even if not predicted initially.

It was pointed out that as a rule, mariners are supportive to marine conservation measures and that one of the aspects that may be lacking is AWARENESS. Many mariners perceive cetaceans as highly mobile and are not aware that they can be harmed by ships. Thus, forming and informing mariners in order to increase AWARENESS may help with STAKEHOLDER INVOLVEMENT and COMPLIANCE. It was mentioned that as part of OCEAN, several actions are planned in that aspect, including a webinar on ship strikes organized by the

Nautical Institute (the webinar has since been carried out and a recording was published[22]). It was also stressed that AWARENESS raising should be extended to the land crews in the industry, as the decisions on schedules and voyage planning are taken at that level.

SYSTEM OPERATIONALITY and SYSTEM INTEGRITY were also discussed and could benefit from the example of other systems already in operation. As mentioned above, there was an agreement that the operational system should be informed by different sources and be as data agnostic as possible. However, one of the important aspects raised was ensuring that SYSTEM INTEGRITY be maintained even if one or more data streams fail. That was an unexpected issue that was raised with the COVID-19 pandemic with the WhaleSafe tool (see 0; 0), when sightings stopped being submitted by several types of marine users. The system did not collapse because the protocols did allow for data stream failure.

Another aspect of SYSTEM OPERATIONALITY that was discussed was the standardization of the SENSIVITY utilized to issue warnings. A question was raised about whether it would be advisable to have standardized thresholds levels. One of the specialists involved with the WhaleSafe tool disagreed and argued that it should actually be avoided. There are several points against SENSITIVITY standardization, ranging from specific characteristics of the populations and geographical situation, to different national policies. The WhaleSafe experience shows that having good protocols in place is an important factor, and that although the process may be subjective, discussing the balance between trying to protect the animals and avoiding disturbing shipping operations is a key aspect for SYSTEM OPERATIONALITY.

A final aspect in the SYSTEM OPERATIONALITY of the system is its robustness to abide to international law, and have widespread cultural acceptance and transferability. It was stressed that although OCEAN was an EU funded project, by targeting EU ships it automatically makes it cross border, because European vessels carry a very large proportion of world trade. Within the OCEAN framework that is not viewed as an obstacle. It is inherent to the wide-scope nature of the system that is under development.

3.3 Session II: Prediction of Animal Location – Moderator: Jonathan Earthy

The moderator, Jonathan Earthy, opened by making an introduction to the focal questions for the session:

- How accurately can we predict the presence of marine mammals
  - Where the animals will be once the overhead of processing detections(s) has been added?
  - In an area?
  - Over time?
  - In terms of speed, direction?
- Should we concentrate on presence models or presence/absence models rather than something more complicated?

[22] https://www.youtube.com/watch?v=UPFhG3psS7c

Having these questions as a starting point, the ensuing discussion evolved over the following recurrent subjects:

- DATA SCARCITY and DATA QUALITY.
- MODEL PREDICTIVE POWER.
- PRECISION.
- MODEL VALIDATION.
- SENSIVITY tuning.
- SYSTEM OPERATIONALITY.
- STAKEHOLDER INVOLVEMENT.
- SYSTEM UTILITY and PERFORMANCE EVALUATION.

The specific question about whether speed and direction of animals can be predicted deserved a direct answer as it was not a simple one. The consensus among the specialists was that NO, speed and direction of animals CANNOT be predicted by any existing model framework. This evolved into a discussion of what is the real UTILITY of these models, and how that correlates with MODEL PREDICTIVE POWER and PRECISION aspects.

It was mentioned that from the experience in the US on engagement with the shipping industry in Southern California, the UTILITY of models is more relevant at the planning stage of a voyage, when accounting for speed reduction requirements. Models can be informative in that way and are welcomed by the seafarers as another source of information during voyage planning.

In that respect, the session moderator commented that seafarers are used to probabilistic models for weather forecasting, and that in that sense PRECISION could be traded by UTILITY if the models were indeed informative.

On the other hand, still based on the experience with the shipping industry in Southern California, when the issue is to avoid collisions, mariners also expect a level of PRECISION of the locations where animals are present which is not attainable by a model. That is where other data streams can be invaluable, by pin-pointing locations where animals have been detected.

Another aspect of model UTILITY is the MODEL PREDICTIVE POWER. One of the concepts that was hinted at several times was that models are bounded by the data used to fit them. Most importantly, as was put by one specialist, "(...) *the model is always trying to tell you how the animals respond to the environment, as the environment exists in the training dataset that you give it*.". In the face of climate change, that can influence how animals respond to changes in their environment, models can become unreliable and obsolete very quickly. That touches on the problem of DATA SCARCITY and DATA QUALITY.

One of the questions put forward was how much data are necessary for MODEL VALIDATION. Among the specialists, there was a generalized feeling that this is not an easy question, because it will depend on many factors. This had already been discussed in the earlier session (see 3.2), and the general consensus among the specialists is that model evaluation will need as much data as possible, and that data needs depend on the number and complexity of the questions being asked.

Reference was made to bio-assimilative models that can integrate new data upon becoming available and the model 'adapts' to that new information. This was proposed as "(...) *the future of best integrating data*", but was also acknowledged that currently there is not much experience with that approach". In the future, bio-assimilative models could be an answer to changing conditions, to maintain or increase MODEL PREDICTIVE POWER under changing conditions, and to DATA SCARCITY by continuously increasing sample size.

Another question on the list, "whether it would be best to utilize a presence/absence or presence-only modelling approach", was only briefly discussed with one specialist being of the opinion that for the goals in this discussion, either can work despite presence/absence being the gold-standard.

Another focus of the discussion was on SENSIVITY tuning or, in other words, how to decide thresholds in presenting model data and when to issue warnings. This discussion evolved, or continued, from the discussion in the previous session (see 3.2). Two main approaches were identified: 1) use a single threshold value for 'risk/no risk' classification, or 2) use a scale-based and more flexible system with different risk categories. Both approaches have advantages and drawbacks.

In a multi-level system, the thresholds are more subjective and can be confusing. What is the difference between 'High' and 'Very High' [risk of ship strikes]? The interpretation can be subjective depending on who decides and the users' own biases. On the other hand, the system could be more flexible, as thresholds can be changed in relation to each other metrics, depending on users' feedback and changes in actual risk. In the case of the WhaleSafe tool (see 2.1.2.6; 2.2.1.10), subjectivity was tackled by discussions among specialists, but also by STAKEHOLDER INVOLVEMENT. Risk level numbers and colour codes were chosen in part to be familiar to users, and to be similar to other well-accepted standards. Another problem with a multi-level approach is that it demands more internet bandwidth, may be more complex to present to the user and may not be practical, or even acceptable, for standard navigation communication protocols.

A binary system, with only one level is more easily applied and transmitted, and involves less subjectivity. On the other hand, it does not convey as much information.

One comment from a specialist was that the choice of system is tied to whether it is under a mandatory or voluntary scheme. In a mandatory scheme, a single threshold value is the most common approach and is normally linked to specific values defined by regulations. Systems with multiple SENSIVITY levels are possible in voluntary schemes, but as discussed earlier, these tend to have lower levels of compliance.

SYSTEM OPERATIONALITY was a recurrent topic in the discussion. One of the aspects discussed was where to focus efforts in order to have the best results. Given the problems with DATA SCARCITY, it was argued that focus should be on data-rich areas, or high-risk areas that have already been identified, in order to leverage existing information. It was mentioned that the IWC has already identified populations of concern (see 0) and that these could be a starting point. It was also mentioned that data may already exist, but not yet explored, specifically in the case of satellite remote sensing.

Throughout the discussion, the moderator and the OCEAN project leader stressed that this was in fact not the mandate of the project. Test sites have been decided, or are under discussion within the project consortium, but do not necessarily need to be align within the IWC areas of concern, more so because it was acknowledged that the list is not comprehensive. The goal of OCEAN is to create a robust system to alert mariners of risks along their voyage, and not to operationalize the system.

Notwithstanding, the discussion shed light on challenges for future SYSTEM OPERATIONALITY as part of the OCEAN warning environment (or for that matter any such system) in the EU. The OCEAN Project WILL create solutions for real-time cetacean detection and data transmission, namely from sightings reported through the mobile application being developed in OCEAN, and acoustic detections from the 'smart' sonobuoys integrating a detection and classification algorithm, also under development within the OCEAN Project (WP4).

However, good SYSTEM OPERATIONALITY will only be achieved if these solutions are deployed throughout EU waters. Also important, as mentioned by several of the workshop participants, currently there are few systems in place to provide marine mammal data in real time, within the EU or elsewhere. Only by implementing robust reporting systems based on sighting reporting systems, and a network of 'smart' sonobuoys such as those being developed in the OCEAN project, will SYSTEM OPERATIONALITY be accomplished.

Cetacean distribution models are also under development within the OCEAN Project, but as demonstrated in the discussions, models must be updated and re-fitted with other environmental conditions or new species, and that process is data-hungry. The problem of DATA SCARCITY had already been raised in the previous session (see 3.2), and was raised again during this session. In this aspect too, SYSTEM OPERATIONALITY will only be attained by tackling DATA SCARCITY problems.

System PERFORMANCE EVALUATION was another topic that was discussed extensively. Several specialists stressed that quantifying the effect of the system in reducing incidents and protecting whales is essential to assess SYSTEM UTILITY and foster STAKEHOLDER INVOLVEMENT. Nevertheless, it was acknowledged that this is extremely difficult to attain. Currently there are no tested methods to collect direct evidence of ship strike reduction. On the other hand, quantifying population trends would only be possible by using long data-series, extending over many decades, and would be plagued by confounding factors.

The consensus in the floor was that system PERFORMANCE evaluation by quantifying reduction of the number of incidents is not feasible in the time-frame of a project such as OCEAN.

However, a suggestion of using proxies for STAKEHOLDER INVOLVEMENT and compliance could help in implementing System PERFORMANCE EVALUATION.

3.4 Session III: Data Fusion, Interfaces, Flow – Moderator: Francisco Rodero

The moderator for this session was Francisco Rodero who made a brief introduction about the goals of the session discussion:

- Data Fusion: how do we empower the overall detection capability – and which data/information do we need to do so?
- (Dynamic?) weighting of data sources
  - Short-term?
  - Longer-term?
  - Learning system?

The ensuing discussion evolved over the following recurrent subjects:

- DATA ASSIMILATION and INTEGRATION.
- DATA STANDARDIZATION.
- DATA MANAGEMENT.
- END USERS.
- TIME COHERENCE.
- PRECISION.
- SCALE.
- SYSTEM INTEGRITY and OPERATIONALITY.

The type of data, qualitative or quantitative, was again discussed, with one expert suggesting that experience with the WhaleSafe tool (see 2.1.2.6; 2.2.1.10) suggested that qualitative data is more flexible, especially when a one data stream fails, which relates to SYSTEM INTEGRITY. A system based on qualitative data can be tailored to have different rules with different scenarios when combining multiple data streams, which can accommodate data stream failure. In that sense, the idea of using bio-assimilative models, already mentioned in earlier discussions (see 3.3) was highlighted, but since these are still in their infancy it was acknowledged that this solution is not feasible within a 36 months long project.

There was general agreement from several specialists that design of the system should have END USERS in mind and were preferably involved from the beginning of the development phase. The data collection system has to be simple otherwise it will become a burden to end users and the system will not be used. In that respect, a set of only a few and simple questions, preferably with pre-defined answers, that can be in the form of 'drop down' lists or similar, is the most efficient way of collecting relevant information. Necessary metadata such as geographical position, time, is easily collected from smart-phones and similar equipment, or from the navigation equipment on larger vessels. Another advantage of having pre-defined answers is that it limits the number of possible answers, decreases response variation, and, in turn, decreases issues with DATA ASSIMILATION and INTEGRATION.

As discussed earlier (see 3.2), to leverage different data sources, for example sightings, the system must ingest data with different formats. However, some level of DATA STANDARDIZATION is necessary, or solutions to ingest non-standardized data must be implemented. One of the proposed solutions for non-standardized data is the development of application programming interfaces (APIs) for data translation among systems. In relation to that, the OCEAN project leader informed the floor that development of APIs is intended in the project and that those will be made public/open source. One of the participants reminded that the Joint Nature Conservation Committee (UK) has already produced work towards coordination of data protocols and standards within the Joint Cetacean Protocol (JCP)[23]. This information was welcomed and it was stressed that tools such as JCP are a good step towards easier DATA ASSIMILATION and INTEGRATION.

Aside from DATA STANDARDIZATION, DATA VALIDATION was also briefly discussed. It was noted that some systems are based on human-led data validation and that this affects the time frame at which data can be published. For example, sightings reported by non-specialists may need validation prior to publication if the goal is to have sightings classified to species level. It was suggested that as real-time data validation is difficult, there are possible ways of automating alerts by interpreting multiple detections of animals in the same area as a higher confidence of animal occurrence, even if the species is not known. This also relates to PRECISION (level of identification) and SCALE. The level of precision, in terms of time, space, and the level of species identification will have to be decided. The time to process sightings can be extended if the life-span [the time a sighting stays visible in the public system] of the sighting is set to days. On the other hand, the level of identification required can possibly be low (e.g. whale instead of blue whale) depending on the SENSIVITY required. In this aspect, it was also noted that the system SENSIVITY can be affected by the perceived/documented threat level, which can vary both among, and within species (e.g. between different populations). A decision about using multiple thresholds, or a single one for populations of the same species with different threat levels, will have to be made. The alternative, is not taking into account threat level and treating all species as equally important. Nevertheless, the floor was informed by those responsible for the development of the sightings reporting app within the OCEAN project, that sightings will be dealt with by algorithms to enable near-real time reporting and not validated manually.

One important issue raised during the discussion related to TIME COHERENCE. Time can create problems DATA ASSIMILATION and INTEGRATION in several manners. Different systems, even those in the same equipment, may have different time-stamps. Time can problematic even when using GPS, as GPS time has to undergo time adjustments that can make time 'go backwards'. This can become a major issue and can bring down systems if there are no protocols implemented in the system to deal with this issue. However, there are

[23] https://data.jncc.gov.uk

conventions, best practices, and tested ways for dealing with these problems that can be implemented in an early stage. Solving those time discrepancies will need to be contemplated both at DATA ASSIMILATION and INTEGRATION levels, to guarantee SYSTEM INTEGRITY and OPERATIONALITY.

SCALE and PRECISION also have to be taken into account both in time and space. For example, PRECISION is highly relevant in the localization of acoustic sources when using an array of acoustic stations, because the equipment clocks need to be synchronized in order to calculate differences in the time of arrival of sound signals to each hydrophone. Normally, that synchronization needs to have a PRECISION of milliseconds. On the other hand, if the goal is just to know if animals are present in a given area, clock drift among equipment is not of great concern, as long as the drift is inferior to the PRECISION level of the detection reporting. For example, if the life-span of detections in a system is one day, errors of minutes do not matter. One participant stressed that based on their experience, in order to guarantee SYSTEM INTEGRITY and SYSTEM OPERATIONALITY, detailed documentation is essential.

Another aspect relating to SYSTEM OPERATIONALITY refers to the format(s) in which the information will be conveyed to the END USERS. Bandwidth can be an issue in marine communications. Thus, although the development of more informative, multi-level and map-based solutions to transmit the information to END USERS can be reviewed, raster files (as those used in heat maps) can be data heavy and may not be a feasible solution for all applications. For example, in areas with no [or expensive] internet access, data light solutions, such as polygons, are preferable. The same applies to standard protocols such as in the case of virtual marine Aids to Navigation (virtual AToNs).

3.5 Session IV: Collaboration – Moderator: Erik Styhr Petersen

The final session was moderated by Erik Styhr Petersen who presented the several dimensions of the single question open for discussion:

- How do we collaborate here on?
  - How can we keep working together?
  - How can we support what you are doing?
  - How can we share data?

The discussion main recurrent subjects were:

- COLLABORATION.
- DISSEMINATION.
- AWARENESS.
- DEMONSTRATION.
- SYSTEM OPERATIONALITY.

The discussion was opened with a suggestion to make, in the extent possible, all datasets public to foster COLLABORATION. Additionally, for the same reason, to have open-source coding to facilitating transferring the results to other systems and to foster data and knowhow sharing. The comments were well received by the moderator (and incidentally the project leader), who let the floor know that that, as much as possible, code produced in the OCEAN Project will go into open source, as per the grant agreement with the EC. Likewise, the Data Dissemination Plan of the OCEAN Project has dispositions for the publication of datasets under the FAIR data principles, apart from proprietary and sensible datasets.

In an answer to a question about the DISSEMINATION strategy of the OCEAN Project, the moderator also informed the floor that several ways of communication, not only to disseminate project results, but to stimulate COLLABORATION are in place. These include a website[24], and the *Maritime Stakeholders Forum*, and the *Technology Feedback Forum*. An invitation was extended to all present, to consider joining either or both of these *fora* by submitting their interest to the OCEAN Project.

One participant commented that although most in the room would probably like to contribute and collaborate further, time was always a constraint. Since there is no funding involved, the amount of person-hours that can be devoted to collaboration is restricted. The moderator clarified that the participation in these *fora* carries no obligations, being voluntary. On the contrary, they will act as a two-way communication avenue by and with the OCEAN Project. Another participant stressed that even if participants in the *fora* do not want, or do not have the time, to participate in a particular or any discussion, this can be a way of staying connected and updated with developments. It also serves to support good time and effort management; by allowing participants to stay informed and in contact, decisions can be more informed manner and some alignment of goals can be achieved. Conversely, the participation of representatives of the OCEAN Project in bodies represented in the workshop was encouraged. In particular, the invitation extended by Dr O'Loughlin for participation in the IWC-SSWG Expert Panel (see 0) was reinforced[25].

The particular aspect of scientific COLLABORATION was also discussed and, in principle, the researchers in the room were happy with that prospect. Scientific COLLABORATION is something that scientists are used to undertake, and are usually open to forge new scientific partnerships. However, this type of relationships must be backed by specific questions and data. The involvement of students at MSc and PhD level was also desirable.

In the scope of the work being developed in the OCEAN Project, the Nautical Institute is preparing a series of AWARENESS videos focusing on different aspects of navigation safety, including whale ship strikes. It was suggested that this could be another opportunity for COLLABORATION, not only to obtain advice from the specialists in the workshop, but to make these videos available as another tool for anyone working on the subject.

[24] http://ocean-navigation-awareness.eu/

[25] Meanwhile the OCEAN Consortium agreed in proposing Captain Aly Elsayed of the Nautical Institute to represent the OCEAN Project in the IWC-SSWG Expert Panel

One suggestion from a representative of the Regional Government of the Azores, which was well received, was to adapt the videos to different audiences, to obtain the widest reach possible. The moderator stressed that this is indeed a goal of the OCEAN Project, specifically by trying to involve not only the SOLAS-fleet but also the non-SOLAS segment. In following the suggestion, the OCEAN Project will try to have a targeted dissemination effort into that community.

While discussing scientific COLABORATION, a parallel discussion not related to the subject of this session occurred, pertaining to DEMONSTRATION and SYSTEM OPERATIONALITY. There was curiosity over the methodology that will be used in the DEMONSTRATION phase of the project. The moderator was questioned about the production of a risk analysis to decide about where monitoring assets such as sonobuoys would be [definitively] installed in order to maximize the return from the monitoring system. The moderator suggested that this question was based on a misconception about the OCEAN Project being focused on the development of a cetacean monitoring program. Instead, the OCEAN Project pivots around establishing the infrastructure ("European Navigational Hazard Infrastructure") to ensure that ships can be reached, when existing data supports generating warnings about the presence of marine mammals, lost containers or other threats to navigational safety. The mandate of the OCEAN Project is not to make decisions about where assets should be deployed, or how the system should be rolled out across hotspots in Europe or, indeed, across the world. This is beyond the remit of the project. Nevertheless, this raised a question already discussed in an earlier session (see 3.3) about future SYSTEM OPERATIONALITY. Once the European Navigational Hazard Infrastructure is operational, it will depend on relevant and reliable data streams based on acoustic and visual detections, remote sensing, and model predictions. These systems will have to be functional and widespread across the EU waters to guarantee SYSTEM OPERATIONALITY in the long-term.

3.6 Closing Session

With the end of the discussion sessions, a brief closing session followed, during which the Organization of the *Workshop on Marine Mammal Ship Strike Mitigation* thanked all the speakers, the assistance, as well as the technical and catering personnel. Special appreciation was extended to the Sea School of the Azores – EMA, in the name of Ana Rodrigues and all the staff, for opening the doors of the institution and providing logistical support.

During the Closing Session, many of the participants praised the workshop organization and outcomes, as well as the venue and all those involved in organizing and running the workshop. These demonstrations of approval were well received and understood as a qualitative measure of success.

4 Conclusions

The *Workshop on Marine Mammal Ship Strike Mitigation* served three purposes:

1. To bring the OCEAN project up to the state of the art in cetacean ship strike mitigation technologies and procedures;
2. To align the work developed within the project with other efforts to reduce incidents involving vessels and marine mammals;
3. To foster collaboration between different actors in cetacean ship strike mitigation.

During the workshop, the OCEAN partners had the opportunity to interact directly with some of the lead world specialists in cetacean ship strike mitigation, learning from their combined *know-how*, tested mitigation measures, past errors, and challenges still to be tackled. On the other hand, the workshop also served to inform these same specialists about the OCEAN project ambition of creating a system supporting an enhanced navigational situation awareness and improved means to perform mitigating actions conductive to a reduction in cetacean ship-strike risk.

The discussion sessions were tailored at answering specific questions aimed at improving the efficiency of the forthcoming work to develop the enhanced navigational situation awareness system predicted in the project.

During these discussions, several challenges were identified and possible ways of tackling those were debated. These discussions will serve to guide some of the project's forthcoming work in a more focused way. In particular, discussions highlighted the importance of an early involvement of end-users in the development phases of the systems and of the importance of creating systems that can be scalable and informed by different data sources. These conclusions reinforce the strategy already adopted in the OCEAN project, serving as a reassurance of the work plan in course. Discussions in data-limitations, protocols and data standards will also assist in the forthcoming work.

Importantly, some of the conclusions of the discussions go much beyond of the scope of the project goals and pertain fundamental challenges in cetacean ship-strike mitigation. Specifically, it was clear from the workshop discussions that utilizing environmental niche models or density models to predict risk areas (as included in the OCEAN framework) is one of the most powerful tools to reduce ship strike risk. Nonetheless, it was also stressed that there is a profound scarcity of data to create these models at relevant temporal and spatial scales for most of the oceans. Programs to obtain these data in a standardized and regular basis are necessary to enable the widespread use of this approach in reducing cetacean ship-strike risk.

Likewise, it was also concluded that although the system being developed in the OCEAN project is an important step towards cetacean ship-strike mitigation, its strength will depend on the existence of reliable data streams based on acoustic and visual detections, remote sensing, and model predictions. The conditions to have these data streams in a regular and widespread manner will have to be guaranteed across the EU waters.

5 References

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6 Annex 1: The Consortium

Høgskulen på Vestlandet	Inndalsveien 28 P.O Box 7030 5020 Bergen, Norway	https://www.hvl.no/en/
KYSTVERKET NORWEGIAN COASTAL ADMINISTRATION	Flathauggata 12 5523 Haugesund, Norway	www.kystverket.no
	Heroon Polytechniou 9 Zographou campus 15780 Athina, Greece	www.ntua.gr
CIMNE EXCELENCIA SEVERO OCHOA	C Gran Capitan, Edifici C1, Campus Nord UPC SN 08034 Barcelona, Spain	www.cimne.com
TELEDYNE RESON Everywhereyoulook	Fabriksvangen 13 3550 Slangerup, Denmark	www.teledynemarine.com/resor
OKEANOS	Rua Da Mae De Deus Reitoria Apatado 1422 9501 801, Ponta Delagada S Miguel Acores Portugal	www.uac.pt
KONGSBERG	Kongsberg Maritim: Strandpromenaden 50 Po box: 1009 3183 Horten, Norway	www.kongsberg.com
KONGSBERG	Kongsberg Seatex: Pirsenteret 7462 Trondheim, Norway	www.kongsberg.com
UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH	Calle Jordi Girona 31 08034 Barcelona, Spain	www.upc.edu
IRISH FERRIES	Alexandra Road Ferryport D01 W2F5 Dublin, Ireland	www.irishferries.com
IWDG	Merchants Quay V15 E762 Kilrush, Clare Ireland	www.iwdg.ie
The Nautical Institute	Lambeth road 202, SE 7LQ London, United Kingdom	www.nautinst.org
LR	Fenchurch street 71, EC3M 4BS, United Kingdom	www.lr.org

7 Annex 2: Project Summary

The OCEAN project is focused on enhancing operator awareness in navigation, to reduce the frequency of severe accidents like collision and grounding, to mitigate ship-strike risks to marine mammals, and to mitigate the risk presented by floating obstacles to ships.

The OCEAN project will contribute to an improved understanding of accident root causes, and will strive to reduce the resulting human, environmental and economic losses through socio-technical innovations supporting ship navigators.

The OCEAN consortium, coordinated by Western Norway University of Applied Sciences, includes 13 partner organizations across 7 different European countries from the industry, academia, NGOs and end users.

Around 3.000 maritime incidents occur every year in the European maritime fleet. 28% of these accidents are categorised as severe or very severe accidents, resulting in the loss of life onboard, pollution, fire, collisions or grounding. Navigational accidents are dominant in these statistics according to the European Maritime Safety Agency, be it for cargo, passenger or service ships.

The OCEAN project ambition is to contribute to the mitigation of navigational accidents by supporting the navigators to do an even better job than they do presently. The OCEAN consortium will address the most pertinent factors that may contribute to events becoming accidents: training, technical, human or organisational factors, operational constraints, processes and procedures, commercial pressures, and will recommend improvements and amendments to regulations, standards and bridge equipment design approaches.

OCEAN seeks to enhance navigational awareness “on the spot” and to improve the performance of evasive manoeuvring to avoid collision with near-field threats. The project will deliver and demonstrate several human centred innovations. For example, the 4D Situation Awareness Display which will be developed in the OCEAN project will improve the visualisation of navigational hazards, integrating current bridge information systems with marine mammal and lost floating containers detection and tracking capacity specifically developed by the project.

Going further, the project will design and implement a European navigational hazard data infrastructure to feed multi-source observations and hazard predictions relating to floating containers and large aggregations of marine mammals into the existing distributed maritime warning infrastructure. OCEAN seeks to transfer this data ecosystem to relevant European organisations for deployment and maintenance.

8 Annex 3: Workshop Program

Workshop on marine mammal ship strike mitigation

Platform: Zoom / Meeting ID: 621 176 9591 / Pass: x9Q8cn

24 tuesday

11:00 to 11:30
Ana Rodrigues (Sea School of the Azores)
Welcome

11:30 to 12:00
Visit to EMA

12:00 to 12:30
Erik Petersen (Western Norway University of Applied Sciences)
The OCEAN Project

12:30 to 14:00
Lunch time

14:00 to 14:30
Christina Winkler
Short summary on global ship strikes

14:30 to 15:00
Lydia O'Loughlin (International Whaling Commission)
IWC Ship Strike WG and database

15:00 to 15:30
Russel Leaper (International Fund for Animal Welfare - UK)*
Requirements of data systems to support effective ship strike reduction through routeing changes or targeted speed restrictions

15:30 to 16:00
Coffee Break

16:00 to 16:30
Peter Fretwell (British Antarctic Survey)
Automating the process of finding whales in satellite imagery: current and future developments

16:30 to 17:00
Mark Baumgartner (Woods Hole Oceanographic Institution)*
Automated detection with buoys and gliders and tradeoffs in ship strike management

25 wednesday

9:00 to 9:30
Simone Panigada (Tethys Research Institute)
SEADETECT LIFE Project

9:30 to 10:00
Mónica Silva (Institute of Marine Sciences - Okeanos, UAzores)
AZORES NATURA LIFE IP Project

10:00 to 10:30
Ana Širović (Norwegian University of Science and Technology)
Importance of adapting the acoustic analysis process to the local calling repertoires

10:30 to 11:00
Coffee Break

11:00 to 11:30
Tiago Marques (University of St Andrews, DBA/FCUL/CEAUL)
Effect of cue rates on acoustic detectability

11:30 to 12:00
Emmanuel Skarsoulis (Institute of Applied and Computational Mathematics - FORTH)
An acoustic observatory for sperm whales in the Eastern Mediterranean Sea

12:00 to 12:30
Sérgio Jesus (SiPLAB University of the Algarve)
Smart Cables

12:30 to 14:00
Lunch time

14:00 to 14:30
Manuela Juliano (Institute of Marine Sciences - Okeanos, UAzores)*
Use of circulation models to track drifting objects

14:30 to 15:00
Elliott Hazen (University of California, Santa Cruz)
Assessing trade-offs from static to dynamic management

15:00 to 15:30
Hannah Blondin (NOAA Southeast Fisheries Science Center)*
Matching scales of human and ecological data: Ship strike risk to blue whales (Balaenoptera musculus) in the Southern California Bight

15:30 to 16:00
Coffee Break

16:00 to 16:30
Briana Abrahms (University of Washington)*
Applying dynamic whale distribution models to mitigate ship strike risk

16:30 to 17:00
Anna Nisi (University of Washington)*
Integrating big data to map global distributions of the great whales

26 thrusday

9:00 to 10:30
Discussion

10:30 to 11:00
Coffee Break

11:00 to 12:30
Discussion

12:30 to 14:00
Lunch time

14:00 to 15:30
Discussion

15:30 to 16:00
Coffee Break

*Remote Talk

UK participants in Project OCEAN are supported by UKRI grant numbers 10038659 (Lloyds Register) and 10052942 (The Nautical Institute)

Co-funded by the European Union

9 Annex 4: List of Participants

Speakers (by Program order)	Institution
Erik Petersen	Western Norway University of Applied Sciences
Christina Winkler	Atlantic Technological University, Galway, Ireland
Lydia O'Loughlin	International Whaling Commission
Russel Leaper*	International Fund for Animal Welfare
Peter Fretwell	British Antarctic Survey
Mark Baumgartner*	Woods Hole Oceanographic Institution
Simone Panigada	Thetys Research Institute
Mónica A. Silva	Institute of Marine Sciences - Okeanos; University of the Azores
Ana Širović	Norwegian University of Science and Technology
Tiago Marques	University of St Andrews; DBA/FCUL/CEAUL
Emmanuel Skarsoulis	Institute of Applied and Computational Mathematics - FORTH
Sérgio Jesus	SiPLAB; University of Algarve
Manuela Juliano	Institute of Marine Sciences - Okeanos; University of the Azores
Elliot Hazen	University of California, Santa Cruz
Hannah Blondin*	NOAA Southeast Fisheries Science Center
Briana Abrahms*	University of Washington
Anna Nisi*	University of Washington

*Remote presentations

Remote participants (Alphabetical order)	
Africa Marrero	International Centre for Numerical Methods in Engineering
Gorm Wendelboe	Teledyne Reson A/S
Inês Torres	Institute of Marine Sciences - Okeanos; University of the Azores
Ludwig Houegnigan	Polytechnic University of Catalonia
Pádraig Whooley	Irish Whale and Dolphin Group
Sérgi Perez-Jorge	Institute of Marine Sciences - Okeanos; University of the Azores
Simon Berrow	Irish Whale and Dolphin Group

On-site participants (Alphabetical order)	
Aly Abdelrahman Aly Elsayed	The Nautical Institute
Cláudia Oliveira	Institute of Marine Sciences - Okeanos; University of the Azores
Eivind Rinde	Norwegian Coastal Administration
Francisco Javier Hernando Pericas	Polytechnic University of Catalonia
Francisco Miguel Rodero Blanquez	International Centre for Numerical Methods in Engineering
Frèderic Vandeperre	Institute of Marine Sciences - Okeanos; University of the Azores
Guillaume Frederic Lapeyre	Western Norway University of Applied Sciences
Harvey Stoelinga	Teledyne Reson A/S
Helene Marie Rangnes	Kongsberg Maritime A/S
Irma Cascão	Institute of Marine Sciences - Okeanos; University of the Azores
Joana Miodonski	Azores Regional Government; Regional Directorate for Maritime Policies
João Lagoa	Azores Regional Government; Regional Directorate for Maritime Policies
Jonathan Earthy	Lloyd's Register

On-site participants (Alphabetical order) [continued]	
Katharina Leeb (PhD student)	Institute of Marine Sciences - Okeanos; University of the Azores
Lene Brandsø Reiersen	The Norwegian Coastal Administration
Ludwig Roland Houegnigan	Polytechnic University of Catalonia
Mariana Silva (PhD student)	Institute of Marine Sciences - Okeanos; University of the Azores
Max Klier (MSc student)	Institute of Marine Sciences - Okeanos; University of the Azores
Miriam Romagosa	Institute of Marine Sciences - Okeanos; University of the Azores
Myriam Lebon (PhD student)	Institute of Marine Sciences - Okeanos; University of the Azores
Richard Aase	The Norwegian Coastal Administration
Rita Carriço	Azores Regional Government; Regional Directorate for Maritime Policies
Rui Prieto	Institute of Marine Sciences - Okeanos; University of the Azores
Solveig Lund Witsø	Western Norway University of Applied Sciences
Susana Simião	Azores Regional Government; Regional Directorate for Maritime Policies

10 Annex 5: Workshop Pictures

Figure 7 - Workshop on Marine Mammal Ship Strike Mitigation. Aspect of the round table during discussion sessions.

Figure 8 - Workshop on Marine Mammal Ship Strike Mitigation. Group photo outside Sea School of the Azores – EMA (not all participants present).

Figure 9 - Workshop on Marine Mammal Ship Strike Mitigation. Group photo (not all participants present).