

ESOMM-2024 Programme
8th International Meeting on the Effects of Sound
in the Ocean on Marine Mammals
The Hague, The Netherlands
8-13 September 2024

Conference Organizers

Frans-Peter Lam, TNO

Peer Tas, NL Materiel and IT Command COMMIT

Marije L. Siemensma, Marine Science & Communication

Introduction

This 8th International Meeting on the Effects of Sound in the Ocean on Marine Mammals (ESOMM) in The Hague, the Netherlands, brings together scientists who study the effects of sonar and underwater explosions to share their research results with operational users and regulators and to show how to improve management and regulation of these activities based on science. The knowledge shared during ESOMM will support military operators who need to ensure responsible use of naval sonar systems and underwater explosions.

However, we need to look further than the Navy sector, and it has been the tradition of previous ESOMM conferences to bring together different communities. Not only the military community has worked on the management and understanding of the effects of underwater sound on the marine environment. Other sectors, especially the offshore energy sector—both the oil and gas producers and the renewable energy sector—have made significant investments on this topic, and we would like to encourage the exchange of knowledge between these different communities.

Cooperation between communities is becoming more urgent with the European Marine Strategy Framework Directive (MSFD) and the NOAA Ocean Noise Strategy; regulators and policymakers realize the need to address the effects of all relevant sound sources. To address cumulative effects in the future, we need to combine knowledge across sectors. During the ESOMM-2024 meeting, representatives of different communities

will come together. This provides an excellent opportunity to discuss the important role of sound science in policy and regulation development, and in environmental management.

To better understand and mitigate impacts of anthropogenic sound on marine life, it is of key importance to use all relevant information and to identify and prioritize knowledge gaps so relevant research can be commissioned and communicated. In addition to this, it is also critical to bring together the relevant stakeholders to share insights and develop sustainable solutions. We are looking forward to a successful week with informative and fruitful cross-sector stakeholder discussions.

Frans-Peter Lam, TNO

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Disclaimer: All abstract text appears as it did in the original programme. The journal editors are not responsible for any errors within abstracts as they appear as submitted to the symposium.

Programme Outline

Sunday, 8 September

- Icebreaker and Registration at the Carlton Beach Hotel Scheveningen – 1700-1900 h

Monday, 9 September

- *Registration and Coffee – 0800 h*
- Formal Opening of the Meeting by the Royal Netherlands Navy
- Welcome and Introduction by Organizers; Opening and Scope of ESOMM-2024
- Navy Developments
- *Break*
- International Policy & Regulation, Science & Technology Developments
- *Lunch Break at Carlton Beach Hotel*
- International Policy & Regulation, Science & Technology Developments (continued)
- *Break*
- Science & Technology Developments
- *Reception at The Beach House (closing 1900 h)*

Tuesday, 10 September

- *Coffee – 0800 h*
- Behavioral Response Studies in the Field
- *Break*
- Behavioral Response Studies in the Field (continued)
- *Lunch Break at The Beach House*
- Offshore Wind
- *Break*
- Offshore Wind (continued)
- *Closure – 1645 h*

Wednesday, 11 September

- Several Optional Outdoor Activities (Boot Camp, Swim in the North Sea, Guided Dune Walk) – Starting time: 0730 h
- *Coffee – 0945 h*
- Behavioral Response Studies in the Field
- *Lunch Break at The Beach House*
- TTS, Captive Studies, Masking, Soundscape, Shipping
- *Break*
- Masking, Soundscape, Shipping
- *Closure – 1700 h*

Thursday, 12 September

- *Coffee – 0800 h*
- Joint Industry Programme (JIP) Session
- *Break*
- Joint Industry Programme (JIP) Session (continued)
- *Lunch Break at Carlton Beach Hotel*
- UXO
- *Break*
- Regulation & Mitigation
- Management & Regulation Panel Discussion
- *Closure – 1640 h*
- *Departure for Dinner (timing to be confirmed)*

Friday, 13 September

- *Coffee – 0845 h*
- Population Consequences
- *Break*
- Population Consequences (continued)
- *Lunch Break at Carlton Beach Hotel*
- Seismic, eDNA, Prey Field Mapping
- Closing of Plenary Programme ESOMM-2024
- *Coffee & The End – 1530 h*

Abstracts – ESOMM-2024

(The abstracts below are alphabetically sorted based
on the surname of the first author)

The Global Natural Ocean Soundscape (10-100 Hz): Baleen Whales, Ice Cracking and Seismic Activity

M. Ainslie,^{1*} S. Cheong,² M. Halvorsen,³ P. Harris,² S. Robinson,² and L. Wang²

¹JASCO Applied Sciences (Deutschland) GmbH, Schwentinental, Germany

²National Physical Laboratory, Teddington, UK

³JASCO Applied Sciences (USA), Silver Spring, MD, USA

*michael.ainslie@jasco.com

The global ocean soundscape in the frequency range 10-100 Hz is sometimes characterised as “shipping noise,” originating from “ocean traffic.” Looking beyond the sound from distant shipping, one finds a rich spectrum of natural sounds from baleen whale calls, ice cracking, earthquakes and volcanic eruptions. Sound pressure time series acquired at six hydroacoustic stations of the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty are processed in eleven decade frequency bands, with centre frequencies 10-100 Hz. While some sites (Wake Island and Ascension Island) are dominated by anthropogenic sounds, others (Cape Leeuwin, Juan Fernández, Crozet Islands and Diego Garcia) are at remote locations, where natural sounds, especially baleen whale calls at low frequency (16-25 Hz bands), are more prominent, providing insights into the global natural soundscape. Natural sounds are identified at all six sites. Long term trends (2003-2021) in the natural and anthropogenic sounds are presented.

E&P Sound and Marine Life JIP Acoustic Modelling (JAM) Workshop

M. A. Ainslie,^{1*} M. B. Halvorsen,² S. J. Labak,³ R. Laws,⁴
Z. Li,⁵ K. Lucke,⁶ and R. Racca⁵

¹JASCO Applied Sciences, Schwentinental, Germany

²JASCO Applied Sciences, Silver Spring, MD, USA

³Bureau of Ocean Energy Management, Washington, DC, USA

⁴Havakustik Ltd

⁵JASCO Applied Sciences, Victoria, Canada

⁶German Environment Agency, Dessau-Roßlau, Germany

*michael.ainslie@jasco.com

An underwater acoustic sound source and propagation modelling workshop was held in Cambridge, United Kingdom, in June 2022. The purpose was to facilitate comparisons between models using two methods: first, model verification, which compares predictions from one model with those from another model and utilises a fully specified synthetic test scenario; second, model validation, which compares model results with field measurements. The combination of these two methods provides benchmark data to test the reliability of underwater source and propagation model predictions, benefiting stakeholders by quantifying the error, and thereby providing a measure of confidence in future assessments. The JAM Workshop scenarios included individual airguns, an airgun cluster, an airgun array, a multi-beam echo sounder, and a surface vessel.

The workshop report identifies relevant bioacoustical metrics and assesses the suitability of prediction models to evaluate those metrics. The validation scenarios used data from the 2007-2010 Svein Vaage airgun measurements, the 2007 Seismic Source Characterization Study Northern Gulf of Mexico measurements (airgun array), and the Enhancing Cetacean Habitat and Observation Program (surface vessel). The success of the workshop as foundation for future work rested on the commitment of modellers to share their methods and results, and the consistency provided by compliance with international standards. Eight papers describing participants' approaches and findings have been submitted to a special issue of *The Journal of the Acoustical Society of America*.

Potential of Marine Spatio-Temporal Planning to Mitigate Effect of Noise on Marine Mammals in Highly Biodiverse Coastal Waters

T. A. Akamatsu^{1*}

¹Waseda University, Tokyo, Japan

*akama2@aoni.waseda.jp

Warm coastal waters host numerous vulnerable species. If marine spatial planning excludes habitats of all vulnerable species, there may be no space left for engineering activities. The underwater soundscape varies throughout the day and across seasons, altering the distance at which noise from a source is perceived depending on the masking level. In such scenarios, managing noise temporally should be considered alongside spatial planning.

During spring, small odontocetes appear the coastal waters of Japan Sea, where many offshore wind-farm projects are underway. Implementing soft-start pile driving, along with visual and acoustical surveillance for marine mammals, could be an effective strategy. Finless porpoises exhibit a nocturnal presence pattern, indicating that conducting engineering activities during the day could serve as a shared solution to mitigate noise exposure. The Marine Acoustical Society of Japan published “Guidance on Measurement and Evaluation Methods for Underwater Sounds” in 2021, recommending long-term monitoring of ambient noise to determine the maximum effective distance of anthropogenic noise from a point source.

In addition to Marine Spatial Planning, Temporal Planning will be instrumental in the sustainable management of ocean resources and biodiversity. Unlike other pollutants such as micro-plastics and NO_x, noise dissipates once the source ceases. Anthropogenic noise sources are manageable. Determining a compromise time budget for noise exposure, taking into account the temporal presence patterns of vulnerable species, is an achievable measure.

Canadian Department of National Defence Approach to Marine Mammal Mitigation

C. Binder,^{1*} D. Thomson,¹
and C. Reesor¹

¹Defence Research and Development Canada

*carolyn.binder@forces.gc.ca

An overview of current Canadian Armed Forces marine mammal mitigation practice, recent research efforts at Defence Research and Development Canada (DRDC), and an outlook for how monitoring and mitigation efforts will be updated over the next few years will be provided in this talk. Current practice relies heavily on operators to perform real-time monitoring and mitigation before conducting sonar training. DRDC’s focus has been to identify, advise on, and implement methods to transition marine mammal mitigation from an operator-intensive task to using prediction in the planning stages and automation for real-time tasks. The key components that will be addressed to shift to a planning-focused framework include: developing a monitoring program to characterize how marine mammals use Canadian maritime operating areas; testing innovations in real-time marine mammal detection; understanding how sonar use impacts whales in the relatively quiet waters of Canada’s north; and implementing an integrated dynamic risk management framework.

Designing Offshore Wind Pile Driving to Minimise Estimates of Auditory Injury in Marine Mammals

C. G. Booth,^{1*} M. Matei,¹ M. Chudzińska,¹
P. Remmers,² A. K. Darias O'Hara,¹
U. Verfuss,¹ and M. Bellman²

¹SMRU Consulting

²itap GmbH

*cgb@smruconsulting.com

Pile driving is considered to generate impulsive sounds—which are more damaging to the mammalian ear than exposure to non-impulsive sound. However, the signal of impulsive sound sources loses its impulsive characteristics as a function of distance from the source and could potentially be characterised as non-impulsive beyond a certain distance. Assuming signals are always impulsive can result in significant overestimation of permanent threshold shift (PTS) in marine mammals. The Range Dependent Nature of Impulsive Noise (RaDIN) project explored the current state of knowledge on this issue how available data and model frameworks can plug this knowledge gap to support design and streamline permitting decisions of offshore wind farms. Using a real-world pile driving data and an animat simulation approach to calculate cumulative Sound Exposure Levels we investigate estimate the PTS ranges under different piling scenarios. We highlight where the best available metrics of impulsiveness appear to change close to the pile location (< 5 km) and demonstrate conservatism in PTS/Level A take assessment. These include the pattern of blows as the pile is installed—which is critical in determining the PTS ranges. Our work suggests that real world hammer logs generally result in markedly lower PTS ranges when compared to a typical EIA-style PTS estimation. We also highlight the key future needs to further elucidate the issue of how impulsive noise could be better characterised and impact assessments improved.

A Comparison of Measured Sound Levels from Conventional and eSource Airgun Arrays and Their Impact on Marine Mammals in the Southern North Sea

J. Brinkkemper,^{1*} P. van Tol,¹ and N. Hall²

¹WaterProof Marine Consultancy & Services B.V., Lelystad, The Netherlands

²ONE-Dyas B.V., Amsterdam, The Netherlands

*joost.brinkkemper@waterproofbv.nl

Marine seismic surveys use low frequency (5-100 Hz) impulsive sound, emitted by an array of airguns, to map the seabed geology. These surveys are mostly executed for oil and gas exploration, but a recent increase is seen for carbon capture and storage (CCS) projects. While only low frequencies penetrate the seabed, traditional airguns emit broadband sound pulses with energy in frequencies >> 1 kHz. These higher frequencies are particularly audible to harbour porpoises, which are the focus of underwater sound impact assessments in Germany and the Netherlands. The novel eSource airguns are designed to release air in a more controlled way, reducing the emission of higher frequency sound and thereby minimizing the impact on marine mammals. We present underwater sound measurements conducted during offshore verification tests with eSource airgun arrays and compare measured levels and frequency content with conventional arrays. The measurements show a significant reduction of energy in frequencies > 100 Hz and, when accounting for species-specific auditory weighting curves, the impact on marine mammals is expected to be significantly reduced. The current methodology for environmental impact assessments in Germany and The Netherlands, however, are based on the broadband sound exposure levels and thus fail to stimulate the industry to use these lower impact arrays.

Body Condition Predicts Foraging Strategy and Response to Sonar in a Deep-Diving Top Predator

A. Burslem,^{1*} P. Miller,¹ and S. Isojunno²

¹*Sea Mammal Research Unit, University of St Andrews*

²*Centre for Research into Ecological and Environmental Modelling*

**acb35@st-andrews.ac.uk*

Lipid-store body condition influences how animals balance the risk of starvation against other perceived threats, such as predation. Animals in poor condition may be expected to prioritise immediate foraging needs over protection of future assets; tolerating greater risks to obtain foraging benefits. However, in some species where condition influences escape or defensive abilities, an opposite response pattern can emerge. Similar trade-offs are expected to drive response to anthropogenic noise. We used DTags to quantify tissue density (a proxy for body condition) and record behaviour in 29 free-ranging sperm whales and tested for an association between body condition and behaviour during undisturbed baseline periods and sonar exposures. Less dense individuals (in better body condition) were more likely to employ a deep-diving foraging strategy during baseline and showed smaller reductions in foraging performance during sonar exposures compared with denser individuals. At a sound exposure level of 160 dB re 1 $\mu\text{Pa}^2\text{s}$ and after controlling for other covariates, GAMM modelling predicted a reduction in probability of buzz initiation (a proxy for prey capture attempts) of 20-41% relative to baseline for animals with a body density of 1031 kg/m^3 . For those with a body density of less than approximately 1029.75 kg/m^3 , the models predicted no significant decrease. These results are consistent with state-behaviour feedback predicted to exacerbate disturbance impacts from repeated or multiple stressors, with potential to inform predictions of their population consequences.

UK Position on Clearance of Unexploded Ordnance (UXO) in the Marine Environment

S. Canning^{1*} and N. Hill²

¹*Joint Nature Conservation Committee (JNCC)*

²*UK Department for Environment, Food & Rural Affairs (Defra)*

**sarah.canning@jncc.gov.uk*

The UK and its devolved governments have national and international obligations relating to the management of our seas and protecting habitats and species, and are committed to achieving good environmental status through the UK Marine Strategy.

Large numbers of explosive ordnance were left undetonated in our seas following both world wars. The level of offshore development expected in coming years to support the UK's net zero targets increases the potential for these devices to be encountered and risk to human life. The UK Government recognise the importance of clearing these devices when constructing offshore developments but also the impacts this can have on the marine environment.

First published in 2021, the UK and devolved governments, regulators and statutory advisors have a joint position statement on UXO clearance, requiring developers to prioritise the use of low noise clearance methods that will have a reduced environmental impact compared to traditional clearance methods. To support this, the UK Government has also funded research projects and stakeholder engagement to further our understanding of how UXO clearance impacts our environment, and methods that can be employed to reduce this. This has led to the development of guidance for when undertaking investigative surveys for UXOs; guidance for those applying for marine licences to clear UXO, including what constitutes suitable evidence of reduced environmental impact when proposing what clearance method to use; and a protocol to measure underwater sound during UXO clearance.

Behavioral and Physiological Responses of Oceanic Dolphins to Military Sonar

C. Casey,^{1*} J. Durban,¹ F. Visser,² J. Calambokidis,³ H. Fearnbach,⁴ N. Kellar,⁵
S. Fregosi,¹ H. Clayton,³ J. Fahlbusch,³ K. Flynn,³ A. Friedlaender,⁶
V. Janik,⁷ J. Oswald,⁷ S. Leander,⁴ M. Oudejans,²
H. Scharf,⁸ A. Vanderzee³, and B. L. Southall¹

¹*Southall Environmental Associates, Inc., 9099 Soquel Drive, Aptos, CA 95003, USA*

²*Kelp Marine Research, 1624 CJ Hoorn, The Netherlands*

³*Cascadia Research Collective, 218 1/2 W. 4th Avenue, Olympia, WA 98501, USA*

⁴*SR3 SeaLife Response, Rehabilitation and Research, 2003 S. 216th Street #98811, Des Moines, WA 98198, USA*

⁵*Marine Mammal and Turtle Division, Southwest Fisheries Science Center, National Marine Fisheries Service, 8901 La Jolla Shores Drive, La Jolla, CA 92037, USA*

⁶*Institute of Marine Sciences, University of California Santa Cruz, 115 McAllister Way, Santa Cruz, CA 95060, USA*

⁷*Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, Fife KY16 8LB, UK*

⁸*The University of Arizona, 617 N. Santa Rita Avenue, PO Box 210089, Tucson, AZ 85721-0089, USA*

*cbrettcasey@gmail.com

Millions of social oceanic delphinids are exposed to and presumably affected by military sonar annually; however, empirically measuring its impact on their behavior is challenging. Consequently, no study has experimentally tested the effects of mid-frequency (3-4 kHz) active sonar (MFAS) on dolphins. We integrated drone-based photogrammetry and focal group movement, passive acoustics, and broad-scale visual observations to measure behavioral responses of short- and long-beaked common, bottlenose, and Risso's dolphins to controlled exposure experiments (CEEs) of military MFAS. Fifty CEEs were conducted across all species, yielding hundreds of hours of acoustic and group sampling data, hundreds of thousands of spatially explicit photogrammetry measurements, and nearly 200 biopsy samples. In our initial analysis of short- and long-beaked common dolphins, we used Bayesian hidden Markov models to evaluate response probability and persistence during CEEs. We commonly detected changes in sub-group movement and aggregation during MFAS exposures but not in controls. In short-beaked common dolphins, a direct relationship between response probability and received level (RL) was observed. Long-beaked common dolphins showed less consistent responses, although contextual differences in some CEEs may have limited which movement responses could be detected. These results represent the first experiments on the effects of MFAS on social delphinids and indicate that these species may be more sensitive to military sonar than previously presumed.

The Development and Implementation of a NATO Sonar Risk Framework

B. R. Colbert^{1*}

¹*U.S. Navy*

*benjamin.r.colbert.civ@us.navy.mil

Naval sonar can have adverse effects on marine mammals. However, sonar, in particular anti-submarine warfare sonar, is a critical tool for ensuring the safety and security for naval forces worldwide. Acknowledging both the necessity of joint training activities involving sonar and the potential impacts of these activities, the North Atlantic Treaty Organization (NATO) has developed a guide for assessing and mitigating the impacts of naval anti-submarine warfare sonar. The Anti-Submarine Sonar Risk Mitigation (ASRM) guide outlines critical biological, environmental, and mission-related factors which effect the risk. The guide additionally advises planners on actions and procedures which can reduce the environmental risk. The ASRM guide ensures Allied naval activities are enabled while upholding NATO's steadfast commitment to environmental stewardship.

The Interaction of Physiological Stress, Pollutant Load, and Acoustic Disturbance on the Foraging Behavior and Reproductive Success of Elephant Seals

D. P. Costa,^{1*} R. R. Holser,² B. I. R. McDonald,³
S. H. Peterson,⁴ J. T. H. Ackerman,⁴ and D. E. Crocker⁵

¹*Department of Ecology and Evolutionary Biology,
University of California, Santa Cruz, CA, USA*

²*Institute of Marine Sciences, University of California, Santa Cruz, CA, USA*

³*Moss Landing Marine Lab, Moss Landing, CA, USA*

⁴*U.S. Geological Survey, Western Ecological Research Center, Dixon Field Station, Dixon, CA, USA*

⁵*Sonoma State University, Rohnert Park, CA, USA*

**costa@ucsc.edu*

The effects of multiple stressors on female northern elephant seals were examined by conducting an experimental manipulation where individuals were exposed to acoustic disturbance at-sea coupled with experimentally elevated cortisol. Health metrics (energy store, stress hormone, immune status, contaminant burden) and vital rates were measured before and after the post-breeding foraging trip. Natural variation in mercury burden had additive and synergistic effects with cortisol on the endocrine (T3, T4, and rT4) and immune (IgG) systems. Energy gain varied over a foraging trip (foraging success) and was correlated with circulating blood cortisol level (GLMM $p < 0.001$). Females with very poor energy gain had cortisol levels 20 times normal levels and exhibit a lower probability of pupping the following season. Differences in energy gain were not associated spatial distribution or diving depth in our experimental post-breeding data ($n = 63$) or our long-term data across post-breeding and post-molting trips ($n = 463$). Females with lower energy gain rates had significantly lower mean dive durations. Elephant seals provide an experimental system to study the interaction of multiple stressors on vital rates on a capital breeding marine mammal that provides insight into other more difficult to study marine mammals.

Stochastic Dynamic Programming as a PCoD Assessment Tool

D. P. Costa,^{1*} S. K. Adamczak,¹ and K. A. Keen¹

¹*University of California, Santa Cruz, Santa Cruz, CA, USA*

**costa@ucsc.edu*

As the Population Consequences of Disturbance (PCoD) framework continues to grow as a tool to assist conservation and management, novel methods for implementing this framework have been developed. One such method is Stochastic Dynamic Programming (SDP), which has become an oft-used modeling tool that integrates bioenergetics, optimization theory, and individual-based simulations to inform PCoD. SDP is becoming increasingly popular in environmental studies, but its inner workings are complex and remain a black-box for many regulators and other stake holders. This lack of knowledge can create barriers between model developers and users and can hinder implementation in management settings when decision makers typically require answers fast. Here, we broaden the understanding of SDP models and aim to incite interest in the continued application of these models within the PCoD framework. We will take a close look into the mechanics of SDP models to increase accessibility and comprehension. We take a deep dive into the underlying theory behind SDP models and why they have been an effective tool for PCoD assessments. Additionally, we will review the insights gained from SDP models and introduce future applications of this modeling framework to explore ecologically relevant questions.

U.S. Navy Compliance

C. Cowan^{1*}

¹*United States Fleet Forces Command*

^{*}*christy.g.cowan.civ@us.navy.mil*

The U.S. Navy is committed to complying with environmental laws and minimizing effects on protected resources while supporting military readiness. The main driver for these efforts is the expiration of Marine Mammal Protection Act Letter of Authorization (LOA) after 7 years. Renewing an LOA initiates an updated analysis. To provide compliance coverage for most activities, the Navy analyzes large “study areas.” The process of applying for an LOA is split into three stages—before, during, and after modeling. Before modeling, about three years into the process, the Navy’s Bioacoustics Analysis and Applied Research Team (BAART) compiles new research to develop criteria & thresholds for determining physiological effects and Behavioral Response Functions (BRF) for determining behavioral effects. Also, during this period, marine species density estimates are updated for each study area and the Navy Acoustic Effects Model (NAEMO) is updated with the latest science and technology. Modeling begins about four years into the process and takes six to twelve months to complete. During modeling, simulated animals (animats) are distributed in the modeling space, NAEMO simulations run to create exposure data for animats, and criteria & thresholds and BRFs applied to simulation data to estimate effects. After modeling, BAART analyzes the NAEMO output to determine the takes expected from Navy training and testing. This analysis is delivered about five years into the process and incorporated into the application for an LOA and all required consultation documents.

Assessing Beaked Whale Behavioral Response to Naval Sonar Using a Hierarchical Hidden Markov Model

S. L. DeRuiter,^{1*} Y. Li,¹ F. Nsengiyumva,¹ S. Watwood,²
D. Sweeney,³ B. Rone,³ K. Dolan,² S. Coates,³
R. Andrews,³ E. Falcone,³ and G. Schorr³

¹*Department of Mathematics & Statistics, Calvin University, Grand Rapids, MI, USA*

²*Ranges, Engineering and Analysis Department, Naval Undersea Warfare Center, Newport, RI, USA*

³*Marine Ecology and Telemetry Research, Seabeck, WA, USA*

^{*}*stacy.deruiter@calvin.edu*

Biologging developments (SMRT and Lander II tags) have made it possible to record high-resolution movement data for days to weeks, often with surface geolocations and acoustic recordings. The resulting complex datasets promise rich insights into whale behavioral responses to acoustic disturbance, but present huge analytical challenges. First, software development to calibrate, process, and archive data was necessary. Analysis then required integration of data across vastly different time-scales, with the aim to characterize behavioral responses of beaked whales (*Ziphius cavirostris*) near the Southern California Anti-Submarine Warfare Range to mid-frequency active sonar at both fine and coarse temporal resolution. We formulated a hierarchical hidden Markov model to model behavior simultaneously at coarse (foraging-dive-cycle) and fine (5-minute) scales. We report model results from 7 SMRT tags spanning 271 foraging dive cycles, 26 with sonar. Initial results quantify response probability as a function of received sound levels, with responses including longer inter-foraging intervals, reduced echolocation, and greater variation in activity levels at fine scale. We also address challenges arising in attempts to model expanded datasets that combine data from different tag types and exposure intensity measures, including modeled sound levels and estimated source-whale distances from Navy records; and we detail ongoing work using a Bayesian approach to assess individual differences and better incorporate measurement uncertainty and missing values.

Sound Field Verification: U.S. Offshore Wind Construction Regulatory Framework

S. Denes^{1*} and A. Conrad¹

¹*Center for Marine Acoustics, Bureau of Ocean Energy Management*

**samuel.denes@boem.gov*

Development of commercial scale offshore windfarms in the U.S. reached a major milestone in 2023 with the commencement of installation of wind turbine foundations at two windfarms. Two more windfarms have commenced pile driving in 2024. As part of the regulatory approvals process, U.S. federal regulators including BOEM and NOAA are requiring that developers measure the noise generated during foundation installation in a process referred to as Sound Field Verification (SFV). As part of the permitting process, developers are required to predict noise levels generated during impact pile driving. Regulators use those estimates to determine mitigation and monitoring zones which become conditions of project approvals. The intention of SFV is to ensure that the noise generated during construction will not lead to greater ranges to effects, and thus more impacts on marine life, than what was considered in the modeling process. Developers must measure pile-driving noise from foundations that are deemed to be representative of their modeled activity to establish propagation loss estimates; these measurements are made along multiple radials and ranges from the foundations. After initial “thorough” SFV is conducted, at all remaining foundations within a wind farm, developers must measure the noise at a nominal distance of 750 m. Current requirements, potential future requirements, evaluation processes, corrective actions, and results will be discussed.

Royal Netherlands Navy Approach of Responsible Use of Underwater Environment for Military Operations

P. Dröge^{1*}

¹*NLD MOD – Material & IT Command*

**p.droge@mindef.nl*

The use of active sonar to detect underwater threats and the clearance of underwater explosives by using kinetic methods are still essential in the current time frame to carry out the tasks of the Royal Netherlands Navy. However, by fulfilling her mission the Royal Netherlands Navy is fully committed to reduce the impact on the environment according to national and international regulations and based on solid scientific research and proved practice. To support the Royal Netherlands Navy in its efforts to mitigate the negative effects on the underwater environment the Material & IT Command conduct research and live experimentation in cooperation with TNO. Results of this R&E is directly implemented operating procedures and support tools for the operators at sea. During this talk insight is provided in the way how this is achieved.

Harnessing Seafloor Telecommunication Cables for Enhanced Marine Mammal Monitoring: A Comparative Study of Distributed Acoustic Sensing and Hydrophone Arrays

C. Erbe,^{1*} D. McCorry,² E. Sidenko,¹ A. Gavrilov,¹ H. Debens,²
O. Collet,¹ B. Gurevich,¹ R. Isaenkov,¹ R. McCauley,¹
P. Shashkin,¹ K. Tertyshnikov,¹ and R. Pevzner¹

¹Curtin University

²Woodside Energy

*c.erbe@curtin.edu.au

Sustainable management of marine industries (e.g., oil and gas, construction, subsea mining, defense, shipping/ports) typically requires baseline assessments and monitoring of marine fauna. In the case of vocal marine fauna such as whales, this is commonly achieved by passive acoustic monitoring using moored acoustic recorders. Recent literature has demonstrated the capability of fibre-optic telecommunications cables (FOC) on the seafloor to detect low-frequency (< 100 Hz) sounds of nearby whales. Installing an interrogator at the FOC, the dynamic strain induced in the cable by sound waves in the ocean may be measured—a technique called distributed acoustic sensing (DAS). Time series and spectrograms of strain may feature whales and other sound sources—much like pressure time series recorded by hydrophones. The difference and potential advantage of DAS is the simultaneous sensing along the length of the cable, potentially covering a larger monitoring area and enabling beamforming and thus tracking of sound sources in near or real time. We compared the performance of DAS to that of a conventional hydrophone array in a 2-month field trial off Western Australia. With controlled vessel passes we determined the sensitivity, angular dependency, and detection range of both systems. Migrating pygmy blue and Omura's whales were recorded and tracked. We discuss the pros and cons of both technologies, and future development needs if existing FOC infrastructure is to be dual-purposed for whale detection for environmental monitoring and management.

BOOMIN at the Whales: Behavioral Observations of Marine Mammals to Impulsive Noises at the Individual Level

E. A. Falcone,^{1*} G. S. Schorr,¹ S. N. Coates,¹
D. A. Sweeney,¹ S. L. DeRuiter,² B. K. Rone,¹
R. P. Morrissey,³ and S. L. Watwood³

¹Marine Ecology and Telemetry Research

²Calvin University

³U.S. Navy, Naval Undersea Warfare Center

*efalcone@marecotel.org

While there is a growing body of knowledge surrounding the behavior of marine mammals exposed to a variety of anthropogenic sound sources, including navy sonar, vessels, pingers, and air guns, the effects of some impulsive sounds are poorly understood. Some of these impulsive sounds are prevalent in the Southern California Range Complex, ranging from small “seal bombs” to occasional large explosions associated with missile detonations. Additionally, non-explosive, high-velocity projectiles—ranging from small arms fire to large missiles—routinely impact the surface during training with a detectable acoustic signature. Navy permits account for impacts of explosive training and testing, but the nature and extent of the impulsive sound fields that might elicit behavioral reactions remain virtually unknown. Here, we report preliminary findings of a pilot study using high-resolution acoustic tags to monitor the behavior of *Ziphius cavirostris*, *Balaenoptera musculus*, and *B. physalus*, and the sound levels they were exposed to, during a series of controlled underwater detonations in 2023. In this experiment, seven charges with

explosive weights up to 18.1 kg were detonated with tagged whales at distances of 29 to 80 km. We also summarize data from 15 *Ziphius cavirostris* that were tagged in an ongoing sonar response study, which were incidentally exposed to impulsive sounds during deployment. While in its earliest stages, this study suggests some impulsive sounds elicit responses from beaked whales similar to those described for navy sonar, including extended foraging disruption.

The Use of Active Multibeam Sonar in Wildlife Monitoring

D. Gillespie,^{1*} G. Hastie,¹ R. Harris,¹
J. Montabaranom,¹ and C. Sparling¹

¹Sea Mammal Research Unit, University of St Andrews, St Andrews, UK

*dg50@st-andrews.ac.uk

For several decades, Passive Acoustic Monitoring (PAM) has been one of the go-to technologies for detecting and tracking marine mammals. PAM can detect over a wide area, works at night, and is less affected by sea state and meteorological conditions than visual studies. PAM is however limited to animals that are vocally active, making it ineffective for many species and while detection of presence is relatively straight forward, 3D tracking is generally harder in practice than it is on paper. A relatively new technology, which has increasing application in animal monitoring, is high frequency multibeam sonar, which can detect and track silent animals. These typically operate at frequencies well above the hearing range of marine mammals, causing little or no acoustic disturbance. On the other hand, they are only effective at short ranges, typically a few 10's of metres and species identification within the data is challenging. In this presentation, I will show how these devices are being successfully used to study fine scale movement of seals and small cetaceans at specific locations, primarily associated with marine energy, and also as a mitigation tool to detect animals entering areas where they may come into conflict with human activities. An automatic sonar detect and track module has been developed as an extension to the widely used PAMGuard software and can run concurrently with passive acoustic detectors. I will present an overview of the devices, the data that can be derived from them, the software, its performance and likely future directions for this technology.

Workshop Marine Mammal Noise Impact Research/Funding Priority BOEM

S. Guan,^{1*} S. Mendes,¹ and J. Lee¹

¹BOEM

*Shane.Guan@boem.gov

The Bureau of Ocean Energy Management (BOEM) and the UK Joint Nature Conservation Committee (JNCC) organized an in-person workshop on Marine Mammal Noise Impacts Research and Funding Priorities (Workshop) before the Effects of Sound in the Ocean on Marine Mammals (ESOMM) conference on Sunday, 8 September 2024. The purpose of the Workshop is to assess the current state of science and to discuss research and funding priorities among international funders, marine mammal bioacousticians, regulatory agencies, industry and consultants, and NGOs. This presentation provides a summary of the Workshop.

Behavioural Response Research: A Synthesis of Data, Questions, and Analyses as They Relate to Current and Future Navy Needs

C. Harris,^{1*} S. Isojunno,¹ and L. Thomas¹

¹*Centre for Research into Ecological and Environmental Modelling,
University of St Andrews, St Andrews, UK*

**catriona.harris@st-andrews.ac.uk*

The behavioural response of marine mammals to navy sonar has been a research area funded by U.S. and European Navies for around two decades. This has motivated the collection of vast quantities of baseline and exposure data across a diversity of marine mammal species in different exposure contexts, alongside analytical method and tool development. We present a synthesis of available data from behavioural response studies (BRS) relating to navy sonar across research programs, the questions that have been addressed through BRS research, and the analysis methods used. This synthesis effort during 2024 will catalogue the available data from both controlled exposure experiments (free-ranging and captive) and observational studies, the scientific questions that have been asked and addressed, and the analysis methods that have been applied to different datasets. The synthesis will provide a useful resource for prioritizing future BRS efforts and understanding the data available to meet current and future navy needs (e.g., developing dose-response functions for environmental compliance). Critically, and for future planning, the synthesis will allow consideration of whether existing data may be used to answer questions for which they were not originally intended, e.g., through combining data across different projects and sampling platforms. We will also identify gaps in the methods available to analyze data in a manner that directly addresses outstanding navy questions and needs.

Exciting News from NOAA! Focusing on Quieting, Debunking a Myth, and Updating Acoustic Behavioral Harassment Criteria

J. Harrison,^{1*} A. Scholik-Schlomer,¹ L. Hatch,²
J. Gedamke,³ and S. Van Parijs⁴

¹*U.S. National Marine Fisheries Service, Office of Protected Resources*

²*U.S. National Ocean Service, Office of National Marine Sanctuaries*

³*U.S. National Marine Fisheries Service, Office of Science and Technology*

⁴*U.S. National Marine Fisheries Service, Northeast Fisheries Science Center*

**jolie.harrison@noaa.gov*

In recognition of continuing increases in human activity along earth's coastlines and farther offshore into deep water environments, in 2016 NOAA launched its Ocean Noise Strategy to better understand and manage the impacts of underwater noise pollution on protected marine species and their habitats. The Strategy emphasizes the importance of developing and using quieter sources to better address the global rise in underwater background noise, as well as the impacts of specific noisy events. In this presentation, we are excited to highlight how growing federal support for quieting efforts and technological innovation are laying the groundwork for meaningful beneficial changes in the global soundscape. NOAA strongly supports the development and use of quieter sources and is taking this opportunity to assure innovators and operators that the use of these sources can proceed successfully along with the application of the acoustic behavioral harassment criterion for continuous noise sources (120 dB Root-Mean-Square Sound Pressure Level) currently utilized within the U.S. regulatory framework. Further, NOAA has begun the process of updating its acoustic behavioral harassment criteria and will present a summary of the proposed changes to our approach, which better incorporate context and variability, noting that these revisions will undergo extensive review (including peer and public review) and that guidance and tools to simplify the transition to the new criteria will be provided.

Regional and Site-Specific Acoustic Soundscapes of the Atlantic Deep Water: Insights from the ADEON Network and Sediment Modeling

K. D. Heaney^{1*}

¹*Applied Ocean Sciences*

**Kevin.heaney@appliedoceansciences.com*

For 4 years, the Atlantic Deep Water Ecosystem Observing Network (ADEON), measured the acoustic soundscape using 7 bottom mounted landers off the coast of the South East United States (from Florida to Virginia). A shipping and noise model was built to generate regional sound maps, as well as to perform site-specific modeling for frequencies ranging from 20 Hz to 3150 Hz. The regional sound maps reveal that water depth is the key driver to local sound levels followed by the local geo-acoustic properties. It is predicted that the sound can be as much as 10 dB higher on the seafloor than at depths of 10 m. The site specific (where landers were deployed) model was run with a wide range of sediment uncertainty in the model, given our lack of knowledge of the sediment structure in water depths of 200 to 800 m deep, far from shore. A simple qualitative comparison of the soundscape measurements with the model provides immediate insight into the type of sediment at each lander position. Using this estimated sediment type, quantitative comparisons between the model and the data are made. Various methodologies for extending this modeling to include marine mammal vocalizations will be presented.

Sound and Marine Life Joint Industry Programme (JIP)

D. Hedgeland^{1*} and A. Bucki¹

¹*Sound and Marine Life Joint Industry Program (JIP)*

**David.Hedgeland@uk.bp.com*

The Sound and Marine Life Joint Industry Program (JIP) is globally recognized as a valued contributor to the generation of knowledge through funding research on the potential effects of anthropogenic sound on marine life. The collaborative nature of the JIP combined with the wealth of scientific information for over 15 years has resulted in a trusted and respected presence in the international regulatory, scientific and NGO stakeholder communities. Renewable energy resources are being developed globally to meet ambitious energy targets and at the same time there is continued demand for oil and gas resources. The JIP aims to contribute to addressing the challenges common to many offshore industry activities by being a platform for cross-company and cross-sector knowledge exchange and education between, regulator, academic and other stakeholders for the funding and coordination of scientific projects, meetings, and technology solutions.

The Updated iPCoD Model: Using an Energetic Pathway to Assess the Effects of Piling Noise on Harbour Porpoise Populations

V. Hin,^{1*} M. Chudzińska,² C. G. Booth,²
F. Wilder,² and J. Harwood²

¹Wageningen Marine Research, IJmuiden, The Netherlands

²SMRU Consulting, St. Andrews, UK

*Vincent.Hin@wur.nl

The interim Population Consequences of Disturbance (iPCoD) framework was developed to assess impacts from construction of offshore renewable energy developments on marine mammal populations. Possible consequences of exposure to piling noise related to wind turbine construction include disturbance that could cause marine mammals to move away or change behaviour, or auditory injury in the form of permanent threshold shift (PTS). Provided with a piling schedule and the number of animals exposed, the iPCoD model predicts the population trajectory with and without simulated disturbance and PTS. To translate exposure to disturbance to vital rates (survival and probability of giving birth), the iPCoD framework uses expert elicitation outcomes. As an alternative, dynamic bioenergetic models can be used to predict changes in individual body condition in response to disturbance and how these changes may affect individual vital rates. In addition, these models can also consider individual variation in energetic requirements during different life history stages and account for the state of the environment (e.g., prey availability). Recently, bioenergetic models have been developed for the five species represented in iPCoD. Here we describe a new version of the iPCoD framework that uses bioenergetic modelling to assess the impact of disturbance on individual vital rates for one of these species, the harbour porpoise. This new version of iPCoD also allows users to include compensatory effects of density dependence.

First Empirical Hearing Test Conducted in a Baleen Whale

D. S. Houser,^{1*} P. H. Kvadsheim,² L. Kleivane,³
J. Mulsow,¹ R. A. Ølberg,⁴ C. A. Harms,⁵
J. Teilmann,⁶ and J. J. Finneran⁷

¹National Marine Mammal Foundation

²Norwegian Defence Research Establishment

³LKARTS Norway

⁴Dyreparken

⁵North Carolina State University

⁶Aarhus University

⁷Naval Information Warfare Center Pacific

*dorian.houser@nmmf.org

Understanding ocean noise impacts on baleen whales is impeded by a lack of empirical measurements of baleen whale hearing. To collect the first empirical audiogram from a baleen whale, a catch-and-release system (CARS) for temporarily catching and holding adolescent minke whales (*Balaenoptera acutorostrata*) was developed. The intent was to catch the whales during their summer migration to the Arctic and conduct auditory evoked potential hearing tests. In the first year of the program, it was demonstrated that the CARS could guide whales into a basin for temporary holding. In the second year, a minke whale was caught in the basin and corralled into an aquaculture pen for a hearing test. The whale was released prior to testing because of an unexpected tonic immobility and tachypnea. Following modifications to the handling procedures, two minke whales were caught in the third year of the effort. Measures of the auditory brainstem response and information on the frequency range of hearing were obtained. The whales were found to be sensitive to sound frequencies of at least 45 kHz and potentially as high as 90 kHz. A fourth year of field effort is planned for June 2024 to complete the hearing tests. Data from the hearing tests will directly inform regulators and noise producers on the types of sound sources that are audible to minke whales and potentially related baleen whale species.

A Synthetic Literature Review and Mechanistic Dose-Detection Framework for Understanding Individual Responses to Human-Altered Sensory Landscapes

S. Isojunno,^{1*} A. Bennett,² C. Harris,¹ E. Pirotta,¹
L. Thomas,¹ and P. Tyack³

¹*Centre for Research into Ecological and Environmental Modelling, University of St Andrews, St Andrews, UK*

²*School of Applied Sciences, University of Abertay, Dundee, UK*

³*Scottish Oceans Institute, University of St Andrews, St Andrews, UK*

**si66@st-andrews.ac.uk*

Understanding the drivers and consequences of individual-level response to anthropogenic activities is important for preventing population-level impacts of human disturbance on wildlife. However, considerable uncertainty remains in models attempting to predict behavioural and physiological responses and their fitness consequences. We address this by incorporating mechanistic knowledge of response drivers into individual-level effects models. We synthesize multi-disciplinary literature to identify both proximate (e.g., ecological, behavioural) and ultimate (evolutionary) drivers of response and derive a new modelling framework. The “Functional dose-detection-response” (FDDR) framework consists of three key components: the probability of detection, the probability of response given detection, and potential effects. These components are mediated by the environment and individual status, and incorporate both exogenous and endogenous drivers of sensory processing. We apply the framework in case studies of marine mammal responses to noise, for which the first stage of the model, exposure and probability of detection, is relatively well understood. Through mechanistic simulations, we show how assumptions about response drivers lead to different probability, type, and fitness consequences of response. We also identify knowledge gaps for improved understanding of physiological responses, individual health, and life history outcomes. We conclude by discussing how the FDDR framework can inform the development of models and studies of the population consequences of disturbance.

Strong Behavioural Reactions of Bottlenose Dolphins to Short Startle Sounds

V. M. Janik,^{1*} B. Zein,¹ H. Hiley,² I. Haber,¹
J. N. Oswald,¹ and T. Götz¹

¹*Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK*

²*Scottish Association for Marine Science, Scottish Marine Institute, Dunstaffnage, Oban, UK*

**vj@st-andrews.ac.uk*

Recent studies demonstrated that eliciting the acoustic startle reflex leads to strong and lasting avoidance responses as well as sensitization in pinnipeds and harbour porpoises. However, studies on other cetaceans are missing. We conducted controlled exposure experiments with wild bottlenose dolphins in Scotland exposing them to five startle signals of 200 ms duration each. Taking animal distance into account, the received level of startle sounds was estimated to be 140 to 147 dB re 1 μ Pa for the first sound with lower levels in subsequent exposures as the animal moved away. In control trials, the sound source vessel stopped and lowered the transducer but did not produce sounds. 13 treatment and 13 control trials were carried out on groups of bottlenose dolphins (mean group size 5 animals). Movement responses were recorded with a theodolite and a camera tracking method and were compared between startle sound exposures and control trials using GLMMs and GAMMs. Comparisons of movements before, during and after exposures with those in control trials showed that dolphins changed direction and significantly increased their speed after the onset of exposures but not after control treatments. The resulting increase in distance from the sound source vessel was 2-3 times larger after exposures than after control stops. These results show that dolphins show a pronounced avoidance response to a total sound exposure of only one second when sounds elicit the startle reflex. This occurs when sounds have a rise time of less than 50 ms to a level of 80 dB above the hearing threshold.

Auditory Masking Parameters for Pinnipeds

R. Jones,^{1*} J. Sills,¹ N. Packard,¹
A. Bowles,² and C. Reichmuth¹

¹*Institute of Marine Sciences, University of California, Santa Cruz, CA USA*

²*Hubbs Sea World, San Diego, CA, USA*

**ryajones@ucsc.edu*

Despite its importance within marine habitats, most of what we know about auditory masking is based on terrestrial species and theoretical assumptions. To fill data gaps and improve models that predict active listening space, we measured detection thresholds for tonal sounds with trained seals, sea lions, and walruses in the presence of precisely varied noise conditions. To evaluate how the spectral content of noise contributes to masking, we determined the frequency bandwidth of noise that interferes with the detection of a given signal (“critical bandwidth”; CBW). All subjects showed an expected increase in absolute CBW with increasing frequency. While data for the sea lion and walrus were similar, the seal exhibited narrower CBWs that increased as a constant percentage of center frequency, suggesting additional specialization for hearing in noise. To examine how noise level contributes to masking, we gradually increased noise amplitude from a level of no effect to capture masking onset. The data revealed a frequency- and bandwidth-dependent transition zone that occurs before complete masking is evident. The reported parameters are especially useful as they can be applied to estimate masking effects for pinnipeds in air or water. Our findings identify the frequencies where these species are most vulnerable to noise, highlight differences in auditory biology among pinniped lineages, and enable improved predictions of the extent of masking in environments dominated by anthropogenic and natural noise. [Work supported by the U.S. Navy Living Marine Resources Program.]

Temporary Hearing Threshold Shift (TTS) in Harbor Porpoises, Harbor Seals and California Sea Lions: Pattern of Hearing Loss, Recovery and Testing the Equal-Energy Hypothesis

R. A. Kastelein,^{1*} L. Helder-Hoek,¹ L. N. Defiliet,¹
L. Van Acoleyen,¹ N. Jennings,² and J. M. Terhune³

¹*SEAMARCO*

²*Dotmoth.co.uk*

³*University of New Brunswick*

**rk@seamarco.nl*

Susceptibility to temporary hearing threshold shift (TTS) depends in part on the frequency, SPL and duration of the sound causing the shift. After exposing five individuals of three coastal marine mammals (a harbor porpoise, two harbor seals and two California sea lions) for 1 h to a continuous one-sixth-octave noise band centered at 8 kHz, we measured TTS and recovery at three hearing frequencies. In all three species, the largest TTS occurred half an octave above the center frequency of the fatiguing sound, at the hearing frequency 11.3 kHz. The onset SELs of TTS, based on significant difference from control values in the first four minutes after exposure, were: 168 (harbor porpoise), 180 (harbor seal), and 178 dB re 1 μ Pa²s (California sea lion). These results are needed to improve auditory weighting functions and thus enhance regulatory protection of marine mammals that are exposed to anthropogenic noise at sea. The equal-energy hypothesis was tested by exposing individuals of each species to the same noise band at 5-7 sound pressure levels for 2-80 min; all combinations of level and duration resulted in the same fatiguing sound exposure level for each species. For the combinations tested, the equal-energy hypothesis was upheld (TTS was consistent). These results will allow the extrapolation of data from previous TTS studies to real-world exposures of these marine mammal species at sea. Funding for these studies was provided to SEAMARCO by: Ecowende consortium (Windpark Hollandse Kust West), Living Marine Resources (U.S. Navy), and the Netherlands Ministry of Defence.

Spatial and Temporal Sensitivities of an Endangered Predator to Acoustic Stressors

K. A. Keen,^{1*} E. Pirotta,² E. A. McHuron,³
J. Fiechter,⁴ A. S. Friedlaender,⁴
B. L. Southall,^{4,5} and D. P. Costa^{1,4}

¹*Department of Ecology and Evolutionary Biology,
University of California, Santa Cruz, Santa Cruz, CA, USA*

²*Centre for Research into Ecological and Environmental Modelling,
University of St Andrews, St Andrews, Scotland, UK*

³*Cooperative Institute for Climate, Ocean, and Ecosystem Studies,
University of Washington, Seattle, WA, USA*

⁴*Institute of Marine Sciences, University of California, Santa Cruz, Santa Cruz, CA, USA*

⁵*Southall Environmental Associates, Inc., Aptos, CA, USA*

*keen@ucsc.edu

Changes in prey abundance, composition, and distribution influence predators' foraging ecology, potentially exacerbating the effects of human stressors on population dynamics. In the California Current, interannual variability in krill and fish abundance affect humpback whale distribution. These factors consequently mediate their exposure to existing (e.g., naval sonar) and proposed (e.g., offshore wind) noise-generating stressors. We explored potential spatio-temporal vulnerabilities on the endangered Central America distinct population segment using an individual-based model within a stochastic dynamic programming framework. We simulated stressors using a Monte Carlo approach and tracked individuals' reproductive and movement decisions over a 21-year period to quantify the effect of stressors on population vital rates. Emergent model properties included interannual shifts in diet and seasonal changes in body condition, consistent with wild populations. The spatial use patterns of simulated whales were driven by intra- and inter-annual variability, which influenced the effects of stressors on vital rates. Overall, stressors located offshore central California had the greatest impact on vital rates, particularly during spring and summer. However, the magnitude of the effect depended on the stressor's temporal characteristics. Models such as this can provide a general framework to identify sensitive feeding times and areas for vulnerable populations, providing a quantitative basis for comparing different stressor scenarios associated with our expanding offshore footprint.

New Developments in Cetacean Audiogram Models

D. R. Ketten,^{1*} A. A. Tubelli,² and A. Zosuls³

¹*Woods Hole Oceanographic Institution, Woods Hole, MA, USA*

²*Massachusetts Eye and Ear Infirmary, Boston, MA, USA*

³*Boston University, Boston, MA, USA*

*dketten@whoi.edu

In prior work, we produced biomechanical Finite Element Models (FEM) from middle ear transfer functions (METF; affects peak sensitivity) and frequency place maps (FPM; total frequencies to which an ear can respond) to estimate minke (*Balaenoptera acutorostrata*) and humpback (*Megaptera novaeangliae*) hearing ranges. Bottlenose dolphin (*Tursiops truncatus*) and harbor porpoise (*Phocoena phocoena*) FPMs were also calculated. Our current effort expands models for all four species to include threshold calculations using modified land mammal Frequency-Sensitivity model methodologies. FPMs were obtained from microCT scans, basilar membrane histology, and nanoindentation measurements. METF and FEM frequency response simulations used these data and laser doppler measurements of stapes footplate velocities. Odontocete responses extended to 125 kHz (the limit of our measurement capability) but FPMs indicate frequency responses at 160-200 kHz. Mysticete frequency responses were measured at bone vs glove finger sites to assess best sensitivity input locations. A preliminary minke whale model indicates METF peak sensitivities at 1.5-7 kHz and FPM ranges of 17 Hz - 36 kHz and functional range of 25 to 33 kHz; humpback data show a FPM of 15 Hz - 32 kHz and 20 Hz - 30 kHz functional range. Mysticete bandpass responses found peak sensitivity

to be 0.5 kHz-2 kHz for stimuli at the glove finger. However, these are single specimen results; additional specimen analyses are required to determine representative species values. Supported by JIP and IOGP.

DEMASK, Policy Scenarios for Noise Management in the North Sea

N. A. Kinneging^{1*}

¹*Rijkswaterstaat*

**niels.kinneging@rws.nl*

The North Sea is one of the busiest shipping areas in the world, shared with other human activities such as fishing and tourism. With ambitious plans to produce energy from offshore wind farms, major changes will occur in the North Sea in the next decades. The marine ecosystem is at risk of being impacted by all these human activities, making it crucial to manage the sea more sustainably.

Underwater noise, both impulsive and continuous noise, is recognized as a pollutant caused by all human activities at sea. For various marine mammal species in the North Sea depends on sound, due to the high turbidity. Marine management of the North Sea therefore must address underwater noise.

After the successful completion of the Jomopans project in 2022 a successor project, DEMASK, has started in January 2024. DEMASK will develop policy scenarios for underwater noise management and a method to quantify the effectiveness of those scenarios to mitigate noise pollution and its effects on marine life. These scenarios will contain the predicted developments for offshore wind and shipping, as well as options for mitigation of the effects of underwater noise.

DEMASK aims to bring together policy makers, NGOs, and the maritime industry in the management of the underwater soundscape of the North Sea. The project will enable stakeholders to take measures that contribute to a well-managed soundscape and strengthen the marine ecosystem.

DEMASK is an acronym for “Development and evaluation of noise management strategies to keep the North Sea healthy.”

Additional Impact of UXO by Future Offshore Wind in The Netherlands

N. Kinneging,^{1*} S. Versteeg,²
E. Rotshuizen,¹ and M. L. Siemensma¹

¹*Rijkswaterstaat*

²*Arcadis*

**niels.kinneging@rws.nl*

To meet the ambition on the reduction of CO₂ emissions many countries have developed plans for offshore renewable energy, primarily in the form of wind energy. For these plans enormous areas on sea have been reserved. For the North Sea this may lead to a spatial coverage up to 25% and these areas need to be save for the construction of the wind farms. At the same time it is well known that on the bottom of the North Sea a large amount of unexploded ammunition (UXO) from WWII can be found. It is therefore plausible that during the development of offshore wind farms many UXO will be found and have to be removed. At this moment the most common method of UXO removal on the Dutch Continental Shelf (DCS) is detonation, which poses a major risk for the population of marine mammals. In a desk study commissioned by the Offshore Wind Ecological Programme (Wozep) various historic sources have been reviewed as well a number of databases containing information on UXO encounters in the North Sea. An estimate is made on the possible effects of these extra UXO encounters and removals on the most common marine mammal in the North Sea, the harbour porpoise. Although the available information is not complete, these estimates are included into the assessment of the environmental effects of offshore wind on the DCS.

The Fourth Phase of the Sea Mammals and Sonar Safety Project (3S4)

P. Kvadsheim,^{1*} P. Miller,² F. Lam,³ P. Wensveen,⁴
C. Binder,⁵ P. Tyack,² F. Samarra,⁴ and S. von Benda-Beckmann³

¹Norwegian Defence Research Establishment (FFI)

²Sea Mammal Research Unit, University of St Andrews, Scotland, UK

³TNO, The Netherlands

⁴Life and Environmental Sciences, University of Iceland

⁵Defence Research and Development Canada

*phk@ffi.no

3S is an international collaboration studying how naval sonar affects cetaceans. Since 2006 we have deployed 242 tags to 6 species, conducted 157 controlled sonar exposure experiments and published more than 30 papers on effects of sonar on marine life. Initially the focus was to establish dose-response relationships to estimate the number of animals disturbed. Later we addressed specific questions like the effect of ramp-up and what are the main drivers of responses (SPL/SEL or range to the source). The fourth phase of the project (3S4) started in 2023 with the aim to investigate whether exposure to Continuous Active Sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional Pulsed Active Sonar (PAS) signals. We also aimed to investigate how well responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration of 6-8 hours. A sea trial was conducted off the coast of Norway in October 2023 to collect data to address these research questions. The experimental design was to use real-time GPS location data of multiple tagged subjects and move the sonar source vessel to achieve repeated dose escalation CAS and PAS exposures to killer- and humpback whales. Ongoing analyses will test for sensitization or habituation during extended exposures, as well as comparing feeding cessation and avoidance responses during CAS and PAS, and the potential that CAS signals might mask social sounds. A second research trial following the same design is scheduled for Oct 2024.

Too Loud: A Singing Humpback Whale Responds to Ship Noise

M. Lammers,^{1*} A. Kügler,² and E. J. Zang¹

¹NOAA – Hawaiian Islands Humpback Whale National Marine Sanctuary

²Syracuse University

*marc.lammers@noaa.gov

Humpback whales (*Megaptera novaeangliae*) are a species of marine mammals frequently impacted by anthropogenic noise, and vessel noise specifically, due to their common occurrence in coastal waters where vessel traffic is often high. We report on an event in which a singing male humpback whale tagged in Hawai'i with an acoustic tag was opportunistically exposed to elevated levels of engine noise from a transiting commercial tugboat towing a barge within a few hundred meters of the whale, providing the opportunity to observe and measure the whale's reaction. Although the whale continued to produce its song during the exposure, notable behavioral and acoustic changes occurred. The whale's stereotyped diving observed during nine song cycles prior to the arrival of the tugboat and barge changed when noise from the tugboat became prominent. Similarly, the whale's vectorial dynamic body acceleration (VeDBA), measured by the tag's tri-axial accelerometers was consistent and cyclical during the period before the arrival of the tug and barge, but increased and became variable when noise from the tugboat was present in the tag's recordings. Once the noise abated, diving behavior and VeDBA returned to the previous patterns. Lastly, notable changes were seen in the structure of the song when the tug and barge were near. The whale sang normally before and after the exposure, but substantially changed the unit and phrase structure while the vessels approached and abruptly interrupted its singing when the vessels were closest.

Updates on BOEM's Management of Ocean Noise

J. Lewandowski^{1*}

¹*Bureau of Ocean Energy Management (BOEM)*

^{*}*Jill.Lewandowski@boem.gov*

The mission of the Bureau of Ocean Energy Management (BOEM) is to manage development of U.S. Outer Continental Shelf (OCS) energy, mineral, and geological resources in an environmentally and economically responsible way (the size of the U.S. OCS is approximately 3.2 billion acres). BOEM applies more than 30 environmental Federal regulations, statutes, executive orders, international agreements, and policies into our decisions across our four programs: oil and gas, renewable energy, and non-energy minerals (sand and gravel or hard minerals, critical minerals), and carbon sequestration (emerging program). Activities under all phases of these programs introduce noise making it essential for BOEM to effectively understand and manage impacts. In 2020, BOEM launched its Center for Marine Acoustics (CMA) to build the bureau's expertise and strengthen its role in managing and understanding underwater sound. This presentation will summarize BOEM's role in ocean noise issues and current work by our CMA.

Vessel Speed Reductions to Reduce Ocean Noise Pollution

C. Malinka,^{1*} R. Aronson,² K. Trounce,³
L. Hatch,⁴ and J. Wood⁵

¹*SMRU Consulting, UK*

²*Washington Maritime Blue, USA*

³*Vancouver Fraser Port Authority, Canada*

⁴*National Marine Sanctuaries, NOAA, USA*

⁵*SMRU Consulting, USA*

^{*}*Cm@smruconsulting.com*

Noise pollution and acoustic disturbances from shipping is of concern for marine life, and there have been several initiatives to reduce it via vessel speed reduction (VSR) programs. These programs comprise voluntary speed restrictions to shipping vessels which are encouraged during seasons of biological sensitivity, such as when the shipping lanes overlap with occupied critical habitat for endangered whales. Here, we highlight two VSR programs in the Pacific northwest: the ECHO Program (Enhanced Cetacean and Habitat Observation Program), run by the Vancouver Fraser Port Authority in Canada, and the more recent Quiet Sound Program, occurring in the approaches to the Ports of Seattle, Tacoma, and Everett. These schemes are monitored via passive acoustics along the vessel routes to quantify the efficacy of the voluntary slowdowns in reducing ambient noise levels and to document the acoustic occurrence of the endangered Southern Resident killer whale (*Orcinus orca*). Both programs use environmental data (wind and current speeds), as well as AIS data from vessels and boats, to identify periods appropriate for evaluating noise mitigation. ECHO and Quiet Sound have been running for 7 and 2 years respectively and have each demonstrated reductions in broadband sound (10 Hz-50 kHz or 100 kHz) intensity of ~50%. To accommodate the growing interest in the environmental sustainability of global shipping, we go on to recommend community practices to streamline the analysis and communication of noise reduction benefits during VSRs, and to remove barriers to participation in other areas.

Establishing a Passive Acoustic Monitoring Network Along the U.S. Atlantic Outer Continental Shelf

M. Martin,^{1*} E. Staaterman,¹ M. Reeve,¹
and H. Kates Varghese¹

¹*Center for Marine Acoustics, Bureau of Ocean Energy Management*

**morgan.martin@boem.gov*

The U.S. Atlantic coastline is poised to undergo rapid change in the coming years, as the construction of offshore wind farms is already underway. By 2026, several hundred wind turbine foundations will be in the water. There are many questions regarding the potential impacts of offshore wind development on marine species. For example, will the presence of this new infrastructure result in measurable changes to the distributions of marine species? Will some species be attracted to the structures, while others avoid them? The Bureau of Ocean Energy Management is required to assess and monitor the impacts of its permitted activities on marine life to better inform future leasing decisions, and to ensure compliance under the National Environmental Policy Act. Given the critically endangered status of the North Atlantic right whale, whose migratory corridor overlaps with some of the most reliable wind resources on the Atlantic Outer Continental Shelf, one driving question has garnered significant attention among stakeholders: will there be a measurable change in baleen whale distributions as a result of offshore wind development? To answer this question, BOEM, along with regional partners, is establishing a Passive Acoustic Monitoring network along the Atlantic coastline to listen for whale vocalizations and monitor for potential changes in marine soundscapes. We have established a model to work with industry and other partners to ensure adequate sampling across key geographic areas. BOEM and its partners have created best practices for instrument calibration, data QA/QC, and data

The UK Marine Noise Registry and Its Role in Impulsive Noise Monitoring and Management

S. Mendes^{1*}

¹*Joint Nature Conservation Committee*

**sonia.mendes@jncc.gov.uk*

The UK Marine Noise Registry (MNR) was established in 2015 following a commitment in the UK Marine Strategy (UKMS) to monitor and manage underwater noise to the extent that it does not have adverse effects on marine ecosystems and species at the population level. The MNR collates data on human activities in UK seas that produce loud, low to medium frequency impulsive noise, i.e., seismic surveys, sub-bottom profiling, impact pile driving, explosive use, military sonar (declassified), acoustic deterrent devices, and multibeam echo-sounders.

Submitting data to the MNR is a licence requirement for most such activities. Data include where and when the noisy activity occurred, and where available, sound source properties such as the frequency, maximum airgun volume, maximum hammer energy, TNT equivalent, sound pressure level. The data in the MNR is used for a variety of purposes. For example, every six years, the UKMS's Assessment of Good Environmental Status of the UK seas tracks the spatio-temporal distribution of impulsive sound sources.

The upgraded MNR (2023) introduced two new functions, following feedback from users: the disturbance and cooperation tools, enabling assessments of the potential noise disturbance footprint of activities within MPAs for harbour porpoise, and user interaction to resolve instances when advised noise limits could be exceeded. Users now also have the option to directly obtain custom data in the form of maps and tables, which can be useful for planning purposes and cumulative impact assessments as well as retrospective assessments.

Considering the Impact of Sound on Bering Sea Marine Mammals in the Context of Climate Change

J. L. Miksis-Olds,^{1*} K. D. Seger,² and J. J. Johnson³

¹Center for Acoustics Research & Education, University of New Hampshire, Durham, NH, USA

²Applied Ocean Sciences, Springfield, VA, USA

³Woods Hole Oceanographic Institution, Woods Hole, MA, USA

*j.miksisolds@unh.edu

Climate-induced changes related to ecological degradation, altered migration patterns, and changes in species distribution and diversity contribute to cumulative impacts in the context of the effects of sound on marine mammals, but are often difficult to measure or include in risk assessments. A decade of data from the Bering Sea provided a unique opportunity to assess how variability in a dominant regional oceanographic feature, the Bering Sea Cold Pool, manifests in the presence and vocal foraging behavior of beluga, killer, and sperm whales. Vocal foraging dynamics of ice-associated and seasonally migrant species suggest that sperm whales spend more time searching for prey in warm years during a reduced Cold Pool but are more successful at capturing prey during cold years when the Cold Pool is stronger. Beluga whale foraging vocal activity was relatively consistent across climate regimes but peaked during the warm regime. Killer whale foraging vocal activity peaked in both warm and cold regimes with indicators of different ecotypes exploiting changing prey conditions across climate regimes. Foraging activity of odontocete apex predators may serve as a sentinel indicator of future ecosystem change that is linked to a diminishing Cold Pool as water temperatures rise and seasonal sea ice decreases due to climate change. With an increased understanding of odontocete foraging response to variability in the Bering Sea Cold Pool, future risk assessment and management of marine mammals to sound exposure in this region can be better directed for individual species or ecotypes.

Automatic GPS Tracking of Tagged Cetaceans to Conduct Controlled Exposure Experiments at Sea

P. Miller,^{1*} E. Hayward,¹ D. Gillespie,¹ P. Wensveen,² F. Samarra,²
S. van IJsselmuide,³ M. van Riet,³ F. Lam,³
P. Kvadsheim,⁴ C. Hunter,⁵ and P. de Saint Leger⁶

¹Sea Mammal Research Unit, University of St Andrews

²Life and Environmental Sciences, University of Iceland

³TNO, The Netherlands

⁴FFI, Norway

⁵LOTEK (currently at Wildlife Computers)

⁶CLS Argos

*pm29@st-andrews.ac.uk

In addition to recording whale behaviour, a key function of animal-attached tags is to enable a focal follow of one subject—required for positioning a sound source to achieve a desired exposure design. Real-time tracking has typically been done with observers spotting the tagged whale (aided with VHF signals from the tag) and recording its range and bearing. Here we describe an automatic system for GPS tracking of multiple tagged whales. A Lotek F6G149A GPS-Argos unit (as part of a suction-cup attached Mixed-Dtag++), records FastGPS positions and relays them to ARGOS. Real-time tracking is accomplished by intercepting and decoding the ARGOS data packets on the source vessel. Testing and refinement over 2021-2023 led to its successful use in the 3S4 study of how killer and humpback whales respond to extended duration sonar exposure. Pilot tests in Iceland confirmed the critical importance of tag placement flat on the body between the blowhole and dorsal fin. Using a custom high-performance antenna 25 m above sea level on the *HU Sverdrup II*, positions were reliably received < 10 min after they were recorded on the tag out to distances up to 18 km—the distance to the horizon. A Matlab program "CEE Tool" was developed to use real-time GPS positions in the 3S4 sonar experiments, and a PamGuard module has been developed to support smaller scale experimental efforts. Automatic GPS tracking is a fundamental advance that enables at-sea experiments to be conducted at lower cost and more reliably, including during darkness or rough weather when visual tracking is impossible.

Project WOW Acoustic Sampling Strategies, Platforms, and Initial Results

D. P. Nowacek,^{1*} A. Rice,² B. L. Southall,³ B. Murray,⁴
E. Adams,⁵ F. Jensen,⁶ H. Rosenbaum,⁷ J. Redfern,⁸
J. Haxel,⁹ J. Kohut,¹⁰ K. Williams,⁵ L. Thomas,¹¹
L. Thorne,¹² M. Fuentes,¹³ P. N. Halpin,¹⁴
S. E. Parks,¹⁵ and T. A. Mooney¹⁶

¹*Duke University, Nicholas School of the Environment and Pratt School of Engineering*

²*Cornell University, Center for Conservation Bioacoustics*

³*Southall Environmental Associates, Inc. and Duke Marine Lab*

⁴*Duke University, Nicholas Institute for Energy, Environment, and Sustainability*

⁵*Biodiversity Research Institute*

⁶*Aarhus University*

⁷*Wildlife Conservation Society, New York*

⁸*New England Aquarium,*

Anderson Cabot Center for Ocean Life

⁹*Pacific Northwest National Laboratory*

¹⁰*Coastal Ocean Observing Lab, Rutgers University*

¹¹*Centre for Research into Ecological and Environmental Monitoring, University of St Andrews*

¹²*State University of New York, Stonybrook*

¹³*Earth, Ocean and Planetary Sciences,
Florida State University*

¹⁴*Nicholas School of the Environment, Duke University*

¹⁵*Syracuse University*

¹⁶*Woods Hole Oceanographic Institution*

*dpn3@duke.edu

The Wildlife and Offshore Wind project (WOW) is a multi-institutional study of potential interactions between offshore wind development and marine mammals, birds, and bats off the east coast of the U.S. The marine mammal work is focused on passive acoustics, making use of several platforms to obtain data in a variety of situations. First, we used multi-sensor acoustic recording tags; we deployed 17 suction-cup tags on adult fin whales in coastal waters near the Southfork and Vineyard Wind projects, both of which were actively involved in construction. The tag attachment durations ranged from 0.2 to > 19 hours with a median attachment time of 1.9 hours. We recorded typical 20 Hz calls as well as calls *ca.* 120 Hz. Next, we deployed sets of six bottom-mounted acoustic recorders (Cornell Rockhoppers) in and around the Vineyard Wind lease area, arranged to maximize detection coverage for right whales. The first set of Rockhoppers has just been retrieved, and data are being processed to look at both whale vocal activity as well as construction related noise. The third platform we are employing is a floating, autonomous acoustic drifter (Medusa, Loggerhead Instruments & WHOI). The new Medusa is an inexpensive, rapidly deployable option for relatively short-term acoustic monitoring. We deployed four Medusas on two occasions during the tagging cruise off Massachusetts, and we will deploy them again in 2024, likely with the implementation of onboard acoustic detection and classification. Finally, via projects led by WOW PIs, we are incorporating glider-deployed PAM.

Uncrewed Aerial Systems Aid to Advance Field Studies of Construction Sound Exposure of Fin Whales in Southern New England Waters

S. E. Parks,^{1*} D. Adcock,¹ A. Burgess,² A. Pensarosa,³
C. Zadra,³ and D. P. Nowacek⁴

¹Bioacoustics and Behavioral Ecology Lab, Department of Biology, Syracuse University, Syracuse, NY, USA

²New England Aquarium, Boston, MA, USA

³Ocean Alliance, Gloucester, MA, USA

⁴Duke University Marine Lab, Beaufort, NC, USA

*sparks@syr.edu

Data collection of the effects of sound on free-swimming baleen whales can be challenging. Monitoring sub-surface behavioral responses, coincident with the timing of sound exposure, requires attachment of biologging devices which is often a rate limiting step for opportunistic observations of the response to activities in the environment or as part of planned behavioral response studies. As part of a collaborative research study on Wildlife and Offshore Wind, our team collected data from fin whales (*Balaenoptera physalus*) in the wind energy development regions south of Martha's Vineyard in Massachusetts, USA. Using an uncrewed aerial system (UAS) enabled remote deployment of suction cup acoustic biologging tags on these highly maneuverable animals without needing to make close approaches with the research vessel. A total of 28 tags were deployed, with 17 tags remaining attached to the whales between 10 minutes – 19 hours. The spatial de-coupling of the research vessel from the tagging process enabled highly efficient tag deployments. The UAS platform enabled additional data collection include high resolution video of behaviors and behavioral associations, photo identification images, photogrammetry images for body size and body condition assessment, and remote collection of exhalations for stress and sex hormone assessment. This presentation will highlight the advantages and challenges of using these versatile platforms for data collection from species that are difficult to approach for tag deployment with previously utilized methods.

Understanding the Cumulative Effects of Multiple Stressors on Marine Mammals – An Overview of the Population Consequences of Multiple Stressors (PCoMS) Project

L. Thomas,¹ E. Pirotta,^{1*} C. Harris,¹ A. Barratclough,² D. P. Costa,³
D. Crocker,⁴ A. Hall,⁵ J. Harwood,¹ S. Kraus,⁶ P. Miller,⁵ M. Moore,⁷
T. Photopoulou,¹ R. Rolland,⁶ L. Schwacke,⁸ S. Simmons,⁹ C. Smith,²
B. L. Southall,¹⁰ R. Takeshita,² and P. Tyack⁵

¹Centre for Research into Ecological and Environmental Modelling, University of St Andrews, St Andrews, UK

²National Marine Mammal Foundation, San Diego, CA, USA

³Institute of Marine Sciences, University of California, Santa Cruz, CA, USA

⁴Department of Biology, Sonoma State University, Rohnert Park, CA, USA

⁵Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK

⁶Anderson-Cabot Center for Ocean Life, New England Aquarium, Boston, MA, USA

⁷Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

⁸Marine Mammal Commission, Bethesda, MD, USA

⁹SMRU Consulting, Scottish Oceans Institute, University of St Andrews, St Andrews, UK

¹⁰Southall Environmental Associates, Inc., Aptos, CA, USA

*ep343@st-andrews.ac.uk

Marine mammal populations are exposed to an expanding diversity of anthropogenic stressors, within the context of climate change and natural processes. Assessing cumulative effects is required by many jurisdictions, but neither scientific theory nor data are adequate to meet regulatory requirements. The Population Consequences of Multiple Stressors (PCoMS) project started in 2020, with the overall goal of advancing the

understanding of the cumulative risk of multiple stressors on marine mammals through an interdisciplinary working group and a series of case studies. Our conceptual framework uses health indicators to accumulate short-term effects and to estimate their impact on survival and reproduction. The framework has been applied to: (1) North Atlantic right whales (*Eubalaena glacialis*)—investigating how prey availability interacts with the effects of entanglements, vessel strikes and noise on health; (2) common bottlenose dolphins (*Tursiops truncatus*)—testing experimentally whether behavioural responses to vessel approaches depend on the impact of chemicals on individuals' health; (3) northern elephant seals (*Mirounga angustirostris*), led by a team at the University of California Santa Cruz. These case studies are demonstrating the benefits of long-term monitoring and the ability to measure health indicators and exposure to stressors. To this purpose, we have also been exploring the use of epigenetics as a new technology to assess stressor exposure and health.

Diving to the Seafloor: Investigating Cuvier's Beaked Whale (*Ziphius cavirostris*) Foraging Behaviour

N. J. Quick,^{1*} C. P. Kootstra,² C. B. Embling,¹ F. H. Jensen,³
B. L. Southall,⁴ and A. J. Read⁵

¹*School of Biological and Marine Sciences, University of Plymouth, Plymouth, UK*

²*Marine and Freshwater Research Centre, Atlantic Technologic University, Galway, Ireland*

³*Department of Ecoscience, Aarhus University, Aarhus, Denmark*

⁴*SEA, Inc, Aptos, CA, USA*

⁵*Duke Marine Lab, Duke University, Beaufort, NC, USA*

**nicola.quick@plymouth.ac.uk*

Cuvier's beaked whales (*Ziphius cavirostris*) perform deep foraging dives, but data are limited on how dive depths relate to the seafloor. We analysed acoustic data from digital acoustic recording tags (DTAGs) from five Cuvier's beaked whales off Cape Hatteras, and two Cuvier's beaked whales off the Southern California Bight. Echolocation clicks and buzzes were identified, and echograms were constructed to detect seafloor echoes, determine seafloor depth and calculate foraging altitude. Echolocation clicks were recorded for 16 deep (mean depth: 1365 ± 263 m) foraging dives during which whales spent a median of 52% of dive time clicking. Seafloor echoes were identified in 14 deep dives and were detected from over 700 m. There was a median of 56 prey capture attempts per dive recorded between 471-1992 m depth, but 55% of all foraging activity occurred between 850-1150 m. Most foraging activity (70%) occurred within 200 m of the seafloor, suggesting a preference for benthopelagic slow moving prey and confirming foraging behaviour close to the seafloor. Exposure to MFAS led to echolocation cessation or delay, limiting the whale's foraging activity. Dive depths after MFAS exposure suggest whales dive near the seafloor even in the absence of echolocation and despite challenges of reflection, masking and reverberation of noise from the ocean bottom. Our results suggest foraging and navigation in bathymetrically complex environments, but also suggest echolocation behaviour is supported by prior spatial knowledge that may influence the behavioural response observed after exposure to MFAS.

The Soundscape and Harbour Porpoise Presence in and Around an Offshore Windfarm

J. M. Ransijn,^{1*} J. A. Brinkkemper,² P. M. van Tol,²
S. C. V. Geelhoed,¹ M. Olivierse,² and R. C. Snoek²

¹Wageningen Marine Research, Wageningen University and Research, Wageningen, The Netherlands

²WaterProof Marine Consultancy & Services B.V., Lelystad, The Netherlands

*janneke.ransijn@wur.nl

The swift expansion of offshore wind energy development in European waters has sparked concerns regarding their potential environmental impacts. We studied harbour porpoise (*Phocoena phocoena*) presence during the operational phase of Borssele wind farms located in the southern part of the Dutch EEZ. The passive acoustic monitoring network consists of cetacean click detectors at 14 locations in and outside the windfarms, co-located with broadband hydrophones at 4 locations. Preliminary results indicate that ambient sound levels inside the windfarms are dominated by low-frequency sound emitted by the turbines, while ambient sound levels outside the windfarm are higher and deemed typical for an environment close to a shipping lane. Seasonality in harbour porpoise acoustic activity was observed, with higher detections with decaying sea surface temperature. This corresponds with previous studies at Dutch offshore wind farms and patterns in coastal sightings, aerial surveys, and strandings (i.e., higher porpoise density in winter and early spring). Porpoise acoustic activity increased during the night and around slack tide, possibly related with enhanced foraging opportunities. The monitoring network enables studying the soundscape in and around an offshore windfarm within a part of the North Sea with the highest shipping density, and the impact of an offshore windfarm on the presence and activity of harbour porpoises. This research is part of the WOZEP ecological programme of Rijkswaterstaat.

Proposed Underwater Noise Limits for Offshore Wind Construction in the U.S.

M. Reeve,^{1*} M. Martin,¹ H. Kates Varghese,¹ A. Conrad,¹
S. Denes,¹ E. Staaterman,¹ and J. Lewandowski¹

¹BOEM

*molly.reeve@boem.gov

The Bureau of Ocean Energy Management's (BOEM) Center for Marine Acoustics (CMA) developed proposed noise mitigation measures to meet the Outer Continental Shelf Lands Act's (OCSLA's) "undue harm" requirement, reduce and monitor impacts, and bolster compliance with the Endangered Species Act and Marine Mammal Protection Act. While these measures are aimed at reducing impacts to key species, such as the critically endangered North Atlantic right whale, their implementation will also benefit a host of other marine life. The CMA considers these proposed measures to be mature and ready for integration with project NEPA reviews and plan approvals. Currently, the proposed measures are focused on three areas: (1) Received Sound Level Limits for pile driving, (2) Sound Field Verification for pile driving, and (3) Long-Term Passive Acoustic Monitoring (pre, during, and post-construction). Additional measures are still being considered and may be added to address, among other concerns, vessel quieting and the application of relativistic risk frameworks during plan development.

Using Continuous-Time Discrete Space Models to Assess Horizontal Avoidance in the Atlantic Behavioral Response Study

R. S. Schick,^{1*} W. R. Cioffi,¹ D. S. Johnson,²
and B. L. Southall¹

¹Southall Environmental Associates, Inc., Aptos, CA, USA

²NOAA Fisheries Pacific Islands Research Center, Honolulu, HI, USA

*robschick@sea-inc.net

One of the primary questions regarding behavioral responses to noise is horizontal avoidance. In controlled exposure experiments (CEEs), the position of the source, as well as the position of focal animal are known. Using this information, researchers can document movement patterns, before, during, and after exposure to determine if animals left the area. Across 13 CEEs from 2017-2022, we exposed 65 individual beaked whales (*Ziphius cavirostris*) equipped with satellite tags to simulated mid-frequency active sonar. We binned the animals into 4 groups, depending on the received level (RL) of sonar: control (no sonar), < 100, 100-120, and > 120 dB RMS. We fit a continuous time discrete space model to the movements of individuals during the 24 hours preceding and following exposure, wherein we constructed an exposure covariate comprised of the distance of the sound source. We found an increasing percentage of animals exhibiting horizontal avoidance in the period following exposure with increasing RL. Percent significant in each RL bin (respectively) were: 16.7%, 23.5%, 35.6%, and 43.8%. To test sensitivity, we created a series of ghost exposures 48 hours in length during the baseline, pre-exposure portion of the tag record. We found the model produced false positives at a rate of 30%. In addition to these results, we will discuss best practices when using this class of models, and extensions of the model to dynamic covariates built from a combination of ambient noise and sonar exposure. This should enable refined inference on the dynamic role of exposure on movement.

(Even More) Factors Affecting the Behavior of Beaked Whales on a Military Training Range

G. S. Schorr,^{1*} S. L. DeRuiter,² B. K. Rone,¹ D. A. Sweeney,¹
S. N. Coates,¹ R. D. Andrews,¹ K. A. Dolan,³ E. A. Falcone,¹
S. M. Jarvis,³ and S. L. Watwood⁴

¹Marine Ecology and Telemetry Research

²Calvin University

³U.S Navy, Naval Undersea Warfare Center

⁴susan.m.jarvis.civ@us.navy.mil

*gschorr@marecotel.org

The Sound & Motion Recording Telemetry (SMRT) tag—a high-resolution, multi-sensor, acoustic device that can be deployed on beaked whales for days or weeks—is providing an unprecedented view of these difficult to study species and the sound fields in which they live. As of April 2024, 16 SMRT tags have been deployed on *Ziphius cavirostris* on or near the Southern California Anti-submarine Warfare Range (SOAR) to collect behavioral data from whales exposed to Mid-Frequency Active Sonar (MFAS), which is routinely used in training exercises there. In addition to accurately characterizing MFAS exposures, including signal type, duration, duty cycle, and received levels at the whale, these tags record all sounds the whale is exposed to, allowing us to recognize potential sources of acoustic disturbance, both anthropogenic and naturally occurring, during what would otherwise be considered “baseline” behavioral data. Further, they are allowing us to document the detailed behavior of multiple whales during the same exposure events, and tease apart some of the intrinsic and extrinsic factors that may mediate responsiveness. Key among these are signal type, novelty of the signal, duty cycle, cumulative received energy and individual residency status, with animals that appear more resident to SOAR less responsive than those that are not sighted regularly. These factors underscore the complexity of characterizing—and thus managing—responses at the population level, even with the best available data, in a region as noisy as Southern California.

Behavioral Responses of Goose-Beaked Whales (*Ziphius cavirostris*) to Military Sonars

B. L. Southall,^{1*} D. Alvarez,² W. Cioffi,² S. L. DeRuiter,³
H. Foley,⁴ C. Harris,⁵ A. Harshbarger,² S. Isojunno,⁵
J. Joseph,⁶ T. Margolina,⁶ D. Nowacek,² N. Quick,⁷
A. Read,² R. Schick,¹ J. Shearer,² Z. Swaim,²
D. A. Waple,² D. E. Webster,⁸ and J. Wisse²

¹Southall Environmental Associates, Inc., Duke University Marine Laboratory

²Duke University Marine Laboratory

³Calvin University

⁴National Oceanic and Atmospheric Administration

⁵University of St. Andrews

⁶Naval Postgraduate School

⁷Plymouth University

⁸Bridger Consulting

*Brandon.Southall@sea-inc.net

The Atlantic Behavioral Response Study is a multi-disciplinary collaboration with the U.S. Navy to quantify mid-frequency (1-10 kHz) active sonar (MFAS) effects for marine mammals. We will present baseline behavior and MFAS response results for goose-beaked whales (*Ziphius cavirostris*). Our study site is a biologically rich area where Navy coordination is possible and MFAS occurs but at lower rates than sonar ranges where many BRS' have occurred. We use multi-scale tagging approaches with strategically programmed satellite-transmitting tags yielding weeks of coarser position and diving data and shorter, fine-scale movement and acoustic tags. Controlled exposure experiments (CEEs) provide exposure-response results for different sound sources, including: no noise controls ($n = 20$), experimental pulsed active sonar (PAS; $n = 53$), naval vessel PAS ($n = 34$) and continuous active sonar (CAS). Responses are evaluated relative to key variables (received level [RL], behavioral state, and horizontal range) and specifically assess spatial avoidance, changes in diving and foraging behavior, and social response. Response results for PAS CEEs will be given; CAS studies are ongoing. We observed subtle behavioral changes in control CEEs at similar, low rates as the lowest (< 100 dB) MFAS RLs but a clear escalation of avoidance and diving responses with increasing RL for 100-140 dB exposures. Results amplify earlier indications of *Ziphius* sensitivity to MFAS by substantially expanding sample sizes and temporal scales, but suggest differences in aspects of response from studies on ranges.

A Behavioral Response Study with Baleen Whales and Marine Vibrators

B. L. Southall^{1*}

¹Southall Environmental Associates, Inc.

*Brandon.Southall@sea-inc.net

This talk will describe the development, planning, early stage pilot results, and ongoing field effort for a new study investigating the behavioral responses of large whales to marine vibrators. These sources, also referred to as marine vibroseis, are being developed as potential alternatives to seismic airgun surveys, with a number of presumed environmental benefits related to the dramatically reduced underwater radiated noise bandwidth. While the restriction of output energy to frequencies generally below 100 Hz almost certainly mitigates potential impacts for many marine species utilizing higher frequency bands, the potential effects for species that utilize very low frequencies are unknown. The objective is to apply controlled exposure experiments (CEEs) with proven tools to obtain novel data on the behavioral responses of very low frequency, endangered baleen whales to marine vibrators in realistic operational conditions. Key study elements include locating, tagging, and tracking blue and/or fin whales and conducting CEEs using multi scale tag approach with fine-scale short duration (hours to days) and coarser scale longer duration (days to

weeks) data. CEEs have been conducted to date with smaller-scale simulations (experimental sources) but are progressing to include recently developed, full-scale marine vibrator sources. Data from animal-borne tags are augmented with passive acoustic monitoring, whale focal follows, photo identification, and body condition data. Initial pilot effort results and ongoing trials with full scale sources will be discussed.

Offshore Wind Site Characterization Surveys Not Likely to Result in Incidental Take

E. Staaterman,^{1*} C. Ruppel,² T. Weber,³
H. Kates Varghese,¹ S. Labak,¹ and P. Hart²

¹Center for Marine Acoustics, Bureau of Ocean Energy Management

²United States Geological Survey

³University of New Hampshire

*erica.staaterman@boem.gov

Use of active acoustic sources is critical for non-invasive mapping, exploration, and characterization of the marine environment. Offshore wind companies use a suite of high-resolution geophysical (HRG) sources to survey the seafloor in order to characterize their lease areas before preparing a construction plan. There have been some concerns about the potential impacts of active acoustic sources on marine species. Here we evaluate HRG sources based on output source level, transmission frequencies, directionality, beamwidth, and pulse repetition rate. Using published population distributions of marine animals (mammals and turtles) on the U.S. Atlantic, Pacific, and Gulf Coasts, we apply Monte Carlo simulations to determine the probability of an animal being ensounded by various HRG sources. In addition, we use sound propagation models to constrain received sound levels for animals along a vessel's track. Based on a combination of criteria, we show that many commonly used HRG sound sources, including multibeam echosounders (MBES), towed and hull-mounted Chirps, sidescan research sonars, split-beam (fisheries) sonars, 3-plate boomers, low-powered sparkers, ADCPs, and navigational/tracking acoustics are *de minimis*, which means they are not likely to result in incidental take of marine mammals. Based on this finding, BOEM is focused on regulating sounds related to offshore wind construction activities, rather than site characterization.

Recovery Patterns from Low Level Temporary Hearing Threshold Shifts (TTS) in Harbor Porpoises, Harbor Seals and California Sea Lions Will Interfere with Effective Quiet Level Determinations

J. M. Terhune,^{1*} R. A. Kastelein, L. Helder-Hoek,
L. Defiliet, and L. Van Acoleyen

¹Department of Biological Sciences, University of New Brunswick, Saint John, NB, Canada

*terhune@unb.ca

Temporary hearing threshold shifts (TTS) vary with the exposure duration, sound pressure level (SPL), fatiguing sound frequency, and hearing test frequency. We examined the recovery patterns of harbor porpoises (*Phocoena phocoena*), harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*) exposed to continuous narrow band noise levels for 1 h that resulted in 2 to 16 dB TTS. TTS was deemed to have occurred when the detection threshold was raised by more than 1.9 dB. Recovery patterns of the three species were similar. Recovery 8 min post-exposure was slightly influenced by the hearing test frequency. A segmented linear regression model found break points near 6 dB initial TTS levels in all three species. When the initial TTS was > 6 dB, mean recoveries were 5 to 7 dB after 8 min. When the initial TTS was < 6 dB, 50% recovered within 4 min and 82% recovered within 8 min. An effective quiet SPL will never result in TTS even after long duration exposures. The quick recovery of small TTS levels makes determination of effective quiet SPL difficult to measure. Unmasked hearing sensitivity cannot be

used because once the fatiguing sound is turned off, the subject's hearing sensitivity will have recovered before the testing time is completed. The rapid recovery from < 6 dB initial TTS means that measures to identify effective quiet levels will have to use the absence of a change in critical ratio (CR) thresholds (tested in the presence of the fatiguing sound) rather than unmasked threshold determinations.

Unveiling Population Consequences of Underwater Noise on North Sea Harbour Porpoise PCoD Using a Novel Integrated SDP-ABM Modeling Approach

N. A. M. Tuhuteru,^{1*} S. K. Adamczak,² S. Accornero,¹
J. B. Mortensen,¹ L. O. Mortensen,¹ K. M. Bryndum,¹
O. S. Petersen,¹ D. P. Costa,² and F. Thomsen¹

¹DHI A/S

²University of California, Santa Cruz

*natu@dhigroup.com

The PCoD (Population Consequences of Disturbance) framework aims to address population responses to human disturbances by integrating behavior, physiology, and vital rates. The harbor porpoise is an ideal study species for PCoD due to its sensitivity, constrained physiology, and unique life history. By coupling a Stochastic-Dynamic-Programming (SDP) model and an Agent-Based Model (ABM), we aimed to further develop the data-driven PCoD model for harbor porpoises in the North Sea. The SDP model tracks behavioral decisions and changes to vital rates using optimization theory to define decisions over a range of internal states, including bioenergetics. It is a key component of PCoD as it models species' states over the long term. However, the SDP's value was previously limited by not fully considering individual movements. The ABM approximates individual movement on a fine scale in response to environmental variables and pressures. By coupling these two models, our approach utilizes the SDP model's optimization framework within the ABM framework, enabling agents to make movement and reproductive decisions that maximize their fitness in the face of disturbance. The ABM responses to disturbance were integrated into the SDP model. Population responses to disturbance will then be assessed by comparing baseline and acoustic disturbance scenarios with respect to population variables. Given the complementary nature of the integrated modeling approach, we anticipate this model will yield more realistic predictions of population consequences.

The Process of, and Developments in, Assessing Ecological and Cumulative Effects from Offshore Wind in the Netherlands, Specifically Regarding Underwater Sound on Marine Mammals

M. Verdonk,^{1*} M. Graafland,¹ and M. L. Siemensma²

¹Rijkswaterstaat – Zee en Delta

²Rijkswaterstaat – WVL

*meik.verdonk@rws.nl

The Netherlands are working towards sustainable energy availability. When implementing the plans and permits for large-scale development of offshore wind energy, the government takes different interests at sea into consideration. The Dutch "Framework for Assessing Ecological and Cumulative Effects" (KEC) focuses on potential cumulative effects on populations of protected species due to the construction and exploitation of offshore wind, e.g., effects of collision and habitat loss on birds and migrating bats, effects of underwater sound during construction and operation on marine mammals and ecosystem effects. If necessary, permitting regulations and additional research are proposed. There is an important interplay between KEC, Environmental Impact Assessments and the Dutch Offshore Wind Ecological Programme (Wozep). KEC is regularly updated, incorporating new policy decisions, and new knowledge that is retrieved from Wozep, PhDs or ecological windfarm tenders.

KEC started in 2015 with calculating cumulative effects of underwater sound of pile driving on harbour porpoises and seals, which led to underwater sound thresholds as mitigation measure. Potential effects are quantified by applying population modelling (iPCoD). KEC played a role in the substantive and methodological development of topics included in the underwater noise calculations, methodologies, and research related to parameters used in the models. With regard to the calculations of the cumulative effects of underwater sound on marine mammals, insights into the process, plans and wishes for the future are shared.

The Deep-Sea Prey Scope of Deep-Diving Toothed Whales

F. Visser,^{1*} H. J. Hoving,² E. Hazen,³ S. Dolan,⁴ M. Guilpin,⁵
M. Oudejans,⁶ J. Stefanschitz,² V. Merten,² and
S. Baumann-Pickering⁴

¹Kelp Marine Research, Royal NIOZ, The Netherlands

²GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany

³NOAA SWFSC, USA

⁴Scripps-UCSD, USA

⁵Royal NIOZ, The Netherlands

⁶Kelp Marine Research, The Netherlands

*fvisser@kelpmarineresearch.com

Beaked whales can be highly sensitive to naval sonar, posing significant risks at population-level. A major limitation in our understanding of sub-lethal effects, such as impeded foraging, is the near-absence of knowledge of beaked whale prey fields. We conducted direct observations of prey and predator and their interactions in the physical environment of the foraging zones, aiming to test the hypothesis that local prey characteristics drive foraging decisions in Cuvier's beaked whales. In a long-term, collaborative and multi-disciplinary study of CBW at the Azores, we combined 1. biologging, 2. surface echo sounders, 3. deep-sea multi-sensor mooring equipped with echo sounders and passive acoustic recorders, 4. eDNA sampling across the water column and 5. high-resolution optics of CBW deep-sea prey. Cephalopod richness and biomass were highest in CBW foraging habitat, while fish richness was homogeneously distributed. Highest cephalopod richness was detected above the deep scattering layer, while fish richness was highest in surface waters. Prey concentrations showed strong annual variation, and seasonal trends. Our analysis suggests that CBW habitat holds higher cephalopod diversity, a pattern not observed for fish, higher biomass in the deep-scattering layer and increased CBW foraging activity during periods with enhanced prey biomass. Our matched approach enables the assessment of the prey scope in and outside of CBW foraging habitat. Hence, combined, we are moving towards a characterization of CBW prey scope and foraging decisions.

BOOMIN: Behavioral Observations of Marine Mammals Around Impulsive Noise

S. L. Watwood,^{1*} K. A. Dolan,¹ E. A. Falcone,²
S. L. DeRuiter,³ R. P. Morrissey,¹ and G. S. Schorr²

¹Ranges, Engineering and Analysis Department, Naval Undersea Warfare Center, Newport, RI, USA

²Marine Ecology and Telemetry Research, Seabeck, WA, USA

³Department of Mathematics and Statistics, Calvin University, Grand Rapids, MI, USA

*stephanie.l.watwood.civ@us.navy.mil

While many efforts have been made to understand the behavioral effects of Navy sonar on marine mammals, there are many data gaps around the behavioral effects of explosive events on marine mammals. In an effort to fill this data gap, an explosive behavioral response study was performed in July 2023, where six explosive charges were detonated within a 3-hour period on the eastern edge of the Southern California Anti-Submarine Warfare Range (SOAR). The explosions included four 10 lb, one 20 lb, and one 40 lb C4 explosive charge, with all explosions detonated underwater within 0.5 m of the air-water interface.

Acoustic measurements as a function of depth, and ranges between approximately 100 m and 5000 m from the source, were recorded by a team from UW Applied Physics Laboratory and the Naval Research Laboratory. Passive acoustic monitoring was performed for the 4 hours before and after the explosive event. Fewer *Ziphius cavirostris* groups were found on the east side of SOAR during the event, as compared to before and after. However, initial analysis suggests no differences among time periods for half hour counts of *Ziphius* foraging groups, the number of foraging clicks detected per group, or the durations of foraging group dives occurring over the whole range. Comparisons for the detections of additional species will also be presented.

Environmental DNA (eDNA) Monitoring of Marine Mammals

M. Weise^{1*} and S. Weiss¹

¹Office of Naval Research

*michael.j.weise@navy.mil

Environmental DNA (eDNA) offers a powerful tool to discover, map, monitor, and manage living resources by leveraging methods developed in the forensic and genetic sciences. Through eDNA analysis, the simple act of collecting water can lead to critical insights into aquatic biodiversity—from microbes to whales—with a tool that is non-invasive and can be scaled to meet the demands of large-scale surveys. Many biological survey tools in use today are labor intensive, time consuming and expensive. Recent decreases in costs of genetic sequencing, the relative ease of collecting water samples compared to other biological survey methods and improved understanding of the reliability of eDNA measurement have resulted in the emergence of a powerful complement to traditional biological surveys. Realizing the full potential of eDNA applications will require committed support and broad community involvement to continue gaining scientific and technological advances. Here we will discuss the ONR Marine Mammals & Biology (MMB) program investments to advance eDNA monitoring of the marine environment. Active areas of research and technological development include the estimation of species abundance (i.e., Navy sound effects models), implementation of autonomous eDNA technology to increase sampling efforts, and integration of eDNA products with other types of observations across space and time scales ranging from traditional *in-situ* organismal surveys to satellite remote sensing, animal telemetry.

Navy Marine Species Research and Monitoring Efforts

M. Weise,^{1*} S. Weiss,¹ A. Kumar,² and M. Shoemaker²

¹Office of Naval Research

²Living Marine Resources Program

*michael.j.weise@navy.mil

The U.S. Navy continues to be a world leader in marine species research and monitoring, having funded marine research programs, surveys, and data collection efforts since 1992. The Navy has three major research and monitoring programs, including the Office of Naval Research (ONR) Marine Mammals and Biology (MMB) program conducts basic research, the Living Marine Resources (LMR) Program conducts applied research, and the Marine Species Monitoring (MSM) Program conducts Fleet and System Command research and monitoring. The MMB program supports basic (6.1) and applied research (6.2) and technology development related to understanding the effects of sound on marine mammals, including physiological, behavioral, ecological and population-level effects. The mission of the LMR 6.4 program is to develop, demonstrate, validate and assess the data, methods and technology solutions to study protected living marine resources that may be affected by training and testing activities. The Navy's MSM is responsible for meeting specific requirements for monitoring and reporting on military readiness activities that include Fleet training events and Navy-funded research, development, test and evaluation activities. The Navy partners with federal agencies, universities, research institutions, federal laboratories, and private researchers around the world to better understand marine species ecology and physiology. Here we will discuss how the programs are organized, the status, the challenges and latest key topics of interest.

Low-Visibility Detection Techniques for Marine Mammals

L. Williamson,^{1*} J. Cook,¹ A. Taylor,¹ and B. Williamson¹

¹*Ocean Science Consulting Ltd*

**lw@osc.co.uk*

Mitigating impacts of noise on marine mammals is a crucially important and hugely costly aspect of many offshore industrial operations, which can cause considerable delays when detection is not feasible using traditional methods. Detection has primarily been achieved using Marine Mammal Observers (MMOs) who detect mammals visually, and Passive Acoustic Monitoring (PAM) which detects vocalising mammals. These techniques are well established and validated; however, they have limitations, e.g., MMO can only provide mitigation during daylight and good visibility, and PAM can only detect soniferous species and individuals when they are vocalising, and may be affected by other operational noise. In this study we compared MMO and PAM detections of mammals with detections made using novel methods of Infra-Red (IR) cameras, RADAR, and SONAR. Through a combination of both shore- and vessel-based trials, we have detected mammals on all instruments and provided a proof of concept that these instruments have potential to improve poor-weather and night-time detections in future. This can help to reduce costly operational delays, whilst improving protection for the ocean's marine mammals.

Assessing the Impact of North Sea Wind Farm Development on Marine Mammal Populations

C. A. F. de Jong,^{1*} F. Heinis,¹ A. M. von Benda-Beckmann,¹
F-P. A. Lam,¹ and N. M. Risser¹

¹*TNO*

**christ.dejong@tno.nl*

The Dutch “Framework for Assessing Ecological and Cumulative Effects” (KEC) focuses on potential cumulative effects on the populations of species to be protected due to the construction and operation of offshore wind farms. The impact of underwater noise on marine mammal populations is one of the main focus areas. The framework is regularly updated, incorporating new knowledge, obtained from the Offshore Wind Ecological Research Programme (Wozep) and from scientific literature. It is applied to quantify the potential effects of the latest plans for large-scale development of Offshore wind on the North Sea on mammal populations as well as of mitigation measures, that can be taken in the site decisions to prevent the risk of population decline.

In this presentation we will provide an update of the status of the recent development of KEC 5.0 that will incorporate the potential effects of geophysical surveys, clearance of unexploded ordnance and of vibropiling, in addition to the current assessment of impact piling, as well as application of an updated version of the interim population consequences of disturbance (PCoD) model from SMRU.

CEE Tool; Real-Time Whale Tracking for Controlled Exposure Experiments

S. P. van IJsselmuide,^{1*} M. W. G. van Riet,¹ P. J. Wensveen,²
P. J. O. Miller,³ C. M. van der Stappen,¹ F-P. A. Lam,¹
and P. H. Kvadsheim⁴

¹TNO Netherlands

²University of Iceland

³University of St Andrews

⁴FFI Norway

*sander.vanijsselmuide@tno.nl

The development of automatic (near) real-time whale tracking using intercepted ARGOS FastGPS packets, in addition to more traditional means to track tagged animals, has many benefits. One of these are the execution of more efficient and reliable Controlled Exposure Experiments (CEE), but efficient handling and plotting of multiple input data sources is required for experiment operators to make optimal decision to achieve an exposure design. In order to support the 3S4 experiments at sea a tool was developed that combines the automatic whale positions with several other relevant data streams, like the source vessel position, AIS tracks and bathymetry. A planning module in CEE Tool enables prediction of distance from the source vessel to the whale based upon hypothetical source vessel trajectories relative to each whale's track. The CEE Tool was used very successfully during the 3S4 sonar experiments in October 2023 and proved already very useful in the execution of CEEs. Work will continue on improving this tool for the upcoming 3S4 sonar experiments in October 2024. A laptop demo of the tool will be available at ESOMM-2024.

Quantifying the Environmental Footprint of Naval Sonar Operation

A. M. von Benda-Beckmann^{1*} and F-P. A. Lam¹

¹Acoustic Sensor & Sonar Systems, TNO, The Hague, The Netherlands

*sander.vonbendabeckmann@tno.nl

Research over the past two decades has shown that anthropogenic activities that produce loud underwater sounds, such as active sonar, can interfere with important marine mammals behaviour. To evaluate acceptable levels of disturbance, more insight is required in how much disturbing activities animal populations are exposed to, and what the effects of the activities are on individual and populations. A risk-assessment framework was implemented to determine the total disturbance to marine mammals ("sonar footprint") caused by naval active sonar operations. This framework follows the international trend within the European Union (EU) to evaluate the accumulation of disturbance over large areas and over long timeframes, which are compared to occurrence of marine mammals. The assessment consists of a combination of information on active-sonar use, sound propagation, and dose-response relationships that quantify how sensitive marine mammals are to sound and their marine mammal distributions. The assessment method is demonstrated using controlled exposure experiments with marine mammals involving two 1-2 kHz active sonars and highlight current gaps in knowledge. A poor understanding of how long-term consequences of disturbance to marine mammals limits the ability to assess the significance of disturbance. Nevertheless, the output of the assessment can be used to identify which sensitive species are mostly affected, which sonars contribute most to the sonar footprint, and how the footprint compares to other underwater sound producing activities.

SALIENT – Towards Alternative UXO Clearance in the Netherlands

A. M. von Benda-Beckmann,^{1*} F-P. A. Lam,¹ and COMMIT TBD²

¹*TNO, Acoustic Sensor and Sonar Department, The Hague, The Netherlands*

²*COMMIT, Onderwater Gevechtstechnologie, Utrecht, The Netherlands*

**sander.vonbendabeckmann@tno.nl*

The southern part of the North Sea is littered by unexploded ordnance (UXO), which are a remnant from the first- and second world war. In the Netherlands, the Royal Netherlands Navy (RNLN) is tasked with clearing UXO. Current practice is to remove UXO by means of detonation. The underwater explosion generated by the detonation poses a risk to the marine life, especially the harbour porpoises, which is sensitive to underwater noise and commonly present in the North Sea. Mitigation measures have been implemented to reduce the impact of underwater explosions. However there remains an impact on marine life, especially from larger aerial bombs and mines commonly encountered on the North Sea. In this talk we introduce the national research program SALIENT (Safe And Low Impact Explosives Neutralization Technology) that is aimed at developing knowledge on alternative underwater explosive clearance methods for the RNLN to reduce the impact of UXO clearance on the environment.

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