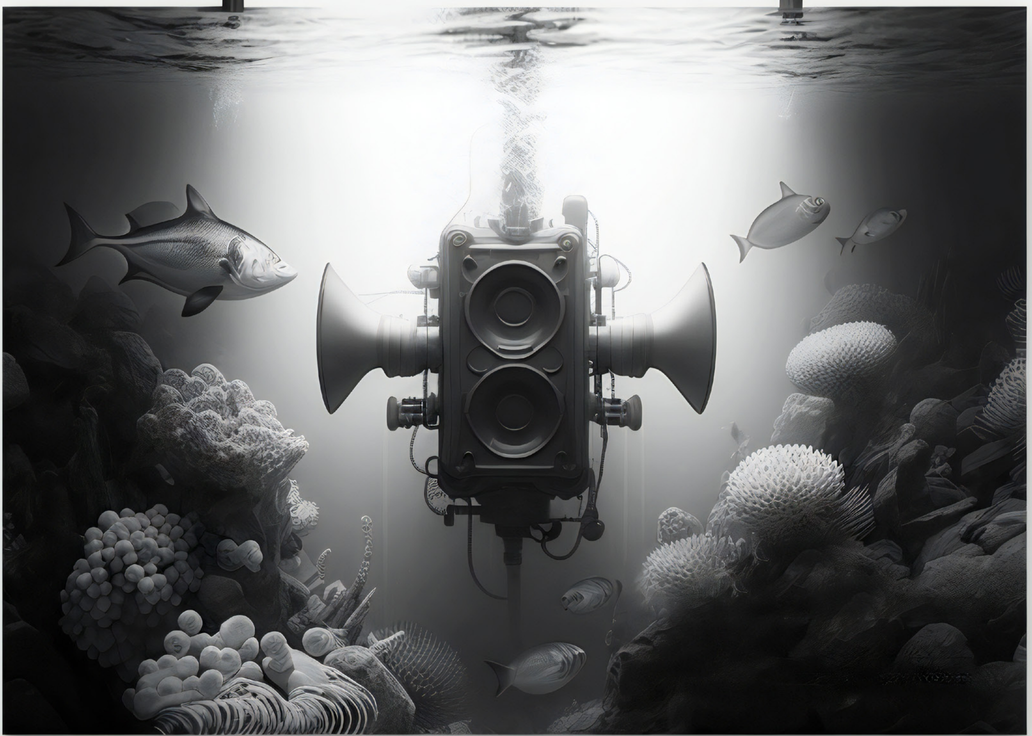
Towards an Acoustically Sound Ocean

OCEANOISE 2023

Vilanova i la Geltrú, BARCELONA 22-26 MAY

Programme & Abstract Book



An International Conference and Exhibition on Ocean Noise

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

AJUNTAMENT DE Vilanova i la Geltrú

BOEM Bureau of Ocean Energy Management

JASCO APPLIED SCIENCES

AUDITORI EDUARD TOLDRÀ VILANOVA I LA GELTRÚ

SONSETC.COM Making Sense of Sounds

THE SENSE OF SILENCE

OCEAN SOUND

ARAEX Grands Spanish Fine Wines

LA CAVALE

THE Grand WINES SINGULAR SPANISH ESTATES

CONFERENCE CHAIRS
Michel André, Peter Sigray, and Tom Akamatsu

SCIENCE COMMITTEE
Tom Akamatsu, Michel André, Eric Baudin, Chi-Fang Chen, Christ de Jong, Christine Erbe, Thomas Folegot, Kevin Heaney, David Hedgeland, Michael Jenkerson, Frans-Peter Lam, Jill Lewandowski, Klaus Lucke, Michael Macrander, Bruce Martin, Sonia Mendes, Nathan D. Merchant, John Potter, Roberto Racca, Stephen Robinson, Peter Sigray, Ana Širović, Marta Solé, Brandon Southall, Frank Thomsen, Katherine White

ORGANISING COMMITTEE
Michel André, Steffen De Vreese, Florence Erbs, Alexandre Gracia Calvo, Pablo Pla Caro, Toni Sánchez, Marta Solé, Mike van der Schaar

Front page art by Steffen De Vreese

PROGRAMME

OCEANOISE 2023

Vilanova i la Geltrú, BARCELONA 22-26 MAY

<table>
<tr><th>May 22-26</th><th>Monday 22</th><th>Tuesday 23</th><th>Wednesday 24</th><th>Thursday 25</th><th>Friday 26</th></tr>
<tr><td>08:00 - 09:00</td><td>Registration</td><td></td><td></td><td></td><td></td></tr>
<tr><td>09:00 - 09:30</td><td>Opening</td><td>Registration</td><td>Registration</td><td>Registration</td><td>Registration</td></tr>
<tr><td>09:30-10:15</td><td rowspan="3">Renewable Energy</td><td>Sonar</td><td rowspan="3">Riverine and coastal</td><td rowspan="3">Behaviour</td><td rowspan="3"></td></tr>
<tr><td>10:15 - 10:45</td><td>Keynote</td></tr>
<tr><td>10:45 - 11:00</td><td>5 min talks[3]</td></tr>
<tr><td>11:00 - 11:30</td><td>Coffee Break</td><td>Coffee Break</td><td>Coffee Break</td><td>Coffee Break</td><td rowspan="2">Inter-session General Discussion</td></tr>
<tr><td>11.30 - 12:30</td><td rowspan="2">Impulsive sounds</td><td rowspan="3">Shipping</td><td rowspan="2">Management and Policy</td><td rowspan="3">Mitigation</td></tr>
<tr><td>12:30 - 13:00</td><td rowspan="2">Wrap-up</td></tr>
<tr><td>13:00 - 13:30</td><td>Keynote</td><td>Keynote</td></tr>
<tr><td>13:30 - 15:30</td><td>Lunch</td><td>Lunch</td><td>Lunch</td><td>Lunch</td><td>Lunch</td></tr>
<tr><td>15:30 - 17:00</td><td>Mapping and Modeling</td><td>Soundscapes</td><td>Seismic</td><td rowspan="2">Sensitivity and pathology</td><td rowspan="7"></td></tr>
<tr><td>17:00 - 17:30</td><td rowspan="2">5 min talks[2]</td><td rowspan="2">5 min talks[3]</td><td rowspan="2">5 min talks[4]</td></tr>
<tr><td>17:30- 18:00</td><td>5 min talks[5]</td></tr>
<tr><td>18:00 - 19:00[1]</td><td>Posters</td><td>Posters</td><td>Posters</td><td>Posters</td></tr>
<tr><td>19:00 - 20:00</td><td rowspan="2">Ice-breaker</td><td rowspan="3"></td><td rowspan="3"></td><td></td></tr>
<tr><td>20: 00 - 23:00</td><td rowspan="2">Banquet</td></tr>
<tr><td>23:00 - 02:00</td><td></td></tr>
</table>

[1] Wine tasting
[2] Renewable Energy, Impulsive sounds, Mapping and Modeling, Particle motion.
[3] Shipping, Soundscapes.
[4] Management and Policy, Seismic, Polar.
[5] Behaviour, Sensitivity and Pathology, Mitigation.

Date: Monday 22/05 - 09h30-11h00

RENEWABLE ENERGY

Chairs

Sonia Mendes
JNCC, UK
Frank Thomsen
DHI Group, Denmark

How loud will it be? Scaling laws for offshore pile driving noise

Jonas von Pein
Hamburg University of Technology, Germany

The effects of piling on pelagic fish communities using bottom moored echosounders

Elisabeth Debusschere
Flanders Marine Institute (VLIZ), Belgium

A new methodology to manage and regulate construction noise related impacts of US offshore wind farms

Jonas Mortensen
DHI A/S, Denmark

Seals and offshore wind farm construction: synthesis and future directions

Katherine Whyte
St. Andrews University, UK

Can offshore wind farm noise affect hearing and behaviour of marine mammals?

Frank Thomsen
DHI A/S, Denmark

Atlantic Deepwater Ecosystem Observatory Network (ADEON), Potential effects of underwater noise from floating offshore wind on marine mammals and fishes

Adrian Farcas
CEFAS, UK

Date: Monday 22/05 - 11h30-13h00

IMPULSIVE SOUNDS

Chairs

Roberto Racca
JASCO Applied Sciences, Canada
Stephen Robinson
NPL, UK
Klaus Lucke
JASCO Applied Sciences, UK

Strategies and implementation of underwater noise monitoring during piling construction in offshore wind farms in Taiwan

Chiao-Ming Peng
OceanSound Co., Taiwan

Interpreting sound exposure ranges from concurrent pile driving operations – an agent-based modelling approach

Klaus Lucke
JASCO Applied Sciences, UK

RaDIN: Range-dependent nature of impulsive noise

Cormac Booth
SMRU Consulting, UK

Modelling the effectiveness of noise abatement systems for large pile driving and explosive clearing operations in the full context of the propagation environment

Marie-Noël Matthews
JASCO Applied Sciences, Canada

In-situ acoustic characterisation of unexploded ordnance (UXO) disposal using high and low order detonation method

Sei-Him Cheong
National Physical Laboratory, UK

Environment-friendly blasting at sea (R&D project NAVESS)

Michael Bellmann
Institute for Technical and Applied Physics (itap), Germany

Date: Monday 22/05 - 13h00-13h30

KEYNOTE

The Effects of Ocean Noise—It sometimes seems we're making slow progress?

Christine Erbe
Centre for Marine Science and Technology, Curtin University, Perth, Australia

Date: Monday 22/05 - 15h30-17h00

MAPPING AND MODELLING

Chairs

Thomas Folegot
Quiet-Oceans, France
Kevin Heaney
Applied Ocean Sciences (AOS), USA

Lessons learned from multi-site validation of shipping noise maps using field measurements

Rosalyn Putland
CEFAS, UK, The Netherlands

Quantitative Comparison of Regional Soundscape Measurements and Models

Kevin Heaney
Applied Ocean Sciences (AOS), USA

Comparing soundmaps based upon their acoustic energy densities

Ozkan Sertlek
JASCO Applied Sciences, Germany

Sound particle motion modelling and mapping

Christ De Jong
TNO Acoustics & Sonar, The Netherlands

How much sound from recreational boating in Croatia is missing in Automated Identification System-based sound maps?

Thomas Folegot
Quiet-Oceans, France

Simulations of the noise exposure from a high-density shipping lane in Kattegat with the JOMOPANS-ECHO source level model

Dag Glebe
Swedish Environmental Research Institute, Sweden

Date: Monday 22/05 - 17h00-18h00

SHORT TALKS AND POSTERS

RENEWABLE ENERGY

PURE WIND: imPact of soUnd on maRine Ecosystems from offshore WIND energy generation

Ana Širović
Norwegian University of Science and Technology, Norway

Monitoring the effects of Norway's first offshore floating wind farm on demersal fish

Kate McQueen
Institute of Marine Research, Norway

Potential biological impacts of infrasonic acoustical energy produced by offshore wind turbine energy generation

Michael Stocker
Ocean Conservation Research, USA

Noise radiation measurements of an electric-hybrid passenger ferry

Torbjörn Johansson
IVL Swedish Environmental Research Institute, Sweden

MAPPING & MODELLING

On the use of an underwater sound speed dataset to bridge the gap between ocean acoustics and climate change

Alice Affatati
University of Trieste and National Institute of Oceanography and Applied Geophysics - OGS, Italy

Examining the global warming induced changes to the Arctic Ocean soundscape

Kevin Heaney
Applied Ocean Sciences

PARTICLE MOTION

Particle velocity measurements of low order deflagration shaped charge for explosive ordnance disposal

Leroy Morton
Loughborough University, UK

Measurement of Acoustic Particle Motion: Acoustic Impact on Fish and Invertebrates

Robert Lee
Seiche, UK

Date: Tuesday 23/05 - 09h30-10h15

SONAR

Chairs

Frans-Peter Lam
TNO, The Netherlands

BRS overview and historical perspective

Brandon Southall
Southall Environmental Associates, USA

The Sea mammals & Sonar Safety (3S) project: BRS results, current trends and future outlook

Frans-Peter Lam
TNO, The Netherlands

Quantifying the environmental footprint of naval sonar operations

Sander von Benda-Beckmann
TNO, The Netherlands

Date: Tuesday 23/05 - 10h15-10h45

KEYNOTE

We cannot manage what we cannot measure – Is DAS a game-changer in ocean soundscape mapping?

John Potter
Norwegian University of Science and Technology (NTNU) Norway

Date: Tuesday 23/05 - 10h45-11h00

SHORT TALKS AND POSTERS
(MORNING SESSION 10H45-11H00)

SHIPPING

Estimation of propeller cavitation inception speed and detection of its occurrence based on onboard vibration data

Kamal Kesour
Innovation maritime, Canada

The contribution of climate change on the propagation of shipping noise in the North Atlantic Ocean

Luca Possenti
NIOZ, The Netherlands

Evaluation of the JOMOPANS-ECHO source level model with measurements in Swedish waters

Mikael Svedendahl
Department of Defence Technology, Swedish Defence Research Agency (FOI), Sweden

Date: Tuesday 23/05 - 11h30-13h30

SHIPPING

Chairs

Eric Baudin
Bureau Veritas, France
Christ de Jong
TNO, The Netherlands

URN measurements in the SATURN project; measuring vessel noise signature in deep and shallow waters under different measurement standards and class societies' notations

Roberto Yubero
TSI, Spain

Source measurement methods – the impact of averaging and directivity

Carl Andersson
IVL Swedish Environmental Research Institute, Sweden

MARS project: 2 years of feedback from an opportunistic ISO-17208 observatory of acoustic signatures and internal vibrations of ships in the St. Lawrence seaway

Cedric Gervaise
CHORUS, France

Methodological analysis for the identification and extraction of ocean shipping noise

Myriam Lajaunie
Service Hydrographique et Oceanographique de la Marine (SHOM), France

Re-routing of a shipping lane changed the underwater soundscape in Kattegat

Mathias Andersson
Swedish Defence Research Agency

Ship URN self-estimation in the context of LIFE-PIAQUO project

Tomaso Gaggero
University of Genova, Italy

Underwater sound comparison between full electric and diesel electric conditions for a road ferry

Renaud Gaudel
Damen Shipyard, The Netherlands

PONANT cruise line management of underwater noise

Daoud Wassim
PONANT, France

How to silence ships: preliminary results from the SATURN project

Frans Hendrik Lafeber
Maritime Research Institute Netherlands (MARIN), The Netherlands

Date: Tuesday 23/05 - 15h30-17h00

SOUNDSCAPES

Chairs

Christine Erbe
Curtin University, Australia
Brandon Southall
Southall Environmental Associates, USA

A simple spectral classifier to provide robust indicators for the Ocean Sound EOV
Bruce Martin
JASCO Applied Sciences, Canada

Sources of patterns in soundscapes
Simone Bauman-Pickering
Scripps Institution of Oceanography University of California, USA

Using CNN classifiers as underwater sound source detectors: learning about noise
Clea Parcerisas
Flanders Marine Institute (VLIZ) / Ghent University, Belgium

Implications of altered active space for marine life, and how that might be used as a mitigation metric
Rianna Burnham
Fisheries and Oceans, Canada

Acoustic monitoring of the Northern Adriatic Sea, a transnational assessment run in the Mediterranean Sea
Marta Picciulin
CNR- Institute of Marine Sciences, Italy

Date: Tuesday 23/05 - 17h00-18h00

SHORT TALKS AND POSTERS
(AFTERNOON SESSION 17H00-18H00)

SHIPPING

Assessing the Impact of Ship Traffic Noise on Short-Fin Pilot Whales in South Tenerife: Implications for Conservation and Management

Olivia Marín-Delgado
BIOECOMAC, University of La Laguna, Spain

Evidence of Impacts of Underwater radiated noise on the Vocalization of Coastal Dolphins

Roee Diamant
University of Haifa, Israel

A study on the temporal variability of underwater noise with AIS and V-pass data around high ship density in Korea coastal waters

Sungho Cho
Korea Institute of Ocean Science & Technology, Korea

SOUNDSCAPES

Analysis of hydrophone sound recordings in a dolphin habitat with high exposure to recreational shipping noise, monitoring, classification of sounds using deep learning CNN artificial neural network, analysis of dolphin sounds in noisy environments with special focus on modulations

Attila Aradi
University of Miskolc, Hungary

Soundscape of an Urban Shark Nursery

Clemency White
University of Exeter, UK

Variation in soundscape characteristics across temporal and spatial scales of a shallow water coastal PAM array; Exploring marine soundscapes as a tool for automating sound source detection in large datasets

Ellen White
University of Southampton, UK

Deuteronoise: A first approach to noise characterisation in Venice and Adriatic basins

Rosa Ma Alsina-Pagès
La Salle (URL), Spain

Date: Wednesday 24/05 - 09h30-11h00

RIVERINE AND COASTAL

Chairs

Chi-Fang Chen
National Taiwan University, Taiwan
Tom Akamatsu
Sasakawa Peace Foundation, Japan

Large-scale monitoring of Indo-Pacific humpback dolphins and finless porpoises using multiple static acoustic sensors

Songhai Li
Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, China

Impact of Pile-driving and Assessment of Offshore Windfarm Operational Noise on Fish Vocalization Behaviour

Shashidhar Siddagangaiah
National Taiwan University, Taiwan

Foiling yachts and dolphins: how international regattas temporarily change regional soundscapes, and the potential impacts for dolphins.

Matthew Pine
University of Victoria, Canada

The impact of underwater noise generated by offshore wind farm construction on the ecology of cetaceans in the western waters of Taiwan

Chiao-Ming Peng
OceanSound CO., LTD.Taiwan

A guidance on measurement and evaluation methods for underwater sounds focusing on offshore windfarms

Tom Akamatsu
Ocean Policy Research Institute, the Sasakawa Peace Foundation, Japan

Acoustic and Visual Investigation of Estuary Habitat on Indo-Pacific Humpback Dolphin (Sousa chinensis) in Yunlin, Taiwan

Chi-Fang Chen
National Taiwan University, Taiwan

Date: Wednesday 24/05 - 11h30-13h00

MANAGEMENT AND POLICY

Chairs

Jill Lewandowski
BOEM, USA
Peter Sigray
KTH, Sweden

TG Noise Recommendations on EU threshold values for underwater noise

Peter Sigray
KTH, Sweden

Update on Current Efforts to Address Underwater Vessel Noise at the International Maritime Organization (IMO)

Michelle Sanders
Transport Canada, Canada

Germany offshore wind pile driving noise received level limit

Carina Juretzek
Federal Maritime and Hydrographic Agency, Germany

Setting noise limits for offshore wind pile driving in the U.S.

Jill Lewandowski
Bureau of Ocean Energy Management (BOEM), USA

Canada’s Efforts to Address Underwater Vessel Noise

Michelle Sanders
Transport Canada, Canada

The IUCN Western Gray Whale Advisory Panel: Managing noise from offshore oil/gas exploration and production through a multi-stakeholder process

Doug Nowacek
Duke University Marine Lab, USA

Date: Wednesday 24/05 - 13h00-13h30

KEYNOTE

Underwater noise management in perspective

Nathan D. Merchant
Centre for Environment, Fisheries and Aquaculture Science (Cefas), UK

Date: Wednesday 24/05 - 15h30-17h00

SEISMIC

Chairs

David Hedgeland
BP, UK
Michael Jenkerson
ExxonMobil, USA

The General Dynamics Applied Physical Sciences Marine Vibrator: A New Paradigm in Seismic Ensonification Options for Seismic Surveys

Daniel Roy
APS, USA

Marine Vibrators - Idea to Realisation

Ed Hager
Shearwater, UK

Behavioral Response Studies with Baleen Whales and Marine Vibroseis

Brandon Southall
Southall Environmental Associates, USA

Operational and Engineering Mitigation Options for Seismic Surveys

Vladimir Nechayuk
ExxonMobil, USA

Monitoring and modelling approaches for estimating sound exposure of moving subjects from concurrent seismic surveys

Roberto Racca
JASCO Applied Sciences, Canada

Characterisation of noise emitted by sub-bottom profilers and its potential effects on marine mammals

Craig Stenton
Ocean Science consultants, UK

Date: Wednesday 24/05 - 17h00-18h00

SHORT TALKS AND POSTERS

MANAGEMENT AND POLICY

DORI, a line of underwater acoustic recorders with high acoustic performances and large storage capacity

Caroline Magnier, Abyssens, France

Cetaceans and underwater noise monitoring in the South Atlantic Ocean

Eduardo Marcon, PETROBRAS - Petróleo Brasileiro S.A., Brazil

Best Available Technology (BAT) and Best Environmental Practise (BET) for Mitigating Three Noise Sources: Shipping, Seismic Airgun Surveys, and Pile Driving

Lindy Weilgart, OceanCare & Dalhousie University, Canada

The Offshore Wind Environmental Evidence Register (OWEER): a new tool for cataloguing and assessing key evidence gaps in environmental research in offshore wind

Lisa Mogensen, JNCC, UK

Piling noise and cetacean protection in offshore wind farm development

Pey-Yi Lee, National Taiwan Ocean University, Taiwan

SEISMIC

A lot of pressure? The copepod Acartia sp. is more sensitive to a rapid pressure drop that occurs close to seismic airguns than Calanus sp.

Emilie Hernes Vereide, Institute of Marine Research, Norway

Comparing the effects of novel marine vibrator technology to conventional airguns on the behaviour of wild, spawning cod

Lise Doksaeter Sivle, Institute of Marine Research, Norway

Zooplankton swimming behavior during real-life seismic survey airgun blasts

Saskia Kühn, Kiel University, Germany

Assessing effects of seismic surveys on marine life in South African waters

Steve Kirkman, Department of Forestry Fisheries and Environment, South Africa

POLAR

A year within the Arctic marine soundscape near Cambridge Bay, Nunavut important gateway for ship traffic passing through the Northwest Passage

Annika Heimrich
University of Victoria, Canada

Date: Thursday 25/05 - 09h30-11h00

BEHAVIOUR

Chairs

Ana Širović
Norwegian University of Science and Technology, Norway
Katherine Whyte
BIOSS, UK

Time to talk. A case for including behavioural complexity into management

Karen de Jong
Institute of Marine Research, Norway

Behavioral responses of Cuvier's beaked whales to simulated military sonar

Brandon Southall
Southall Environmental Associates, USA

Effects of anthropogenic noise and natural soundscape on larval fish behavior in four estuarine species

Emily Waddell
Texas A&M University at Galveston, USA

Noise-induced vocal plasticity in harbour seal pups

Andrea Ravignani
Max Planck Institute, Germany

Vessel noise exposure impacts harbour porpoise energy balance

Laia Rojano-Doñate
Aarhus University, Denmark

Environmental influences on calling behaviour of midshipman fish

Annebelle Kok
University of Groningen, The Netherlands

Date: Thursday 25/05 - 11h30-13h30

MITIGATION

Chairs

Bruce Martin
JASCO Applied Sciences, Canada
Michael Macrander
Integral Consulting Company, USA

Mitigation Measures as Means to Minimize the Effects of Ocean Noise: Considering the Full Range of Options

Michael Macrander
Integral Consulting Company, USA

Mitigation and Monitoring for Offshore Wind: Industry Perspectives

Laura Morse
N/A, USA

Marine Mammal Risk Mitigation Strategies for the Canadian Armed Forces

Craig Ressor
Defence Research and Development, Canada

Managing noise in a marine mammal protected area using area-time limits

Sonia Mendes
JNCC, UK

Advancing vessel technologies to contribute to a quieter marine soundscape

Michelle Sanders
Transport Canada, Canada

Cavitation Inception Speed of merchant ships: analysis and discussion based on data collected in the ECHO program

Max Schuster
DW-ShipConsult GmbH, Germany

Small reductions in cargo vessel speed dramatically reduce noise impacts to marine wildlife

Charlotte Findlay
Aarhus University, Denmark

Vessel Noise Mitigation: A Focus On Achievable Noise Reduction

Marie Noel Matthews
JASCO Applied Sciences, Canada

Strategic approaches to mitigation: Cross-sectoral partnerships to address priority issues

Brandon Southall
Southall Environmental Associates, USA

Date: Thursday 25/05 - 15h30-17h30

SENSITIVITY AND PATHOLOGY

Chairs

Marta Solé
LAB - UPC, Spain
Michel André
LAB - UPC, Spain

Sensitivity of zooplankton to noise: impaired feeding
Katja Heubel, Research and Technology Centre West Coast, Kiel University, Germany

Physiological and behavioural effects of exposure to a commercial seismic survey on the pale octopus, Octopus pallidus
Ryan Day, University of Tasmania, Tasmania

AquaVib: a laboratory setup for exposing aquatic organisms to low-frequency sounds. Preliminary results for various marine invertebrate species
Pablo Pla, Laboratory of Applied Bioacoustics, BarcelonaTech (UPC), Spain

Stability between some and differences between others: which factors drive changes in calling rhythms in Sciaena umbra? A potential influence of boat noise
Marta Picciulin, CNR - Institute of Marine Sciences, Italy

Investigating Noise-Induced Physiological Stress, Hearing loss and Behavioral Disruption in Fish
Raquel Vasconcelos, University of Saint Joseph, China

Assessing the effects of noise across spatial and temporal scales: from whales to diatoms
Francis Juanes, University of Victoria, Canada

A multimodal, evidence-based approach to assessing cetacean central auditory pathways in the context of acoustic trauma—the ventral cochlear nucleus as an example
Ksenia Orekhova, University of Padova, Italy

Correlation between permanent noise-induced hearing loss and cochlear damage in a harbour seal
Maria Morell, University of Veterinary Medicine, Hannover, Germany

Investigating Sensitivity: A Three-Dimensional Reconstruction of Striped Dolphin's External Ear Canal Neural Network
Steffen De Vreese, Laboratory of Applied Bioacoustics, BarcelonaTech (UPC), Spain

Date: Thursday 25/05 - 17h30-18h00

SHORT TALKS AND POSTERS

BEHAVIOUR

Testing the impact of antropogenic noise on behavior, reproduction and transgenerational effects in marine medaka (Oryzias melastigma)

Andreia Ramos
University of Saint Joseph, China

Decreased resting and nursing in short-finned pilot whales when exposed to louder petrol engine noise of a hybrid whale watch vessel.

Patricia Arranz
University of La Laguna, Spain

MITIGATION

The SATURN Virtual Research Environment Tools for Noise Mitigation

José Antonio Díaz
PLOCAN, Spain

SENSITIVITY AND PATHOLOGY

The Noisesome: a transcriptomic approach of the DeuteroNoise JPI-Oceans consortium to understand how marine food webs are affected by noise contamination.

Eva Rodríguez Quintana
Departament de Genètica, Microbiologia i Estadística, Universitat de Barcelona, Spain

ORCHESTRA: Ecosystem responses to constant offshore sound spectra

Maarten Boersma
Alfred-Wegener-Insititut Helmholtz-Zentrum für Polar- und Meeresforschung, Germany

ABSTRACTS

HOW LOUD WILL IT BE? SCALING LAWS FOR OFFSHORE PILE DRIVING NOISE

von Pein, J.; Lippert, T; Lippert, S;von Estorff, O.

Jonas von Pein
jonas.pein@tuhh.de
Hamburg University of Technology
Hamburg University of Technology, Denickestr. 17, 21073 Hamburg

Offshore renewable energies such as offshore wind or floating solar power are usually fastened to the seabed by piles. These can be monopiles with relatively large diameters or anchoring piles of the foundation structure with comparably small diameters. Both types of piles are typically driven into the seabed to their final penetration depth using percussive pile driving. The pile driving process leads to high sound levels within the water. Often, the influence of the emitted acoustical energy on the marine fauna needs to be assessed. To protect the marine life, limits have to be fulfilled in many countries. The emitted sound levels can usually only comply with these limits, if noise mitigation measures are applied. With increasing dimensions of the structures, i.e. the offshore wind turbines, the foundations and therefore the pile diameter of the piles increase. To overcome the soil resistance with a bigger pile, higher strike energies and bigger hammers are necessary. Furthermore, it is aimed for using monopiles also at greater water depths, which again causes an increase of pile sizes. To assess the influence of the different parameters on the sound levels, numerical models have been developed that accurately predict the noise emission. However, such models are often only available to experts. Furthermore, these models rely on parameters that are usually not available at an early stage of the planning phase. This presentation is intended to show how scaling laws for unmitigated and mitigated pile driving scenarios can be applied to scale the influence of the parameters strike energy, pile diameter, ram weight, and water depth on the emitted sound levels. Examples for different future pile driving scenarios and the respective influence on the impact are provided to demonstrate which ranges of sound levels have to be dealt with in the future.

THE EFFECTS OF PILING ON PELAGIC FISH COMMUNITIES USING BOTTOM MOORED ECHOSOUNDERS

Debusschere E, Hubert J; Demuynck, J; Berges, B; Muñiz, CF; Slabbekoorn H

Elisabeth Debusschere
elisabeth.debusschere@vliz.be
Flanders Marine Institute (VLIZ)
Jacobsenstraat 1, 8400 Oostende

The number of offshore wind turbines in the Southern North Sea is expected to increase substantially in the coming years, due to the increased effort by EU countries. Since the beginning of the offshore wind farm construction, concerns have been raised on the impact of construction noise on marine fauna. A multitude of studies have been published on this topic and it is apparent that one group is underrepresented, namely the pelagic fish. Wild ranging pelagic fish can be observed using bottom moored scientific echosounders. Fish biomass can be derived with the 70 kHz transducer, while the 200 kHz split-beam transducer provides more detail on the fish behaviour. Number of fish schools, depth of the fish schools, fish school size can be derived from these sensors. Four sets were deployed during construction work in two offshore wind farms in The Netherlands. Consequently, the four echosounder sets could sample pelagic fish during the installation of more than 30 monopiles, grasping the effects at different distances to the sound source. The underwater sound was simultaneously recorded on each of the four multi-purpose mooring. This study will elaborate on the scientific method used to assess the impact of pile driving at different distances to the sound source on pelagic fish behaviour and will provide preliminary results on the effects of pile driving on the pelagic fish communities.

A NEW METHODOLOGY TO IMPROVE MARINE MAMMAL TAKE ESTIMATES FOR US OFFSHORE WIND FARMS IN RELATION TO UNDERWATER NOISE

Mortensen, JB; Bell, MA; Mortensen, LO; Tuhuteru, N; Thomsen, F;

Jonas Brandi Mortensen
jbm@dhigroup.com
DHI A/S
Agern Alle 5, 2970 Hørsholm, Denmark

The very ambitious plans to establish offshore wind farms in the US and elsewhere will lead to impacts on marine mammals that have to be predicted and managed comprehensively so that planned project can go ahead while simultaneously minimizing environmental footprint. One new way of assessing noise related effects are agent based models that take the movement of marine mammals into consideration. This makes such models potentially very powerful tools for environmental risk assessments. Yet, data on the spatiotemporal distributions of marine mammals are often scarce and associated with high level of variation and uncertainty. It is therefore common practice when using ABMs to apply a wide range of conservative assumptions to prevent an underestimation of potential impacts. This has led to a situation were using ABMs to make predictions more powerful has in reality lead to gross overestimation of actual exposure estimation and risks. Here we present a new way of applying ABMs in offshore wind farm impact assessments including a Monte Carlo modelling extension to an existing agent-based modelling (ABM) framework for marine mammal exposure in relation to underwater noise. Our new way to use ABMs addresses the issue of uncertainty whilst decreasing the risk of exposure overestimation. In that way we bring back ABMs to what they really are: very powerful tools to be used in environmental regulation and management.

SEALS AND OFFSHORE WIND FARM CONSTRUCTION: SYNTHESIS AND FUTURE DIRECTIONS

Whyte, KF; Hastie, GD; Russell, DJF, Wright, P

Katherine Whyte
katherine.whyte@bioss.ac.uk
Biomathematics and Statistics Scotland (BIOSS)
Biomathematics and Statistics Scotland, JCMB, The King's Buildings, Peter Guthrie Tait Road, Edinburgh, EH9 3FD, UK

Transitioning to renewable energy is essential in mitigating climate change and improving energy security; however, it is important to consider the potential impact of new technologies on wildlife. For animals that spend extended time periods underwater, such as marine mammals, a key environmental concern are the high intensity sounds produced during pile driving for offshore wind farm construction. Over the past decade, a series of studies have investigated the interactions between harbour seals (Phoca vitulina) and offshore wind farm construction. Here, I present an overview of our current understanding using data from 24 harbour seals fitted with GPS tags during the construction of Lincs offshore wind farm (UK), and how this relates to knowledge gaps and future directions for this area of research. Previous (and ongoing) work in this area have substantially improved our understanding of the potential effects of pile driving sounds on seal hearing, spatial distribution, movements, and dive behaviour; however, information on how responses vary with factors such as location, habitat type, species, and how seals interact with offshore wind farms in the long-term is critical to ensure that seals can co-exist with developments at the scales currently being envisaged for the industry.

CAN OFFSHORE WIND FARM NOISE AFFECT HEARING AND BEHAVIOR OF MARINE MAMMALS

Thomsen, F, Stoeber, U, Sarnocinska-Kot, J

Frank Thomsen
frth@dhigroup.com
DHI A/S
Agern Allee 5 2970 Hørsholm, Denmark

Offshore wind farms are part of the transition to renewable sources of energy and both the total numbers and sizes of wind turbines are rapidly increasing. While the impact of underwater sound related to construction work has been in the focus of research and regulation, few data exist on the potential impact of underwater sound from operational offshore wind farms (OWF). Here, we synthesize the knowledge gained on operational noise from OWF and its potential effects on marine mammal behavior. In a case study, effects of a 10- and 20-MW direct drive OWF turbine on the hearing of marine mammals were assessed. In general, impact ranges for PTS were small (i.e., up to 50 m from the sound source) and are thus likely negligible. The same was true for TTS impact ranges for 10 MW. However, impact ranges for TTS from a 20 MW turbine could reach a little over 700 m for low frequency cetaceans. Such impact rages could lead to impact areas from single turbines overlapping. In that case, the whole wind farm can be considered an impact area. We conclude that for larger size wind turbines, operational noise needs to be considered in sufficient detail as a part of the environmental impact assessment in the wind farm planning phase. In addition, further observations and modeling efforts are necessary to increase the accuracy of the estimates.

POTENTIAL EFFECTS OF UNDERWATER NOISE FROM FLOATING OFFSHORE WIND ON MARINE MAMMALS AND FISHES

Farcas, A; Faulkner, RC; Merchant, ND; Putland, RL

Adrian Farcas
adrian.farcas@cefas.gov.uk
Centre of Environment Fisheries and Aquaculture Science (CEFAS)
Cefas, Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

Floating Offshore Wind (FLOW) is a relatively novel technology which will enable the offshore wind energy sector to expand into deeper waters. In contrast to fixed wind turbines, the potential effects of underwater noise from FLOW turbines are poorly understood. To help improve knowledge in this area, we assessed the potential acoustic impacts on sensitive marine mammal and fish species during the installation and operational phases of FLOW. Using a key habitat for UK FLOW development (the Celtic Sea) as a case study, numerical modelling was conducted using illustrative scenarios of dredging, vessel activity, anchor piling and operational turbine noise at two example locations. For impact piling, the predicted temporary hearing impairment (TTS) from cumulative noise exposure scaled with the number of anchoring piles installed within 24 hours. Additionally, some modest effect zones were predicted for permanent hearing impairment (PTS) in harbour porpoise, and for mortality and recoverable injury in fish species for scenarios with multiple piles installed within 24 hours. For the non-impulsive activities, only modest TTS ranges were predicted for fish exposed to continuous 24 h dredging. Operational noise produced by illustrative 10- and 24-turbine arrays was also modelled using in-situ measurement data from an operational FLOW development reported in the literature. Modelled sound pressure levels (SPLs) for these operational FLOW developments increased with the number of turbines and windspeed, but in general SPLs were relatively low, at <130 dB. For a given windspeed, the SPL was relatively uniform inside the perimeter of the turbine array (within 5 dB), and largely insensitive to the number of turbines in the array (for the same turbine spacing). These relatively low noise levels are likely to be masked in high ambient noise environments, such as near shipping or other noise-generating anthropogenic activities. Overall, there remain significant knowledge gaps on noise from FLOW which increase uncertainty – and therefore risk – for impact assessment of prospective FLOW developments, not least the noise levels generated by the installation of FLOW turbine anchors, whether by pile driving or otherwise. Focused work to measure noise from such activities in a standardised way should be undertaken as a priority for new FLOW installations.

STRATEGIES AND IMPLEMENTATION OF UNDERWATER NOISE MONITORING DURING PILING CONSTRUCTION IN OFFSHORE WIND FARMS IN TAIWAN

Chiao-Ming Peng

Chiao-Ming Peng
pcmtsl@ms7.hinet.net
N/A
No. 46, Aly. 28, Ln. 337, Nanzixin Rd., Nanzi Dist., Kaohsiung City 811546 , Taiwan (R.O.C.)

In recent years, Taiwan is developing several offshore wind farms. To reduce the impact of underwater noise on the environment, the Environmental Protection Agency has referred to ISO18406 and IEC 61260-1 to formulate underwater noise measurement methods (NIEA P210.21B) as a monitoring standard for piling noise. To comply with the localization policy, the personnel, instruments, and procedures that perform monitoring operations must comply with local regulations, and services must be provided locally. When the underwater noise exceeds the threshold, there are also regulations for punishing developers. Monitoring operations are usually carried out in real-time while piling operations. The challenge for the piling operation is to ensure that the noise reduction measures are operating normally and that the monitored underwater noise level must not exceed 160 dB. This threshold is calculated based on the SEL(30s) divided by the pile counts per 30 seconds, but not just a single strike sound exposure level. Due to the different understanding of measurement methods, operators often have doubts about the adjustment of hammer energy and piling frequency, and even cause the soft-start was also exceed the threshold. This study illustrates Taiwan's experience in implementing underwater noise monitoring, which can be used as a reference for developers and constructors.

INTERPRETING SOUND EXPOSURE RANGES FROM CONCURRENT PILE DRIVING OPERATIONS – AN AGENT-BASED MODELLING APPROACH

Dufault, SG; Weirathmüller, MJ, Zeddies, DG; Lucke, K

Klaus Lucke
klaus.lucke@jasco.com
JASCO Applied Sciences (UK)
The Flint Barn, St Clair's Farm, Wickham Road, Droxford, Hampshire, SO32 3PW, United Kingdom

Impact hammering of the piles used as foundations for wind turbine generators in offshore wind farms introduces impulsive sound into the water column. This impulsive sound has the potential to adversely affect marine fauna, and therefore regulations, including mitigation and monitoring, are put in place to protect sensitive species. Regulatory criteria impose sound exposure thresholds that define areas over which mitigation measures are required. Agent-based modelling is used to estimate exposures of marine animals to sound by using simulated animals (animats) to sample 3D sound fields with movement rules derived from marine animal studies. In our methodology, each animat's closest point of approach (CPA) to the sound source is recorded in the simulation and used to define the exposure range (ER). The ER95% is the horizontal distance from the sound source that includes 95% of the CPAs of all animats in the simulation whose sound exposure level exceeds a given threshold. ER95% can be used to estimate monitoring zones for mitigation in a manner that is realistically accurate because it includes the behavior of the animal. In contrast, traditional methods assume that a receiver remains stationary for the duration of the sound event. This presentation will show results of test simulations to demonstrate the challenges of interpreting ER95% for monitoring and mitigation purposes in realistic situations where concurrent impulsive sources are operating.

RADIN: RANGE-DEPENDENT NATURE OF IMPULSIVE NOISE

Booth, C., O'Hara, A.K.D & Matei, M from SMRU Consulting Remmers, P. from itap GmbH

Cormac Booth
bellmann@itap.de
itap GmbH
Marie- Curie-Strasse 8, 26129 Oldenburg, Germany

A key issue for offshore wind farm consent is the emission of underwater noise during the disposal of items of unexploded ordnance and during the installation of turbine and offshore substation foundations using impact pile driving. These noise sources introduce high-amplitude impulsive underwater noise into the marine environment, which can result in physical or auditory injury to marine mammals and fish. Impulsive sounds are more damaging to the mammalian ear than non-impulsive sounds due to their ability to increase the hearing threshold faster. This means less sound energy is needed to induce a temporary (TTS) or permanent hearing threshold shift (PTS) for an impulsive sound, than for a non-impulsive sound. Therefore, different sets of noise thresholds for TTS- and PTS-onset have been recommended for impulsive and non-impulsive sound sources in Southall, Finneran, Reichmuth, Nachtigall, Ketten, Bowles, Ellison, Nowacek, and Tyack [(2019). Aquat. Mamm. 45, 125-232]. In discussing the development of criteria for TTS- and PTS-onset, Southall et al. (2019) acknowledge that acoustic signals produced by impulsive sources lose their impulsive characteristics as a function of distance from the source and could be characterized as non-impulsive beyond a certain distance. The changes in signal characteristics with distance generally result in exposures becoming less physiologically damaging with increasing distance as sharp transient peaks become less prominent. The Southall et al. (2019) criteria for TTS- and PTS-onset proposed that, while keeping the same source categories, the exposure criteria for impulsive and non-impulsive sound should be applied based on the signal features likely to be received by the receptor (i.e., the marine mammal) rather than those emitted by the source. The funded R&D project RaDIN aims to provide a more comprehensive understanding of how the impulsive characteristics of sounds from impact pile driving and unexploded ordnance detonations change with increasing distance from the source. The findings of this project will be incorporated into a tool for future impact assessments. This presentation will provide an overview of the metrics of impulsiveness that have been identified in studies of noise-induced hearing loss and soundscape analysis. Additionally, the empirical data sets will be presented, along with the next steps and the timeline of this funded R&D project.

SESSION: Pile Driving & other Impulsive Sounds

MODELLING THE EFFECTIVENESS OF NOISE ABATEMENT SYSTEMS FOR LARGE PILE DRIVING AND EXPLOSIVE CLEARING OPERATIONS IN THE FULL CONTEXT OF THE PROPAGATION ENVIRONMENT

Wood, M; Quijano, J; Matthew, M-N; Pace, F

Marie-Noël Matthews
marie-noel.matthews@jasco.com
JASCO Applied Sciences (Canada)
68 Arnold Drive, Nepean, ON, Canada, K2H 6W3

Noise Abatement Systems (NASs) such as single or double Big Bubble Curtains are increasingly being deployed as mitigation methods to minimise harmful noise exposure to marine life, effectively reducing the range of exposure to levels of sound that have the potential to cause physical injury. Many regulators are routinely demanding the estimation of the effectiveness of NASs as integral part of the impact assessment for offshore wind farms given that unexploded ordnance (UXO) clearing campaigns and percussive driving of extra-large piles (>10m diameter), both of which generate high levels of impulsive sound, are the norm in new planning applications. This work explores two different approaches for incorporating NASs both in the near and the far field within the sound propagation modelling. In the first approach, we introduce in the medium one or more regions with defined acoustic permeability that can be positioned at any range from the source, thus simulating the effect of bubble curtain rings or similar barriers. In the second approach, we apply the frequency-dependent mitigation performance curve of the NAS to the marching field of a parabolic equation model. These approaches enable the modelling of impact ranges from arbitrary sources, including pile driving and explosions, in a manner that considers waterborne sound propagation as well as seafloor borne energy that could bypass the attenuation from a NAS deployed in the water column. The methods allow to explore at the planning stage the maximum potential of any NAS achievable through its optimal placement along the propagation path, as well as to assess the ability of meeting a specified threshold on a project- and location-specific basis.

IN-SITU ACOUSTIC CHARACTERISATION OF UNEXPLODED ORDNANCE (UXO) DISPOSAL USING HIGH AND LOW ORDER DETONATION METHOD

Cheong, SH, Robinson, SP, Wang, LS, Lepper, PA, Hartley, J

Sei-Him Cheong
sei-him.cheong@npl.co.uk
National Physical Laboratory, UK
Hampton Road, TW11 0LW, London, UK.

European seas are littered with unexploded ordnance (UXO) which pose a hazard when constructing offshore developments such as wind turbine installations. The favoured removal method is to explode them by detonating an additional donor charge placed adjacent to the munition, a process known as high-order detonation. This disposal has a number of adverse environmental consequences, such as risk to marine mammal populations from the high sound levels produced. There has been a significant increase in the number of controlled Explosive Ordnance Disposal (EOD) due to the UK and Europe commitment to the transition to green energy. This study describes work to study the characteristics of the sound produced during the EOD operations and its range of influence. This included analysis of in-situ UXO measurement data obtained during EOD campaigns at a number of UK windfarm sites and the use of deflagration charges on UXO during a trial in Danish water in order to investigate the effect of low order disposal method on the acoustic output and its potential to reduce environment impact. Measurement were made using underwater recorders and results were presented as the sound pressure pulses along with their spectra, the levels of peak sound pressure and sound exposure are presented as a function of range from the source. Measured levels are compared to data from a shallow-water propagation model, and to widely-adopted exposure level thresholds used for marine mammals, illustrating the potential for injury at distances of several kilometres. In addition, the measurements were made in both in a controlled field experiment in a flooded quarry and in-situ in the ocean, with the results demonstrating that the deflagration method offers a substantial reduction in output over traditional high order methods, with its peak sound pressure being much more predictable than for high order detonations.

ENVIRONMENT-FRIENDLY BLASTING AT SEA (R&D PROJECT NAVESS)

Euhus, A, Müller, T; Janßen, M; Gerlach, S

Michael A Bellmann
bellmann@itap.de
itap GmbH
Marie-Curie-Strasse 8, 26129 Oldenburg

Unexploded ordinance (UXO) is a major health and safety concern and environmental issue, which poses significant risk to offshore construction projects. As part of a construction project, it is required to locate, identify and dispose any UXO located in the area of development before the start of construction. Explosive ordnance disposal is usually carried out by blasting, which generates underwater noise posing a possible risk to marine wildlife. Marine mammals may be at risk of fatality, auditory injury and disturbance (Southall, et al., 2019) (Lucke, Siebert, Lepper, & Blanchet, 2009) (Kastelein, Schop, Hoek, & Covi, 2015). Some studies are available which provide hints on the most important site- and project-specific influencing parameters on blasting noise (Robinson, et al., 2022). However, there are currently only a few measurement data publicly available. Therefore, there is a lack of scientific knowledge on how to reduce the noise generated and emitted during UXO blasting. In the funded R&D Project NAVESS by the Federal Agency for Nature Conservation, supported by the German Navy, the underwater noise caused by mitigated and unmitigated detonation of new ammunition were measured in distance between 750 m and 10 km. Different layouts of single and double Big Bubble Curtains (BBC) were used as noise abatement systems. The aim of this R&D project is to investigate the most important site- and project-specific influencing parameters on blasting noise such as place of the detonation (on the seabed or in the water column), transmission loss, hydrophone height or (TNT-equivalent) charge weight. An evaluation of the achievable noise reduction by application of single and double BBCs according to DIN SPEK 45653 (017) will also be possible. Within a first measurement campaign 21 detonations with TNT-equivalent charge weights from 0,085 kg to 66 kg were monitored by 12 measurement positions, partly with two hydrophone heights, in different distances and cardinal directions to the blasting position. The distinctive feature of this study is the use of new ammunition, so that the exact TNT-equivalent mass of the detonation can be determined. In addition, blastings with and without BBCs were performed under nearly identical project- and site-specific conditions. First results regarding the source level of such defined detonations and its sound propagation over long distances as well as possibilities of the noise reductions will be presented.

THE EFFECTS OF OCEAN NOISE—IT SOMETIMES SEEMS WE'RE MAKING SLOW PROGRESS? NOT SO.

Christine Erbe

Centre for Marine Science and Technology, Curtin University
Australia

Ocean noise and its potential effects on marine life have been studied intensely for 40 years. Our community has been growing steadily. Papers are coming out at an ever-increasing rate. At every conference, we are hungry for new data, new research outputs. But are we making progress as a community at a reasonable rate? Does progress sometimes seem slow to you? Are we running in circles? Let me take you on a journey over the last decade. Working on a book on Marine Mammal Bioacoustics (including noise), it has been a race to stay up-to-date with the literature, and regular, big advancements have repeatedly required stepping back, reworking, updating, editing. We've drawn the line, we're almost there. Join me in revisiting just some of the major developments from the last 10 years.

LESSONS LEARNED FROM MULTI-SITE VALIDATION OF SHIPPING NOISE MAPS USING FIELD MEASUREMENTS

Putland, RL; de Jong, CAF; Binnerts, B; Farcas, A; Andersson, M; Fischer, J; Kinneging, N; Robinson, S; Tougaard, J; Merchant, ND

Rosalyn Putland
rosalyn.putland@cefas.gov.uk
Centre for Environment, Fisheries and Aquaculture Sciences (Cefas)
Cefas Laboratory, Pakefield Road

Advances in soundscape modelling have made it possible to map underwater noise over large areas and long timescales, and to test various mitigation scenarios such as ship speed reduction or spatial restrictions. However, if such maps are to be used by decision makers, they must be validated against field measurements to ensure confidence in their predictions. The Joint Monitoring of Ambient Noise in the North Sea (JOMOPANS) programme carried out a multi-site validation of monthly and annual shipping noise maps for 2019 and 2020. International partners provided data from a wide range of locations to test the model performance under various bathymetry, sea state, seabed, and water properties. Spectral, spatial, and temporal differences between predictions and measurements were analysed, with differences linked to uncertainty in model input data and additional sources of anthropogenic noise in the measurements. Here, we present the lessons learned from this first-of-its-kind international monitoring effort, and discuss implications for the developing field of ship noise mapping and its use to support the effective management of this most pervasive of underwater noise sources.

QUANTITATIVE COMPARISON OF REGIONAL SOUNDSCAPE MEASUREMENTS AND MODELS

Heaney, K; Murray, J; Heaney, A; Martin, B

Kevin Heaney
kevin.heaney@appliedoceansciences.com
Applied Ocean Sciences
11006 Clara Barton Dr., Fairfax Station, VA 22039, USA

An array of seafloor mounted acoustic recording devices (the JASCO AMAR Lander) was deployed continuously in 7 sites off the US East coast outer continental shelf (OCS) for the Atlantic Deep Ecosystem Observing Network (ADEAN) from November 2017 through 2021. This time-series provides measures of the underwater acoustic soundscape in 1-minute decidecade band sound pressure level (SPL) for frequencies ranging from 5 Hz to 10 kHz. As part of this work, two soundscape models were developed. A regional model computes the shipping and wind SPL for a select set of decidecade bands for the entire OCS. This model has a temporal sampling interval of 1 hour. Decidecade levels were computed for 20 Hz, 63 Hz, 125 Hz, 200 Hz and 400 Hz. This model was a major undertaking computationally, particularly in the volume of data produced. The second model was a site-specific model, where the soundscape was computed for each lander position. With a single receiver location, this problem was 2 orders of magnitude easier. As a result, the time resolution was 5 min and uncertainty was included by computing a 28 member ensemble for each snapshot. The monte-carlo method of capturing uncertainty included a random draw of shipping source level (per ship), oceanography (temporally sampled over the month), ship source depth and a linear sweep through the geo-acoustic uncertainty. On the OCS the sediment uncertainty is huge, as the seafloor can range from medium to hard sand all the way to silt and mud. This widespread in sediment uncertainty led to a 20 dB spread in predicted levels. Comparison of the model with the measurements provided an approach (matching medians) to performing a geo-acoustic inversion. Three of the six sites compared for January 2019 had sediments which matched the climatology (silt). Three other sites required a change in the sediment to a sand seafloor. Video observations as well as core samples near two of those sites confirmed that the sediment was sand and not silt or mud. A qualitative comparison of the shipping and wind noise model will be presented using the inverted sediment profiles.

COMPARING SOUND MAPS BASED ON THEIR ACOUSTIC ENERGY DENSITIES

Sertlek H.O.; Ainslie M.A; MacGillivray A.O.; Pace F.; Racca R.; Wood M.

Ozkan Sertlek
ozkan.sertlek@jasco.com
JASCO Applied Sciences (Germany)
JASCO Applied Sciences GmbH Lise-Meitner-Straße 9 24223 Schwentinental
Deutschland

Identifying the contribution from individual sound sources to the soundscape helps understand, manage, and mitigate the risks arising from underwater noise, and facilitates comparison between different regions. Sound maps are commonly used to visualise the spatial distribution of underwater sound in a specified frequency band and time window, and thus contain detailed information about the soundscape. Various metrics could be used to analyse and compare the sound maps as a post-processing step. One of these metrics is the acoustic energy density which can be easily computed from the sound maps. This work demonstrates the use of acoustic energy density for various purposes. In the first example, the shipping sound maps are calculated for the Southern North Sea and the Northern Adriatic Sea before and during the Covid19 pandemic. The acoustic energy densities are used to rank the contribution of the different ship types and compare the results at two selected regions. In the second example, the acoustic energy density is used in convergence tests for the different spatial resolutions for the sound maps of the NAVISON project. These examples show that acoustic energy density could be used as a complementary output in the soundscape modelling to improve the results during the pre-and post-processing steps.

SOUND PARTICLE MOTION MODELLING AND MAPPING

de Jong, CAF; Binnerts, B; Oppeneer, VO; Ainslie, MA; Wood, MA

Christ de Jong
christ.dejong@tno.nl
TNO Acoustics & Sonar
Oude Waalsdorperweg 63, 2597AK, The Hague, Netherlands

Underwater sound maps usually present sound pressure level, with a specified frequency and depth weighting. Such maps are used to assess the potential impact of anthropogenic underwater sound on aquatic animals. However, many fish and invertebrate species are more sensitive to the particle motion associated with the sound field than to the sound pressure. The Horizon 2020 project SATURN (Solutions at Underwater Radiated Noise) studies the effects of shipping sound on marine animals and possible mitigation. Sound particle motion effects on fishes and invertebrates are being quantified in laboratory studies. The presented studies focus on quantifying the sound exposure. Different models for sound particle motion have been tested for a selection of benchmark scenarios, and model validation experiments have been performed. Results of these studies are presented to illustrate in which cases detailed sound particle motion modelling is required and when quantifying the sound pressure provides an appropriate approximation to the exposure.

HOW MUCH SOUND FROM RECREATIONAL BOATING IN CROATIA IS MISSING IN AUTOMATED IDENTIFICATION SYSTEM-BASED SOUND MAPS?

Folegot,T; Gallou R; Chavanne R; Picciulin, M; Ghe

Thomas Folegot
thomas.folegot@quiet-oceans.com
Quiet-Oceans
525 avenue A. de Rochon, 29280 Plouzane, France

Recreational boating is an omnipresent activity in coastal areas: many studies provide empirical evidence that, when in sufficient numbers/presence, they may influence ambient sound levels. Recreational vessels are currently not comprehensively accounted in the Automated Identification System (AIS) maritime data since they are not legally obliged to carry an AIS transponder. As a result, underwater sound levels in coastal areas may be largely underestimated by modelling effort. The objective of this study is to evaluate the uncertainty in sound mapping related to the known gap of recreational vessel data in the AIS. A case study has been conducted in the Croatian waters of the Northeastern Adriatic Sea, at the western side of the Cres-LoŠinj archipelago in the framework of the EU Interreg IT-HR Soundscape project. Part of this archipelago is a Site of Community Importance for bottlenose dolphins (Tursiops truncatus) (Cres-LoŠinj SCI, HR3000161) within the European Union NATURA 2000 ecological network. It is also a well-known tourist destination, characterized by the intense nautical tourism especially during summer months. A theodolite survey was conducted from June until September 2020 with an alternating schedule at three set hours (09:30h, 13:30h, and 17:30h) and from October 2020 until March 2021 with an alternating schedule at two set hours (9:30h and 13:30h) during the day. The survey was performed using an observation platform from fixed points on land to collect data on the positions and number of vessels, divided into nine different categories, visible within the study area. A methodology has been developed that uses the theodolite data to complement the AIS dataset with a realistic estimation of recreational vessel traffic. A comparison of the underwater sound levels under-estimated due to the lack of recreational boat sound inputs in the original AIS data with the sound levels based on the enhanced AIS data has been done. The period of analysis was during the summer following the first lockdown due to Covid19. Two different scenarios have been evaluated (i) a first scenario where the recreational boating is considered the only source of sound in the study area, (ii) a second scenario that includes all the vessel traffic and the natural component of sound originated by the wind. Results show that the sound generated by the recreational activity in summer in this region is only marginally contributing to the overall sound levels.

SIMULATIONS OF THE NOISE EXPOSURE FROM A HIGH-DENSITY SHIPPING LANE IN KATTEGAT WITH THE JOMOPANS-ECHO SOURCE LEVEL MODEL

Glebe, D; Andersson, MH; Bensow, RE; Lalander, E; Svedendahl, M

Dag Glebe
dag.glebe@ivl.se
Department of Process Modelling and Digitalisation, IVL Swedish Env. Research Inst., Gothenburg, Sweden
Aschebergsgatan 44

The environmental pressure that underwater radiated noise has on the marine environment is often visualised with Soundscape maps. A common basis for such calculations is source level (SL) models, such as the JOMOPANS-ECHO (J-E) model. Another approach based on the J-E model, but with simplified calculations, was evaluated in a project to evaluate the impact of underwater radiated noise from ships in an area in Kattegat with heavy traffic and sensitive habitats. In a series of simulations, the sum of the momentary noise exposure from all the ships trafficking the area at certain times was calculated for a number of immission points. The simulations included both calculations of a real case based on the actual speed of the ships in the area, as well as hypothetical cases with their speed adapted to speed limits at 11 and 13 knots, respectively. The calculations were based on AIS-data of the area from 2021, sampled from whole days (24 hours) during the whole year. Since a number of ships did not correspond accurately to the vessel classes of the J-E model (e.g. RoRo ships), some alternative approaches were evaluated to test the robustness of the simulation. The simulations confirmed several of the effects that were implied in the models. For instance, the net effect of a speed reduction is a reduction of noise level in the affected area. The extra time ships spend in the area has very little significance for the resulting reduction. The simulations showed that the noise level will be fairly constant over time and place for immission points located a few kilometres away from the heavily trafficked route. Therefore, also the resulting noise reduction showed very small variations in the area over the year. The average noise reduction which can be achieved with a speed limit of 11 knots in the area was estimated to approximately $\Delta L_{eq} \approx 4$ dB in the simulations.

PURE WIND: IMPACT OF SOUND ON MARINE ECOSYSTEMS FROM OFFSHORE WIND ENERGY GENERATION

PURE WIND consortium

Ana Širović
ana.sirovic@ntnu.no
Norwegian University of Science and Technology
TBS, Bynesveien 47, N-7018 Trondheim, Norway

Sounds from offshore wind farms (OWF) are among the main contributors of anthropogenic noise to the marine environment. Substantial effort has been expanded on understanding possible impacts of noise resulting from the development stages of the OWF lifecycle, but despite 30 years of their operation in the EU waters, our understanding of the impacts of the operational phase on marine ecosystems is more limited. In this consortium, we aim to address this gap by expanding our knowledge of the radiating noise and the biological consequences of these operations and placing them in appropriate regulatory contexts, including provisions for adaptive mitigation advice. From the source and medium side, we will quantify key features of radiated noise from fixed and floating OWF, to increase understanding and simulate cumulative effect of clusters on radiated noise, helping us to identify sensitive habitats in cross-basin soundscapes. From the biological perspective, we will identify spatial and qualitative use of operating OWF by top predators, harbour porpoises and harbour seals, and study the impacts of OWF noise on fish and zooplankton. These efforts will advance our knowledge of acute and cumulative effects of operational OWF noise across the food web. Harmonising and combining these two sides, we will develop knowledge and tools for integration of all aspects of noise production and propagation from operational OWF to facilitate assessment of planned OWF expansion for spatial planning and environmental impact. Finally, we will synthesise relevant learnings and best practices from EU and international experiences with fixed offshore wind development and translate for application in the development of policy, mitigation, and regulation for the floating OWF within national EU frameworks, as well as internationally. With expected substantial expansion in OWF infrastructure globally as part of the green shift, our data and approaches will help facilitate this transition while minimizing impacts on the marine ecosystems.

MONITORING THE EFFECTS OF NORWAY'S FIRST OFFSHORE FLOATING WIND FARM ON DEMERSAL FISH

McQueen, K, Gundersen, S, Hareide, NR, et al.

Kate McQueen
kate.mcqueen@hi.no
Institute of Marine Research
P.O. Box 1870 Nordnes, 5817 Bergen, Norway

Wind farm operational noise will increasingly contribute to anthropogenic noise in the oceans, as the offshore wind power industry continues to grow. The noise produced by wind farm operations is continuous and low frequency, overlapping with the hearing ranges of fish. Continuous anthropogenic noise can impact fish by causing stress, masking communication, interfering with predator-prey interactions, and impacting reproduction. Floating offshore wind farms (FOWF) are a novel development, and there are currently minimal data available about their impacts on marine ecosystems. In the Norwegian part of the North Sea, the largest FOWF currently existing globally is under construction. This new FOWF is located close to a known Atlantic cod (Gadus morhua) spawning site and overlaps with spawning grounds of other commercially and ecologically important demersal fish species. The aim of this ongoing study is to gather data on the fine-scale distribution of demersal fish before, during and after construction of this novel FOWF. Baseline data on the local demersal fish assemblage around the FOWF site were collected from a 10-day survey in March 2022, during the spawning period of several demersal fish species, and immediately before wind farm construction began. Using a chartered commercial fishing vessel, 4 replicates of 8 gillnet fleets were set at increasing distance from the wind farm site, at 0 - 20 nmi. Fish sampling from the gillnet sets provided information on abundance and species richness, and biological information including maturity stages, stomach contents, weight, and length. This survey will be repeated in March 2023, now that some of the turbines are in place and have been in operation for several months. The results from the 2022 survey indicate that abundance and distribution of fish species varied along the transect in relation to depth, as expected. The data from the 2023 survey will reveal how the fine-scale spatial distribution of demersal fish may have changed due to the operation of several floating wind turbines at the site. Potential effects of the FOWF on demersal fish include attraction of predatory species to the wind farm as a novel feeding ground. Another possibility is that noise produced by the operating turbines may deter fish from the area, or impact spawning or predator-prey interactions. Monitoring changes in fish assemblages is a key step towards understanding the impacts of FOWF on marine ecosystems.

POTENTIAL BIOLOGICAL IMPACTS OF INFRASONIC ACOUSTICAL ENERGY PRODUCED BY OFFSHORE WIND TURBINE ENERGY GENERATION.

Michael Stocker

Michael Stocker
mstocker@OCR.org
Ocean Conservation Research
PO Box 559 Lagunitas, CA 94938, USA

Offshore wind turbine farms are being planned and installed throughout the coastal areas of the global ocean. These will be introducing a panoply of noises into the environment, from siting, through installation, to operations, and eventually decommissioning. Noise concerns from these activities are typically framed within frequency bands of concern defined by governmental regulatory agencies. A less considered noise source are the various infrasonic noises generated by large rotating blades in a pressure-dynamic medium. One of these noises are the very low frequency “thumps” generated by the motion of the turbine blades as they intersect the “stagnate wind area” on the windward side of the mast. The period of these thumps is correlated to the frequency of blade intersection with the mast. A second source of infrasonic energy is the gradual collapse of tip vortices generated by the sudden air pressure gradient transitions as the turbine blades harvest directional energy from the oncoming wind and converts it to the tortional energy that drives the turbine. These “infrasonic” sources contain a lot of energy and is in the perceptual range of migratory birds and baleen whales. Given that whales and birds use “infrasonic” sound and barometric pressure signals for navigation and migration cues, the installation of thousands of turbines globally may impose significant impacts on migratory birds along avian coastal migratory routes. Additionally, increasing infrasonic noise throughout the ocean is likely to impact and compromise mysticete communication channels and potentially infrasonic navigation cues used by these animals.

NOISE RADIATION MEASUREMENTS OF AN ELECTRIC-HYBRID PASSENGER FERRY

Johansson, T; Andersson, C

Torbjörn Johansson
torbjorn.johansson@ivl.se
IVL Swedish Environmental Research Institute
Aschebergsgatan 44, 41133, Gothenburg, Sweden

With increasing incentives to reduce carbon emissions, the shipping industry is looking for sustainable propulsion solutions. At the same time, the electrification of the land-based transport system is also spreading into shipping. Many expect that such modern propulsion will not only reduce carbon emissions, but noise emissions as well. As part of a larger research project, we have measured the noise radiation from an electric hybrid passenger ferry in electric and hybrid propulsion modes. Our results show that electric propulsion leads to a reduction of noise emissions by up to 10 dB in the frequency range between 100 Hz to 200 Hz. This reduction can be directly tied to the removal of a series of harmonics related to the ignition rate of the diesel generator. At the same time, radiation of airborne noise was measured with much larger reductions. Overall, the underwater noise is only reduced in a small frequency range, which is due to the fact that most of the noise is created by the propeller. This can be compared to a similar situation on land, where electrical cars are only quieter at low speeds, above which the noise emissions are dominated by tyre- and aerodynamic noise. Similarly, electrical ships are likely only substantially quieter at speeds below the cavitation inception speed, such that the noise otherwise would be dominated by engine noise. This means that ships with electrical propulsion have to be considered separately in future trials when studying the relations between slow-steaming and noise emissions, as they likely are much quieter at these slow speeds.

ON THE USE OF AN UNDERWATER SOUND SPEED DATASET TO BRIDGE THE GAP BETWEEN OCEAN ACOUSTICS AND CLIMATE CHANGE

Affatati, A; Scaini, C.; Salon, S

Alice Affatati
aaffatati@ogs.it
University of Trieste and National Institute of Oceanography and Applied Geophysics - OGS
via Weiss 2 and Via Beirut 2, Trieste, Italy

Few datasets assess underwater acoustic variables such as sound speed. We computed a 3D global ocean sound speed dataset in the period 2006-2016, and estimated the projected relative sound speed differences at the end of the century (RCP8.5 scenario). Temporal trends in the acoustic properties of seawater in 3D global datasets can be useful to better predict the environment of marine species that perform vital functions in the entire water column. Our results highlighted that sound speed is expected to increase globally as a consequence of climate change. In particular, we identified two areas (“acoustic hotspots”) where the climatic signal is larger than the seasonal variability and the model uncertainty at 50 and 500 m depths. The identification of acoustic hotspots supports the analysis of anthropogenic pressures and the evaluation of cumulative and synergistic impacts. We assessed sound propagation in the present and future scenarios for the characteristic frequency of the up-call produced by a North Atlantic right whale (Eubalaena glacialis) vocalizing in the acoustic hotspots at 50 m depth. The formation of a surface duct will improve communication at ranges of 1-2 km in the future scenario. We are currently working on a new global sound speed dataset with a spatial resolution of 1/12 degree, spanning 27 years, using a global reanalysis provided by the EU Copernicus Marine Service. The new multi-decadal global sound speed dataset provides a starting point for mapping and modeling expected changes in underwater sound propagation. Global-scale sound speed datasets also support a wide range of applications, such as the identification of areas where substantial changes are expected (hotspots), and the definition of specific monitoring efforts. Although reanalysis datasets are often used in oceanography, to the best of our knowledge the application to ocean acoustics is novel and unexplored. The new multi-decadal reanalysis 3D dataset will benefit from the inclusion of acoustic parameters, aiding in assessing impacts on marine ecosystems linked to climate change. Future work will explore other climate scenarios to evaluate how sound propagation will differ for other pathways. We also plan to improve the uncertainty assessment of our modeling results using in situ data collected from ARGO floats. 20 years of global data are already available, and it would be crucial to compare sound speed trends in recent years.

EXAMINING THE GLOBAL WARMING INDUCED CHANGES TO THE ARCTIC OCEAN SOUNDSCAPE

Heaney, K; Verlinden, C; Seger, K; Verlinden, K; Heaney, A

Kevin Heaney
kevin.heaney@appliedoceansciences.com
Applied Ocean Sciences
11006 Clara Barton Dr., Fairfax Station, VA 22039, USA

The most notable effect of the impact of man-made climate change on the planet has been the precipitous loss of sea-ice extent in the Arctic Ocean. With declining sea-ice extent the soundscape of the Arctic is undergoing rapid change. The Arctic is home to many endemic marine mammal species who have evolved in an ocean soundscape dominated by ice covered acoustic propagation free from anthropogenic sound sources. An Arctic soundscape model has been developed to hindcast and predict shipping sound pressure levels (SPL) relative to the background wind/ice levels. A study, funded by the World Wildlife Fund (WWF), NOAA and the Government of Canada for the Protection of the Arctic Marine Environment (PAME), computed the shipping levels at multiple frequencies for the years of 2013-2019, using an AIS database. Increases of greater than 6 dB were found in many areas of the Arctic. In this paper, the modeling approach and the results will be presented. A new study is looking at forecasting the shipping noise to 2030. It is expected there will be an increase in shipping, made possible by the retreating sea-ice. AOS developed a shipping noise model, which propagates acoustic energy from each ship position to all positions in the Arctic, including the effect of under-ice propagation (where appropriate). An economics and sea-ice extent model for the forecast shipping levels of 2030 has been developed, providing an indication of the expected changes in the soundscape in the absence of governmental mitigation strategies.

PARTICLE VELOCITY MEASUREMENTS OF LOW ORDER DEFLAGRATION SHAPED CHARGE FOR EXPLOSIVE ORDNANCE DISPOSAL

Morton, L; Lepper, P; Cheong, S; Wang, L; Robinson, S

Leroy Morton
l.morton@lboro.ac.uk
Loughborough University, NPL
20 Windsor close Newhall Swadlincote Derbyshire

The United Kingdom's goal of achieving net zero carbon emissions by 2050 has accelerated the development of offshore wind power generation along its coastline. However, this construction results in noise pollution and particle motion components that can harm the surrounding environment. One significant contributor to noise pollution during offshore wind farm construction is the clearing of unexploded ordnances (UXO) that litter the UK coastal regions. The use of deflagration charges, a smaller shaped charge or low order explosive device that split the casing and make the ordnance inert for removal of the UXO can alter the acoustic output of high order to the equivalence of the low order shaped charge, severely reducing the impact on underwater wildlife. This study presents the results of an evaluation of several methodologies and different sensing types for collecting particle velocity data of a short high energy explosive source at a relative close proximity. A propagation description of the particle velocity of a UXO in the water column is evaluated against theoretical models derived from pressure sensing methodologies. The analysis of the equations and comparison of the captured data highlights the advantages and pitfalls associated with each system. The research sheds light on the impact of UXO detonation on marine taxa, contributing to future planning and mitigation efforts for offshore wind farm construction. The findings of this study have broader implications beyond offshore wind farms, providing insights into the impact of human activities on the marine environment. Understanding the impact of UXO detonation on underwater wildlife is critical for minimizing the impact of offshore wind farm construction on marine ecosystems.

MEASUREMENT OF ACOUSTIC PARTICLE MOTION: ACOUSTIC IMPACT ON FISH AND INVERTEBRATES.

Lee, R

Robert Lee
r.lee@seiche.com
Seiche
Bradworthy Industrial Estate Langdon Road, Bradworthy Holsworthy, Devon EX22 7SF, UK

As offshore developments grow at a rapid pace it is important that we fully understand our impact on the marine environment. Marine acoustics is a significant area of research and has been used to establish our impact ranges on marine mammals around offshore construction. Mitigations are often used now to ensure that marine mammals are kept safe around offshore work. The same is not true for fish and invertebrates. However, fish and invertebrates do not hear in the same way as marine mammals and so a different measurement technique is required. Fish and invertebrates detect sound by picking up the vibration of the molecules in the water. To measure this, we have used a technique that relies on a neutrally buoyant sphere. This sphere responds to acoustic excitation, this excitation is then measured with an accelerometer and the velocity vector of the sound wave can then be calculated. By using this technique we can improve our understanding of the marine soundscape and improve our impact on fish and invertebrates. This project is specifically focused on the impact from large scale offshore construction and the high amplitude sounds that are associated with this. As such the sensor prototype that we have developed is aimed at these higher amplitude sound waves. These are the sound waves likely to cause the most damage at long range in an instant. As opposed to the masking sounds of lower amplitude sources. So far the prototype system has been tested in a tank with data analysis ongoing. We are aiming to complete further testing this year with a sea ready prototype.

BRS OVERVIEW AND HISTORICAL PERSPECTIVE

Brandon L. Southall

Brandon Southall
Brandon.Southall@sea-inc.net
Southall Environmental Associates, Inc Duke University Marine Laboratory
9099 Soquel Dr., Aptos, CA 95076

This talk will provide an overview of the arc of now two decades of research on behavioral responses of marine mammals to active sonar. Early drivers included litigation and some of the first widely recognized mortal stranding events. Initial adaptations of behavioral response studies (BRS) from established methods from terrestrial taxa required both substantial initial modifications as well as lessons learned through challenges. Evolutions of these methods tuned to different species, contexts, and source types (eventually including operational military sonar systems) have occurred rapidly and have benefited from substantial interdisciplinary, inter-institutional, and international collaboration. Twenty years of BRS with sonar have yielded major insights into the nature, probability, and consequences of exposure to sonar in a growing number of marine mammal taxa.

THE SEA MAMMALS & SONAR SAFETY (3S) PROJECT: BRS RESULTS, CURRENT TRENDS AND FUTURE OUTLOOK

Lam, FPA; Kvadsheim, PH; Miller, PJO; Wensveen, PJ; Binder, C

Frans-Peter Lam
frans-peter.lam@tno.nl
senior scientist Acoustics & Sonar Netherlands Organisation of Applied Scientific Research TNO
Oude Waalsdorperweg 63, The Hague, NL

Behaviorial Response Studies (BRS) have been important to reveal critical knowledge on the impact of the use of military sonar. The 3S project started around 2006 and has delivered a substantial part of the BRS data from experiments in the field. This paper will provide an overview of the project and highlight some of the most recent results (like the response to continuous active sonar, CAS), together with an outlook of future plans that will be evaluated with a perspective of trends in other noise contributions.

QUANTIFYING THE ENVIRONMENTAL FOOTPRINT OF NAVAL SONAR OPERATIONS

von Benda-Beckmann, AM; Lam, FPA

Alexander von Benda-Beckmann
sander.vonbendabeckmann@tno.nl
TNO
Ouder Waalsdorperweg 63

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 mammal behaviour. To determine acceptable levels of disturbance more insight is required on how much disturbing activities mairne mammal populations are exposed to, and what the effects of the activities are on individuals animal and populations. We implemented a risk-assessment framework 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 is carried out by combining information on active-sonar use, sound propagation, and insights on dose-response relationships that quantify how sensitive marine mammals are to sound and their marine mammal distributions. We demonstrate the assessment method 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.

WE CANNOT MANAGE WHAT WE CANNOT MEASURE – IS DAS A GAME-CHANGER IN OCEAN SOUNDSCAPE MAPPING?

John Potter

Norwegian University of Science and Technology (NTNU) Norway

Traditional acoustic sensing methods in the ocean are generally expensive and sparse. We are now embarking on a new era, beyond the ´century of undersampling´, enabled by marine robotics and other technical advances. One of these is Distributed Acoustic Sensing (DAS). DAS is an exciting idea that has been around for a couple of decades, but which has only recently reached sufficient signal-to-noise to be considered a practical sensing system. DAS is able to turn a Fibre-Optic (FO) cable into a string of virtual hydrophones using a photo-electronic `interrogator´. The interrogator is able to sense along more than 100km of FO cable with (typically) 4m resolution, resulting in an unprecedented long array of some 25,000 or more virtual hydrophones. Recent results from data acquired from two FO cables off Svalbard in the high north have shown that we can detect, locate and track multiple whales (including swim speed and direction) along a corridor around a cable over 60km long by 19km across. An example 5 hours data tracked some 8 fin whales simultaneously. We believe that DAS as an exciting new tool for remote real-time acoustic sensing in the ocean that could be developed and integrated with other observational systems to empower responsible management and risk mitigation through near real-time information from extended regions

ESTIMATION OF PROPELLER CAVITATION INCEPTION SPEED AND DETECTION OF ITS OCCURRENCE BASED ON ONBOARD VIBRATION DATA

Kamal Kesour; Jean-Chritophe Gauthier Marquis; Marie-Laurence Bazinet; Paul Camerin; Cédric Gervaise; Sylvain Lafrance

Kamal Kesour
kkesour@imar.ca
Innovation maritime
53 rue St germain Ouest

Underwater radiated noise (URN) generated by marine transport has been continuously increasing over the last decades, to the point of being recognized as a major environmental problem. This increase in noise level is closely related to the increase in the number and size of commercial vessels. Adverse effects of underwater noise have been established for various species, including mammals, fish, and invertebrates. The ship's URN is mainly composed of machinery noise, propeller noise, and hydrodynamic noise. Machinery noise is considered dominant at low speeds, while propeller noise dominates at high speeds when the propeller cavitation becomes more important. Detection of cavitation and its inception is crucial to reducing the propeller noise and mitigating the impact on the surrounding aquatic environment. This abstract discusses the use of onboard vibration data to estimate the cavitation inception speed and detect its occurrences. By analyzing the vibration data generated by the propeller, unique frequency patterns generated by cavitation can be identified and used to indicate the onset of cavitation. In this context, Detection of Envelope Modulation On Noise (DEMON) is employed along with vibrational levels to indicate the occurrence of cavitation. The effectiveness of the algorithms used for analyzing the onboard vibration data has been tested on three ships with different lengths, and the results show that this method of detecting cavitation is accurate and reliable across various vessels. The use of onboard vibration data has the potential to become a standard practice for detecting propeller cavitation, estimate URN and reducing noise pollution in the maritime industry, thereby mitigating the adverse effects of underwater noise on marine species.

THE CONTRIBUTION OF CLIMATE CHANGE ON THE PROPAGATION OF SHIPPING NOISE IN THE NORTH ATLANTIC OCEAN

Possenti, L; Reichart, GJ; de Jong, C; Lam, FP;

Luca Possenti
luca.possenti@nioz.nl
NIOZ
PO Box 59 1790 AB Den Burg (Texel)

Since the industrial revolution oceans have become substantially noisier. The main source of this increase is shipping together with climate change is altering the oceans globally. In the coming century, we will witness an increase in seawater temperature, ice melting, a decrease in ocean pH and a rise in the frequency of storms. In the North Atlantic seawater temperature is projected to decrease due to the Atlantic Meridional Overturning Circulation (AMOC) current system slowdown. To explore the impact of climate change on shipping noise, we modelled sound at 125 Hz from a single ship navigating in deep waters. We calculated the propagation losses with the parabolic equation acoustic model RAM taking into account sound absorption and sound speed profiles. The worldwide effect of climate change was explored as the difference between 2022 and 2099 assuming two different climate scenarios (Shared Socioeconomic Pathways 8.5 and 4.5) for atmospheric and seawater temperature, salinity, pH and wind speed. The results show a global increase of sound speed at different depths (from 5 to 640 m) except for the North Atlantic Ocean and the Norwegian Sea where in the upper 125 m sound speed will decrease by up to 40 m s-1. This decrease in sound speed results is consistent in the two climate scenarios where a new sub-surface duct is visible in the upper 300 m allowing ship noise to propagate over large distances (>500 km). We relate the appearance of this new sub-surface duct with the slowing down of AMOC. The increase of sound speed in other regions will not have a significant effect on sound propagation that will remain similar to those of the current day. Also, at 125 Hz sound absorption will decrease by more than 50 % but the effect on the PL will be negligible (<1 dB).

EVALUATION OF THE JOMOPANS-ECHO SOURCE LEVEL MODEL WITH MEASUREMENTS IN SWEDISH WATERS

Svedendahl, M; Lalander, E; Glebe, D; Bensow, RE; Anderss

Mikael Svedendahl
mikael.svedendahl@foi.se
Department of Defence Technology, Swedish Defence Research Agency (FOI)
Swedish Defence Research Agency 164 90 Stocholm-SE

Source level (SL) models such as the JOMOPANS-ECHO (J-E) model are used to produce soundscape maps, which are later used to study the environmental pressure that underwater radiated noise has on the marine environment. It is therefore necessary to evaluate the models on their agreement with measured data, even though the SL of individual ships will deviate. This is especially important when applying the J-E model on a different composition of ship classes, sizes, and speeds than the ECHO dataset range used to develop the model. The J-E SL model was evaluated using data from opportunistic measurements of commercial ships trafficking Swedish waters and passing a cabled real-time hydrophone station in relatively shallow (46 m) waters. More than 250 ship passages were detected using Automatic Identification System (AIS) data recorded locally, and suitable time periods in the recorded acoustical data were selected based on several criteria, including the closest approach distance and the minimum distance to other ships. Common ship classes in the measurement data set were Tankers and General cargo ships and the evaluation showed a discrepancy between the model and the SL measurements, most likely due to smaller and slower ships compared to the ECHO dataset. In terms of number of passages, RoRo ships were the most common ship type in the measurement dataset, while this class does not exist in the J-E model. Therefore, an in depth analysis of this particular ship type was done that showed that the SL measurements of the RoRo class showed similarities to the predicted SL spectra of the J-E classes Vehicle Carriers and Container ships.

URN MEASUREMENTS IN THE SATURN PROJECT; MEASURING VESSEL NOISE SIGNATURE IN DEEP AND SHALLOW WATERS UNDER DIFFERENT MEASUREMENT STANDARDS AND CLASS SOCIETIES' NOTATIONS.

Yubero, R.

Roberto Yubero de Diego
roberto.yubero@tsisl.es
TSI
Avda. Pío XII, 44 torre 2 bajo izquierda – 28016. Madrid. Spain.

In November 2022, TSI executed an eleven-day test campaign to measure the URN signature for a specific vessel for deep and shallow water, following different procedures described in international standards or classification societies' notations. These tests, performed within the EU-funded project SATURN, aimed to compare the selected procedures regarding instrumentation, deployment, test execution, data processing and obtained vessel signature. It was also intended to study the results differences, probably caused by the different procedures followed. Furthermore, being part of the ISO working group allowed TSI to test the available committee draft of the first international standard to measure vessel noise in shallow water, the ISO 17208-3, where TSI provided feedback as an end user to the ISO working group. The test campaign lasted 11 days, while 9 of them were dedicated to performing the measurements. These tests covered 8 instrumentation setups (hydrophone depths), with 4 different deployments (drifting buoy, surface buoy moored, and two hydrophone seabed configurations), performing the measurements at fixed speeds (7kn, 8kn, 9kn, 10kn, 11kn) and fixed power (66% of Maximum Continuous Rate; approximately 11kn). The complete setup was deployed and recovered every day (9 times in total), spending in water more than 45 hours, where almost 190 vessel passes were measured, and 80 background noise measurements were recorded, ending up with more than 140 GBytes of acoustic raw data. The instrumentation used for performing the tests was: i) 1 communication surface buoy, ii) 3 hydrophones, iii) 2 GPS (one to track the vessel position and the other to monitor the communication buoy location) and iv) 1 CTD (Conductivity, Temperature and Depth transducer) to measure the sound speed profile in the water column and to also record the lowest hydrophone depth. During the tests, the TSI's CourseAssistant© software was used to continuously compute the vessel-buoy distance, providing the required course that would allow the vessel's captain to meet the target CPA for each pass, notably reducing the number of invalid passes and therefore reducing the testing time, with the consequent fuel consumption reduction. Finally, the gathered raw data were processed using the TSI's URNSoftware© tool. The current findings of the measurements are shown in this paper.

SOURCE MEASUREMENT METHODS – THE IMPACT OF AVERAGING AND DIRECTIVITY

Andersson, C; Johansson, T

Carl Andersson
carl.andersson@ivl.se
IVL Swedish Environmental Research Institute
Aschebergsgatan 44, 41133, Gothenburg, Sweden

With the upcoming regulations on underwater noise from the EU and the updated guidelines on underwater noise from the IMO, measurements of noise emissions from ships will likely be more common. Several classification societies have developed measurement procedures, and ISO has one published measurement standard with more on the way. Most of these measurement methods are thorough, involving measurements when the ship is sailing in certain test courses and averaging the emitted acoustical power in with specific methods. Essentially, this is to average over any directivity that the acoustical source has. The averaging will only faithfully represent the noise emission if the ship was operated in a consistent way over the entire test course, which sometimes presents significant logistical difficulties. One simple way to relax the requirements on both the logistical aspects of sailing a ship in a strict test course, as well as the subsequent data processing, is to determine the ship source signature from a much shorter time-segment of the signal received at the hydrophone. Here, we compare two simplified methods to quantify the radiated noise: using a short segment at the closest point of approach; and using a short time segment selected from when the highest level was received at the hydrophone. We use these two methods as well as a straightforward average of the radiated noise to quantify the radiated noise from 91 ship passages in lake Mälaren in Sweden. We compare the results from the simplified methods with the averaging method to see how large the influence of ship directivity is on the calculated source power. Early results indicate that these simplified methods typically deviate 1 dB from the averaged method, as well as 1 dB from each other. We also see up towards 10 dB deviations between the methods for single passages, mostly in the frequency range below 150 Hz. This indicates that these methods are not interchangeable, and that the purpose of a measurement must be considered when performing a measurement. If the result will be used as the input to a noise map, it is reasonable to average over the directivity. If the result will be used to judge close range environmental impact, perhaps the peak output power is also relevant.

MARS PROJECT: 2 YEARS OF FEEDBACK FROM AN OPPORTUNISTIC ISO-17208 OBSERVATORY OF ACOUSTIC SIGNATURES AND INTERNAL VIBRATIONS OF SHIPS IN THE ST. LAWRENCE SEAWAY

Cedric Gervaise, P. Cauchy, P . Mercure-Boissonault, G. St-Onge, K. Kesour, JC. Gauthier-Marquis, ML.Bazinet, P. Camerin, S.c Lafrance

Cedric Gervaise

CHORUS Research Institute, France

The MARS project, 2021-2024, co-funded by Transport Canada, the Ministère de l'économie et de l'innovation du Québec, SODES, IMAR, ISMER, MTE inc, OpDAQ inc and the shipowners FEDNAV, Desgagnés, CSL, Algoma is an ambitious project in Eastern Canada that simultaneously measures the acoustic signatures of volunteer or opportunistic vessels and internal vibrations of vessels to assess the noise radiated by ships, identify the causes and finally propose and test solutions for reducing radiated noise. The MARS project is based on a station for measuring the acoustic signatures of vessels located near the St. Lawrence seaway (22 +- 3 vessels / day) in a flat channel 350 meters deep. The measuring station is compatible with the ISO-17208 standard. It makes it possible to measure the signatures of voluntary vessels (150 per year) at the cost of a slight deviation from their normal course (5 minutes of delay max) and it makes it possible to capture more than 1000 opportunistic signatures. The signature measuring station is complemented by instrumentation specifically developed to measure the internal vibrations of ships (8 per year) as they pass through the station in order to identify the internal sources that generate radiated underwater noise. In the presentation, we will detail the instrumentation developed for the project and we will give feedback from 2 seasons of operation (May-November 2021, 2022). Then we will study the accuracy of measuring signaturesthanks to the multiple passages of same shipsseveral months apart and thanks to the passages of sister-ships. We will present how we analyze these signatures to evaluate the contributions due to cavitation and machinery. Starting from two ships of very different design (Ro-Ro with pod, bulk carrier), we will present the vibration diagnostics on board and how we can identify the sources of radiated noise. Finally, we will identify several perspectives under development such as the estimation of the URN and the detection of cavitation from on-board vibration measurements.

METHODOLOGICAL ANALYSIS FOR THE IDENTIFICATION AND EXTRACTION OF OCEAN SHIPPING NOISE.

Lajaunie, M; Ollivier, B; Pihan, H; Kinda, G.B;

Myriam Lajaunie
myriam.lajaunie@shom.fr
Service Hydrographique et Oceanographique de la Marine (SHOM), France
13, rue du Châtellier, 29200 Brest, France

In some areas of the global oceans, ocean ambient noise has experienced an important intensification in the past decades, due to the global increase in marine traffic and anthropogenic activities at seas. In this context, the 11th descriptor of the Marine Strategy Framework Directive (MSFD) aims at quantifying, monitoring the evolution and evaluate the impact of the anthropogenic contribution to ocean ambient noise, ultimately to guide the European legislation in the regulation of anthropogenic activities at seas. The monitoring of the anthropogenic contributions to ocean noise relies notably upon the ability to separate these contributions from noise generated by natural sources. Extracting a certain type of perturbation from a random noise of natural origin represents a very different challenge when targeting impulsive noise (such as airguns or pile-driving) or continuous noise, slowly emerging from the natural ambient noise (such as shipping noise). The research proposed here faces this last challenge, and exposes an analysis of available methods that could enable to extract shipping noise within underwater acoustic recordings operated through vertical hydrophones antennas located at different positions in deep and shallow waters in the French EEZ.

RE-ROUTING OF A SHIPPING LANE CHANGED THE UNDERWATER SOUNDSCAPE IN KATTEGAT

Andersson, MA; Lalander, E; Larsson Nordström, R.

Mathias Andersson
mathias.andersson@foi.se
Department of Defence Technology, Swedish Defence Research Agency
Swedish Defence Research Agency, Stockholm, Sweden

In July 2020, the main route for commercial ships in Kattegat, Route T, was split into two: one route for large ships and one for smaller ships closer to the Swedish coast. The potential effect of this major re-routing on the marine environment, for example on the communication space, is investigated in this study. In particular, the focus is the harbour porpoises (Phocoena phocoena) and one of their prey, the Atlantic cod (Gadus morhua). Both species use natural sound for orientation and cods communicate at low frequencies (<200 Hz). Data on ship movement, wind, sound speed profile and both modelled and measured sound levels were recorded for one year before the rerouting and one year after. In addition, two methods were utilized to study any impact of the change in environment on the selected species. The results revealed a generally high sound pressure level along the shipping lanes. The rerouting resulted in an increase in number of passing ships, from 5600 to 16300, causing an increased noise level, in the 1/3 octave band with the centre frequency of 100 Hz, along the coastal route, in both northern (by 5-6 dB) and southern (3-4 dB) Kattegat. The shipping noise has also extended over a larger area. The acoustic habitat quality in terms of communication range has decreased for species like the cod but not for harbour porpoises. However, their ability to detect natural sounds has been reduced. The harbour porpoises potentially avoid larger areas due to more ships in the new shipping lane after the re-routing.

SHIP URN SELF-ESTIMATION IN THE CONTEXT OF LIFE-PIAQUO PROJECT

Gaggero, S; Gaggero, T; Tani, G; Villa, D; Rizzuto, E; Viviani, M;

Tomaso Gaggero
tomaso.gaggero@unige.it
University of Genova
Via Montallegro 1, 16145, Genova, Italy

Underwater radiated noise from commercial ships has a negative impact on the marine fauna. Even if worldwide compulsory requirements for ships have not yet been established by the International Maritime Organisation (IMO), at national or regional levels several voluntary requirements and good practices have been established for noise control and reduction. Possible strategies for ship underwater noise control and reduction range from optimized design for new constructions, to propeller or machinery refitting for existing ships, to operational actions valid in both cases. All the above-mentioned strategies are implemented in the context of the LIFE-PIAQUO project. As regards the latter, and in particular noise impact operational management by the crew, a fundamental aspect is represented by the possibility of knowing the amount of noise emitted by ships in a specific working condition. To carry out a self-estimation of underwater radiated noise, the application of the Operational Transfer Path Analysis technique is analyzed. OTPA technique takes advantage of vibration information coming for a set of accelerometers onboard to give a real time estimation of the URN. In the present work an overview of the preliminary results in the context of the LIFE-PIAQUO project is reported and indications on the applicability of the technique for URN are discussed.

UNDERWATER SOUND COMPARISON BETWEEN FULL ELECTRIC AND DIESEL ELECTRIC CONDITIONS FOR A ROAD FERRY

Gaudel R

Renaud Gaudel
renaud.gaudel@damen.com
N/A
Avelingen-West 20, 4200 AA Gorinchem, The Netherlands

Based on the underwater sound measurements of 87m road ferries in different operating conditions, a comparison was made between two configurations: full electric (power generated by batteries only) and diesel electric (power generated by genset). For these two conditions the same vessel speed (i.e. electric motor and propellers speed) was considered. Since the dominant source was the gearing from the thruster's Z-drives, no significant difference in underwater sound was observed between the two conditions. This was also observed in the prediction models using finite element analysis. The conclusion is that despite the assumption that full electric propulsion can achieve lower underwater sound levels, it might not always be the case. It should then be taken into account in future design and mitigation plans to reduce the impact of underwater sound on marine life.

PONANT CRUISE LINE MANAGEMENT OF UNDERWATER NOISE

Wassim Dadoud

Wassim Daoud
wdaoud@ponant.com
PONANT France

PONANT is a leading cruise line company that is committed to minimizing its impact on the marine environment. As part of this commitment, PONANT has recognized the importance of reducing the underwater noise generated by their vessels. We will discuss the measures taken by PONANT to address this issue and the impact of these measures on marine ecosystems. PONANT's efforts to minimize underwater noise include the use of electric propulsion systems, which significantly reduce noise levels compared to traditional propulsion systems. The company has also installed an underwater detection system on its vessels to monitor the noise levels generated and adjust operations accordingly. In addition, PONANT has partnered with leading scientific organizations to study the impact of underwater noise on marine life and develop best practices for minimizing this impact. These partnerships have resulted in the implementation of guidelines for navigating in sensitive areas and a commitment to reducing engine noise during wildlife observation activities. By minimizing URN, PONANT is not only contributing to the protection of marine life but also enhancing the guest experience. Reducing noise levels can create a more peaceful and enjoyable environment for passengers, enhancing the overall cruise experience. The URN notation granted to Le Jacques-Cartier by Bureau Veritas is a significant achievement for PONANT and demonstrates the company's commitment to sustainable tourism and responsible environmental practices. By minimizing the ship's impact on the marine environment, PONANT is contributing to the long-term health and sustainability of the oceans while also enhancing the guest experience for its passengers. Through these efforts, PONANT has demonstrated a strong commitment to responsible environmental practices and has set an example for the wider cruise industry. Our presentation will showcase PONANT's leadership in addressing the issue of underwater noise and highlight the importance of industry-wide efforts to minimize the impact of cruise ships on the marine environment.

HOW TO SILENCE SHIPS: PRELIMINARY RESULTS FROM THE SATURN PROJECT

Frans Hendrik Lafeber

Frans Hendrik Lafeber
f.lafeber@marin.nl
Maritime Research Institute Netherlands (MARIN)

Shipping is one of the main contributors to anthropogenic underwater radiated noise (URN). Two of the biggest noise sources of a ship are the machines inside the ship – their vibrations excite the hull, which then radiates noise into the water – and the cavitation – the formation of vapour bubbles in regions of low pressure – on the propellers. Methods to reduce the contribution of those noise sources are topic of the EU-funded Horizon 2020-project SATURN (Solutions AT Underwater Radiated Noise). Within that project, several mitigation technologies are being investigated:
- Updating the propeller design to delay the onset of cavitation and to reduce the amount of cavitation
- Replacing the propeller by a different, quieter, propulsor concept ? Using a layer of air bubbles to reduce the machinery-induced noise
- Inject air bubbles into the cavitation to dampen the collapse and thus reduce the noise.
A boundary condition for these solutions is that the emissions (such as CO2, NOX, etc.) of the ship should not increase or, ideally, even decrease. For the propeller design, for example, the efficiency level should be maintained while making the propeller quieter. The propeller performance is studied by means of numerical methods. These allow for a quick evaluation of many thousands of propeller designs, which are generated using genetic algorithms. The results thereof show the trade-off between efficiency and noise and the best propeller can be found. For the machinery noise study, model tests were carried out where a ship model was excited by a shaker to mimic the main engine. A layer of air bubbles, which should cover the vibrating part of the hull, was released from porous hoses in a recess in the hull. The noise reduction due to the air layer was determined by comparing measurements of the URN with and without air layer. Air injection into the cavitation was investigated on model scale by releasing air bubbles from a duct upstream of the propeller. The noise-reducing effect of the air was determined by measuring the URN of a cavitating propeller with and without air injection. The model tests concerning the use of air bubbles have been completed. The analysis of the model tests and the propeller design studies are currently ongoing. This presentation will give an overview of the work carried out so far including some preliminary results.

A SIMPLE SPECTRAL CLASSIFIER TO PROVIDE ROBUST INDICATORS FOR THE OCEAN SOUND EOV

Martin, SB; Hotkani, MM; Bousquet, JF.

S. Bruce Martin
bruce.martin@jasco.com
JASCO Applied Sciences
20 Mount Hope Avenue, Dartmouth, NS, Canada

The study of underwater sound has progressed rapidly over the past 20 years with many research groups proposing diverse methods for analyzing soundscapes. The International Quiet Ocean Experiment (IQOE) has led the effort to build an acoustic monitoring community to find consensus in approaches to Passive Acoustic Monitoring (PAM). Meetings sponsored by the IQOE have proposed that a one-minute sample time of the acoustic spectrum should be the standard unit for soundscape reporting. The IQOE consensus was a key input to an ISO Working Group developing standard 7605 for PAM data analysis and reporting. The IQOE has also developed an Implementation Plan for the Ocean Sound Essential Ocean Variable (EOV). The Plan provides a roadmap for researchers to provide PAM data to the international community. This data addresses the core mission of the Global Ocean Observation System (GOOS), which seeks observations that can help society: (1) understand and manage climate changes, (2) maintain ocean health, and (3) monitor threats and provide forecasts and warnings. For the Ocean Sound EOV to reach its full potential, countries and individual researchers will be encouraged to contribute their data. ISO 7605 will provide a framework for standardized data collection, calibration, analysis and reporting of sound pressure levels with known temporal observation windows and frequency resolutions. However, it does not provide guidance on data analysis that yields indicators to directly address the observation goals of GOOS. In this work, long-term acoustic recordings are analyzed from a wide variety of water depths and locations to develop a robust soundscape classification algorithm. For each minute of data, the wind speed is estimated using a cubic function of power spectral density (PSD) at 6 kHz and recording depth. The classification algorithm employs the PSD level at twelve frequencies in the range of 0.03-30 kHz, as well as spectral slopes and kurtosis to identify minutes with rain, drizzle, heavy and light shipping, fin and blue whales, as well as odontocete clicks and whistles. A key objective is developing a low-power system that can be operated on autonomous platforms. The classification algorithms are being embedded on a processor using Xilinx's Zynq System-on-Chip that produces a 32-kHz hybrid millidecade spectrum in real-time.

SOURCES OF PATTERNS IN SOUNDSCAPES

Baumann-Pickering, S

Simone Baumann-Pickering
sbaumann@ucsd.edu
Scripps Institution of Oceanography University of California San Diego
9500 Gilman Drive, La Jolla, CA 92093-0205, USA

Soundscapes are complex composite acoustic environments made up by contributions from biotic, abiotic, and anthropogenic sources. These sources are readily identifiable by human analysts in long-term, autonomous passive acoustic data but are more difficult to capture in an automated manner. Describing marine soundscapes based on sound levels gives an incomplete picture of complexity and context. This may at times be misleading in a management application unless sources contributing to these levels are quantified and possible interactions of sources better understood. Over recent years, efforts have been made to a) calibrate across time and instrument response for a consistent metric by using ambient sound from wind as a guiding factor; b) develop software to generate soundscape metrics in the Matlab-based package Triton – the Remora (plug-in) “Soundscape Metrics”; c) assess contributions of sources in tens of years of cumulative passive acoustic data and how it relates to temporal cyclical patterns such as day, lunar cycle, season; and d) to automate the separation and classification of chronic and transient sources using long-term spectral averages.

USING CNN CLASSIFIERS AS UNDERWATER SOUND SOURCE DETECTORS: LEARNING ABOUT NOISE

Parcerisas, C; Igaz-Kaya, İ; Botteldooren, D; Devos, P; Debusschere, E; Schall, E.

Clea Parcerisas
clea.parcerisas@vliz.be
Flanders Marine Institute (VLIZ) / Ghent University
Slipwaykaai 2, 8400, Oostende, Belgium

Passive acoustic monitoring (PAM) creates massive amounts of valuable data to monitor fauna with bioacoustic methods. The continuously increasing volume of PAM data make the manual review of these data by human experts more and more impractical. Automatized approaches to process and analyze data are required to gain knowledge on spatio-temporal patterns of soundscapes, species presence and behavior. With the raise of the development of high-performance Convolutional Neural Networks (CNN) for speech recognition and computer vision, there has been an increase in CNN application for underwater sound sources recognition. These applications are usually based on the use of spectrograms featuring high temporal and spectral resolutions as the graphical input to the models. CNNs have a great potential to detect and differentiate underwater sound sources in spectrograms, but when it comes to automatic classification methods it still remains a challenge to cope with low signal-to-noise ratios, simultaneous species presence, and overlapping vocalizations. Furthermore, classifier algorithms are sometimes applied to segmented snippets with the objective of detecting all the signals in long-term recordings. The fact that noise is the dominant class (usually more than 95% noise in marine PAM data) which results in highly imbalanced datasets affects the performance of most models if not tackled accordingly. In this project we explore which effects have (1) the size of the dataset for the classification of different marine mammal's vocalization, (2) the testing of the model on unseen data from a new location, and (3) the proportion of noise in the training and testing dataset on the performance of a classic CNN model to detect baleen whale sounds in a real-world bioacoustic open-access dataset recorded in different locations of the Southern Ocean. Knowing these effects can help us better assess the potential of using CNNs to detect and classify underwater sound sources.

IMPLICATIONS OF ALTERED ACTIVE SPACE FOR MARINE LIFE, AND HOW THAT MIGHT BE USED AS A MITIGATION METRIC

Burnham RE, Vagle S

Rianna Burnham
rianna.burnham@dfo-mpo.gc.ca
Fisheries and Oceans Canada
Institute of Ocean Sciences

Increases in ambient noise levels globally have been attributed to a globalisation of the economy and an increased reliance on oceanic transportation routes. The additions are most acute along major shipping routes, but can propagate to areas remote to the source. Coastal areas near large urbanised areas and ports also demonstrate elevated ambient noise levels. More and more, these increases are being realised as a hindrance to species success, recovery and ultimately population survival. Impact is currently defined by quantifying changes in soundscapes, and the potential for behavioural modifications and temporary or permanent hearing loss. Here, we explore different species-centric metrics to understand the potential impact on whales from changes in the sound field. The potential of interference to successful communication calling or echolocation use through masking is suggested as a means to quantify disturbance, identify hotspots of impact for species, and understand the level of acoustic stress they may experience over time and space. We look to a case study of the endangered southern resident killer whale in an area of critical habitat to understand how the effective use of acoustic signals to way-finding, maintain group cohesion, and identify and capture prey could be impacted by current levels of presence as well as near-future predicted increases. How this masking metric, and its application to knowing the time or area that might be impacted by noise, can be used to guide the development of mitigation measures is also discussed.

ACOUSTIC MONITORING OF THE NORTHERN ADRIATIC SEA, A TRANSNATIONAL ASSESSMENT RUN IN THE MEDITERRANEAN SEA

Picciulin M et al (37 authors)

Marta Picciulin
marta.picciulin@gmail.com
CNR-National Research Council, ISMAR - Institute of Marine Sciences
Venice, Castello 2737/f

Human-generated noise has been recognized as a pollutant for aquatic animals, claiming for underwater soundscape monitoring. Worldwide several monitoring programs have been carried out but very poor data are available for the Mediterranean Sea, despite it being a biodiversity hot-spot. SOUNDSCAPE project is the first yearly continuous acoustic monitoring project, that encompasses nine stations in the Northern Adriatic Sea both on the Croatian and Italian sides. Stations located close to harbors, shipping lines and touristic areas resulted to have higher and more variable noise levels than those sited close to protected/managed areas. Seasonal variation in sound pressure levels was observed, mostly related to weather conditions. Median sound pressure levels are similar to those characterizing other busy EU basins. However, by including the COVID-19 related lockdown period, in the monitoring period, the presented dataset could reflect a reduced human activity in the study area; in its turn higher levels could be hypothesized during a business-as-usual period

LARGE-SCALE MONITORING OF INDO-PACIFIC HUMPBACK DOLPHINS AND FINLESS PORPOISES USING MULTIPLE STATIC ACOUSTIC SENSORS

Li, S; Dong, L; Caruso, F; Lin, M; Liu, M

Songhai Li
lish@idsse.ac.cn
Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences
28 Luhuitou Road

Passive acoustic monitoring (PAM) is increasingly being adopted as a non-invasive method for the assessment of ocean ecological dynamics. PAM is an important sampling approach for acquiring critical information about marine mammals, especially in areas where data are lacking and where evaluations of threats for vulnerable populations are required. The Indo-Pacific humpback dolphin (IPHD, Sousa chinensis) and finless porpoise (IPFP, Neophocaena phocaenoides) are coastal species which inhabit tropical and warm-temperate waters from the eastern Indian Ocean throughout Southeast Asia to central China. The distribution pattern of these animals around the Hainan Island (China) is unclear, but evidences for a resident population of both the species have recently emerged. An array of passive acoustic platforms was deployed at depths of 10–20 m (the preferred habitat of humpback dolphins, and potential habitat of finless porpoises), across sites covering more than 100 km of coastline. In this study, we explored the spatiotemporal patterns of distribution and acoustic behavior of these species by using the PAM data through supervised machine learning algorithms. Our work demonstrates that the distribution and habitat use of the coastal and resident odontocetes can be monitored over a large spatiotemporal scale, using an array of passive acoustic platforms and a data analysis protocol that includes both machine learning techniques and spectrogram inspection.

ASSESSING THE IMPACT OF SHIP TRAFFIC NOISE ON SHORT-FIN PILOT WHALES IN SOUTH TENERIFE: IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

Marín-Delgado, O; Johnson, M; Aguilar de Soto, A

Olivia Marín-Delgado
olivia.marin.03@ull.edu.es
BIOECOMAC, University of La Laguna, Tenerife, Canary Islands, Spain
San Cristóbal de La Laguna, 38200

Low-frequency anthropogenic noise, particularly from shipping activities, is a growing concern for the acoustic environment of marine animals, including whales. This study, within Solutions to Underwater Radiated Noise (SATURN) project aims to investigate the impact of underwater noise from vessels on short-fin pilot whales (Globicephala macrorhynchus) in the Special Area of Conservation Teno-Rasca, located in the South of Tenerife, Canary Islands. This area includes a commercial harbor and two smaller ports hosting intense ferry, whale watching and recreational vessel traffic, as well as areas with lower marine traffic. During 2021 and 2022, we deployed digital acoustic tags (DTAGs) on 17 short-fin pilot whales, which recorded sound generated by both the whales and passing ships for a total of 106 hours, as well as GPS data of the location of the whales. We related the location of the whales with respect to the harbors with the noise budget received in the tags. This was extracted from long-time spectrogram analyses and extracting vessel passages from the acoustic records of the tags. The results evidence spatial differences in the acoustic quality of the waters within the ZEC and are readily applicable to Environmental Assessments of new harbor developments in the area.

EVIDENCE OF IMPACTS OF UNDERWATER RADIATED NOISE ON THE VOCALIZATION OF COASTAL DOLPHINS

Diamant R., Scheinin A.

Roee Diamant
roee.d@univ.haifa.ac.il
University of Haifa
Haifa, Israel

With the large increase in human marine activity, our seas have become populated with boats and ships projecting acoustic emissions of extremely high power that often affect areas of up to 20 square km and more. The underwater radiated noise (URN) level from large ships can exceed 100 PSI and is wideband, such that even at distances of several kilometres from the vessel, the acoustic pressure level is still high with a clear disturbance impact on the hearing and behavior of marine fauna. While standards were set to limit the transmitted acoustic power per exposure the magnitude of noise from ships remains under-explored. Bridging this gap, we report on a quantitative study that examines if and how shipping URN is a main factor of disturbance. While a variety of marine animals may be affected by shipping URN, we focus on two coastal dolphin species – the Bottlenose dolphin (Tursiops truncatus) and the Common dolphin (Delphinus delphis). Dolphins are known to express stress also through acoustics manners. The large range of distribution of these two species makes them ideal representatives in this study as they show plasticity in habitat choices and can migrate to another environment in case of a strong disturbance, such as sound. They are apex predators in the Israeli marine environment, thereby acting as sentinel species and important bioindicators. In this talk, we will present the results of a quantitative study performed to examine the relation between shipping URN and the vocalization of coastal dolphins. We explored the dolphins' response to vessels by deploying two long-term acoustic recorders near a shipping lane and a dolphin habitat in Eilat, Israel. Using a deep learning method, we detected 50,000 whistles, which were clustered to associate whistle traces and to characterize their features to discriminate dolphin behavior. Post processing included noise cancellation, whistle clustering and feature selection, as well as manual tagging. The whistles were categorized into two classes, representing the presence or absence of a nearby vessel. We obtained true positive and true negative rates exceeding 90% accuracy on separate, left-out test sets. Data is shared with the community for reproducibility and further research. We argue that this success in classification serves as a first systematic proof for the impact of shipping URN on dolphins' behavior.

A STUDY ON THE TEMPORAL VARIABILITY OF UNDERWATER NOISE WITH AIS AND V-PASS DATA AROUND HIGH SHIP DENSITY IN KOREA COASTAL WATERS

Cho, S; Kim, H; Kim, S; Kim, M; Kang, D

Sungho Cho
shcho@kiost.ac.kr
Korea Institute of Ocean Science & Technology
KIOST, 385, Haeyang-ro, Yeongdo-gu, Busan, KOREA

In areas with frequent ship traffic, such as ports and coastal areas, ship noise dominates underwater noise in the low-frequency band below 1 kHz. This study analyzed underwater noise below 1 kHz in over a period of 14 days using SRH (Self-Recording Hydrophone), which is deployed in the water, collected in the high-traffic coastal waters in Korea. The study area is a port where various types of large vessels and fishing boats are constantly present. In addition to the installation of the AIS system on large ships, small ships in Korea are obliged to install the V-PASS (vessel pass) system. The system, introduced in 2013, is one of the location transmitters for small fishing boats (below 10 tons) and is an automatic communication device that must be installed on all fishing boats in order to quickly respond to marine accidents. During the same period of underwater noise measurement, the navigational information from the large vessels and fishing boats was obtained using AIS and V-PASS system. A technique for modeling shipping noise was applied to compare and analyze the observed underwater noise data. In the shipping noise modeling technique, the source level of individual ships was calculated using an empirical formula (ROSS, 1987). The transmission loss from the ship to the receiver was calculated using the Range-dependent Acoustic Model. In this study, we present the results of a comparison and analysis of underwater noise measurement data obtained through sea trials with ship noise modeling data based on AIS and V-PASS System. We also discuss the limitations and causes of the differences between the measurements and the modeling, and propose research directions to overcome these limitations.

ANALYSIS OF HYDROPHONE SOUND RECORDINGS IN A DOLPHIN HABITAT WITH HIGH EXPOSURE TO RECREATIONAL SHIPPING NOISE, MONITORING, CLASSIFICATION OF SOUNDS USING DEEP LEARNING CNN ARTIFICIAL NEURAL NETWORK, ANALYSIS OF DOLPHIN SOUNDS IN NOISY ENVIRONMENTS WITH SPECIAL FOCUS ON MODULATIONS.

Varga, AK

Attila Aradi
aradi.attila@gmail.com
University of Miskolc, Hungary
3331 Tarnaszentmaria, Egri u 43, Hungary

In the Adriatic Sea of Croatia, we conducted hydrophone underwater sound recordings in dolphin habitat in the Veli Losinj area of the Adriatic Sea, in a water area highly noisy with recreational and tourist vessels. The recorded underwater sound files were classified using an artificial neural network, Tensorflow CNN algorithm. We also automated the detection of dolphin sounds in the large sound files using deep learning. In this way, large sound files can be processed quickly without human manual monotonous work. In noisy environments, dolphins use the higher frequency “quieter” frequency spectrum weighted by the spectral sensitivity of their auditory system above the noisy frequency spectrum. Dolphins use modulations to make whistle sounds unique, and dolphin’s frequency and amplitude modulations also a potential indicator of emotional states, including danger, alertness and stress. Dolphin whistle sound files recorded in a noisy environment were demodulated using Gnu Radio python function blocks. From the amplitude- and frequency-modulated whistle signal, we generated the baseband modulating signals generated by the dolphin individual that make the whistle sounds unique. The baseband modulating signal generated by the dolphin contains a lot of interesting information, the profiling of which is the subject of further investigation.

SOUNDSCAPE OF AN URBAN SHARK NURSERY

White, CE; Hobbs, C; Williams, B; Witt, MJ; Radford, AN; Macdonald, C; Simpson; SD

Clemency White
cew237@exeter.ac.uk
University of Exeter, UK
Hatherley Building, University of Exeter, EX4 4PS

Soundscaping has been used as a tool for understanding habitat health and developing contexts for animal behaviour across taxa, as well as identifying the presence and patterns of noise pollution in the environment. Anthropogenic noise has been shown to have negative consequences on a range of marine taxa, including marine mammals, teleost fish and invertebrates. Yet, despite our understanding that sharks are sensitive to low-frequency sounds (<1500Hz) and display multiple behavioural responses to sound, we have a very limited understanding of if and how they respond to anthropogenic noise. This is particularly concerning considering that the spectral characteristics of many anthropogenic noise pollutants, including motorboat noise, overlap with shark hearing sensitivities. Further, shark-boat interactions happen in a variety of contexts that influence their behaviour and conservation, such as commercial fishing, depredation and provisioning for tourism. Therefore, soundscaping key shark habitat is a valuable first step to understanding the acoustic context of shark hearing and identifying the biological and anthropogenic sounds they may be detecting and responding to in-situ. We begin to address this by providing the first soundscape conducted in the context of shark hearing. Using the Biscayne Bay (Miami, FL) as a study site, we verified the presence of three species of juvenile shark (Ginglymostoma cirratum, Sphryna mokarran and Negaprion brevirostris) that have restricted home ranges within the bay. This area is directly adjacent to the major city of Miami, and the nursery area directly overlaps with a popular site for boating, fishing and coastal recreation. Using a combination of hydrophones and accelerometers, we characterised the temporal trends and relative contributions of biophony and anthrophony in the bay across both the pressure and particle motion domain. Further, using machine learning algorithms, we quantified boat activity and described how noise levels vary on diel and weekly cycles, and during exceptional events such as 4th July celebrations. We discuss our results in the context of coastal resource management and how bioacoustics could contribute to shark conservation and protection.

VARIATION IN SOUNDSCAPE CHARACTERISTICS ACROSS TEMPORAL AND SPATIAL SCALES OF A SHALLOW WATER COASTAL PAM ARRAY; EXPLORING MARINE SOUNDSCAPES AS A TOOL FOR AUTOMATING SOUND SOURCE DETECTION IN LARGE DATASETS

White, E; White, P; Bull, J; Risch, D; Beck, S

Ellen White
elw1g13@soton.ac.uk
School of Ocean and Earth Science, University of Southampton, UK
Flat 1, 85-87 Hill Lane, Southampton, SO15 5QU UK

Passive acoustic monitoring (PAM) of marine environments has led to an explosion in the quantity of acoustic data, at scales unsuitable for human analysis. There is a growing demand for sophisticated detection and classification algorithms capable of automating the identification of specific marine sound sources, to reduce manual labour and extract meaningful information on appropriate timescales to research and industry projects. Research and development of sophisticated AI systems require a baseline understanding of ambient noise levels, across seasonalities and temporal ranges of the environment in the algorithm will be deployed in. Characteristics of ocean noise vary regionally, with shallow water coastal regions controlled by an abundance of environmental features. Understanding small-scale variation in soundscape components in shallow water environments is essential to build up an understanding of how automated detections systems may behave when deployed over large datasets which vary in noise characteristics. In this work passive acoustic data is analysed for the detection and classification of marine sound sources using broadband and third-octave level (TOL) sound pressure levels to understand the effect of biology, geophony and anthropogenic sound sources on baseline ambient noise trends across a shallow water coastal PAM array. The effect of soundscape variation across a network of nine PAM moorings, from the COMPASS array (West of Scotland), is investigated to characterise small-scale seasonal and diurnal trends in anthropogenic and biological sound source contributors, using data collected between 2018 and 2020. This work demonstrates inter-site variability in soundscape characteristics, despite close geographic locations, as a result of environmental factors, highlighting the importance of site-specific baseline data for developing automated approaches to mining big acoustic datasets. We highlight the difficulty of predicting site specific noise trends due to local correlations with tidal and weather features. To demonstrate the ability to detect marine sound sources in long-term PAM datasets we couple PAM data with AIS and oceanographic modelling data to correlate ambient noise trends with site specific events. We illustrate the ability to mine large PAM datasets for labelled acoustic frames using long term ambient noise analyses.

SOUNDSCAPE IN A NORTHERN PATAGONIAN FJORD WITH SALMON FARMS

Hinojosa, I.A.; Aviles, E.

Ivan A. Hinojosa
ihinojosa@ucsc.cl
Departamento de Ecología y CIBAS, Facultad de Ciencias, Universidad Católica de la Santísima Concepción, Chile. ESMOI, Facultad de Ciencias del Mar, Universidad Católica del Norte, Coquimbo, Chile COPAS COASTAL, Universidad de Concepción, Chile
Alonso De Ribera 2850 - Concepción - Chile

In the Patagonian Fjords (Chile) an explosive development of salmon aquaculture has occurred, making Chile the second largest salmon producer in the world. Several environmental impacts of this industry on marine ecosystems have been identified. However, descriptions of the underwater soundscape near the sea-based salmon installations are scarce. A continuous recording of ~45 hours was conducted using a calibrated hydrophone (0.02–60 kHz) anchored at 20m depth (2m from bottom) and 250m from a salmon net pen. Thirteen noises were identified. The dominant noise had a peak frequency of ~80 Hz, probably due to electric generators (SPLRMS ~120 dBre1µPa). The second dominant was ~2500 Hz, probably from automatic feeding systems or well-boats in use (SPLRMS ~142 dBre1µPa). Outboard motor noises were also present (SPLRMS ~130 dBre1µPa). During only one-hour, anthropogenic noises were absent (SPLRMS ~100 dBre1µPa), where snapping shrimps and fish sounds were found. Therefore, the soundscape was strongly dominated by anthrophony from the salmon net pen with 97% of the total time and ~40 dBre1µPa higher than natural sounds. Moreover, the highest noise was estimated as ~200 dBre1µPa at 1m from the net pen. Therefore, it is raising the necessity to evaluate the effects of these noises on the marine fauna.

DEUTERONOISE: A FIRST APPROACH TO NOISE CHARACTERISATION IN VENICE AND ADRIATIC BASINS

G. Zambon, L. Manni, F. Ristoratore, A. Spagnuolo, A. Teaca, C. Cañestro, M. Chatzigeorgiou, I. Guarneri, S. Candiani, M. Bozzo, G. J. Ginovart-Panisello, E. R. Quintana, F. La Torre, G. Sabbadin, E. De Lisa and R.M. Alsina-Pagès

Rosa Ma Alsina-Pagès
rosamaria.alsina@salle.url.edu
Human-Environment Research (HER) - La Salle (URL)
Sant Joan de la Salle, 42, 08022 Barcelona

Among noise sources, maritime traffic is of relevance on animal wellness, although its impact is not much known nowadays in many European sea-basins. Furthermore, most of the analysis have had an almost exclusive focus on vertebrates, in which noise involves the mechanoreceptor cells of the ear and can cause hearing impairment or deafness. But homolog cells have been discovered in tunicates, marine invertebrates closely related to vertebrates, thus opening the research question on their ability to sense and be affected by noise. Tunicate mechanoreceptors sense sound waves and particle movement, and therefore are predictable targets of noise pollution. JPI Oceans project Deuteronoise, recently started, aims to characterize the noise pollution caused by maritime traffic in selected sites of the North Adriatic Sea, Lagoon of Venice, North Sea, Black Sea, and Barcelona shore, characterize the gathered sounds and afterwards, test its effects on behavior, nervous system and sensory organs, immune system, and resilience in marine invertebrates closely related to vertebrates (deuterostomes): hemichordates, echinoderms, cephalochordates, and tunicates. All these animals are common in European seas and cover different levels of the trophic network, from the holoplankton-meroplankton to sessile or sedentary primary consumers. Noise levels have started to be recorded on site, to be analyzed and, after characterization, will be simulated in the laboratory, in order to conduct a behavioral, morphological and genetic survey on sampled animals living in acoustically polluted vs non-polluted areas. Recordings and measurements have started in the Lagoon of Venice, and also in two different sites in the North Adriatic Sea. First results analyzed in the laboratory allow us to identify the passages of different kind of ships, and the presence of several characteristic frequences. Several clear differences between sites have started to be identified, which will allow to generate simulate noise pieces in order to test in the laboratory with all deuterosomes.

IMPACT OF PILE-DRIVING AND ASSESSMENT OF OFFSHORE WINDFARM OPERATIONAL NOISE ON FISH VOCALIZATION BEHAVIOUR

Shashidhar, S; Chi-Fang, C

Shashidhar Siddagangaiah
shashi.18j@gmail.com
Underwater Acoustic Laboratory, Department of Engineering Sciences and Ocean Engineering, National Taiwan University
Taipei, Taiwan

Offshore windfarms have recently emerged as a renewable energy solution. The effects of pile-driving and long-term impacts on fish vocalization behavior are largely unknown. We investigated the variations of fish chorusing intensity and duration during the construction (2016) and the fish vocalization seasonal phenology during the operational phases (2017–2018) of the wind turbines at the Eastern Taiwan Strait (ETS). At the ETS, two types of fish choruses (Types 1 and 2) were found to repeat over a diurnal pattern. In the 2?days after the pile driving, Type 1 chorusing showed lower intensity and longer duration, while Type 2 chorusing exhibited higher intensity and no changes in its duration. Our findings document, for the first time, different behavioral responses of two chorusing types exposed to pile-driving and windfarm noise pressure. Wind turbine operation was significantly higher in autumn and winter compared to other seasons. Furthermore, the operational noise was highly correlated with the wind speed and did not influence the seasonal fish chorusing and followed the annual phenology of fish chorusing commencing in spring, peaking in summer, starting to diminish in autumn, and falling silent in winter. Because offshore windfarms installations are growing in magnitude and capacity worldwide, this study provides essential insights for policymakers and constitutes an important reference for assessing the effects of noise from pile driving and operational noise on fishes.

FOILING YACHTS AND DOLPHINS: HOW INTERNATIONAL REGATTAS TEMPORARILY CHANGE REGIONAL SOUNDSCAPES, AND THE POTENTIAL IMPACTS FOR DOLPHINS.

Pine, MK; Findlay, CR; Hague, E; McWhinnie, L.

Matthew Pine
mattpine@uvic.ca
University of Victoria & Styles Group Acoustics
12 Muritai Road, Milford, Auckland

Competitive sailing regattas are significant sporting events commonly held within coastal marine environments. These events attract thousands of additional spectator vessels, resulting in substantial changes to the coastal soundscape, potentially exposing marine animals to noise levels that far exceed ’normal’ for that region. In recent decades, technological advancements have led to the development of foiling yachts over 15m in length, which can exceed 100 kmh-1 and may pose significant collision risk to marine mammals. Furthermore, there is spatial overlap between marine mammal habitat and regattas, smaller race courses which tend to see vessel huddling and multiple races per day held near shore to allow for land-based spectators. The high spatial densities of vessels, including high-speed foiling boats, during these regattas in areas overlapping with marine mammal habitat introduces several vessel- and race-specific risks that relate to marine mammals, including potential vessel strike, changing acoustic soundscape affecting strike risk, and disturbance. To better understand the associated risk related to noise, hydrophones were placed around several racecourses before, during and after two large sailing regatta events (the Prada Cup and America’s Cup, both near Auckland, New Zealand), between January and March 2021. Analyses showed a dramatically altered soundscape during the regattas that extended well beyond the racing times, which can be attributed to sharp increases in recreational boating activity associated with the regattas. The acoustic signature from the foiling race boats themselves was difficult to detect in hydrophone recordings, with hydrodynamic noise occasionally visible on spectrograms for approximately 10-15 seconds. Considering the high velocity of these foiling boats in combination with their demonstrated low associated noise profiles, there is potential that the foiling boats may pose a significant strike risk to marine megafauna as they may be difficult to detect acoustically. This may be further exacerbated by heightened noise levels in the race area due to recreational boat onlookers, potentially reducing the likelihood that animals could detect the quieter high speed foiling boats, again potentially increasing the likelihood of strike for some species.

THE IMPACT OF UNDERWATER NOISE GENERATED BY OFFSHORE WIND FARM CONSTRUCTION ON THE ECOLOGY OF CETACEANS IN THE WESTERN WATERS OF TAIWAN

Chiao-Ming Peng

Chiao-Ming Peng
pcmtsl@ms7.hinet.net
N/A
No. 46, Aly. 28, Ln. 337, Nanzixin Rd., Nanzi Dist., Kaohsiung City 811546 , Taiwan (R.O.C.)

The offshore wind farm development in the western waters of Taiwan is in full swing. In 2022, this study used the passive acoustic recorder system at four stations in the surrounding waters of the wind farm. Measure for 14 days in March, April, June, and September. The measurement time includes the stoppage and the construction phase so that the impact of the underwater noise of different construction conditions of the wind farm on the ecology of cetaceans in the sea area can be compared. Although the time for underwater acoustic recording is mainly around summer, the research results show that the underwater noise of ships and pilings generated by the wind farm project has a certain impact on the activity of cetaceans near the shore. The time for recording cetacean sounds will increase with the distance from the noise source. It shows that cetaceans are moving away from noisy environments. The use of passive acoustic systems to accumulate long-term cetacean ecological data will help the government formulate ecological conservation strategies and effectively reduce the impact of marine engineering on the ecological environment.

A GUIDANCE ON MEASUREMENT AND EVALUATION METHODS FOR UNDERWATER SOUNDS FOCUSING ON OFFSHORE WINDFARMS

Tomonari Akamatsu

Tom Akamatsu
akamatsu.tom@gmail.com
Ocean Policy Research Institute
Ocean Policy Research Institute, the Sasakawa Peace Foundation, Tokyo, Japan

Carbon neutral is the global agenda in these years. Offshore windfarm is expected to be the major renewable energy sources. During construction and operation, intensive pulse noise and long-term continuous noise are radiated due to pile driving and windmill rotation. In 2021, we proposed a guidance on measurement and evaluation methods for underwater sounds based on discussion among a study group organized by Marine Acoustics Society of Japan. The guidance focuses on the method of underwater noise measurement and assessment of the effect of noise on aquatic animals. Long-term recording using a fixed recorder is recommended to identify the background noise level and its seasonal changes in the potential construction site. Measurement of received sound levels to three directions from the pile up to 6 km is recommended to know the asymmetric noise field due to complicated shallow water propagation. The distance at the background noise level masks radiated sound is defined as “safe distance”. Noise impact assessment should be conducted in the area within this distance. This guidance is not completed yet. It should be revised according to the field tests. In addition, noise exposure criteria for each species in the ocean is required.

ACOUSTIC AND VISUAL INVESTIGATION OF ESTUARY HABITAT ON INDO-PACIFIC HUMPBACK DOLPHIN (SOUSA CHINENSIS) IN YUNLIN, TAIWAN

Hu, WC; Lin, CH; Chou, LS; Chen, CF

Chi-Fang Chen
chifang@ntu.edu.tw
National Taiwan University
No. 1 Roosevelt Road Section#4, Daan District, Taipei, Taiwan

Acoustic and visual surveys of Indo-Pacific humpback dolphins (Sousa chinensis) were conducted in the estuary of the Xinhuwei creek, Yunlin, Taiwan in 2021. Underwater acoustic recorders and temperature-depth data loggers were deployed at two locations in the estuary. The total duration of valid data for each station is at least 19 consecutive days during each season. Dolphin's click-trains and whistles were counted by a supervised detection method. The results show that the trend of click-trains (echolocation and foraging sounds) is positively correlated with sea temperature. The most active foraging behavior occurs during the daytime of summer. Whistles (social and communication sounds) are most common during spring. The number of click-trains and whistles are larger at the deeper measuring station (water depth of 11 meters) except in winter. The acoustic detections were also coincided with visual surveys, thus confirmed the findings in both. This research was funded by Formosa Petrochemical Corporation.

TG NOISE RECOMMENDATIONS ON EU THRESHOLD VALUES FOR UNDERWATER NOISE

Fabrizzio, j. Sigray P.

Peter Sigray
sigray@kth.se
KTH Royal Institute of Technology. Department of Engineering Mechanics/Marine Engineering/Sensing & Environment
Teknikringen 8, plan 4, SE - 100 44 Stockholm, Sweden

The process and rationale that led the Technical Group on underwater Noise (TGNoise) to the definition of threshold values for underwater noise in the EU is described. For both criteria, D11C1 (impulsive noise) and D11C2 (continuous noise) of the Marine Strategy Framework Directory the threshold values are described and discussed.

UPDATE ON CURRENT EFFORTS TO ADDRESS UNDERWATER VESSEL NOISE AT THE INTERNATIONAL MARITIME ORGANIZATION (IMO)

Sanders, M

Michelle Sanders
michelle.sanders@international.gc.ca
Transport Canada
Canada

The International Maritime Organization (IMO) has recognized that commercial shipping is one of the main contributors to underwater radiated noise (URN), which has adverse effects on critical life functions for a wide range of marine life. Over the last 6 years, Canada has shown international leadership through submissions of papers, technical and policy workshops, to promote the adoption of quiet ship design standards and technologies, and in 2021, the Marine Environment Protection Committee (MEPC) accepted the proposal from Canada and co-sponsors Australia and the United States, to review the 2014 Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life and identify next steps to further prevent and reduce underwater radiated noise and encourage action, therefore adding the issue of underwater noise to the work program of MEPC. In January 2023, the Ship Design and Construction (SDC) Sub-committee agreed to a revised version of the Guidelines, which encourages the development of Underwater Vessel Noise Management Plans; the revised guidelines have been referred to MEPC 80 for approval at the next meeting in July 2023. This presentation will discuss efforts made at the IMO to address underwater vessel noise, as well as provide an overview of the revised Guidelines and remaining next steps.

GERMANY OFFSHORE WIND PILE DRIVING NOISE RECEIVED LEVEL LIMIT

Juretzek, C; Schmidt, B., Boethling, M.

Carina Juretzek
carina.juretzek@bsh.de
Department of Engineering Mechanics/Marine Engineering/Sensing & Environment
SE - 100 44 Stockholm, SWEDEN

Since 2008, compliance with a dual sound pressure threshold for pile driving has been mandatory for all BSH-approved wind farm construction projects in the German Exclusive Economic Zone (EEZ) to prevent TTS in harbor porpoises. An important function of regulatory agencies is to demonstrate and evaluate the applicability, efficiency, and effectiveness of noise mitigation measures. This requires both a scientific understanding of noise impacts and consideration of normative aspects of noise mitigation. The process of establishing noise mitigation procedures in plans and permits by regulatory agencies involves several steps. A step-by-step approach is outlined here, in which most of the measures described are implemented can be implemented simultaneously. Potential measures include the appropriate maritime spatial planning to avoid conflicts with nature conservation, site development for offshore wind farms to avoid undesirable activities in time and space, coordination of activities to avoid cumulative effects, and the application of technical noise abatement systems to reduce noise at the source. To increase the acceptance of the application of noise abatement measures, the technical measures should meet a number of requirements: (a) they are applicable and affordable, (b) they are state of the art or at least advanced in development, (c) their effectiveness can be evaluated with standardized procedures. Here, we present the status of the German receivel level regulation practice and discuss lessons learnt and further developments at various scales.

SETTING NOISE LIMITS FOR OFFSHORE WIND PILE DRIVING IN THE U.S.

Lewandowski, J.; Denes, S.

Jill Lewandowski
jill.lewandowski@boem.gov
Bureau of Ocean Energy Management
45600 Woodland Road, Sterling, VA 20166, USA

The United States has set a target of 30GW of offshore wind energy by 2030 which has sparked substantial interest in development along the U.S. North Atlantic coast. Here, one major issue of concern is the effects of pile driving noise on the highly endangered North Atlantic right whale (Eubalaena glacialis), a species in continued decline with approximately 350 individuals remaining. While other locations worldwide have set noise limits for high frequency cetaceans (e.g., harbor porpoise), none exist for low frequency cetaceans, like the North Atlantic right whale. Further, challenges remain in the efficacy of available quieting technology to significantly reduce low frequency noise (especially in 7 Hz to 35 kHz range). This presentation will provide the U.S. Bureau of Ocean Energy Management's approach to setting an initial pile driving noise limit for low frequency cetaceans and seek feedback on how to strengthen this limit for projects five plus years from development.

CANADA'S EFFORTS TO ADDRESS UNDERWATER VESSEL NOISE

Sanders, M

Michelle Sanders
michelle.sanders@international.gc.ca
Transport Canada
High Commission of Canada, Canada House, Trafalgar Square, London, SW1Y 5BJ

Canada is committed to a safe, clean, efficient and sustainable marine transportation that improves marine safety and responsible shipping, while supporting economic growth. Since 2018, the Government of Canada has taken a number of actions to address the negative effects of increased underwater noise from marine shipping on the protection and recovery of whales at risk, particularly the Southern Resident Killer Whale (SRKW) on the pacific coast. This includes mandatory distance approaches and interim sanctuary zones, voluntary slowdowns and the establishment of a national working group on underwater vessel noise reduction targets to inform a national policy on noise management planning. This presentation will introduce Canada's efforts in addressing underwater noise and preliminary recommendations from the working group on setting vessel source underwater radiated noise targets and potential effects of reducing noise in the marine environment.

THE IUCN WESTERN GRAY WHALE ADVISORY PANEL: MANAGING NOISE FROM OFFSHORE OIL/GAS EXPLORATION AND PRODUCTION THROUGH A MULTI-STAKEHOLDER PROCESS

Nowacek, DP, Southall, BL

Douglas Nowacek
dpn3@duke.edu
Nicholas School of the Environment & Pratt School of Engineering
Duke University Marine Laboratory, 135 Duke Marine Lab Rd., Beaufort, NC 28516
USA

The Western Gray Whale Advisory Panel (WGWAP), convened by the International Union for the Conservation of Nature (IUCN), had noise as one of its primary focal areas for reducing risk associated with offshore oil/gas development by the Sakhalin Energy Investment Company (SEIC). The Panel was charged with addressing threats/risk to western gray whales (WGW) across their range as well as the cumulative threats. This was the most significant policy challenge as the noise guidelines set by the government of the Russian Federation were almost universally less stringent than those recommended by the WGWAP, and there were many operators on the Sakhalin shelf, not all of whom participated in the process. The most significant science challenge was determining noise exposure guidelines. The WGWAP process was quite successful in many ways, and despite the challenges one of the most successful was the creation and implementation of exposure guidelines. As a group (i.e., SEIC, WGWAP, and IUCN) we created noise exposure guidelines for impulsive noise, and these were 163 dB RMS for behavioral disturbance. Finally, the implementation of these guidelines was extensive and broadly successful, particularly for seismic surveys. The system included: bottom mounted passive acoustic recorders (including real time reporting and archival systems), a 'perimeter monitoring line' which was the area that encompassed 95% of the whale distribution, vessel and land-based monitoring, and a command center where the lead MMO was stationed and, importantly, had the ability and the authority to call for a shut down if whales were detected in the disturbance zone(s). This work represents a milestone in noise management and marine mammal protection as it was a result of a broad collaboration of stakeholders from geophysicists to acoustic modelers to industry representatives to MMOs. The cross-institutional partnerships focused on strategic, actionable approaches to address challenging ocean noise conservation issues evolved after the project into the Global Alliance for Managing Ocean Noise (GAMeON).

UNDERWATER NOISE MANAGEMENT IN PERSPECTIVE

Merchant Nathan D.

Cefas

Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

What might we learn from history when it comes to tackling underwater noise pollution? Which key factors have brought about the environmental and conservation breakthroughs of the past? And how might this understanding shape our expectations and guide our actions for the future management of underwater noise pollution at a global scale?

THE GENERAL DYNAMICS APPLIED PHYSICAL SCIENCES MARINE VIBRATOR: A NEW PARADIGM IN SEISMIC ENSONIFICATION

Roy, D; Nichols, B; Fasano, J; Sutton Z

Daniel Roy
droy@aphysci.com
General Dynamics Applied Physical Sciences
475 Bridge St, Groton CT, 06340

Two of the General Dynamics Applied Physical Sciences Marine Vibrator systems, under development since 2013, successfully completed an open-water offshore test (known as the PILOT test) in European waters between September and October of 2022. The test was conducted with the assistance of Kappa Offshore Solutions and was supported by the Marine Vibrator Joint Industry Project (MVJIP) sponsors, ExxonMobil, Shell and TotalEnergies, in association with the Texas A&M Engineering Experimentation Station. A brief history of the project will be presented, including the fabrication and test of a ¼-scale transducer for model validation, extensive testing of the system both at Seneca Lake and in flooded quarries, the present status of the system including select results from the PILOT test as processed by our real-time quality assurance application, and an overview our future plans. These plans include a behavioral response study involving Blue and/or Fin whales funded by the IOGP E&P Sound & Marine Life JIP. Finally, concurrently with the preparation, and planning of the BRS study, Applied Physical Sciences is exploring methods to reduce both the size and weight of the deployed portion of the system, known as the Integrated Projector Node. The reduced size and weight will simplify deployment, recovery, operations, and maintenance of the system.

BASS MARINE VIBRATOR – FROM IDEA TO REALIZATION

Hager E., Melbo.A, Supawala.M

Edward Hager
EHager@shearwatergeo.com
Chief Geophysicist, Shearwater
2 City Place, Beehive Ring Rd, Gatwick, West Sussex RH6 0PA, UK

Airguns have remained to be the preferred acoustic sources for seismic data acquisition for more than 50 years. Unlike land acquisition, where vibrators have made significant advances, in marine seismic airguns have continued to be the preferred choice because of their performance both in terms of signal suitability for seismic imaging purposes and operational reliability. The first marine vibrators were introduced in the 1960's. However, compared to airguns these early vibrators were bulky, slow and failure prone. Over the last few years, there has been a renewed interest in marine vibrators. The drivers are reduced environmental impact, with a lower peak output as well as less total energy emitted. In addition, marine vibrators offer novel geophysical benefits. Currently we are developing a new modern marine vibrator named BASS (Broadband Acoustic Seismic Source). The goal is to produce a robust and hi-fi vibrator system that is offering improved data quality or higher productivity, as an alternative to airgun sources. However, for such a new product to succeed in the market, it also needs to be flexible to suit different survey objectives, and reliable to be able to operate in a real-life environment. In this talk, we will discuss what the system can do, the signal characteristics and the system development that has taken this product from an engineering idea to its first offshore field trial.

BEHAVIORAL RESPONSE STUDIES WITH BALEEN WHALES AND MARINE VIBROSEIS

Brandon Southall

Brandon Southall
Brandon.Southall@sea-inc.net
Southall Environmental Associates
9099 Soquel Drive, Suite 8, Aptos, CA USA 95003

This talk will review the planning and early stage pilot results for a new study investigating behavioral responses of large whales to marine vibroseis sources being developed as potential alternatives to seismic airgun surveys. The objective is to apply systematic controlled exposure experiment (CEE) methods using proven tools and well established baseline data 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 but will include novel operational marine vibrator sources recently developed. Tag data are augmented with passive acoustic monitoring (PAM), whale focal follow, photo identification, and body condition data. Initial pilot effort results as well as plans for full scale source CEEs to be conducted will be discussed.

OPERATIONAL AND ENGINEERING MITIGATION OPTIONS FOR SEISMIC SURVEYS

Jenkerson M, Nechayuk V

Vladimir Nechayuk
vladimir.nechayuk@exxonmobil.com
ExxonMobil
22777 Springwoods Village Pkwy, Spring, TX USA

Seismic surveys are conducted in support of oil and gas exploration and site clearance for well drilling and windfarm installations offshore. Studies showed that the low frequency, high intensity signals produced by seismic sources have the potential to induce physiological and behavioral changes in marine mammals, fish and invertebrates. A number of engineering and operational solutions are available to reduce the acoustic output from a seismic array with the optimum solution dependent on the specific environmental issue. Different techniques can reduce different components of the sound (peak, bandwidth, SEL, duty cycle). New technologies can have significant cost and engineering hurdles to overcome, but may significantly reduce environmental impact without compromising the quality of the seismic data.

MONITORING AND MODELLING APPROACHES FOR ESTIMATING SOUND EXPOSURE OF MOVING SUBJECTS FROM CONCURRENT SEISMIC SURVEYS

Racca, R; Zykov, MM; Fershalov, MY; Jenkerson, MJ

Roberto Racca
roberto.racca@jasco.com
JASCO Applied Sciences (Canada)
2305–4464 Markham Street, Victoria BC, V8Z 7X8, Canada

When an endangered population of whales shares coastal waters with an oil and gas production field where seismic surveys are taking place, an effective mitigation strategy requires accurate mapping of the sound field from the airgun arrays to enable estimation of the exposure at the visually tracked location of each animal. During a season of seismic surveying off North-East Sakhalin Island in 2015 involving multiple sources operating concurrently, an unprecedented level of monitoring took place which included real-time and archival measurement of seismic pulses received at numerous sites throughout the region of interest. The data were used both operationally and in post-analyses to calibrate and adjust the predictions from sound propagation modelling to yield reliable sound exposure histories for whales in the region. Novel approaches were developed to resolve practical challenges which included the attribution of long-range propagated pulses to the correct source, the reconstruction of reliable metrics from distorted and mutually interfering measured pulses in a complex sound transmission environment, and the local calibration of model estimated pulse levels through adaptive interpolation dependent on the geometric distribution of surrounding measurement stations. The resulting geospatial estimation of sound exposure informed a variety of multivariate analyses of the effects of the seismic surveys on whale distribution and behaviour, the findings of which were recently published.

CHARACTERISATION OF NOISE EMITTED BY SUB-BOTTOM PROFILERS AND ITS POTENTIAL EFFECTS ON MARINE MAMMALS

Stenton, CA; Williamson, LD; Bolgan, M; Hodgson, Z; Todd, VLG

Craig Stenton
cs@osc.co.uk
Ocean Science Consulting Ltd.
Ocean Science Consulting Ltd., Spott Road, Dunbar, UK, EH42 1RR

Geophysical acoustic surveys form a vital component of many offshore activities. Different geophysical survey methods are used for ensuring vessels safety, as well as actively identifying features of interest on the sea floor. One such survey method involves use of a Sub-Bottom Profiler (SBP), –which produces a highly directional sound signal at specific frequencies and pulse rates – to derive surface and subsurface characteristics of the seafloor. In addition to intentional sound signals, SBPs may also produce extraneous noise which can propagate into the environment. SBP sound levels and frequency distributions, and potential impacts are poorly quantified and understood. To characterise noise levels produced by SBPs, opportunistic noise recordings were conducted during operational deployment of two different SBP designs (chirper and parametric), each producing signals (and extraneous noise) with different acoustic characteristics. These data were analysed to determine acoustic signatures of non-directional noise produced by each model of SBP. To better understand potential risk to marine mammals, propagation characteristics of these noise signatures were modelled using ray-tracing in a variety of scenarios to investigate effects of water-column depth, current speed, water temperature, sound-velocity profile, and seafloor substrate. Transmission loss functions were then derived for each propagation scenario and simplified equations produced allowing for simplified estimation of noise propagation and duration of exposure. These values were then used to estimate durations required for Temporary- and Permanent Threshold Shift (TTS and PTS) for different marine mammal groups The chirper SBP produced noise in a 1-10 kHz range, with each pulse having a calculated source Pressure Level (SPL) of 161.2 dB0-Pk re 1 µPa and a Sound Exposure Level (SEL) of 127.1 dB re 1 µPa2 s – both values falling below the thresholds for inducing TTS and PST in all marine mammal hearing groups at 500 m from source. Furthermore, at this distance, the highest risk group, low-frequency cetaceans, would require >100 days of SBP exposure to exceed TTS thresholds. The parametric SBP produced noise in a 75-125 kHz range, with each pulse having a calculated source SPL of 181.0 dB0-Pk re 1 µPa and an SEL of 136.3 dB re 1 µPa2 s. Accounting for hearing group frequency sensitivity, only Very-High Frequency (VHF) cetaceans were considered at risk of TTS or PTS. Weighted single-pulse source SEL levels were sufficient to invoke TTS in VHF cetaceans, with exposure tolerance at 500 m from source varying between 4.4–440 hours depending upon propagation conditions. With the exception of VHF cetaceans, risks to marine mammals posed by extraneous noise produced by the two SBPs models investigated here is considered minimal. Moreover, for VHF cetaceans (and other hearing groups), risks are contingent on the specifications of the equipment, specific deployment parameters, likely propagation conditions, and animals remaining in the ensonified region for an extended period, which is considered highly unlikely for these mobile species.

CETACEANS AND UNDERWATER NOISE MONITORING IN THE SOUTH ATLANTIC OCEAN

Spengler, A; Paula, TP; Marcon, EH; Pereira, D; Miranda, C

Eduardo Marcon
eduardomarcon@petrobras.com.br
PETROBRAS - Petróleo Brasileiro S.A.
Av. Horácio de Macedo, 950. Rio de Janeiro. Brazil

The increase of marine underwater noise and its impact on cetaceans is a fast-growing concern among the scientific community, environmental agencies and the offshore industry. However, to reach robust evidence of anthropogenic effects on marine species, it is crucial to map the cetacean's distribution that inhabit the region and the existing noise levels over time. The knowledge about cetaceans and underwater noise in the western margin of the South Atlantic Ocean were very scarce up until 2015, when Petrobras set up two pioneer initiatives: the Santos Basin Cetaceans Monitoring Project and the Santos Basin Underwater Soundscape Monitoring Project (respectively, PMC-BS and PMPAS-BS, in Portuguese acronyms). These two projects meet requirements of the environmental licensing process conducted by the Brazilian federal environmental agency, (IBAMA), for oil and gas exploration and cover an area over 36,000 km2. During the first 6 years, PMC-BS collected data through 12 onboard and passive acoustic monitoring (PAM) surveys, 12 aerial surveys and 12 telemetry campaigns, totalizing an effort of 843 field days and more than 176,000 km travelled. PMPAS-BS' data collection involved the deployment of 234 acoustic drifting profilers, 1 glider continuously monitoring the region, 6 mooring lines equipped with acoustic recorders at 3 different depths and 3 bottom mounted structures installed in coastal waters. Nearly 143,000 hours of recordings recovered from gliders and mooring lines and over 5,400 hours of acoustic recordings processed by the profilers were used to build a 3D depict of the underwater soundscape over the years. An acoustic propagation model considering AIS information of all anthropogenic sources was also developed and validated against measured data. Cetacean vocalizations detected in PMPAS-BS recordings are supplied to PMC-BS for identification and cataloging of the species. PMC-BS also uses PMPAS-BS's data in habitat modeling. Due to the interference inherent in the PAM methodology for low frequencies, PMPAS-BS data are very important to complement the study of baleen whales' vocalizations, since the recordings made by the glider have excellent quality. It is expected that both projects will be executed while the oil and gas exploration and production activities last in Santos Basin, considering adjustments based on the obtained results and development of new technologies, providing data and information for scientific studies and research.

BEST AVAILABLE TECHNOLOGY (BAT) AND BEST ENVIRONMENTAL PRACTISE (BET) FOR MITIGATING THREE NOISE SOURCES: SHIPPING, SEISMIC AIRGUN SURVEYS, AND PILE DRIVING

Weilgart, LS

Lindy Weilgart
Linda.Weilgart@Dal.Ca
OceanCare & Dalhousie University
1596 John Brackett Dr, Herring Cove, NS B3V1G8 CAN

The application of Best Available Technology/Techniques (BAT) and Best Environmental Practice (BEP) is required under several international conventions. For shipping noise, this includes minimizing cavitation by, e.g., better maintenance and optimizing the propeller design to the hull and to usual operating conditions, which often improves efficiency as well. Focusing quieting on the 10-15% of the noisiest ships will go furthest in reducing overall shipping noise. Slow steaming, or reducing ship speed, from an average of 16 kts to 14 kts (12% speed reduction) as was done in the Mediterranean, probably reduced the overall broadband acoustic footprint by over 50%. No retrofitting is required, and greenhouse gas emissions are reduced. For seismic airgun surveys, quieting technologies, such as Marine Vibroseis, that could replace airguns show the most promise, as much of the energy (the mid- or high-frequencies) emitted by airguns is wasted and unused. A controlled sound source, like Marine Vibroseis, tailor-made to the specific environmental conditions and without the damaging sharp rise time of airguns would also likely be more environmentally friendly. Mitigation measures for airgun surveys should show proof of their efficacy and should include: avoiding sensitive areas and times and not proceeding in conditions of poor visibility such as at night. Quieting technologies would almost certainly require much fewer mitigation measures. Many new quieting technologies and alternative low-noise foundations have been developed for pile driving, mainly due to the German government's noise limit. The great variety of quieting technologies and noise abatement systems for pile driving is in stark contrast to the lack of innovation that is occurring for quieter alternatives to the seismic airgun, where, for instance, MV has been in development since 2008, yet little progress is evident. At least 150 marine species have shown documented impacts from ocean noise pollution, but it has been difficult to specify the exact scenarios where ecosystem and population consequences from underwater noise will occur. Therefore, managing this threat requires a precautionary approach. Application of quieting technologies that reduce sound at source will likely be the most effective way to reduce the environmental impacts of underwater noise, and quieting methods that also reduce greenhouse gas emissions or encourage technological innovation should be especially encouraged.

THE OFFSHORE WIND ENVIRONMENTAL EVIDENCE REGISTER (OWEER): A NEW TOOL FOR CATALOGUING AND ASSESSING KEY EVIDENCE GAPS IN ENVIRONMENTAL RESEARCH IN OFFSHORE WIND

Mogensen, L

Lisa Mogensen
lisa.mogensen@jncc.gov.uk
JNCC
Joint Nature Conservation Committee, Quay House, 2 East Station Road, Fletton Quays, Peterborough, PE2 8YY

The Crown Estate, Defra and JNCC have recently published the fourth version of the UK's Offshore Wind Environmental Evidence Register (OWEER1). The register aims to act as a publicly available register of prioritised strategic evidence gaps and current research projects relating to offshore wind developments relating to four receptor groups: fish, ornithology, benthic and marine mammals. The purpose of this register is to act as a live resource to increase understanding and raise awareness of current research, as well as enable debate, discussion and improved consideration for the environment in the industry. The register has been populated by requesting information from a wide range of stakeholders in the offshore wind industry, including academia, developers, statutory bodies, charities, and other research organisations. The register is expanding internationally but is currently predominantly UK focussed. A steering group consisting of UK Statutory Nature Conservation Bodies (SNCBs) has been directing the format and content of the OWEER throughout. Along with general environmental evidence gaps, the register acts as a log of gaps on the effects of underwater noise on marine mammals, fish and benthic organisms. Each gap details species and receptors, recommended research, and estimated cost and time needed to fill it. All gaps have been prioritised based on urgency by a scoring process agreed with the steering group. The register also details current underwater noise-based research projects (predominantly UK based), and research into related mitigation and guidance for all the receptor groups covered. All entries in the register can be filtered and searched for topics and species of interest. This register acts as a central portal of information, but also intends to contribute to reducing consenting risk and to help facilitate expansion of offshore wind energy to meet the UKs ambitious energy and net zero goals. The OWEER can be used to ensure there is no duplication of research effort, and can assist with prioritising environmental research funding to areas with most urgency. More widely, it is hoped the OWEER can foster collaboration both in the UK and internationally and can act as a database for those working in underwater noise and offshore wind industries.

1TCE, Defra, JNCC (2021) Offshore wind environmental evidence register (OWEER) V4. Available from: https://www.marinedataexchange.co.uk/details/3480/2021-jncc-offshore-wind-evidence-and-change-programme-offshore-wind-environmental-evidence-register-/summary [Accessed 31st March 2024]

PILING NOISE AND CETACEAN PROTECTION IN OFFSHORE WIND FARM DEVELOPMENT, TAIWAN

Lee, PY; Chen YY

Pey-Yi Lee
peterlee@mail.ntou.edu.tw
National Taiwan Ocean University
2 Beining Rd, Keelung City, Taiwan,

Offshore wind farm is important for 2050 zero emission. However, protect marine ecosystems is also important. Therefore, regulations and guidelines are necessary for foundation piling of wind turbine. The guideline in Taiwan is that the noise cannot over 160 dB re 1 uPa2s SEL and 190 dB re 1 uPa SPL at 750m from the source point of noise. Based on this, the noise level could be 3.5, 7.5, 16, and 75km for 150, 145, 140, and 130 dB re 1 uPa2s SEL respectively. These circular areas were overlaid with cetacean distributions and illustrate the disturbance to two endangered cetacean species in Taiwan. We suggest to classify the wind field into north, middle, and south, and developing them in regional order to constrain the noise effects and provide refuge areas.

A LOT OF PRESSURE? THE COPEPOD ACARTIA SP. IS MORE SENSITIVE TO A RAPID PRESSURE DROP THAT OCCURS CLOSE TO SEISMIC AIRGUNS THAN CALANUS SP.

Vereide, EH; Khodabandeloo, B; de Jong, K

Emilie Hernes Vereide
emilie.hernes.vereide@hi.no
Institute of Marine Research, Bergen (NO)
Nykirkekaien 1, NO-5004 Bergen, Norway

Airguns used in seismic surveys emit low-frequency sound waves and generate acoustic waves by the sudden release of high-pressure air, which can negatively affect marine life. Much of what is known about the effects of seismic exposure comes from studies on marine mammals and fish, but knowledge of its effects on zooplankton is limited. Therefore, there is an urgent need to explore the underlying mechanisms that may cause damage in these animals. One of the main characteristics of a seismic signal that could cause damage is a rapid pressure drop. Using a new and easily operated pressure tube, we re-created a rapid pressure drop in the laboratory. The effects of this pressure drop on mortality and swimming behavior were tested in two common copepod species, Acartia tonsa and Calanus finmarchicus. In addition, the response of a microbubble subjected to pressure variations in the tube was modelled using dynamic bubble equations, to assess whether microbubble expansion could be excluded as a cause of damage. Mortality in pressure-exposed Acartia sp. was higher than that in the control treatment; however, no effects on mortality were detected in Calanus sp. Furthermore, the mean swimming speed of pressure-exposed Acartia sp. was lower than in the control groups, both immediately and 5 h after treatment. In Calanus sp., the mean swimming speed did not differ between treatments immediately after exposure but did significantly differ between the treatments 5 h after the treatment. The modelling results indicate that microbubble expansion did not occur in this experiment. The results of this study show that a pressure drop can negatively affect zooplankton mortality and behavior. This mechanism may at least partly explain the negative effects of seismic sounds on zooplankton. In addition, these results suggest that Acartia sp. is more sensitive to a pressure drop than Calanus sp., which may be related to size. Thus, this study provides a first documentation and potential explanation of species-specific responses to seismic sounds in zooplankton. Understanding the mechanisms behind (species-specific) effects may help predict the impact of seismic surveys on field populations and inform management as to which species are most sensitive to seismic surveys.

COMPARING THE EFFECTS OF NOVEL MARINE VIBRATOR TECHNOLOGY TO CONVENTIONAL AIRGUNS ON THE BEHAVIOUR OF WILD, SPAWNING COD

Sivle, L.D., McQueen, K., Forland, T., deJong, K., Kvadsheim, P.

Lise Doksaeter Sivle
lisedo@hi.no
Insitute of Marine Research
Postboks 1870 Nordnes, No-5817 Bergen

Much work has been done in recent years to produce alternative sound sources to air guns for use in geophysical surveys. Marine vibrators (MV) are being developed to have a reduced environmental impact due to reduced peak sound pressure, and with reduced output at frequencies > 150 Hz. However, instead of producing an impulse e.g. every 10 sec, a MV may transmit continuously, leaving no room for marine animals to dip-listen between pulses, and to produce relevant sounds themselves. Thus, MV may increase risk of masking. A better understanding of potential impacts of these novel sources are therefore needed, in particular for fish that have their best hearing at the frequencies transmitted. In this study, we tested behavioural responses and vocalization in spawning cod exposed to continuous signals from a a novel MV source and impulses from conventional air-guns at the same sound exposure level Cod behaviour was studied using acoustic telemetry, tracking the movements of tagged fish in time and space. Cod vocalisations were recorded by hydrophones in the spawning area. A marine vibrator (MV) was deployed at the spawning ground, exposing cod to continuous, low frequency sound over a 5-day period. A similar exposure was conducted in the same area the previous 2 years with air guns. This allows for a direct comparison between how air guns and a marine vibrator affect fish behaviour at a sound exposure level relevant for a sound source at a distance of 5-40 km away, representing the sound levels that many fish will be exposed to over a wide range and long period during a geophysical survey. Preliminary results indicate that neither air guns nor MV cause cod to abandon their spawning ground. However, there are indications that some finer scale behavioural changes occurred in response to the MV exposure, including a reduction in acceleration rates and an increase in swimming depth. A slight increase in swimming depth in response to air guns was observed in the previous experiments. Impacts on fish communication may also occur. To our knowledge, this is the first ever experimental exposure of fish to a marine vibrator. Results will help managers to regulate the operations of such novel sources.

ZOOPLANKTON SWIMMING BEHAVIOR DURING REAL-LIFE SEISMIC SURVEY AIRGUN BLASTS

Kühn, S; Vereide, EH; Utne-Palm, AC; deJong, K; Heubel,K

Saskia Kühn
kuehn@ftz-west.uni-kiel.de
Coastal Ecology, Research and Technology Centre West Coast, Kiel University, Germany
Hafentörn 1, 25761 Büsum, Germany

Impulsive underwater noise from airgun blasts used in seismic exploration can be detrimental to marine life. However, little and conflicting data exist on how airgun blasts affect zooplankton despite their crucial role in marine food webs linking phytoplankton to higher trophic levels. Effects of seismic sound on zooplankton (ZoopSeis) is a project led by the Institute of Marine Research (Bergen, Norway), aiming at understanding possible effects of seismic surveys on zooplankton. In May 2022, a team of scientists investigated at what distance (1500 to 50 m) from a regular North Sea seismic exploration the immediate and delayed mortality and behavior of zooplankton was affected. This investigation was conducted in a real seismic survey at an oil-installation site in the North Sea. Here we present the results from the behavioral studies conducted during this exploration. We exposed adult Calanus finmarchicus to real-time seismic airgun blasts by deploying a zooplankton cage from a research ship during a passage of a seismic vessel that was shooting seismic on its transect line. The cage was equipped with a stereo camera set-up allowing to track individual copepod swimming behavior. To compare the swimming behavior between treatments, we induced swarming behavior using underwater light. Individual copepod swimming behavior was analyzed before, during, and after blasts from the seismic vessel during the passage. We hypothesized that airgun blasts would alter the swimming behavior of C. finmarchicus. We predicted that the animals would either be visually stunned (moveless) by instantaneous pressure changes or elicit stress-related behaviors, such as tail flips (escape behavior). Our preliminary results show increased swimming speeds and tail-flip events in C. finmarchicus, during and after airgun blasts compared to control groups (no seismic airgun). We further discuss in what spatial scale copepods are likely of being behavioral affected by airgun blasts. In addition, this study presents a novel method to study behavioral effects of noise on pelagic copepods in the field.

ASSESSING EFFECTS OF SEISMIC SURVEYS ON MARINE LIFE IN SOUTH AFRICAN WATERS

Kirkman, SP; Hlati, K; Huggett, J; Lamont, T

Steve Kirkman
SKirkman@dffe.gov.za
Department of Forestry Fisheries and Environment
Foreshore, Cape town, South Africa

Opposition to offshore oil and gas exploration recently surfaced in South Africa. This appears to be based on concern about fossil fuel extraction from a climate change perspective; concern about risk of upstream petroleum activities to marine ecosystems; and concern about impacts of exploration activities, especially seismic surveys, on marine life and people's livelihoods. Numerous international papers have documented effects or potential effects of seismic emissions on different groups of marine fauna, based on laboratory studies, field studies, or modelling. For some faunal groups such as plankton and fish, there are conflicting findings for the impacts of seismic emissions, such as mortality or behavioural shifts with potential life history consequences, respectively. Few studies have concluded a clear effect of seismic surveys on marine life, although in some cases it has been difficult to exclude seismic surveys as a possible cause to anomalous events. Seismic surveys in South African waters were commomplace for over three decades prior to the highly publicised exploration that was recently proposed for the Wild Coast but was subsequently suspended following a court interdict. There is a need to interrogate historical seismic survey data against relevant biological time series (e.g. fisheries survey or catch data, strandings data), to test if there is any relationship. The need has also been identified for foundational science to investigate the effects of seismic surveys in the context of South Africa's coastal and oceanic environments and unique biodiversity. Thus, a science plan has been developed comprising several interlinked areas of research, including mapping, investigating physical characteristics of seismic noise, effects on marine organisms and fisheries, and effects on people in coastal communities. The research is intended to inform policy on seismic surveys, and to develop standards and guidelines, including appropriate mitigation and monitoring measures.

A YEAR WITHIN THE ARCTIC MARINE SOUNDSCAPE NEAR CAMBRIDGE BAY, NUNAVUT - IMPORTANT GATEWAY FOR SHIP TRAFFIC PASSING THROUGH THE NORTHWEST PASSAGE

Heimrich, AF; Halliday, WD; Juanes, F

Annika Heimrich
annikaheimrich@uvic.ca
University of Victoria, Canada & WCS Canada
5-714 Esquimalt Road, V9A 3L8 Victoria, BC Canada

The Arctic Ocean is an important ecosystem, providing either temporary or long-term habitat for numerous migrating and resident marine species every year. Historically, the Arctic Ocean has had less noise disturbance from anthropogenic activities than other marine areas, due to much less ship traffic and the dampening effects of sea ice. However, as climate change is causing longer ice-free periods during summer, increasing ship traffic within the Arctic is leading to elevated underwater noise levels. Since the underwater soundscape is a crucial habitat feature for marine organisms, it is important to monitor this environment. This study will present the first year-round soundscape analysis of passive acoustic data collected between August 2017 and October 2018 in the Kitikmeot Region of Nunavut, Canada. Acoustic data were analysed for marine mammal and fish vocal presence, with a strong focus on potential overlap between marine animals and ships during the shipping season (August-October). Ringed seal (Pusa hispida) and fish vocalizations were present consistently throughout the year, whereas bearded seal (Erignathus barbatus) vocalizations were present between October and August with a peak during their breeding season. Underwater sound levels were strongly driven by wind speed, sea ice concentration, and ship noise; however, ship noise only occurred between August and October. Our findings suggest that ringed seals are exposed to high amounts of ship noise, raising further concern for a species listed as of Special Concern in Canada (COSEWIC 2019). This study presents the first long-term passive acoustic measurements in the Kitikmeot Region and can be used as baseline for future studies on underwater noise within this region.

TIME TO TALK. A CASE FOR INCLUDING BEHAVIOURAL COMPLEXITY INTO MANAGEMENT.

de Jong, K; Picciulin, M; Andersson, M; Sivle, LD; Amorim, MCP

Karen de Jong
karen.de.jong@hi.no
Institute of Marine Research, Bergen, Norway
Nordnesgate 50

Behavioural responses are complex and variable and therefore often hard to accommodate in management decisions. Current underwater noise management is moving towards an approach where overlap in time and space with species distribution and/or habitats is crucial. This is a valuable approach compared to single exceedance levels. Here we argue that we could take this approach one step further by including the time-scale of relevant behaviours into account. To test this hypothesis we review the effects of different sound types on fish communication in published literature. In addition, we present data from two separate unpublished studies testing the effects of two different sound types (seismic and boat noise) on communication in Atlantic cod. We will discuss the results in terms of how the time-scale of behavioural responses could be integrated in current management approaches.

BEHAVIORAL RESPONSES OF CUVIER'S BEAKED WHALES TO SIMULATED MILITARY SONAR

Brandon Southall

Brandon Southall
Brandon.Southall@sea-inc.net
Southall Environmental Associates; Duke University Marine Laboratory
9099 Soquel Drive, Suite 8, Aptos CA USA 95003

We conducted nine controlled exposure experiments (CEEs) using simulated navy mid-frequency (3-5 kHz) active sonar (MFAS) and four control (known MFAS absence) with tagged Cuvier's beaked whales (Ziphius cavirostris) off Cape Hatteras, NC, USA. During CEEs, three individuals were tagged with high-resolution, short-term movement and acoustic tags (DTAGs) and 43 individuals were tagged with lower-resolution, longer-term movement and dive satellite-transmitting tags. A total of 69 unique exposure-response events occurred during CEEs with and without MFAS. For focal individuals, MFAS received levels (RLs) were experimentally controlled between 110-140 dB (RMS) re: 1μPa at ranges of between 1-10 nm from an experimental vertical line array source transmitted at 212 dB. Incidentally exposed (non-focal tagged) whales were tracked over comparable to much greater ranges (up to > 100 nm). Response analyses using existing and novel time-series statistical methods were applied to quantify individual behavioral changes during MFAS relative to baseline conditions. Responses during and following CEEs included horizontal avoidance of the CEE area, changes in diving behavior, and initial observations of changes in beaked whale social interactions following sonar exposure. As the largest such dataset with known and controlled MFAS exposure obtained to date for beaked whales, results will contribute substantially to probabilistic exposure risk functions for these sensitive species and provide important contrasts for analysis of a similarly large sample of tagged beaked whales exposed to operational Navy sonar in an ongoing study in the same region.

EFFECTS OF ANTHROPOGENIC NOISE AND NATURAL SOUNDSCAPE ON LARVAL FISH BEHAVIOR IN FOUR ESTUARINE SPECIES

Waddell, EE; Širovi?, A

Emily Waddell
ewaddell@tamu.edu
Texas A&M University at Galveston
P.O. Box 1675 Galveston, Texas 77553, USA

Soundscape ecology and larval settlement and orientation triggered by acoustic cues have become widely studied recently. Larval and post-larval forms of many marine organisms, such as multiple species of oyster, crab, lobster, coral, and fish, rely on acoustic cues to orient, settle, or metamorphose. Anthropogenic noises can interrupt those processes in reef fishes, but their impact on a large variety of species is not known. In this study, we examined the effect of anthropogenic and ambient sounds on the orientation behavior of four larval estuarine fishes. Lab-reared, pre-settlement size larvae of red drum Sciaenops ocellatus, southern flounder Paralichthys lethostigma, spotted seatrout Cynoscion nebulosus, and Florida blenny Chasmodes saburrae were individually placed inside an acoustic chamber and exposed to one of four sound treatments—seismic airgun, ship propeller, estuarine soundscape, and control—for six minutes. Both anthropogenic noises caused a significant ($p<0.05$) avoidance behavior in at least one of the four species of larval fish. Red drum, southern flounder, and spotted seatrout initially (first minute) avoided the actively playing speaker when airgun noise played, but avoidance became non-significant as exposure time increased. All species spent less time, on average, near the active speaker when ship noise played for the first minute, three minutes, and full six-minute exposure period, but it was only significant for spotted seatrout for the first three minutes. None of the species were significantly attracted to the ambient estuarine sound. These results indicate that different species react differently to anthropogenic sounds and that larval fish can potentially habituate to anthropogenic noise in less than 10 minutes. Understanding behavioral responses to various sounds is important because proper settlement ensures an organism’s survival, which ultimately affects the population and its success.

NOISE-INDUCED VOCAL PLASTICITY IN HARBOUR SEAL PUPS

Torres Borda, Jadoul, Rasilo, Salazar Casals,...

Andrea Ravignani
andrea.ravignani@mpi.nl
Comparative Bioacoustics Group, Max Planck Inst.
Wundtlaan 1, 6525 XD Nijmegen, The Netherlands

Vocal plasticity can occur in response to environmental and biological factors, including conspecifics' vocalizations and noise. Pinnipeds are one of the few mammalian groups capable of vocal learning, and are therefore relevant to understanding the evolution of vocal plasticity in humans and other animals. Here, we investigate the vocal plasticity of harbour seals (Phoca vitulina), a species with vocal learning abilities observed in adulthood but not puppyhood. To evaluate early mammalian vocal development, we tested 1–3 weeks-old seal pups. We tailored noise playbacks to this species and age to induce seal pups to shift their fundamental frequency (f0), rather than adapt call amplitude or temporal characteristics. We exposed individual pups to low- and high-intensity bandpass-filtered noise, which spanned—and masked—their typical range of f0; simultaneously, we recorded pups' spontaneous calls. Unlike most mammals, pups modified their vocalizations by lowering their f0 in response to increased noise. This modulation was precise and adapted to the particular experimental manipulation of the noise condition. In addition, higher levels of noise induced less dispersion around the mean f0, suggesting that pups may have actively focused their phonatory efforts to target lower frequencies. Noise did not seem to affect call amplitude. However, one seal showed two characteristics of the Lombard effect known for human speech in noise: significant increase in call amplitude and flattening of spectral tilt. Our relatively low noise levels may have favoured f0modulation while inhibiting amplitude adjustments. This lowering of f0 is unusual, as most animals commonly display no such f0 shift. Our data represent a relatively rare case in mammalian neonates, and have implications for the evolution of vocal plasticity and vocal learning across species, including humans. Our results also have implications on how an aquatic mammal may temporary alter their communication in response to noise.

VESSEL NOISE EXPOSURE IMPACTS HARBOUR PORPOISE ENERGY BALANCE

Rojano-Doñate, L; Johnson, M; Madsen, PT

Laia Rojano-Doñate
laiard@ecos.au.dk
Aarhus University
C.F. Møllers Allé 3, 8000 Aarhus, Denmark

Harbour porpoises (Phocoena phocoena) live in coastal waters that face some of the highest shipping densities in the world. Studies suggest that moderate to high levels of vessel noise disrupt their behaviour, but it is not known how often such exposures occur, whether the response to vessel noise is context-dependent, nor the impact that noise-induced behavioural disruptions have on harbour porpoise energy balance (i.e., energy intake vs. expenditure). Here, we test the hypotheses that (i) responses to vessel noise are mediated by diel patterns in individual behaviour, and (ii) that vessel noise reduces net energy gain either by reducing foraging and/or by increased energy expenditure. Using 18 high-resolution sound and movement recording digital tag (DTAGs) deployments on wild porpoises (356 hours of data), we show that porpoises in the Kattegat and Belt Seas are on average exposed to 11 vessel passes (>90dB re 1µPa in the 16 kHz decidecade band) a day. Tagged porpoises during vessel-noise exposures decrease the number of prey-capture attempts (i.e., energy intake) by on average 33% during daytime and 17% during nighttime. Respiration rates (i.e., energy expenditure) also slightly decrease (2%) during daytime exposures, but increase by 4% during nighttime. Despite the higher relative decrease in foraging rate during daytime, the absolute effect of disturbance on the energy budget of the exposed harbour porpoises is bigger during nighttime, highlighting the importance of this diel period in acquiring energy, and denoting higher vulnerability to disturbance. Importantly, these noise-related changes in foraging and respiration rate have a cumulative impact on the energy balance of the exposed porpoises that reduces their daily net energy gain by ~5%. Unless compensated for by increased foraging, this deficit can have important energetic consequences for the growth, reproduction and survival of porpoise populations in industrial coastal areas. Direct measures of the associated energetic costs of exposure are critically needed for Population Consequence of Disturbance (PCoD) models linking disturbance parameters to fitness and population dynamics. Our results can thus inform the management of underwater noise levels and mitigation measures that will aid the conservation of wild populations of porpoises.

ENVIRONMENTAL INFLUENCES ON CALLING BEHAVIOUR OF MIDSHIPMAN FISH

Kok, ACM; Kim, EB; Rowell, TJ; Margolina, T; Joseph, JE; Peavey Reeves, LE; Hatch, LT; Baumann-Pickering, S

Annebelle Kok
a.c.m.kok@rug.nl
University of Groningen
Nijenborgh 7, 9747 AG Groningen, the Netherlands

Fish chorusing can dominate many ocean soundscapes. Environmental features can influence chorusing behaviour, as has been shown for other calling animals. Now, in the Anthropocene, the environment is changing at unprecedented rates, possibly affecting chorusing fish. We investigated how midshipman chorusing across two ocean basins was related to environmental features such as temperature, lunar period, and ambient noise level. As part of the SanctSound project, recordings were taken over a two-year period, from twelve different sites, two oceans (the Atlantic and Pacific), and two species of midshipman fish. Through a combination of manual and automated analysis we investigated links between the environment and chorus presence, peak frequency, and received level. Temperature and lunar period were strong drivers of chorusing behaviour, while there was no clear link between chorusing behaviour and ambient noise. These results show that interacting environmental conditions can affect chorusing of midshipman fish, giving clues how future changes in the environment will alter this dominant feature of ocean soundscapes.

MITIGATION MEASURES AS MEANS TO MINIMIZE THE EFFECTS OF OCEAN NOISE: CONSIDERING THE FULL RANGE OF OPTIONS

Macrander, AM; Martin, B

A. Michael Macrander
mmacrander@integral-corp.com
Integral Consulting Company
2712 78th Avenue Ct. NW, Gig Harbor, WA, USA 98335

Mitigation refers to the implementation of measures utilized to minimize the potential for adverse environmental impacts that may have the potential to result from development related activities. Given the real and possible effects of sound producing activities in the marine environment, mitigation measures are often identified and required as a part of the regulatory review and permitting processes. Mitigation measures are frequently required by regulators and are often linked with monitoring requirements that may serve as triggers for implementation of additional mitigation measures. Many of these monitoring/mitigation combinations have become standard procedures that are broadly adopted and implemented to get marine operations permitted and accomplished. In cases of threatened or endangered populations the monitoring and mitigation requirements have tended to increase over time, increasing their cost and complexity. Beyond noise in the oceans, the concept of mitigation of known, or potential, effects is well established across a broad array of regulatory and conservation practices. The broad hierarchy of Avoid – Minimize – Compensate establishes a clear preference, while also recognizing that alternative measures may, at times, be the preferred option(s). A more complete articulation of mitigation options under US-NEPA includes: (1) Avoiding the impact altogether by not taking a certain action or parts of an action; (2) Minimizing impacts by limiting the degree or magnitude of the action and its implementation; (3) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; (5) Compensating for the impact by replacing or providing substitute resources or environments. In determining the proper balance between preferred mitigations, factors such as perceived intensity of effects, real or perceived efficacy of mitigations, and relative cost/benefits of alternatives are typically considered. In some cases, tools have been developed to aid in the balancing of mitigation to effects, occasionally going so far as to establish exchange rates and balancing potential "debits" against "credits." In some cases, the concept of conservation credits and exchange are quite mature and afford parties to focus mitigation measures where they have the capacity to increase resource recovery, while, at the same time, reducing overall mitigation costs and impacts on development.

MITIGATION AND MONITORING FOR OFFSHORE WIND: INDUSTRY PERSPECTIVES

Morse, L

Laura Morse
laurajmorse@yahoo.com
N/A
44 Deer Pond Rd, East Falmouth MA 02536

The Intergovernmental Panel on Climate Change's latest report highlights the critical need to limit global warming to 1.5 C. A rapid reduction in greenhouse gas emissions is essential to achieving this target. The offshore wind industry has been identified as a substantial contributor to the energy transition that would make such emission reductions possible while continuing meet energy demands to support growth and prosperity. Many countries have set robust targets to achieve rapid offshore wind buildout. Alongside this global demand, the wind industry takes seriously its approach to responsible development and operations in the marine environment. Many companies have established net positive biodiversity targets. In accelerating build out, the industry must also lower the cost of energy to rate payers while ensuring a profitable build. Balancing all these necessary targets is a challenge but it is essential we do so to meet the necessary GHG emission reductions globally. To achieve these goals company's place significant emphasis on tools for mitigating and monitoring impacts to protected species, while also balancing the need for efficient and practicable build. The offshore wind industry's experience to date is primarily in Europe but, as the companies shifts to a more global portfolio, activities are overlapping with species not previously encountered. Development activities in the US serve as an example of the challenges and opportunities that lie ahead for the renewable energy sector. In the U.S. Atlantic waters, the North Atlantic Right whale (NARW) (Eubalaena glacialis) is of significant concern. Listed as endangered, NARW's are at a critical juncture. Recent estimates place the total population at ~340 and declining. Recognizing the risks this population faces and our role as responsible energy developers, the wind industry is taking an approach that aligns with corporate sustainability programs alongside and in addition to the regulatory requirements in the US. The industry is focusing on developing and adapting technologically innovative and verifiable solutions to mitigate and monitor the effects that may result from development activities in a practical manner. Solutions being considered includes deployment of noise mitigation technology and utilization of real-time visual and acoustic detection systems integrated with data collection software that can be networked across multiple vessels in real time. This data sharing and integration substantially increases the collective situational awareness of protected species in the area of operations, allowing for adaptive mitigation that will optimize development that ultimately benefits the ecosystem.

MARINE MAMMAL RISK MITIGATION STRATEGIES FOR THE CANADIAN ARMED FORCES

Rideout, BP; Binder, C; Thomson, DJ; Ressor, C

Craig Ressor
brendan.rideout@forces.gc.ca
Defence Research and Development Canada
9 Grove St., Dartmouth Nova Scotia, Canada, B2Y3Z7

Active sonar training and testing is necessary to ensure well-trained, combat-ready maritime forces. These activities must take place in representative environments to provide value to ocean-going combat forces, thus constraining where they can take place. Timely insight on marine mammal presence near sonar activities can be used to reduce the risk of harm to these organisms. A proposed marine mammal risk mitigation strategy for the Canadian Armed Forces employs a layered approach during sonar training whereby pre-exercise planning, and continuous monitoring during sonar transmissions, work to reduce the risk of harm at different stages of the exercise planning-to-execution process. This multi-faceted approach aims to select times and locations for sonar training and testing which avoids interaction with predicted habitat of vulnerable species and areas of high marine mammal density while monitoring for their presence during active sonar transmissions. This talk will describe recent enhancements to marine mammal risk mitigation approaches employed by the Canadian Armed Forces to provide actionable guidance to military decision makers at different stages which aims to reduce the impact of active sonar emissions on nearby marine mammals.

MANAGING NOISE IN A MARINE MAMMAL PROTECTED AREA USING AREA-TIME LIMITS

Mendes, S

Sonia Mendes
sonia.mendes@jncc.gov.uk
JNCC, Joint Nature Conservation Committee
Inverdee House, Baxter Street, Aberdeen

For the last three years, area-time limits to underwater impulsive noise disturbance have been employed in a marine protected site for harbour porpoise in UK waters. The site was protected due to its persistently high densities of the species, presumably owing to habitat with optimal foraging. The site is however heavily industrialised and therefore a noisy area. Activities in and around the site include geophysical surveys, clearance of unexploded ordnance, and construction activities involving pile driving. Several windfarms have been constructed within the site and more are planned. UK nature conservation agencies produced guidance on how to undertake impact assessments and manage noisy operations to try to limit inevitable noise disturbance in order to maintain the site as a favourable habitat. The approach works equitably across regulated industries, as collectively the resulting disturbance needs to be kept within 20% of the site's area on any given day, and within 10% on average over a season. On certain years when limits were likely to be exceeded, measures were agreed between industry and regulators; these can include noise abatement techniques or alternative less noisy operations, scheduling to avoid temporal overlap with other operations occurring on the same day or season or to avoid higher porpoise density periods. Estimating in-combination exceedance of limits is not easy given the wide temporal envelopes of planned operations, sometimes with estimated durations of a few days but that could happen any time within the licence period, which could last months. In order to make this process easier, a new function is being developed within the UK Marine Noise Registry (MNR), a database recording information on when and where operations resulting in impulsive noise occur, for both past and future planned activities. A probabilistic, simulation-based approach is being trialled to predict the level of risk of exceeding the 10/20% limits. This should alert industry of periods during the year when there are likely already too many operations planned and periods where there is more certainty of headroom. The area-time management approach is not without its challenges but allows some level of activity to continue to take place in a busy protected area whilst limiting noise in time and space and therefore protecting porpoise habitats.

ADVANCING VESSEL TECHNOLOGIES TO CONTRIBUTE TO A QUIETER MARINE SOUNDSCAPE

Butko, A.; Nolet, V.; Trounce, K.; Gilroy, L.; Bae, C.; Davies, K.

Michelle Sanders
michelle.sanders@international.gc.ca
Transport Canada
330 Sparks St., Ottawa, ON K1A 0N8

The sound generated by vessel activity is recognized as an important threat to marine life. Surrounded by 3 oceans, Atlantic, Pacific and Arctic, Canada is home for many marine animals, including several endangered marine mammals, like the Southern Resident killer whales, the North Atlantic right whales and the St. Lawrence estuary beluga. As part of its commitment to reduce the acoustic and physical impacts of vessel activities on endangered marine mammals, Transport Canada launched the Quiet Vessel Initiative (QVI) in 2019, with a view to test and advance new vessel quieting technologies to reduce from source level noise generated by vessels. QVI contributed, and continues to contribute to advancements in the field of research and development by providing funding and support to Canada's Indigenous communities, academic consortia, not for profit organizations and industry, to: build capacity of local communities on understanding of underwater noise; test and implement effective quiet designs into new vessels being built; or testing new real-time technologies to detect marine mammals in busy shipping corridors. This presentation will discuss findings from QVI since its inception, and how these findings may translate into improvements for Canadian marine soundscapes. It will also provide a forward looking into what's next for the Initiative.

CAVITATION INCEPTION SPEED OF MERCHANT SHIPS: ANALYSIS AND DISCUSSION BASED ON DATA COLLECTED IN THE ECHO PROGRAM

Quijano, J.E.; MacGillivray, A.O.; Dolman, J.N.; Schuster, M.; Daniel, J.

Max Schuster
schuster@dw-sc.de
DW-ShipConsult GmbH
Lise-Meitner-STr. 9

Propeller cavitation has been identified as main source for underwater radiated noise of global merchant ship traffic. This physical phenomenon is highly speed-dependent: it occurs above a certain inception speed above which a steep increase over speed of radiated noise level is observed. Below cavitation inception speed (CIS), the speed-dependence of radiated noise levels is less pronounced, therefore ship operation just below CIS would be a reasonable operating condition for local noise reduction in sensitive habitats of marine mammals. To quantify CIS for typical merchant ships like container ships, tankers and bulkers as well as vehicle carriers, measurement data of the ECHO program was investigated. Individual ships of which measurements were available in a wide speed range were selected for automated analysis. Descriptors for identification of cavitation were developed and a subset of results was validated by manual analysis to assess significance of the automatically processed results. This talk outlines the analysis approach and discusses the results to draw conclusions on application of CIS as a basis for speed restrictions, taking into account economic impacts and navigational safety. The results will also be discussed with regards to ship design to identify possible approaches for manipulation of CIS by means of retrofits or considerations in future ship design.

SMALL REDUCTIONS IN CARGO VESSEL SPEED DRAMATICALLY REDUCE NOISE IMPACTS TO MARINE WILDLIFE

Findlay, CR; Rojano, L; Tougaard, J; Johnson, M; Madsen, PT

Charlotte Findlay
charlotte.findlay@bio.au.dk
Aarhus University
C.F. Møllers Allé 3, Building 1130, Aarhus C, 8000

Global reductions in underwater radiated noise (URN) levels from cargo vessels are needed to reduce increasing cumulative impacts on marine wildlife. Concern for the increasing and widespread impacts to marine wildlife, in particular marine mammals, from vessel noise have led regulators to take measures to reduce URN. Three general approaches have been proposed: (1) vessel slowdowns; (2) technological modifications; and (3) increasing the distance between vessels and animals. However, the efficacy of these mitigation measures at reducing impacts to marine wildlife has rarely been quantified. We used a vessel exposure simulation model to examine how reducing fixed pitch propeller vessel source levels through slowdowns and technological modifications, and increasing distance between animals and vessels, can lessen impacts on marine mammals. As the way URN affects animals remains unclear for many species, we used maximum received level, acoustic looming (i.e., peak rate of change in vessel received levels over time), and exposure duration (i.e., time over which vessel noise exceeds the ambient noise) as impact proxies. We show that the area exposed to ship noise reduces dramatically with moderate source level reductions that can be readily achieved with small reductions in speed. For example, a 10 dB reduction in source level results in 90% less area instantaneously exposed to URN from a fixed pitch propeller vessel. Vessel slowdowns are an effective way to reduce source levels: a 10 to 50% reduction in speed decreases source levels by 3 to 18 dB, due to URN scaling with the sixth power of speed regardless of frequency if speed is above the cavitation inception speed. Moreover, slowdowns reduce all impacts to marine mammals despite the longer time that a slower vessel takes to pass an animal. Reductions in noise effects can also be achieved by increasing the distance between vessels and animals, where possible, and by improving the design of the hull and propeller to reduce cavitation noise. We conclude that cumulative noise impacts from the global fleet can be reduced immediately by slowdowns. This solution requires no modification to ships and is scalable – from local speed reductions in sensitive areas to ocean basins. Speed reductions can be supplemented by routing vessels away from critical habitats and by technological modifications to reduce vessel noise.

VESSEL NOISE MITIGATION: A FOCUS ON ACHIEVABLE NOISE REDUCTION

Matthews, M-NR; Austin, M; MacGillivray, AO

Marie-Noël Matthews
Marie-Noel.Matthews@jasco.com
JASCO Applied Sciences (Canada) Ltd
68 Arnold Drive, Nepean, ON, Canada, K2H 6W3

In areas where marine traffic and endangered marine species overlap, the mitigation of vessel noise plays an important role in safeguarding the environment. While long-term reductions in radiated vessel noise can be achieved through engineering measures (e.g., through design initiatives put forward by the International Maritime Organization), immediate reductions can be achieved through operational measures. Promising operational measures for reducing vessel noise in critical habitat areas include slowdowns, route deviations, and convoying. Evaluating the efficacy of these mitigation options is challenging because one must account for their effects on noise emissions and for their impact on the animal's life functions (e.g., foraging, communication, and habitat use). The first step into studying the effectiveness of a mitigation option is to quantify the noise reduction that can be achieved in a specific marine environment. This presentation will discuss various mitigation options that have been modelled and the possible underwater noise reduction that they can achieve; the different metrics used in quantifying noise reduction will be discussed in the context of potential effects on marine mammals. The presentation will then focus on the noise reduction achieved with two mitigation options that have been modelled, applied, and monitored in Canadian waters: a slowdown zone at Swiftsure Bank and the use of convoys along a commercial shipping route at Baffin Island.

STRATEGIC APPROACHES TO MITIGATION: CROSS-SECTORAL PARTNERSHIPS TO ADDRESS PRIORITY ISSUES

Brandon Southall

Brandon Southall
Brandon.Southall@sea-inc.net
Southall Environmental Associates; California Ocean Alliance
9099 Soquel Drive, Suite 8, Aptos CA USA 95003

Potential human noise impacts on marine mammals have been recognized for over a half century, with now decades of increasingly fine-scale documentation of when and where various kinds of effects may (and may not) occur. As scientific documentation and understanding of noise exposure, response, and consequences have grown in detail, complexity, and taxonomic representation, so have management considerations and policy statements and declarations. As it is clear that potential negative impacts are highly species and context dependent, strategic approaches of identifying and prioritizing mitigation approaches are needed. Several current efforts to strategically identify, prioritize, and implement practical noise mitigation approaches will be considered. A common thread, and a key need for effective implementation and broader impact, is moving toward real and open cross-sectoral discussions and partnerships that are focused on actionable solutions with testable, demonstrable results.

SENSITIVITY OF ZOOPLANKTON TO NOISE: IMPAIRED FEEDING

Kühn, S; King, F; Hindenberg, L; Heubel, K

Katja Heubel
heubel@ftz-west.uni-kiel.de
Research and Technology Centre West Coast, Kiel University
Hafentoern1, D-25761 Buesum, Germany

Continuous anthropogenic underwater noise is threatening the marine life worldwide. Many studies focussed on the effects of noise on marine mammals and to a lesser extent on fish and invertebrates. For invertebrates, however, behavioural and physiological responses have been largely overlooked even though copepods are making up a major part of zooplankton that links phytoplankton to higher trophic levels. Within ORCHESTRA (ecOsystem Responses to Constant offsHorE Sound specTRA) we specifically investigate the effects of continuous underwater noise on planktonic predator-prey dynamics both in experimental laboratory and field setups and study feeding, anti-predator, and swarming behaviour of calanoid copepods. In addition to behavioural responses, also physiological responses and alterations in sensory abilities will be investigated. Here we present results of a first study on ingestion and clearance rates of the copepod Acartia tonsa on a motile phytoplankton as a function of prey density exposed to playback boat noise and under ambient control conditions. We hypothesized that noise alters feeding performance. Noise may mask hydromechanical cues of the prey, leading to lower capture rates or adversely affect physiology or morphology of the copepods' mechanosensoric structures that would lead to restrictions in the feeding performance. We measured significantly decreased feeding rates of A. tonsa when exposed to playback boat noise compared to ambient conditions, regardless of prey density. Under noise exposure, capture rates on phytoplankton were lowered while handling times remained the same as in the ambient control treatment as calculated fitting Rogers functional response equation. Using techniques of electron microscopy, we consequently investigate potential noise-induced damages and fusions on mechanosensory hairs of the antennae that may have altered the copepods' ability to orientate, sense, detect, and recognize prey items. In addition, we will elaborate and discuss scope, for upscaling experiments from initial laboratory setups into field conditions to translate laboratory results into noise driven community-effects and to predict the outcome for a changing world with multiple stressors.

PHYSIOLOGICAL AND BEHAVIOURAL EFFECTS OF EXPOSURE TO A COMMERCIAL SEISMIC SURVEY ON THE PALE OCTOPUS, OCTOPUS PALLIDUS

Day, RD; Birbeck, S; McCauley, RM; Semmens, JM

Ryan Day
ryan.day@utas.edu.au
University of Tasmania
Private Bag 49, Hobart TAS 7001

Marine seismic surveys use air guns to create intense, impulsive signals that penetrate over 10km into the seafloor in search of oil and gas deposits. Concerns have been raised over the potential for these low-frequency signals to harm marine invertebrates, with evidence of physiological and behavioural impacts reported in spiny lobsters and scallops. In this study, the effects of exposure to an 8,460 in3 array on the pale octopus were investigated following exposure along a line of a commercial survey. Male and brooding (i.e., caring for eggs) female octopus (n=320) were placed at nominal distances of 0m, 500, and 1000m to the seismic line to determine range of impacts. Exposure to the seismic array was intense, with max peak-peak signals of 222 dB re 1 µPa, cumulative SEL of 209 dB re 1 µPa, particle acceleration of 231 dB re 1 µms-2 and ground acceleration of 151 dB re 1 µms-2 at the closest range. Exposure did not cause mortality in any of the treatments. Exposed eggs showed some developmental delays. Compared to control octopus, which were located in the turning radius of the vessel where the air guns were not operating, exposure significantly reduced feeding, maternal care of eggs and "adventurous" behaviours, with impairment in the neurotransmitter regulating enzyme acetylcholinesterase a potential causative factor. The sensory system of octopus showed damage following exposure, with significantly increased damage to the statocysts. A safe operating range was not able to be defined, as some impacts were limited to close range whereas others affected all three treatments. These results offer further evidence that seismic surveys, and anthropogenic aquatic noise more broadly, have the capacity to harm marine invertebrates and require a better understanding to mitigate negative impacts.

AQUAVIB: A LABORATORY SETUP FOR EXPOSING AQUATIC ORGANISMS TO LOW-FREQUENCY SOUNDS. PRELIMINARY RESULTS FOR VARIOUS MARINE INVERTEBRATE SPECIES

Pla, P; Solé, M; van der Schaar, M; Vieitez, N; André, M

Pablo Pla
pablo.pla@upc.edu
Laboratory of Applied Bioacoustics, Universitat Poltècnica de Catalunya, BarcelonaTech (UPC)
Vilanova i la Geltrú, Barcelona, Spain.

Scientific awareness is rising towards sea invertebrates' sensitivity to the particle motion component of the sound field. Under the SATURN EU-funded interdisciplinary research project (grant agreement No. 101006443), researchers from the Universitat Politècnica de Catalunya, BarcelonaTech (UPC), have developed an experimental laboratory setup: the AquaVib. An interchangeable acoustic chamber equipped with sound pressure, particle acceleration, dissolved oxygen, and temperature sensors, capped at both ends by a pair of 1 kN-electrodynamic shakers, capable of reproducing low-frequency sound cues with characteristics similar to underwater radiated noise (URN) produced by human activity in aquatic environments, e.g. shipping, offshore installation of wind farms. The control in the relative phase between the pair of shakers in two different configurations, i.e. 0 and 180 degrees apart, permits the reproduction of a sound field where the energy contribution of either of its two main components, i.e. sound pressure and particle motion, significantly dominates over the other. Responses to controlled ship URN exposures on various marine invertebrate species (cephalopods, crustaceans and bivalves) related to each of the two sound field components were assessed. We present here preliminary results to show the effects on physiology based on respirometry measurements, ultrastuctural effects on statocysts assessed by Scanning Electron Microscopy, and effects on hatching and larva survival. The project is ongoing and final results in addition to proteomic analysis will help to establish a dose-response relationship with respect to ship URN exposures. The ultimate goal is to identify and quantify risks, and acute and long-term impacts on marine invertebrates directly linked to anthropogenic URN sources exposure, assessing acoustic pressure and particle motion effects separately..

STABILITY BETWEEN SOME AND DIFFERENCES BETWEEN OTHERS: WHICH FACTORS DRIVE CHANGES IN CALLING RHYTHMS IN SCIAENA UMBRA? A POTENTIAL INFLUENCE OF BOAT NOISE.

Picciulin M, Bolgan M, Burchardt LS

Marta Picciulin
marta.picciulin@gmail.com
CNR-National Research Council, ISMAR - Institute of Marine Sciences
Venice, Castello 2737/f

Sound production is an important communication modality that reflects several vital biological processes in many marine animals, including fish. The measurement and analysis of temporal features within single fish sound elements are routinely included in fish bioacoustics studies and such features have been proven to be affected by environmental conditions such as water temperature but can also be affected by human-made acoustic disturbances, as in the case of the brown meagre Sciaena umbra (fam. Sciaenidae) calls. A reliable methodology for the quantification of the temporal patterning along a sequence of elements (i.e. rhythms)has been recently developed, showing that S. umbra sounds have a simple isochronous—metronome-like— rhythm. So far however the geographical consistency of rhythmical properties in relation to different environmental conditions has never been investigated in any fish species. S. umbra calls have been recorded at four different study areas along the Mediterranean basin, characterized by different environmental conditions, i.e.. the highly anthropized Venice inlets (Italy), the highly touristic Palma Bay Marine Reserve (Mallorca, Spain), the urban marine protected area of Miramare (Trieste, Italy), and the Underwater Biotechnological Park of Crete (Greece). While calling rhythms appear stable between three of the locations, they significantly differ for Venice. Here we present a preliminary analysis to evaluate the consistency in the S. umbra isochronous rhythm in relation to the different range of environmental conditions and anthropogenic pressures characterizing the study areas.

INVESTIGATING NOISE-INDUCED PHYSIOLOGICAL STRESS, HEARING LOSS AND BEHAVIORAL DISRUPTION IN FISH

Raquel Vasconcelos

Raquel de Ornelas Vasconcelos
raquel.vasconcelos@usj.edu.mo
Institute of Science and Environment, University of Saint Joseph, Macau, S.A.R., China.

Although anthropogenic noise is known to cause physiological stress and hearing dysfunction in aquatic organisms, limited knowledge is available on the mechanisms underlying noise-induced hearing loss and the impact in early ontogeny in fish. Zebrafish (Danio rerio) has become an important vertebrate model for high-throughput screening of environmental stressors, including ototoxic drugs, and for studying genetic modulators of the inner ear development. My presentation will focus on my past research related to 1) characterization of the natural soundscape and captive noise conditions; 2) impact of noise on auditory sensitivity, inner morphology, and gene expression; and 3) noise-induced effects in early development. Field recordings from the species' natural soundscapes (in Southwest India) showed high diversity in spectral composition across different habitats with a quiet noise window matching with the species best hearing range. Contrastingly, artificial housing systems revealed significantly higher noise levels with potential to cause auditory masking/hearing loss. My group reported first baseline data of noise-induced hearing loss in zebrafish. Results revealed noise level-dependent auditory threshold shifts and sensory/structural recovery in adults. Furthermore, noise exposure also caused sensory loss, physiological stress (eg. higher cardiac rate and cortisol), and behavioral disturbance at the larval stage. Finally, our work provides first data on the interaction between noise and ageing effects in this model species. Current work focuses on the effects of acoustic stress on other freshwater species - the highly vocal and transparent cyprinid Danionella cerebrum; but also on marine fish such as gobies and marine medaka.

ASSESSING THE EFFECTS OF NOISE ACROSS SPATIAL AND TEMPORAL SCALES: FROM WHALES TO DIATOMS

Juanes F

Francis Juanes
juanes@uvic.ca
University of Victoria
Department of Biology, University of Victoria, Vic

Anthropogenic noise is a pervasive and prevalent component of aquatic soundscapes. It is becoming clear that such noise has widespread effects on aquatic organisms. However, it is very difficult to generalize across species or ecosystems because of the large differences in spatial and temporal scales. Some organisms, such as marine mammals are primarily studied in the field, but it is logistically difficult to track individuals or assess the source of noise disturbance. Fishes are more amenable to tank-based studies which although generally represent a smaller spatial scale, can permit long temporal scales. Fish mobility can be challenging in field studies, but nesting and burying fishes or those with small home ranges can be studied at relatively small scales. Finally, invertebrates are least studied; microscopic ones must be studied in the lab where controlled conditions are possible so that specific disturbances can be isolated. In this talk I while present emerging data to address these scale issues. At the largest scales our work on beluga and bowhead whales show distinctive and species-specific responses to vessel noise. New work will tag seals in the Arctic and use playbacks to analyze responses to noise. Our fish related work includes studies of midshipman, a nesting soniferous fish, and several species of rockfish, both of which were studied before during and after the recent pandemic, representing a natural experiment. Our current work on sand lance examines long-term effects of noise during the winter dormancy period. Finally, our recent work on zooplanktonic and biofouling species, including larval mussels, copepods, rotifers and diatoms is lab-based and shows complex responses to noise driving differences in biofilm thickness, larval feeding and settlement, and rotifer reproductive rates.

A MULTIMODAL, EVIDENCE-BASED APPROACH TO ASSESSING CETACEAN CENTRAL AUDITORY PATHWAYS IN THE CONTEXT OF ACOUSTIC TRAUMA— THE VENTRAL COCHLEAR NUCLEUS AS AN EXAMPLE.

Orekhova, K; Hof, PR; Centelleghe, C; Wicinski, B; Selmanovic, E; De Gasperi, R; Gama Sosa, M; Maloney, B; Di Guardo, G; Mazzariol, S

Ksenia Orekhova
ksenia.orekhova@phd.unipd.it
Department of Comparative Biomedicine and Food Science, University of Padova
Via dell'Università 16, 35020 Legnaro (Padova), Italy

The central nervous system (CNS) of cetaceans can be afflicted by infectious disease and overexposed to toxins, contaminants, and noise, triggering neurodegenerative processes that may cause stranding. The validation and quantification of immunohistochemical (IHC) markers of neuronal, glial, and extracellular matrix components can reflect neurodegeneration before the appearance of morphological changes. Neuronal connectivity may change following acoustic damage. While no biomarker is pathognomonic to noise overexposure, a multimodal, systematic approach and evaluation of techniques is necessary to find the most appropriate method. We investigated the bottlenose dolphin (Tursiops truncatus) ventral cochlear nucleus (VCN) using histology, immunohistochemistry, stereology against a subset of IHC markers and morphological neuronal subpopulations, and diffusion tensor imaging (DTI) based on 7-Tesla MRI scans. 33 antibodies associated with CNS pathology were tested, 11 of which were validated using immunohistochemistry, Western blot, and the basic linear alignment search tool. Apaf-1, ß-amyloid peptide, DGK-ζ, NF200, and Bcl-2 were assessed in 20 bottlenose dolphins using a Histoscore, and ß-amyloid peptide, TDP43, fibronectin, phosphorylated neurofilament protein, Iba-1, and GFAP were selected for stereological quantification in one dolphin using StereoInvestigator®. IHC patterns provided additional insight into the condition of the brain compared to routine histopathological analysis. Systematic-random sampling yielded reliable cell counts with coefficients of error (CEs) < 10% for most of the tested markers. Neuronal counts averaged at 316,379 for the VCN, but quantification of morphological subpopulations was limited by higher CEs. Immunoreactivity patterns of fibronectin in the dolphin resembled those of a human brain affected by chronic encephalopathy. Thus, neuroprotective protein expression to offset insults like hypoxia may constitute a noxious response in humans, while representing a physiological baseline in dolphins. This is further underlined by widespread intranuclear neuronal immunoreactivity of ß-amyloid peptide. DTI provided valuable information on VCN connectivity, but it remains a limited option for large-scale analyses due to high cost and logistical difficulties. Systematic biomarker validation and quantification enables an evidence-based approach to monitoring cetacean CNS health, assessing potential acoustic trauma, and translational modeling of human neurodegenerative disease.

CORRELATION BETWEEN PERMANENT NOISE-INDUCED HEARING LOSS AND COCHLEAR DAMAGE IN A HARBOR SEAL

Morell, M; Reichmuth, C; Rojas, L; Sills, J; Duignan, PJ; Siebert, U

Maria Morell
maria.morell@tiho-hannover.de
Institute for Terrestrial and Aquatic Wildlife Research, University of Veterinary Medicine Hannover
Werftstr. 6, 25761 Büsum, Germany

Anatomical insight into noise-induced hearing loss is essential for marine organisms. Correlations between inner ear damage and permanent hearing loss following noise exposure in the same individual are lacking and extremely difficult to obtain for stranded marine mammals. Animals in human care offer the opportunity to combine several techniques to study the auditory system and cases of hearing impairment in a controlled environment. Morphologic and auditory findings from a harbor seal (Phoca vitulina) with a known history of noise exposure over its lifetime are presented. The 32-year-old male seal had a noise-induced permanent threshold shift of at least 8 dB at 5.8 kHz, revealed through repeated behavioral testing. Cochlear analyses using complementary techniques confirmed bilateral auditory damage. Specifically, scanning electron microscopy of the right ear revealed focal sensory cell death involving both inner and outer hair cells from the three rows at 7.6 mm from the apex. This type of lesion is consistent with noise-induced hearing loss. In addition, there was loss of outer hair cells in the apex, as well as sparse loss of outer hair cells in some regions of the cochlea. Immunofluorescence labeling of the sensorineural epithelium in the left inner ear showed comparable findings. Combining morphological and auditory data is crucial to validate predictions of cochlear frequency maps based on morphological features. In addition, our study will improve understanding of how noise-induced hearing loss can be detected in stranding cases, where exposure conditions are unknown.

INVESTIGATING SENSITIVITY: A THREE-DIMENSIONAL RECONSTRUCTION OF STRIPED DOLPHIN'S EXTERNAL EAR CANAL NEURAL NETWORK

De Vreese, S; Luzzati, F; Fogli, M; Corona, C; Palmitessa, C; André, M; Mazzariol, S

Steffen De Vreese
steffen.de.vreese@upc.edu
Laboratory of Applied Bioacoustics, BarcelonaTech (UPC)
Rambla Exposició 1, Vilanova i la Geltrú

Cetaceans, including dolphins, have evolved unique mechanisms to detect sound waves, involving adaptations of structures such as the lower jaws and acoustic fat. While the external ear canal is not directly involved in hearing, it has also adapted to the underwater environment with changes in its morphofunctionality and the involvement of a complex circummeatal neural network with long and convoluted mechanoreceptors. However, the function, morphology, and sensitivity of these receptors to mechanical stimuli remain speculative due to the lack of three-dimensional (3D) studies. In this study, we aimed to reconstruct the complex neural network in a part of the ear canal in striped dolphins to investigate its sensitivity. We obtained postmortem samples of the ear canal from several wild stranded dolphins, which were fixed and processed for histological and immunohistochemical analyses. We used general and confocal microscopy to track the neural structures and their components with the objective to reconstruct them in 3D. The methods and results of the different staining methods were compared and discussed. The results of the two approaches highlight the methodological complexities of working with post-mortem samples from wild stranded animals and the biases and limitations that it generates. We present and discuss the protocols and show preliminary qualitative and quantitative morphological results of convoluted neuronal network of mechanoreceptors and small nerves, providing the 3D characteristics of the mechanoreceptors and its implications for the sensitivity of the ear canal. This study takes us one step closer to investigating the somatosensory sensitivity of the external ear canal as a sensory organ, as a prerequisite to creating biomechanical models of the mechanoreceptors inside a conjunction that is the peripheral hearing apparatus of cetaceans. The 3D reconstruction results provide a basis for further investigations into the function, morphology, and sensitivity of the complex neural network of the external ear canal in cetaceans. Further development will allow for using non-invasive approaches such as biomechanical modelling to study how these animals sense sound and other mechanical stimuli under changing environmental conditions.

TESTING THE IMPACT OF ANTROPOGENIC NOISE ON BEHAVIOR, REPRODUCTION AND TRANSGENERATIONAL EFFECTS IN MARINE MEDAKA (ORYZIAS MELASTIGMA)

Torrado, S; Ramos, A; Gordillo-Martinez, F; Gonçalvez, D; Vasconcelos, RO

Andreia Ramos
andreia.ramos@usj.edu.mo
University of Saint Joseph
Rua de Londres, Macau

Anthropogenic noise is currently recognized as a global environmental pollutant of marine habitats and adequate conservation and management strategies are urgently needed. Hence, it becomes critical to identify the types of anthropogenic noise that are most likely causing negative effects on marine organisms such as fishes. However, limited information is known on the effects of noise on fish reproduction and no information is available on potential transgenerational effects. Marine medaka (Oryzias melastigma) has been established as a model for ecotoxicology research. In this ongoing study, we exposed adult medaka to various noise conditions (shipping) and tested the effects on behavioral stress, fertility and F1 embryonic development. F1 larval fish were also exposed to the same environmental noise versus quiet conditions to test for parental effects. Our results point to noise-induced anxiety in adults exploring a novel environment, but results on reproduction and offspring are still under investigation. This work may provide a baseline understanding of the impact of human made noise on the wellbeing, fitness and the ultimate transgenerational consequences in a marine model.

THE NOISESOME: A TRANSCRIPTOMIC APPROACH OF THE DEUTERONOISE JPI-OCEANS CONSORTIUM TO UNDERSTAND HOW MARINE FOOD WEBS ARE AFFECTED BY NOISE CONTAMINATION.

R. Quintana, E; Ginovart-Panisello, G; Ferràndez-Roldán, A; M. Freixes, M; Vidaña-Vila, E; Martínez-Suquía, C; Arnela, M; Teaca, A; Spagnuolo, A; Ristoratore, F; Zambon, G; Chatzigeorgiou, M; Manni, L; Albalat, R; Alsina-Pagès, RM; Cañestro, C.

Eva Rodríguez Quintana
evarodriguezquintana@ub.edu
Departament de Genètica, Microbiologia i Estadística, Universitat de Barcelona
Avinguda Diagonal, 643, 08028 Barcelona

There is growing concern about the impact that noise from human activities might have on marine life and oceans health. To date, while most of the attention has been paid to the impact of noise in vertebrates (e.g. cetaceans, seals or fish), studies on invertebrates are scarce, and for this reason our knowledge on how noise affect marine trophic webs remains poorly understood. In this context, the DeuteroNoise JPI-Oceans consortium aims to characterize the impact of noise pollution on several species of invertebrates in selected basins across Europe (Italy, Norway, Spain and Romania). The interdisciplinary Barcelona-hub of this consortium made by the Human-Environment Research Group (La Salle-URL) and the EcoEvoDevoGenomeUB Group (University of Barcelona) are characterizing the noise sources, and modelling the soundscapes of different points of the coast of Barcelona, and we are using the zooplanktonic tunicate Oikopleura dioica as the animal model to study the impact of noise pollution of marine food webs. The different noise sources, characterized by means of their frequency, amplitude and duration, registered in the field are reproduced in the lab, and their impact on the biology of O. dioica are studied under control conditions. In addition to the study of impact of noise on behavioural, morphological and reproductive parameters, both in adults and embryos, one of our main focus is to discover all genes that are able to change their expression as an adaptive response to noise (the "noisesome"). To do so, we will perform transcriptomic and differential gene expression analyses in O. dioica that have been put under different conditions of noise. Then, field studies will be performed to validate the results of the characterization of the noisesome in the lab, and to test whether those genes could be used as biomarkers to infer the level of noise impact on different points of the coast with different degrees of acoustic contamination. Finally, a comparative analyses of our noisesome results will be performed with other invertebrates species analysed in the Deuteronoise consortium aiming to identify a conserved noisesome core that could be used as a panmarker of noise stress across many different marine animals to better understand the overall impact of noise on marine food webs and oceans health.

THE SATURN VIRTUAL RESEARCH ENVIRONMENT TOOLS FOR NOISE MITIGATION

Díaz, JA; Delory, E

José Antonio Díaz
jose.diaz@plocan.eu
PLOCAN
Telde, Gran Canaria. 35200. Spain

The SATURN consortium aims to work in harmony with the purpose to identify: a. The sounds that are most detrimental to aquatic species and how they are produced and propagated. b. The short-term and cumulative long-term negative impacts of noise from shipping and boats on three representative groups of aquatic species in rivers and the sea (invertebrates, fish and marine mammals). c. The most promising options for measuring and reducing the negative impacts of ship noise that can be applied to current and future vessels. SATURN will also develop and contribute to the establishment of standards for terminology and methodology to be used across all disciplines working on underwater radiated noise. The objective of the present work is to outline the main tools and methodologies of the SATURN virtual research environment (VRE) which aim to provide solutions and recommendations for underwater noise mitigation, while integrating the needs expressed by the user community. The SATURN VRE will foster use of data and data products, standardized methods, impact of URN on aquatic life, and solutions to decrease ship noise for usability beyond the project. The main objective of the SATURN Virtual Research Environment is to deliver a resource hub for researchers (bio-acousticians, biologists, marine R&D engineers…etc.) to access SATURN results in an interactive way. It will include an advanced housing of technical and analytical tools for processing, analysis and visualization of underwater noise from ships and boats produced by SATURN technical WPs. The environment will allow on-line collaborative experimentation with tools for acoustic signal processing and acoustic metrics relevant to the impact of underwater shipping noise on aquatic life. Data contributors to the VRE will comply with FAIR principles. From the stakeholder group, the task will focus on and engage with researchers interested in underwater noise mitigation and assessment, for requirements and pilot testing. The environment will be deployed and hosted by PLOCAN.

ORCHESTRA: ECOSYSTEM RESPONSES TO CONSTANT OFFSHORE SOUND SPECTRA

Boersma, M; de Jong, K; Bergamasco, K; Vezzi, A; Moens, T; and the ORCHESTRA consortium

Maarten Boersma
maarten.boersma@awi.de
Alfred-Wegener-Insititut Helmholtz-Zentrum für Polar- und Meeresforschung
PO Box 180, 27483 Helgoland, Germany

The increase of anthropogenic underwater noise (AUN) through oil exploitation, shipping and the construction and operation of offshore wind farms (OWF) has altered the marine acoustic environment significantly and is now a global challenge. AUN can harm a variety of taxa by impairing an individual's physiology directly, as well as interfere with fitness relevant behaviours such as communication, orientation, predator avoidance and foraging, all potentially leading to increased mortality and decreased reproduction. Benthic and planktonic invertebrates play a key role as a dynamic link between lower and higher trophic levels in the world's oceans. However, data on the effects of especially continuous AUN on these organisms are scarce, which impedes our predictive capabilities on the effects of AUN on ecosystem functioning and the services marine ecosystems provide. ORCHESTRA, funded within the JPI-Oceans framework on noise in the marine environment, combines interdisciplinary expertise on plankton and benthos, and underwater acoustics from six scientific institutions of four European countries. We aim to fill the knowledge gaps by conducting field studies across basins in order to compare behavioural and physiological impacts on invertebrate key species and communities. Combined with the field surveys, experiments will be carried out in a multiple stressor approach including AUN and warming scenarios, to allow cross-basin comparisons with different temperature regimes. Novel setups will be implemented in order to transfer AUN experiments from the laboratory into the field in order to test AUN effects under realistic conditions. The resulting data will be combined with information on local soundscapes and species abundances to identify in turn areas with the largest risks of being affected by AUN. Our results can be implemented in strategies for the mitigation of AUN impacts on marine ecosystem key species and communities and will contribute to the development of criteria and measures to reach Good Environmental Status in European waters.

DECREASED RESTING AND NURSING IN SHORT-FINNED PILOT WHALES WHEN EXPOSED TO LOUDER PETROL ENGINE NOISE OF A HYBRID WHALE WATCH VESSEL.

Arranz, P. Glarou, M., Sprogis, K.

Patricia Arranz
arranz@ull.edu.es
University of La Laguna, Dpto. Animal Biology.
c/ Los Saltos, 14. La Restinga El Hierro, Spain.

Vessel noise drives behavioural disturbance in cetaceans targeted during whale-watch activities. Despite the growing effort for implementing best-practice principles, currently there are no regulations on whale-watch vessel noise levels. We test the hypothesis that a whale-watch vessel with low noise emission engines will not elicit short-term behavioural responses in toothed whales compared to the same vessel with louder engines. We measured the behavioural responses of 36 resting mother and calves short-finned pilot whales (Globicephala macrorhynchus) to whale-watch vessel approaches (range 60 m, speed 1.5 knts). Treatment approaches with quieter electric engines (140-136 dB) compared to the same vessel operating with louder petrol (151-139 dB) engines (low-frequency – mid-frequency weighted source levels, re 1 μPa RMS@1m) were examined. During petrol engine treatments, the mother's resting time significantly decreased by 29 % compared to the control. The proportion of time nursing for the calf was significantly influenced by petrol engine vessel passes, with an 81 % decrease compared to the control. There were no significant effects on behaviour from the quieter electric engine. These results are consistent with behavioural changes in response to vessel noise leading to an increase of energy consumption by mothers and to a reduction in the energy gain by the calves. Moreover, these results demonstrate that different vessel noise levels can elicit different behavioural responses on cetaceans, even if operators comply with the current, national whale-watching guidelines. Thus, to minimise disturbance on the activity budget of pilot whales, the establishment of source level criteria of whale-watch vessels is recommended. Whale-watch vessels would ideally have source levels as low as possible, <150 dB re 1 μPa RMS@1m and perceived slightly above ambient noise. Lower vessel engine noise will benefit tourists seeking an eco-viewing opportunity, whilst reducing disturbance to cetaceans, ultimately assisting in the sustainability of the whale-watching tourism industry.