International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Cite this Book of Abstracts:
ICES. 2022. Theme Session A – Ecosystem science needed to support a new era of offshore marine renewable energy. ICES Annual Science Conference 2023, Bilbao, Spain.
https://doi.org/10.17895/ices.pub.24440752

Cite an abstract:
[Abstract authors]. 2023. [Abstract title]. CM 2023 /A: [CM code]. In: Theme Session A - Ecosystem science needed to support a new era of offshore marine renewable energy. ICES Annual Science Conference 2023, Bilbao, Spain. https://doi.org/10.17895/ices.pub.24440752

Theme session Report

Ecosystem science needed to support a new era of offshore marine renewable energy

Conveners: Jan Vanaverbeke (Belgium), Daniel Wood (UK), Andrew Lipsky (USA)

The Theme Session aimed at bringing together experts working within the ICES region to share experience and understanding of how offshore renewable energy installations affect both the marine ecosystem and society across large geographical areas and foster collaboration between researchers investigating individual aspects of offshore and marine renewable energy installations, which have commonalities regardless of location to facilitate future multidisciplinary and transboundary research and strategic monitoring programmes. Given the far-reaching consequences of the increasing scale, pace, and magnitude of offshore renewable energy installations for both the ecosystem and society, there is an urgent need for knowledge on ecosystem-wide effects of these developments. Scientific understanding is needed to inform cumulative impact assessments and evaluate socio-economic trade-offs of management decisions with regard to the installation of offshore renewable energy.

The abstract book for the session holds 47 abstracts, which were either presented orally during 2 time slots- September 12 from 3:30-6:00 pm and September 14 from 10:30-2:30 pm) or as posters. According to Whova between 130-136 participants attended these sessions. The session highlighted the diverse effects of increasing numbers of offshore wind installations on many components of the marine environment, both airborne (birds), in the water column (fish, invertebrates) and sediment, and traditional users of the sea. Many of these effects are investigated through monitoring ecosystem effects on the local scale, while there is increasing evidence from the modelling efforts that the installation of multiple offshore wind farms will result in changes in the organic matter distribution at larger geographical scales, as a result of changes in the biology physical oceanography (air-sea interactions, changes in stratification), which can cascade via the marine food web changes in higher trophic levels. While the contributions to the session highlighted the high scientific level within the ICES community of investigating effects of multiple pressures associated with marine offshore renewable energy devices on selected receptors, the way forward is clearly in (1) developing hypothesis-based research along cause-effect pathways to increase the general mechanistic understanding of how renewable energy installations affect (groups of) species and (2) integrate ecology, biology and oceanography in modelling exercises to assess the effects of multiple renewable energy installations on larger geographical areas.

The session revealed a second point of attention, as the proliferation of renewable energy devices will not only affect the marine ecosystem, but it will also directly and indirectly affect the ways on how society uses and manages the marine ecosystem. It becomes increasingly clear that the spatial occupancy of marine renewable energy installations will affect how fisheries will act in the future and therefore how these developments are accepted by society. There are increasing calls for co-location of offshore wind farms and food-provisioning marine activities (e.g., passive fisheries, aquaculture.) through a co-design of the licensed areas from an early planning stage onwards. These developments come with additional challenges for fisheries management with increasing evidence from Europe and North America that large-scale wind energy development (in addition to marine protection area establishment, can disrupt long-term fisheries independent surveys.

The discussion sections within the session highlighted that all of this is taking place against the backdrop of climate change. On the one hand the increasingly evident impacts of climate change emphasize the need for offshore renewable energy. At the same time climate change is compounding the challenges of ecosystem-based management as we see redistributions of receptors in response to warming oceans.

Conclusion

The session showed that there is a huge amount of knowledge and science within and around the ICES working groups. This information can feed into the Roadmap for Offshore Marine Renewable Energy that is currently being developed within ICES. At the same time, it also revealed that streamlining and coordinating the activities of the working groups within ICES is necessary to arrive at holistic science-based advice on how to assess the ecological and societal consequences of this emerging field of human activities. The industrialization of the oceans with renewable energy devices will affect and interact with nearly all aspects of ICES science. This creates challenges for ICES, but also great opportunities to continue to develop great science.

Contents

CM 37: Effect of cable generated electromagnetic fields on early-life stage development of marine species

Silvia Paoletti[1], Robin Brabant, Steven Degraer, Ilona Strammer, Peter Sigray, Niklas Rolleberg, Brian G. Stewart, Johan Aerts, Zoë L. Hutchison, Andrew B. Gill

Electromagnetic fields (EMF) generated from the infield and export power cables are not well understood in the context of effects on marine species and have raised concern with stakeholders. Such EMF are within the range of sensitivity of electro- and magneto-receptive species such as elasmobranchs, crustaceans, and cephalopods, whose conservation status may be comprised if EMF would be shown to disturb or disrupt their biology and/or detection of ecologically important cues. In this study, the effect of EMF on embryogenesis and early-life stage behaviour were investigated in the small spotted catshark (*Scyliorhinus canicula*), European squid and cuttlefish (*Loligo vulgaris* and *Sepia officinalis*), and European lobster (*Homarus gammarus*) through the exposure to realistic weak to intermediate (4-7 µT and 0.06-0.2 mV/m) subsea cable EMF intensities that these species may encounter. A unique, custom-made electrical cable setup was recreated in the laboratory able to generate homogeneous EMF intensities linearly across space and time. Exposed catsharks were observed to have smaller yolks and larger bodies at 18 weeks but displayed similar levels of measured stress compounds and predator avoidance behaviour to control specimens. Exposed squids were bigger at hatching and showed higher chromatophore reactivity than control specimens but exhibited normal swimming behaviour. No differences were visible between exposed and control cuttlefish. Lobsters tested in EMF environments were less efficient in finding shelter and walked longer and more tortuous pathways. Overall, in the presence of realistic intensities of AC cable EMF no acute nor lethal responses to EMF were observed and no statistically significant differences were detected between exposed and control animals. However, there were minor trends and signs of divergence when comparing treatment with control individuals for the catshark, squid and lobster, whilst cuttlefish appeared unaffected. Further investigations and longer-term studies are recommended to inquire on the biological meaningfulness and carry-over effects of the responses observed in early-life stages of marine species.

Keywords: electromagnetic fields, subsea power cable, embryogenesis, early-life stage, behaviour, Scyliorhinus canicula, Loligo vulgaris, Sepia officinalis, Homarus Gammarus

Affiliation: 1 - Royal Belgian Institute of Natural Sciences

Contact information: Silvia Paoletti, spaoletti@naturalsciences.be

CM 49: Electromagnetic fields monitoring and modelling of marine renewable energies

Alessandra Imperadore[1], Pedro A. Vinagre[1], Luis Amaral, Paulo Chainho, Enored Le Bourhis, Florian Tanguy, Laura Zubiate, Enric Villarin, Juan Bald

Recent legislative pieces worldwide demand the decarbonization of industries together with more sustainable use of natural resources to address climate change and global warming. Marine renewable energy (MRE), including offshore wind and ocean energy (e.g., wave, tidal) will play a key role in the transition from energy produced from fossil fuels to energy produced by natural resources. Accordingly, it is expected a rapid increase both in number and capacity of MRE installations to sustain the demand.

MRE installations have the potential to affect the marine environment by different means, for example through physical disturbance of the seafloor during construction activities and by noise and electromagnetic fields (EMF) generated by the devices during the operational phase.

Great uncertainty exists on real impacts from MRE installations, even from some stressors that are monitored frequently, for example underwater noise, and especially from stressors such as the EMF which are much less studied. Research on EMF (and other stressors) is particularly important considering the growth of the MRE sector and especially concerning the scaling up to commercial installations that may include several tenths of submarine cables (including interconnecting and exportation cables).

The European research projects *WESE – Wave Energy in Southern Europe* (2018-2021) and *SafeWAVE - Streamlining the assessment of environmental effects of wave energy* (2020-2023) were dedicated to non-technological barriers to the development of the wave energy sector including environmental monitoring and modelling, consenting, marine spatial planning, and public engagement.

Among other priority topics (as per the State of the Science report) of environmental research, these projects tackled the monitoring of EMF generated by different devices at distinct locations and the modelling of EMF concerning to the scaling up to arrays of those devices.

The aim of the present work is to report and compare the results obtained from monitoring and modelling during the above-mentioned projects and to assess the negative impacts potentially caused to marine fauna from EMF generated by MRE installations. Overall, the results obtained from monitoring surveys suggest little to no interference with marine fauna. Results from modelling, which allowed estimating EMF produced by the devices at rated power, evidence stronger EMF and indicate a potential for behavioural or physiological effects on animals, particularly in the vicinity of the submarine cables. Methodological constraints, lessons learnt and suggestions for future research on EMF are provided.

Keywords: electromagnetic fields, monitoring, modelling, marine renewable energy, environmental impacts, FEMM

Affiliation: 1 - WavEC – Offshore Renewable

Contact Information: Alessandra Imperadore, alessandra.imperadore@wavec.org | Pedro A. Vinagre, pedro.vinagere@wavec.org

CM 64: Monitoring demersal fish assemblages at the site of Norway's first offshore floating wind farm

Kate McQueen[1], Sofie Gundersen[1], Nils Roar Hareide[1,2], Gavin J. Macaulay[1], Anne Christine Utne-Palm[1], Maria Tenningen[1], Karen de Jong[1]

Floating offshore wind farms (FOWF) are a novel development, and there are currently minimal data available about their impacts on marine ecosystems. However, it is expected that both structure and disturbance from the turbines, including noise and electromagnetism, will impact marine animals. The first larger FOWF in the world is currently being constructed in the Norwegian part of the North Sea. This provides a unique opportunity to investigate the effects of this type of infrastructure on marine life.

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 FOWF. Baseline data on the local demersal fish assemblage around the FOWF site were collected from a 10-day survey in March 2022, immediately before construction began. Using a chartered commercial fishing vessel, 4 replicates of 8 gillnet fleets were set at increasing distances from the wind farm site, at 0 - 20 nmi. Fish sampling provided information on abundance and species richness, and biological information including maturity stages, stomach contents, and size. Echosounder transects were also conducted to map pelagic fish distribution in the area. This survey will be repeated in March 2023, now that some of the turbines are in place and have been operating for several months.

Results from the 2022 survey indicate that abundance and distribution of fish varied along the transect in relation to depth, as expected. The survey also confirmed proximity of spawning grounds for commercially important demersal fish to the FOWF site. The data from this survey are considered together with multiyear time-series of data collected from the surrounding area, available from fisheries-independent surveys and fisheries-dependent sampling. These complementary datasets, which capture patterns in species distributions and abundances at different temporal and spatial scales, will contribute to a comprehensive overview of the fish assemblage in this region before the construction of the FOWF. The data from the 2023 survey will reveal how the fine-scale spatial distribution of demersal fish may have changed since the placement and 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. Monitoring changes in fish assemblages is a key step towards understanding the impacts of FOWF on marine ecosystems.

Keywords: renewable energy, species composition, gadoids, elasmobranchs, gillnet

Affiliation:

[1]Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway

[2]Runde Environmental Centre, Rundavegen 237 6096 Runde, Norway

Contact Information: kate.mcqueen@hi.no

CM 113: Atlantic cod (*Gadus morhua*) larvae are attracted by low-frequency noise simulating that of operating offshore wind farms

Alessandro Cresci[1], Guosong Zhang, Caroline M.F. Durif, Torkel Larsen, Steve Shema, Anne Berit Skiftesvik, Howard I. Browman

The number and size of offshore wind facilities (OWFs) is increasing rapidly to meet the demand for renewable energy. When OWFs operate, they produce low-frequency noise at a higher intensity than that naturally present in the sea soundscape. This operational noise propagates from the source location, and potentially impacts fish and other marine organisms dispersing/migrating through the facilities. Any such impact would be relevant for larval stages, which have a limited ability to swim away from OW facilities. Whether directional movement of fish larvae at sea is impacted by low-frequency continuous sound is unknown. We applied a novel approach to investigate these questions that uses *in situ*-based experiments to assess the impacts of OWFs' low-frequency noise on the swimming, orientation of fish larvae of species that could be impacted by the large-scale wind farms. One of these species is the Atlantic cod (*Gadus morhua*), the larvae of which will drift through and in proximity of planned offshore wind facilities in the North Sea and along the Norwegian coast. Using cutting-edge technology, we observed the behavior of Atlantic cod larvae (N = 89) in response to low-frequency sound while they were free-swimming inside neutrally buoyant transparent chambers drifiting in a Norwegian fjord. We transmitted 100 Hz continuous sound in the fjord, in the intensity range of the operational noise produced by OW turbines, and measured the sound pressure and 3-D particle motion associated with the sound. Half of the larvae (N = 45) were exposed to low-frequency (100 Hz) continuous sound, while the other half (N = 44) were observed under the same conditions but without the sound. Exposure did not affect the routine and maximum swimming speeds or the turning behavior of the larvae. Control larvae oriented to the northwest. In contrast, exposed larvae oriented towards the source of low-frequency sound and particle motion. These observations provide a basis to assess how the noise produced by OW turbines might impact dispersal and spatial distribution in this species at a large scale.

Keywords: Offshore wind farms, fish larvae, low-frequency noise, Atlantic cod, behavior, orientation, swimming, dispersal

Affiliation: 1 - Institute of Marine Research, Austevoll Research Station, Sauganeset 16, N-5392 Storebø, Norway

Contact information: alessandro.cresci@hi.no

CM 122: Impact of fisheries exclusions on demersal fish in the southern North Sea

Wolfgang Nikolaus Probst[1], Jennifer Rehren, Vanessa Stelzenmüller, Shubham Krishna, Carsten Lemmen, Kai Wirtz

The extensive development of offshore wind farms (OWF) and implementation of management measures in marine protected areas (MPA) of the EU Natura 2000 network will lead to substantial spatial exclusions of trawl net fisheries in the southern North Sea. Here we analyse how these spatial fisheries exclusions overlap with the distribution of demersal fish and shellfish species. Core areas of distribution were identified for 76 fish species and four shellfish species of commercial relevance in different size classes, resulting in a total of 90 species-size-class combinations (SCC). Species distribution models (SDM) were used to combine information on fishing pressure, OWF locations, submersed structures such as cables and pipelines, topography, hydrography and biochemistry to estimate the probability of occurrence. Our results indicate that fisheries exclusions cover less than 33 % of the core area for ~ 80 % of the SSC. However, OWF can provide additional refuge from fishing, i.e. 33 % of the core area, for ~ 17 % of the SSC. Together, fisheries exclusions from OWF and MPA could cover more than 50 % of the core habitat of ~ 85 % of SSC. OWF thereby may substantially contribute to the political objective of the European Union to protect 30% of its marine area. We argue that the co-objective of conserving marine ecosystem components such as demersal fish and epibenthic fauna should be considered explicitly in marine spatial management, e.g. in when designating sites and licensing the operation of OWF, to foster the achievement of ambitious conservation goals of EU marine policies. We discuss potentials and limitations of SDMs for describing shifts in the distribution of fish under ongoing climate change and altered marine spatial use.

Keywords: offshore wind farms, fish community, species distribution modelling, overlap analysis

Affiliation: 1 - Thünen-Institute of Sea Fisheries, Herwigstraße 31, 27572 Bremerhaven, Germany

Contact Information: nikolaus.probst@thuenen.de

CM 125: A multi-method approach reveals habitat preferences and movement characteristics of *Homarus gammarus* within an offshore wind farm in the Irish sea

Harry Thatcher[1], Charlotte Heaney, Thomas Stamp, Natalie Hold, Pippa Moore, David Wilcockson

As offshore wind energy developments expand globally it is increasingly important to gain an understanding of how marine organisms will interact with these developments. This is particularly true for commercially important species that support industry and coastal communities. The European lobster (*Homarus gammarus*) has been reported within offshore wind farms (OWF) across Europe. However, our understanding of this species interactions with these sites is poorly understood. We set out to investigate the broad habitat use and movement characteristics of *H. gammarus* within an OWF in the Irish sea over a range of spatial and temporal scales. To do this we applied sampling techniques including, (1) Acoustic telemetry, (2) Modelling Catch Per Unit Effort (CPUE) data, (3) Mark-Release-Recapture (MRR), and (4) Baited Remote Underwater Video (BRUV) surveys.

60 lobsters caught from the OWF (2021 – 2022) were fitted with acoustic tags and released across 3 sites. Tagged lobsters displayed high site fidelity to the tagging sites, although instances of lobsters moving between tagging sites were also recorded. More than 50% of lobsters' geographic positions were within a limited distance to the areas of artificial hard substate present at each tagging site. Analysis of a 6-year (2016-2022) commercial catch record of lobsters within the OWF shows that CPUE was significantly greater within areas of artificial hard substate compared with natural soft sediment habitat.

MRR and BRUV surveys were undertaken across the whole OWF and a control site outside the OWF. 600 lobsters including a range of size classes and both sexes were tagged to provide insight into lobster movements at a site scale. BRUV surveys were carried out bi-monthly at specific turbine locations in order to assess the abundance of lobsters present at turbines with varying amounts of artificial hard substrate present. Theses results are currently being analysed.

Our results, to date, indicate that lobsters make use of a range of habitat types within OWFs but prefer areas where artificial hard substrates are present. We postulate this is the result of artificial reef effects taking place as a result of OWF construction, where artificial hard substrates added to a previously soft sediment habitat provides suitable shelter for *H. gammarus*. As such, there is the potential for fishing opportunities to arise from future OWF developments.

Keywords: offshore wind, lobster, acoustic telemetry, habitat use, movement characteristics

Affiliation: 1 - Aberystwyth University

Contact information: Harry Thatcher**,** het25@aber.ac.uk

CM 150: The impact of turbine foundation type on catch rates of cod in the southern North Sea

Karl Michael Werner[1], Holger Haslob, Antje Gimpel, Anna F. Reichel, Vanessa Stelzenmüller

Climate change and global biodiversity loss call for clean energy production systems with minimised ecological impacts. Offshore wind energy production will become the main use of global marine spaces within next decades. Offshore wind turbine foundations can function as artificial reefs but it is unknown if these capabilities apply to different foundation types. The topic of this talk is the impact of foundation type on catch rates of Atlantic cod (*Gadus morhua*), a species under pressure and at risk of local extinction in the southern North Sea, to answer the research question if offshore wind farms can function as artificial reefs. We collected field data around three foundation types, monopiles with rock protection, monopiles with sand bag protection and jacket foundations. Monopile foundations with rock protection on the seabed were able to attract significantly more fish than monopile foundations with sandbag protection and jacket foundations. Fish densities varied on scales as small as few hundreds of meters, meaning that reef effects were spatially restricted. Part of the sampling programme were two recently finalized monopiles with rock protection, which also showed considerably high catch rates. This indicates that colonisation of new turbine structures can go rapidly, if the bottom structure is suitable. Our results imply that offshore wind energy production can be used as tool to combine climate change mitigation with local biodiversity conservation but that a consideration of the wind farm design is required.

Keywords: Atlantic cod, Renewable energy, marine protected area, other effective area-based conservation measures, fisheries ecology, angling

Affiliation: 1 - Thünen Institute of Sea Fisheries, Herwigstr. 31, 27572 Bremerhaven

Contact information: karl-michael.werner@thuenen.de

CM 164: Ecosystem approaches to deal with the nexus of trade-offs between offshore energy and fishing within the context of climate change

Neda Trifonova[1], Nicky Beaumont, Stephen Watson, Claire Szostek, Morgane Declerck and Beth Scott

The UK is the current global leader in offshore wind (OW) with 10.4 gigawatts (GW) installed and a commitment to increase its capacity to 50 GW by 2030. To get to this goal, there has been a dramatic shift in policy to cut approval times for new offshore windfarms from 4 years to 1. Therefore, decarbonising the UK energy supply through increases in OW will require an extremely rapid increase in the use of information on the nexus of the implications of trade-offs between environmental effects, as well as spatial conflicts with other marine uses like food production (fisheries).

The interlinked effects of changes from the introduction of structures, extraction of energy and displacement of fishing actives on the physical environment up through the entire marine ecosystem are needed to provide accurate estimates of cumulative effects of ecological, social, and economic trade-offs. To ensure the minimization of negative impacts and secure wider environmental benefits, an ecosystem-level approach that assesses such changes is essential.

We will present an ecosystem modelling and assessment approach that captures evidence-based impacts of climate change and marine uses on ecosystems and socio-economic impacts. Our proposed approach provides a data-driven, dynamic, and holistic assessment. This approach allows for the multiplicity of interactions amongst different ecosystem components (e.g., physical environment through to plankton, zooplankton, fish, and top predators) across different spatial scales (regional vs shelf-wide). By using prior information on changes over 30 years, this approach also incorporates climate change trends and measures whole ecosystem, as well as individual species population level trends. The method can assess changes in socio-economic value in response to OW deployment scenarios as well as climate change.

A specific case study that will be presented is the “costing” of fisheries displacement from OW developments in the North Sea. A choice of scenarios framed around climate change (e.g., “business-as-usual”) and fisheries (e.g., increase vs decrease in fishing pressure) is being co-designed with input from stakeholders. Through the scenario analysis, outputs in a range of ecological (e.g., stock biomass) and monetary (e.g., Gross Value Added) metrics across a range of spatial scales and their predicted changes over time will be produced. The outputs of population trends in combination with risk maps of ecosystem-level and socio-economic change will provide strategic advice and policy support on the balance of benefits and trade-offs between marine uses to deliver long-term environmental and energy sustainability, as well as economic benefits.

Keywords: dynamic Bayesian network model, ecosystem functioning, cumulative effects, marine spatial planning

Affiliation: 1 - University of Aberdeen

Contact information: neda.trifonova@abdn.ac.uk

CM 165: A fingerprinting approach to unravel the contributors to the organic matter pool of an Offshore Wind Farm

E. Cepeda Gamella[1], P. Boeckx, S. Bodé, U. Braeckman, S. Degraer, T. Moens, J. Vanaverbeke.

Following the European Union's efforts to reduce the emission of Greenhouse gases by 2030 and the growing need for renewable energy, Offshore Wind Farms (OWFs) are flourishing in the North Sea, where they cause changes in the local ecosystem structure and functioning. The turbines provide artificial hard substrates, which are rapidly colonized by epifaunal communities predominantly dominated by blue mussels (*Mytilus edulis*), tube-building amphipods (*Jassa herdmani*), and plumose anemones (*Metridium senile*). Through their suspension feeding activity, they filter a volume of sea water of ca. 7.5 Olympic swimming pools per turbine per day. On the one hand, they thus remove suspended particles, zooplankton, and phytoplankton from the water column but, on the other hand, return faecal pellets (FP) to the environment. This FP production is hypothesized to be the cause of local sediment enrichment observed in several OWFs. Therefore, we aim to quantify the contribution of FP to the local organic matter dynamics in the water columns and carbon accumulation in the sediments surrounding turbines. We have developed isotopic tracers for the FP of the dominant fouling species and the other contributors to the OWF organic matter pool (phyto-, zooplankton, and bacteria-degraded OM) by applying Compound-Specific Stable Isotope Analysis of amino acids (CSIA-AA in species-specific FP and the other components of the marine OM pool. We use the $\delta^{15}N$ signal of AAs with the predominant discriminative power, previously identified through multivariate techniques, as a fingerprint to be applied in Bayesian Mixing Models to estimate the proportional contribution of FP and other components to the OM pool of the OWF environment. As such, we provide an estimate of the importance of the OWF fouling fauna to altered benthic-pelagic coupling processes in OWFs.

Keywords: Fouling fauna, faecal pellets, organic matter dynamics, isotope analysis, stable isotopes, amino acids, isotopic fingerprinting, Mytilus edulis, Jassa herdmani, Metridium senile, offshore wind farm.

Affiliation: 1 - Royal Belgium Institute of Natural Sciences

Contact Information: ecepedagamella@naturalsciences.be

CM 180: A Cumulative Effects Framework for Offshore Marine Renewable Energy

Jared Wilson[1], Kate Searle, Adam Butler, Francis Daunt, Deena Mobbs, Sue O'Brien

The pace of offshore marine renewable energy development is increasing dramatically, to help meet national and international decarbonisation targets and increase energy security. The potential for marine renewables to negatively impact the marine environment is widely acknowledged and impact assessments routinely attempt to quantify these effects. With the increasing number of proposed marine renewable developments, the potential for cumulative effects from multiple developments and across large geographic areas is of increasing concern, particularly for highly mobile marine species such and seabirds and marine mammals.

A range of assessment models and tools have been developed to help in the estimation of potential effects of marine renewables on, and to understand their potential population level consequences. However, these have historically been developed as standalone approaches, focusing on discrete impact mechanisms and with limited integration. The Cumulative Effects Framework (CEF) project was funded by the European Maritime and Fisheries Fund (EMFF) to develop an integrated, consistent, and transparent approach for undertaking cumulative impact assessments for seabirds and marine mammals. It brings together and improves upon existing tools for estimation of collision mortality, displacement, barrier, and underwater noise effects, assigns those effects to the appropriate populations, and undertakes population modelling to better understand population-level consequences.

A data library stores relevant information on marine renewable energy projects and the parameters required to undertake assessments using the various tools available in the CEF. An R package has been produced to integrate the various tools, and to provide maximum flexibility for users to specify the way that the tools operate. A user-friendly online interface allows users to generate effects and population level impacts and provides a clear audit trail of the input parameters and options selected. The CEF has been developed for the UK and focuses upon marine renewables but could incorporate effects estimated anywhere or from any activity and could be adapted for any geographic area.

The CEF has helped to identify and prioritise future research activities to address key data or knowledge gaps that would improve the estimation of cumulative effects. One of the vehicles for addressing key knowledge gaps identified during the development of the CEF is the Predator and Prey Around Renewable Energy Developments (PrePARED) project. PrePARED is a four-year collaborative project, led by Marine Scotland, focusing on understanding how seabirds, marine mammals and fish respond to offshore wind farms, with a core goal delivering data and knowledge to feed directly into the CEF.

Keywords: cumulative, assessment, strategic, seabirds, marine mammals, renewables, ecosystem

Affiliation: 1 - Marine Scotland Science, Scottish Government, Marine Laboratory, 375 Victoria Road, Aberdeen, AB11 9DB, Scotland

Contact information: jared.wilson@gov.scot

CM 184: The large-scale impact of anthropogenic mixing by offshore wind turbine foundations in the shallow North Sea

Nils Christiansen[1], Jeffrey R. Carpenter, Ute Daewel, Nobuhiro Suzuki, Corinna Schrum

Structure drag from offshore wind turbine foundations causes downstream turbulence and deflections of horizontal currents at offshore wind farm sites. While the flow past vertical cylinders has long been studied by laboratory and modeling experiments, the consequences for large-scale ocean dynamics have yet rarely been addressed. In this study, we investigate the regional impact of local structure-induced effects from offshore wind infrastructure using the German Bight area as an example. By implementing a low-resolution structure drag parameterization in a region ocean model, we demonstrate the effects of monopile drag on hydrodynamic conditions for recent offshore wind development levels. Although the anthropogenic mixing is confined at wind farm sites, our simulations show that monopile-induced mixing affects much larger, regional scales. The additional turbulence production emerges as the main driver behind the monopile impacts, leading to changes in current velocities and stratification with magnitudes of about 10%, similar in magnitude to regional annual and interannual variabilities. While the small-scale turbulent wakes have the potential to reduce the mean residual circulation in the German Bight and influence regional stratification, the results suggest significant implications for the marine environment with respect to future offshore wind development and highlight the need for regional consideration of structure-induced mixing effects.

Keywords: offshore wind energy, wind turbines, wakes, turbulent mixing, stratification, modeling

Affiliation: 1 - Institute of Coastal Systems – Analysis and Modeling, Helmholtz-Zentrum Hereon, Germany

Contact Information: nils.christiansen@hereon.de

CM 189: The scour protection layer as 'easy tool' for incorporating the nature-inclusive design principle in offshore wind farm construction

Jan Vanaverbeke[1], Jolien Buyse, Ninon Mavraki, Mirta Zupan, Steven Degraer

Given the emergency of reducing the use of fossil fuels and the realization of the importance of energy independence, the installation of offshore wind farms (OWF) will increase exponentially. In the North Sea alone, up to 25000 turbines will be installed by 2050. A back of the envelope calculation, based on average size of turbines and scour protection layers (SPL) surface, shows that this will result in 12-46 million m² of vertically oriented and 11 - 46 million m² of horizontally oriented artificial hard substrates. Current research focusses on the structural and functional effects of the colonization of the vertical structures by fouling fauna, while there has been considerably less, and more fragmented research on the effects of introducing SPL. By integrating the research conducted on the SPL in Belgian OWFs, the importance of these structures became apparent. The SPL offers habitat for a variety of colonizing invertebrates, which then have a functional importance for food-web structure and functioning. Both a stable-isotope and food-web topology study revealed the importance of the SPL as a feeding ground, as it provides not only increased availability in food sources, but also a wide variety of food sources for higher trophic levels. Species with commercial importance (cod *Gadus morhua*, sole *Solea solea and* plaice *Pleuronectes platessa*) find a wide availability of prey items in this new habitat and are attracted towards it. A comparison between a structurally more complex (the Belwind OWF) and less complex SPL? (C-Power OWF) investigating prey-consumer relationship showed that the fish species can find more prey items in the more complex and diverse environment. An experiment, in which effects of complexity of the SPL on the colonizing fauna were investigated, showed a significant positive effect on species richness. Taking into account that most results are obtained from SPL that are designed only from an engineering and economic perspective, we suggest that designing a structurally more diverse SPL will lead to a more diverse colonizing community. On the one hand, a more diverse community can provide an increased diversity (and therefore stability) of food items for higher trophic levels, and on the other hand it can provide increased availability of shelter/resting places. As such, SPLs are suggested to be priority elements of OWFs that can be designed according to the nature-inclusive design principle.

Keywords: offshore wind farm, scour protection layer, complexity, nature inclusive design

Affiliation: 1 - Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management

Contact information: jvanaverbeke@naturalsciences.be

CM 240: Towards a comprehensive knowledgebase for a sustainable co-location of passive gear fisheries in the vicinity of offshore windfarms

Vanessa Stelzenmüller[1], Holger Haslob, Jonas Letschert, Karl-Michael Werner, Jörg Berkenhagen, Prince Bonsu, Wolfgang Nikolaus Probst

The spatial expansion of offshore wind farms (OWFs) is key for the transition to a carbon free energy sector. The sprawl of OWFs in the southern North Sea is regulated by marine spatial planning (MSP) and exerts increasing pressure on other sectors such as fisheries due to the loss of fishing opportunities. As yet, the quantitative impact of area closures on one side and potential new fisheries resources on the other side is uncertain. The co-location of fisheries in the vicinity of OWFs is therefore increasingly debated and trailed, still good practice examples are lacking. Co-location solutions should be built on a co-development process involving OWF developers, respective fishing communities and MSP authorities based on clear legal foundations and liabilities. However, equally important is a profound ecological knowledge on aggregation and reproduction of commercial species as the basis for fisheries regulations. In this talk, we present current empirical evidence on spill-over potential for brown crab (*Cancer pagurus*) in the German North Sea. For this we compare catch rates of experimental pot fisheries in and around various OWFs differing in depth range and habitat conditions. Furthermore, we use a trawl fisheries experiment around an OWF and long-term survey data from the German Small Scale Bottom Trawl Survey (GSBTS) to illustrate the need for standardized and fit for purpose monitoring strategies to conclude on such ecological benefits. We argue that bottom-up co-location solutions need to be grounded on a comprehensive knowledge base comprising ecological and socio-economic criteria. More international effort is urgently needed to develop good practice guidance for the co-location of fisheries and OWF.

Keywords: co-development, brown crab, GSBTS survey, marine spatial planning, pot fishery

Affiliation: 1 - Thünen Institute of Sea Fisheries, Bremerhaven, Germany

Contact Information: vanessa.stelzenmueller@thuenen.de

CM 259: Pre-construction baseline of spawning cod and their habitat preferences in offshore renewable energy areas

Alison Frey[1], Steven Cadrin

Offshore renewable energy instillation is planned on cod spawning grounds in Southern New England. The spatiotemporal overlap of offshore wind development and cod spawning activities raises concern as cod populations remain below rebuilding targets and cod spawning aggregations are sensitive to human disturbance. Southern New England cod support a recreational for-hire fishery and have long standing commercial, cultural, and economic value. To understand the environmental and habitat preferences for spawning cod in this region, we conducted a 4-year study using acoustic telemetry and biological sampling. In partnership with commercial and recreational fishermen as well as offshore wind developers, we collected data to examine the fine scale distribution of cod and their habitats. Data from four consecutive winter spawning seasons was used to quantify residence, straying, and site fidelity to the primary spawning ground as well as thermal and physical habitat preferences throughout the year. Results indicate that spawning occurs from November to March, with high residence on the spawning ground, some regional distribution beyond the primary spawning ground, and multi-year, annual spawning site fidelity. This study may inform regional management for the co-existence of fisheries and offshore renewable energy and findings can be applied broadly to other regions where cod are present in proposed offshore wind energy areas.

Keywords: Cod, offshore wind energy, acoustic telemetry, spawning, habitat preferences

Affiliation: 1 - University of Massachusetts Dartmouth, School for Marine Science and Technology (SMAST)

Contact Information: Alison Frey, afrey2@umassd.edu

CM 262: Toward a fully coupled framework NEMO-ECOSMO-E2E-OSMOSE and its application for offshore wind farm effect on plankton and fish dynamics

Déborah Benkort[1], Kai Logemann, Karen van de Wolfshaar, Ute Daewel, Corinna Schrum, Sebastian Grayek, Joanna Staneva

With the increase of anthropogenic pressures on marine systems in the North and Baltic Seas, especially due to the expansion of offshore wind farms park, as well as the ongoing climate change, it appears essential to develop effective management measures based on a holistic assessment of this system. To this end, the CoastalFutures project aims to develop a novel cross-scale end-to-end model system (E2E) for the North Sea and the Baltic Sea with the aim to evaluate the impacts of climate change and anthropogenic uses (offshore wind farm, fisheries, etc.) on coastal marine ecosystems, as well as to test different management measures. In this work, we present the first results of our fully 3D model-coupled framework, including a new offshore wind farm configuration. We used here the general circulation model NEMO coupled to the biogeochemistry model ECOSMO-E2E itself coupled to the multi-individual-based model for fish OSMOSE. Preliminary results show how offshore wind farm affect planktonic cycles as well as fish distribution, biomass, abundance and community's composition in the North Sea.

Keywords: 3D coupled biophysical models, offshore wind farm, fish dynamic.

Affiliation: 1 - Helmholtz-Zentrum Hereon

Author contact: deborah.benkort@hereon.de

CM 275: De-risking wave energy environmental impacts: cetacean communities at a wave energy test site in Aguçadoura, in Portugal

Luana C.[1], Inês M.[1], Enric V.[2], Simone T.[2], Miguel A.[1], Pedro V.[1]

Development of marine renewable energy (MRE), including wave energy, is advancing rapidly, presenting a local secure energy source, contributing to grid stability and maximising the potential energy harvested offshore. Plus, MRE is key to battling climate change, proving to be a meaningful tool for countries to reduce greenhouse gas emissions and deliver low-carbon standards. Nonetheless, many energy-rich areas for development of MRE co-exist with important habitats of animal populations. Thus, marine fauna is subject to interactions and potential impacts from the development of such devices.

A wave energy test site, established in Aguçadoura, Portugal, around 6km from the coast, will pave the ground for CorPower Ocean to implement HiWave-5 project. Common dolphins (*Deplinus delphis*), harbour porpoises (*Phocoena phocoena*), risso's dolphins (*Grampus griseus*), pilot whales (*Globicephala melas*), and baleen whales (*Balaenoptera sp*.) have previously been recorded in the area, indicating it is a highly biodiverse area. Furthermore, bottlenose dolphins (*Tursiops truncatus*) and harbour porpoises are protected under the Habitats Directive. Understanding temporal and spatial habitat use of the local populations of cetaceans is key to ensure potential impacts from the development of wave energy devices are minimised.

The present study investigated cetacean presence and abundance for two years before installation of the wave energy device and for one year after installation. Ongoing monitoring started in 2021, in a control and an impact area. Visual surveys were conducted by boat transects in spring, summer and autumn, where data on species, group size, behaviour, calf presence, and environmental parameters were collected. Complementary, passive acoustics data was collected using two F-Pods that were deployed continuously for six months. Detection Positive Minutes (DPM) and train duration were measured and generalised additive models were used to assess its variations according to monitoring area, operational phase, depth, season and water temperature.

The study provides a pioneer characterization of cetacean communities and habitat use in a wave energy area. These findings provide recommendations to developers on mitigating disturbance from wave energy device operation, assisting the sustainable development of wave energy technology. This study complements the traditional use of visual surveys with passive acoustic monitoring, which allowed for a detailed characterisation of seasonal and yearly trends of cetacean populations.

This project NORTE-01-0247-FEDER-040231 has received funding from the Norte Portugal Regional Operational Programme (NORTE 2020), under PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF).

Acknowledgements: European Commission, Swedish Energy Agency, AICEP global, OCEANERA-NET COFUND, EIT Innoenergy.

Keywords: passive acoustic monitoring; marine mammals, habitat use, wave energy device, marine renewable energy

Affiliation: [1]WavEC – Offshore Renewables, [2]CorPower Ocean

Contact Information: Luana Clementino, luana.clementino@wavec.org

CM 315: Cumulative effects of Offshore Windfarms on the future North Sea ecosystem

Ute Daewel[1], Naveed Akhtar, Lucas Porz, Corinna Schrum

The North Sea has become a region in which several economic sectors (e.g. fisheries, renewable energy production, shipping, tourism) compete for space while at the same time marine protected areas and conservation measures are installed. Since the marine ecosystem is highly dynamic and interconnected, none of these sectors and their impacts can be considered independent from the others. Therefore, our research aims at understanding the effects of the individual stressors on the marine environment as well as the interactions and connectivity they have in the limited space of the North Sea. Previous results have shown that the ongoing offshore windfarm (OWF) developments can have a substantial impact on the structuring of the lower trophic part of the coastal marine ecosystems. However, the subsequent effect on higher trophic level production and the combination of effects on the latter remain unclear. Here we present first analyses from scenario simulations with a 3d coupled ecosystem model ECOSMO-E2E, which covers the marine ecosystem from nutrients to macrobenthos and fish.
The objective of the study is to understand the cumulative effects on the North Sea ecosystem caused by large scale OWF clusters. We will particularly explore the interplay between large scale structural changes in the marine ecosystem caused by modifications of the atmospheric conditions and direct interventions, such as fishing closure within the OWFs. For this purpose, we will present a suite of simulation scenarios, in which we i) explore the effect of the individual processes on changes in primary, secondary and tertiary production of the North Sea ecosystem, and ii) combine the processes to quantify the importance of the effects relative to each other.
The scenarios will be performed for a near future wind farm scenario that includes existing and planned large scale OWF clusters. With the proposed study we present baseline information on how changes related to the installations of large-scale OWF clusters affect the ecosystem's productivity and how these changes are transferred through the food chain. Thereby, we want to raise awareness for the expected scales of human interventions and the connectivity of marine systems, and provide a knowledge base for supporting coastal management and monitoring.

Keywords: ecosystem modelling, scenario simulations, ECOSMO E2E, North Sea, fisheries, offshore windfarms

Affiliation: 1 - Institute for Coastal Systems - Analysis and Modelling, Helmholtz-Zentrum Hereon, Max-Planck-Str. 1 D-21502 Geesthacht, Germany

Contact information: ute.daewel@hereon.de

CM 320: Generic approach for a review and characteristics evaluation performance matrix and survey on fisheries-windfarm interactions

J. Rasmus Nielsen[1], Marloes Kraan, Eric Thunberg, Olivier Thebaud, Arina Motova-Surmova, Amber HimesCornell et al. (contributors of surveys, members of ICES WGSOCIAL-WGECON subgroup)

With the stark increase of wind farms in ICES regions seas the need for a better understanding of social and economic impacts of these developments for other users (most notably fisheries) and society at large, grows. WGSOCIAL and WGECON developed an evaluation performance matrix of fisheries-windfarm interactions to assess which social and economic information there currently is in all these different developments. This covers all types of approaches, e.g., development projects, publications, impact assessments, legislations, compensations schemes, etc., taking into account previous reviews. The matrix was set out in the groups as well as in ICES wind farm working groups to be filled in. It focuses on completed and ongoing case studies of wind farm projects directly addressing economic and social aspects of interactions between fisheries and windfarms covering the fishing sector, renewable energy sector, catch sector with fleets/fisheries/catches, harbors, fishing and renewable energy local communities, regions, nations, and international initiatives and stakeholders. First, the generic and standardized approach and evaluation matrix is given together with explanatory notes for the rows in this matrix. After this, the individual case studies and approaches are presented with collected information and results. The survey categorizes different types of examples of what has been done, what is existing, as well as future initiatives and plans, and show how and which criteria have been prioritized. The evaluation and discussion of the survey results, directly point towards what is needed according to providing economic and social evaluations and providing advice on fisheries-windfarm interactions. As such, the survey can directly provide guidelines and advice on future needs and the necessary indicators, scales, methods, participation, etc. to be used for evaluation.

Keywords: Fisheries-windfarm interactions, economic and social interactions, evaluation performance matrix, survey, review, approaches/projects/publications/impact assessments/legislations/compensations schemes/etc.

Affiliation: 1 - Technical University of Denmark, National Institute of Aquatic Resources (DTU-Aqua)

Contact information: J. Rasmus Nielsen**,** rn@aqua.dtu.dk

CM 334: Potential impacts of floating offshore wind farms on vulnerable species in the Mediterranean Sea

Paul Wawrzynkowski[1], Josep Lloret

Floating offshore wind has the potential to allow wind energy developments in the Mediterranean. Although there are currently no large offshore wind farms (OWF) in this region because of its deep waters, new floating wind turbine technology is allowing the proposal of several projects in areas where the wind conditions are optimal. However, some areas where OWF are proposed present a high biodiversity that embrace a diverse set of sensitive or vulnerable species including marine mammals, sea turtles, birds, bats, fish and macroinvertebrates. The unknown and particular potential impacts associated with the floating technology and linked infrastructures were evaluated via a case study. In this study, the OWF projects proposed in the area of Cap de Creus / Gulf of Roses (Spain) allowed us to assess the different impacts by different technologies and components of the OWF (including the associated infrastructure) and stages of OWF life cycle (exploration and planning, installation and commissioning, operation and maintenance, decommissioning and repowering) on different vulnerable taxa inhabiting the area, including the species protected by European Directives and those included in international conventions for the protection of flora and fauna.

Keywords: floating offshore wind technology, ecological impact, vulnerable species, EU-protected species, international conventions

Affiliation: 1 - Institute of Aquatic Ecology, University of Girona, C/ Maria Aurèlia Capmany 69, 17003 Girona, Spain

Contact Information: paul.wawrzynkowski@udg.edu

CM 346: Offshore decommissioning horizon scan: research priorities to support decision-making activities for man-made infrastructure

Silvana N.R. Birchenough[1], Sarah M. Watson, Dianne L. McLean, Brian J. Balcom , Alison M. Brand, Elodie C. M. Camprasse, Jeremy T. Claisse, Joop W.P. Coolen, Tom Cresswell, Bert Fokkema, Susan Gourvenec, Lea-Anne Henry, Chad L. Hewitt, Milton S. Love, Amy E. MacIntosh, Michael Marnane, Emma McKinley, Shannon Micallef, Deborah Morgan, Joseph Nicolette, Kristen Ounanian, John Patterson, Karen Seath, Allison G.L. Selman, Iain M. Suthers, Victoria L. G. Todd, Aaron Tung, Peter I. Macreadie.

Thousands of man-made structures (MMS) have been installed in the world's oceans over the past 70 years, including oil and gas and more recently offshore windfarms, to meet the population's reliance on hydrocarbons and clean energy generation. Over the last decade, increasing concerns on how to deal with decommissioning of these infrastructures has moved up in the research agenda, especially when it reaches the end of its operational life. Options, such as complete or partial removal may or may not present the best option when considering potential impacts on the environment, society, technical feasibility, economy, and future asset liability. Re-purposing of offshore structures may also be a valid legal option under international maritime law where robust evidence exists to support this option. Given the complex nature of decommissioning offshore infrastructure, a global horizon scan was undertaken, eliciting input from an interdisciplinary cohort of 35 global experts to develop the top ten priority research needs to further inform decommissioning decisions and advance our understanding of their potential impacts. The highest research priorities included: (1) an assessment of impacts of contaminants and their acceptable environmental limits to reduce potential for ecological harm; (2) defining risk and acceptability thresholds in policy/governance; (3) characterising liability issues of ongoing costs and responsibility; and (4) quantification of impacts to ecosystem services. The remaining top ten priorities included: (5) quantifying ecological connectivity; (6) assessing marine life productivity; (7) determining feasibility of infrastructure re-use; (8) identification of stakeholder views and values; (9) quantification of greenhouse gas emissions; and (10) developing a transdisciplinary decommissioning decision-making process. This work considered primarily oil and gas structures, but these criteria could help to inform other man-made activities. Addressing these priorities will help inform policy development and governance strategies to support industry and stakeholders with dedicated guidance when considering offshore decommissioning.

Keywords: Decommissioning; Offshore; Subsea; Infrastructure; Oil and gas; Decision-making, evidence-based

Affiliation: 1 - Cefas

Contact information: Silvana.birchenough@cefas.gov.uk

CM 359: Modelled impacts of Offshore Wind Farms on physical mixing and primary production in stratified waters

Arianna Zampollo[1], Rory O'Hara Murray, Beth Scott

The rapid growth of renewable energy development in shelf seas has raised the need to assess the direct and indirect impacts of these new infrastructures on marine ecosystems. At least 260 GW of offshore wind farms (OWFs) are planned to be deployed in the North Sea by 2050 with very large-scale OWFs (fixed and floating) arrays being deployed in Scottish shelf waters in the next 10 years. The targeted regions contain a range of different hydrodynamic conditions from mixed to seasonally stratified water columns with many physical and biological processes predicted to be affected. The spatial extent and temporal differences (pre and post spring bloom) of these affects are uncertain but may impact whole ecosystems, from phytoplankton to top predators.

To investigate the possible effects of wind energy extraction, we have started by modelling areas targeted for future floating and static wind farm deployments with good long-term baseline data. The region of Firth of Forth and Tay Bay (Scotland, UK) has extensive wildlife and exemplifies an ecological and economic area of interest for top predators (seabirds, mammals) and the fishing industry. We used a 3D hydrodynamic model (FVCOM) coupled to a biogeochemical model (ERSEM) to investigate the comparison of two modelled scenarios, one with and one without OWFs in a period in which we have high levels in-situ data (March to July 2003) to validate the coupled model.

Comparing these two scenarios showed an overall decrease in primary production before the bloom (-7%), with a maximum daily decrease of 6% from wind farm deployments. Positive and negative variations in plankton abundance (chlorophyll-a) did not linearly correlate to their distance from OWFs, and large variations were identified close to (1-2 km) as well as far (75 km) from the farms. The wind wake strengthened the stratification in 58% of the domain, positively or negatively affecting the primary production depending on the type of changing hydrodynamic regime (i.e. less to more strongly stratified). Overall, dipoles in sea surface height, temperature and salinity were observed distributed between coastal and offshore waters, centered at OWF locations. The date of spring blooms appeared delayed in less stratified waters, and subsurface concentrations of plankton increased in intensified stratified waters which exhibited slight upwelling.

This study shows that investigating impacts of OWF is imperative to understanding fine scale effects which are likely to influence species (e.g., seabirds and fish) higher up the trophic chain.

Keywords: ERSEM, FVCOM, marine spatial planning, oceanography, primary production

Affiliation: 1 - University of Aberdeen

Contact information: a.zampollo.18@abdn.ac.uk

CM 371: Investigating the potential impacts of offshore renewable energy installations on fisheries in the Iberian Peninsula and Bay of Biscay: A multi-data source study

Miguel Amado[1], Clementino L., Vinagre P., Machado I.

The development of offshore renewable energy sources has gained significant momentum worldwide due to their potential to contribute to a sustainable energy future. However, the installation of offshore renewable energy installations has the potential to affect the existing activities within the marine environment, particularly the fisheries sector. In the Iberian Peninsula and the Spanish Bay of Biscay, provisional and definitive areas have been recently established for the installation of fixed and floating offshore wind energy, leading to concerns about their potential impact on the fisheries sector. This study aims to investigate the potential impacts of these new areas on the fisheries activity in the region.

The study utilizes a multi-data source approach, combining Automatic Identification System (AIS) and Vessel Monitoring System (VMS) data from Global Fishing Watch (GFW) combined with additional sources of data (e.g., EMODnet, national Maritime Spatial Planning portals and available fishing log-books, etc.), to perform a GIS analysis to investigate the potential overlapping effects of offshore renewable energy installation areas on the fisheries activity in the Iberian Peninsula and the Bay of Biscay. The analysis identifies changes or displacement of fisheries that may be caused by the installation of offshore renewable energy projects, the potential economic impacts of these changes on the fisheries sector and solutions for the co-location of fishing and offshore wind projects in the region of study. The outputs of this study include a comprehensive analysis of fishing activity and types of fishing gear used within the newly defined areas for offshore renewable energy installation.

The findings of this study will contribute to a better understanding of the potential impacts of offshore renewable energy installations on the fisheries activity in the Iberian Peninsula and the Spanish Bay of Biscay, a region with long time fishing tradition. The results will be useful for policymakers and stakeholders involved in the planning and management of offshore renewable energy installations which is currently taking place, to minimize any negative impacts on the fisheries sector and to ensure sustainable development of marine resources.

Keywords: offshore renewable energy, fisheries sector, GIS analysis, Automatic Identification System (AIS), Vessel Monitoring System (VMS), environmental impacts

Affiliation: 1 - WavEC Offshore Renewables

Contact Info: miguel.amado@wavec.org

CM 387: Ecological impacts of offshore wind farms: synthesis of scientific evidence and access to knowledge

Ibon Galparsoro[1], Iratxe Menchaca, Joxe Mikel Garmendia, Ángel Borja, Ana D. Maldonado, Gotzon Mandiola, Gregorio Iglesias, Juan Bald

Offshore wind energy (OWE) is widely regarded as one of the most plausible options for increasing renewable energy production and decarbonising the energy supply. However, scaling up OWE production might result in increased environmental risks making the assessment of the ecological implications of OWE a key element when defining its environmental sustainability. In this context, this presentation aims to provide insights into an integrated, structured, and scientifically based understanding of the ecological impacts of OWE. Information on the pressures and impacts of OWE systems has been obtained based on a Systematic Literature Review, the results of which were synthesised by means of a meta-analysis. In total, 867 scientific findings were identified from 158 articles related to the effects of pressures produced by OWE devices on marine ecosystem elements. Only 24 studies investigated more than one pressure, and in 23 studies two or more effects on ecosystem elements were analysed. Most studies investigated biological pressures (63%), followed by inputs of energy and noise (26%), and physical pressures (11%). Almost 62% of the findings are related to biological impacts, reported for 111 birds, 49 fish, 11 mammals, and 39 invertebrate species. The evidence indicated that 72% of the impacts were negative, while 13% were positive. Regarding the impact magnitude, 36% were reported as high, while low and moderate impacts accounted for 18% each. Information theory was used to compute the degree of certainty of the scientific findings, obtaining that, in general, the effect of the impact (positive or negative) has higher certainty than its magnitude. To promote the use of scientific evidence in decision-making by managers, decision-makers, scientists or promoters during the Strategic Environmental Assessment and Environmental Impact Assessment of OWE projects, the results derived from the literature review are freely accessible through WEC-ERA tool (https://aztidata.es/wind-era/). The tool permits the interactive assessment and visualisation of the pressures and ecological risks of OWE. The approach presented reflects the complexity of the interactions between OWEs and the environment.

Keywords: Offshore wind farms, ecological risk, literature review

Affiliation: 1 - AZTI

Contact information: igalparsoro@azti.es

CM 390: Harnessing the Ocean to Tackle Climate Change & Avoiding Maladaptation in the Process

Libby Jewett, Andrew Lipsky

The U.S. Government has just released the first all-of-government Ocean Climate Action Plan. This Plan highlights eight broad thematic areas of action with offshore wind being one. Other areas for changing the climate change trajectory include green shipping and marine carbon dioxide removal which will likely have intersections with offshore wind deployment and compounding interactions with the marine ecosystem. The Ocean Climate Action Plan proposes the possibility of multiple ocean climate solutions being deployed in the same geographic area to enhance the climate mitigation potential and maximize the efficient use of space. For instance, could marine Carbon Dioxide Removal technologies or other marine energy technologies (tidal turbines) be deployed in wind energy areas? How do we ensure these solutions intended to reduce the impact on marine ecosystems do not result in unintended consequences? To move forward smartly, it is imperative that all technological solutions deployed in the ocean be effectively planned and monitored to ensure optimal protection of ocean resources, including fisheries and fishing communities. Climate change is further complicating deployments as it shifts baselines, migratory patterns and abundances of fishery species and marine ecosystems. To prevent maladaptation side effects, offshore wind and other ocean climate solutions projects should be assessed within an ecosystem context--this can include reasonable timelines to adjudicate conflicts, use of: integrated ecosystem assessments, marine strategy evaluations, and/or Tradeoff analyses in order to set up effective ecosystem protection protocols. However, de-conflicting space use and development of assessment tools takes time and this must be weighed against the damage being caused by climate change itself.

Keywords: Offshore Wind, Climate Actions, ecosystem, adaptation, fisheries

Affiliation: NOAA Northeast Fisheries Science Center

Contact Information: libby.jewett@noaa.gov

CM 391: Using genetic estimates of connectivity to explore appropriate spatial scales for offshore windfarm impact assessments: an ecosystem-based case study for the black-legged kittiwake

Chloe P. Cargill, Ella Benninghaus, Beth E. Scott, Kara Layton, Elizabeth Masden, Julie Miller, Lise Ruffino, Lars Boehme, Dafne Eerkes-Medrano, Karen McCoy, Ana Payo-Payo

Offshore wind developments are expanding across the North Atlantic shelf seas. For the Atlantic black-legged kittiwake, *Rissa tridactyla tridactyla* (conservation status: Vulnerable, declining), offshore windfarms present a source of direct mortality (collision with turbines) and sub-lethal effects (energetic costs associated with avoidance). Furthermore, emerging evidence suggests that offshore windfarms alter the surrounding oceanographic environment, with subsequent implications for the availability of fish prey within primary seabird foraging areas. Offshore windfarms can therefore have both top-down and bottom-up implications for the survival, productivity and population viability of the Atlantic black-legged kittiwake. As populations can be connected by immigration and emigration of individuals, even localised impacts have the potential to propagate through to the metapopulation level. In this study, we explore whether connectivity between black-legged kittiwake populations presents a potential mechanism for offshore windfarm impacts to be amplified or neutralised at the level of the metapopulation.

In this presentation we will show how firstly, we assigned individuals sampled for genetic data to groups based on common attributes of colony-level diet data. With our populations thus defined by ecological niche, we then referred to spatially explicit data on foraging ranges, extracting geographic marine areas where the predicted breeding season home ranges of birds overlap with operational or planned offshore windfarm developments. Finally, we build on previous studies by testing the application of existing microsatellite genotype data, for both *R. t. tridactyla* and its obligate parasite, the common seabird tick (*Ixodes uriae*), to quantify immigration and emigration rates of breeding kittiwakes across the population matrix.

Due to a lack of robust empirical data, environmental impact assessments for offshore windfarm developments in the UK currently omit metapopulation dynamics. Through this ecosystem-based approach to estimating immigration and emigration between populations, we highlight the spatial scales at which metapopulations should be considered when assessing the potential impacts of offshore windfarms for the Atlantic black-legged kittiwake. The overarching aim of this project is to improve biological realism in the evaluation of offshore windfarm impacts, and to support the application and use of ecosystem science in this new era of offshore marine renewable energy.

Keywords: metapopulation, prey, microsatellite, North Atlantic, seabird, seabird tick, immigration, emigration

Contact Information: c.cargill.21@abdn.ac.uk

CM 406: Changes in predator and prey in response to operating windfarm turbines

Oihane Fernandez-Betelu[1], Aude Benhemma-Le Gall, Isla M. Graham, Paul M. Thompson, Matthew J. Witt, Anthony Bicknell

With the current rapid expansion in the renewable energy industry, understanding the potential ecological impacts of windfarms on wildlife is critical for informed decision-making and sustainable development. PrePARED (Predators and Prey Around Renewable Energy Developments) is a multi-year collaborative research project that investigates important knowledge gaps that currently hinder the rapid consenting of offshore windfarm development at scale. For the first time, PrePARED will concurrently assess the distribution and behaviour of predators (seabirds and marine mammals) and prey (fish) in and around offshore windfarms in UK waters, providing essential information on the cumulative effects of large-scale development on key species. Here, we present an overview of the project and some preliminary results from the first year. PrePARED builds on more than ten years of strategic research on marine mammals, conducted during the consenting and construction of one demonstrator and two commercial-scale offshore windfarms in the Moray Firth. PrePARED will examine the impact of these operational windfarms on harbour porpoises and their prey communities. At a broad spatial scale (10's of km), we compared acoustic detections of porpoises pre- (2009-2011) and post-construction (2022) using echolocation click detectors (CPODs) in the two operational windfarms and at a reference site that has not yet been constructed. We used these data to assess the effect of operational windfarms on the occurrence and foraging activity of harbour porpoises. At a fine spatial scale (<1 km), we assessed whether 'reef-effects' close to turbines within the two windfarms influenced both harbour porpoises and potential prey fish. We collected simultaneous data using CPODs and Baited Remote Underwater Video (BRUV) systems. Devices were deployed across the two windfarms, at structures (close to turbine jackets, <50 m) and at mid-point locations (between two adjacent turbines), and at reference sites. At the broad-scale, porpoise occurrence increased within the operational windfarm sites post-construction, compared to pre-construction years. Porpoise occurrence was significantly higher within the oldest windfarm compared to the reference site. At the fine-scale, fish species abundance significantly increased close to turbine jackets compared to reference locations, and the effect was greater within the more established windfarm. No differences in either porpoise occurrence or foraging activity were detected between structure and mid-point locations. Our preliminary findings suggest that operating offshore windfarms may have a positive impact on key species. As our study develops, we will generate more comprehensive results and insights that will inform effective decision-making towards sustainable offshore wind energy development.

Keywords: offshore windfarm, passive acoustic monitoring, BRUV, reef-effects, predator-prey

Affiliation: 1 - University of Aberdeen

Contact Information: oihane.fernandez@abdn.ac.uk

CM 408: ECOWINGS (Ecosystem Change, Offshore Wind, Net Gain and Seabirds): a new research project to understand and compensate for the cumulative effects of offshore wind farms on seabirds

Paul G. Fernandes[1], Kate Searle, Esther Jones, Michael Heath, Janine Illian, Dougie Speirs, Adam Butler, Neil Banas, Maria Bogdanova, Fergus Chadwick, Ana Couto, Anastasia Frantsuzova, Jenny Jardine, Jack Laverick, Joshua Lawrence, Oliver Leedham, Kelly MacLeod, Ken Newman, Charlotte Regan, Emma Tyldesley, Sarah Wakelin and Francis Daunt.

Uncertainty around impacts on seabird populations remains a key consenting issue for offshore wind development in the UK, affecting progress towards the increase in deployment of offshore windfarms needed to meet the targets of the British Energy Security Strategy. Seabirds are impacted through collisions, displacement from feeding grounds, and barrier effects on migratory routes or regular flight paths. The cumulative effects of these impacts, the underlying causal relationships behind them, and the extent of habituation over time, are currently not well understood.

ECOWINGS is a new project, funded by the UK Natural Environment Research Council and The Crown Estate's Offshore Wind Evidence and Change Programme. The project aims to transform the existing evidence base on the cumulative effects of offshore wind on key seabird species. It will also establish pathways for strategic compensation to ensure net gain for seabird populations and the wider marine ecosystem, while accounting for the projected effects of climate change. The project will address three research questions which will focus on a region of the UK North Sea, with key species including black-legged kittiwake, common guillemot, razorbill, and Atlantic puffin. The specific objectives of the project are to: Investigate the effects of offshore wind farms on predator-prey interactions and competition among seabird species, including the potential for habituation over time; quantify the cumulative effects of offshore wind on seabirds and the wider ecosystem, and how these effects are scaled up relative to increased offshore wind capacity; test a set of compensation scenarios to achieve net environmental gain for seabirds; create a toolkit to assess whole ecosystem consequences of strategic compensation measures; and ensure that the strategic compensatory measures are robust to future projections of climate change.

In doing this, ECOWINGS will inform the implementation of policy around offshore wind development, providing strategic advice that safeguards the future welfare of seabird populations and the wider ecosystem whilst removing key barriers to progress towards ambitious energy targets. Working from an initial case study region, the project will use modelling to scale results across the North Sea and will produce a suite of online tools to inform policy and management. Here we present the aims and objectives of the project, focussing on the novel technology applied to collect data on seabird prey in and around offshore wind farms, and to model seabird demographics and the wider marine ecosystem.

Keywords: Offshore wind farms, seabirds, fish, net gain, compensation, uncrewed surface vehicles, autonomous underwater vehicles, individual based modelling, population viability analysis, ecosystem modelling

Affiliation: 1 - Heriot-Watt University

Contact Information: p.fernandes@hw.ac.uk

CM 440: Accounting for climate variability and offshore wind energy development in examining future groundfish fishing opportunities on the U.S. West Coast

Amanda J. Warlick[1], Kelly Andrews, Owen Liu, Chris Harvey, Jameal Samhouri, Elliott Hazen

Offshore wind energy development on the West Coast of the United States is occurring rapidly alongside ongoing efforts to understand the potential effects of long-term environmental variability and climate change on ecological systems and socio-economic communities. To minimize potential conflicts between stakeholders, there is a need for spatial planning tools that can identify high use areas and inform tradeoffs between wind energy development and other ocean uses. However, quantifying the impacts to diverse ocean stakeholders can be challenging, as both natural resources and anthropogenic activities vary across space and time. Here we present a framework for evaluating the vulnerability of groundfish fishing communities to displacement by offshore wind energy development and examine how the future overlap of these two marine resource uses may be affected by anticipated climate change. Specifically, we use fishery-dependent catch data available from vessel logbooks to derive annual fishing "footprints" for three separate target species groups along the U.S. West Coast from 1994-2019, and explore environmental correlates of interannual variability in these footprints. Then, we examine potential displacement of fishing activity by offshore wind activities relative to fleets' apparent mobility to derive an overall metric of risk for a given fishing community and species target group. Finally, using projected species' distributions out to the year 2100, we examine how climate-driven shifts in species' distributions will alter the overlap between target species and wind energy areas over time. Results from this analysis highlight a wide range of interannual variability in fishing footprints for both port communities and target species groups, and important spatial shifts in future distributions of targeted species. Combined, these results indicate that vulnerability, adaptive opportunities, and efforts to mitigate lost fishing opportunities will vary across the groundfish fishing fleet. We outline areas for future work and the usefulness of this approach for identifying important fishing areas that could help minimize conflict between stakeholder groups and bolster the resilience of this large, dynamic, and economically important marine ecosystem in light of ongoing and future climatic changes.

Keywords: offshore wind energy, fishing communities, groundfish, displacement, spatio-temporal variability, climate change

Affiliation: 1 - NOAA Fisheries Northwest Fisheries Science Center

Contact Information: amanda.warlick@noaa.gov

CM 449: A step-by-step guide to establish a transdisciplinary approach for co-existence processes for offshore wind development: Recent experiences in Norway

Dorothy Dankel[1], Vibeke Stærkbye Nørstebø[2], Rita Vasconcellos d'Oliveira Bouman[2], Julia Farkas[3], Bjørn Henrik Hansen Marta Pujol[3], Anne Gaspers[1], Eric Young[1], Catherine Banet[4], Karen de Jong[5], Bente Pretlove[6], Christopher Harman[7], Kristina Fröberg[8], Jan Henrik Sandberg[9], Mia Høgi[10], Hanna Bauge[11], Gaute Kandal Hoel[12], Hanne Wigum[13], Sindre Stub[14], Turid Øygard[15], Inger Marie Malvik[16], Kevin Stokesbury[17]

On May 11, 2022, the Government of Norway announced a major ambitious offshore wind initiative: to open areas for offshore wind power production that will generate 30 000 MW of power in Norway by 2040. The Government will award licenses for about 30 GW of offshore wind by 2040 as a measure to meet the target to cut overall greenhouse gas emissions by at least 55% by 2030. The Government’s plan over the next 20 years is 1500 offshore wind turbines in operation[a]. This raises important environmental and co-existence questions with existing and planned activities and interests.

On December 19, 2022, the Kunming-Montreal Global Biodiversity Framework (GBF) was adopted at the United Nations Biodiversity Conference (COP15) in Montreal. One of the ambitious aims for the GBF is for at least 30% of land, coastal and marine areas to be preserved by 2030. Norway has been among the campaigners to get this in place in the agreement, but much work is needed to understand the practicalities of the new Nature Agreement with the pioneering offshore wind development plans. The vast offshore area that is part of Norway’s Economic Exclusive Zone has truly become an ***“Area under Pressure”*** at risk of an unproductive collision course with biodiversity goals, a world-leading offshore fishing industry as well as other activities at sea.

In this talk, we examine the consequences of, and solutions for, marine area management and use of marine area-based resources in Norway. Our specific topic is the development of offshore wind renewable energy in the ocean space. includes cross-sector research questions focusing on co-existence and interdisciplinary collaboration to develop knowledge and solutions related to the societal risk arising from the link between area use and change and climate change, changes in marine ecosystems, encroachments on marine habitats and loss of marine biodiversity.

Reference: a - https://www.regjeringen.no/en/aktuelt/ambitious-offshore-wind-power-initiative/id2912297/

Keywords: offshore wind, transdisciplinary, social-ecological system, coexistence, epistemic justice, marine spatial planning, Responsible Research and Innovation

Affiliation: 1 - SINTEF Ocean, Climate and Sustainability, Bergen, Norway, **2 -** SINTEF Ocean, Climate and Sustainability, Trondheim, Norway, **3 -** SINTEF Ocean, Trondheim, Norway, **4 –** University of Oslo, **5 -** Institute of Marine Research, 6 – DNV, 7 - Norwegian Offshore Wind Cluster, 8 - WWF, 9 - Fiskarlaget, Norwegian Fishermen’s Association, 10 - Pelagisk Forening, Norwegian Pelagic Fishermen’s Association, 11 – Fiskebåt, 12 - Norwegian Ship Owner’s Association, 13 – Equinor, 14 – ZERO, 15 - Offshore Norway, 16 - SINTEF Energy, 17 - University of Massachusetts, Dartmouth, School of Marine Science and Technology

Contact Information: Dorothy.dankel@sintef.no

CM 472: Effects of emerging marine renewable energy technologies: what does this mean for the ecosystem?

Andrea Copping[1], Daniel Wood, Bob Rumes, Lars Golman, Ee Zin Ong, Rachel Mulholland

Offshore renewable energy devices are being deployed around the world with offshore wind leading the way, followed by wave energy converters and turbines harvesting power from wave, tides, large rivers, and persistent ocean currents. In addition there are emerging marine renewable technologies that will harvest, store, and transmit power under development. The potential ecological effects of these emerging technologies have received little attention and the potential for effects on marine animals, habitats, ecosystem and oceanographic processes is largely unknown.

These emerging technologies include those that derive power from seawater gradients including thermal gradients - Ocean Thermal Energy Conversion (OTEC) and seawater air conditioning (SWAC), as well as from salinity gradients. Energy from solar radiation is under scrutiny with deployments of floating photovoltaic installations or floatovoltaics moving out of sheltered bay and reservoirs to the open sea. Investigations are proceeding into storing excess power produced at sea that is not transmitted to land by export cable or used onsite, through a range of energy storage mediums including battery banks, conversion and transport of hydrogen or ammonia. The potential for merging and co-locating several of these emerging technologies has led to investigations into multi-use platforms that may combine several technologies and end uses.

This paper seeks to place the emerging offshore renewable technologies in perspective, to examine what is known about potential effects of these technologies on the marine environment at small and large scale, and to explore knowledge gaps and to recommend research and monitoring studies that will help clarify these effects. This information will be needed to responsibly develop the emerging renewables and to provide a path forward for regulators and advisors to engage with project developers in the pursuit of low carbon power. A description of each of the emerging technologies will be presented, with a review of existing studies, and recommendations for research and monitoring that will clarify effects. An initial assessment of the likely risks posed by these technologies will be provided.

Keywords: offshore renewable energy, emerging technologies, environmental effects

Affiliation: Pacific Northwest National Laboratory and University of Washington

Contact Information: andrea.copping@pnnl.gov

CM 481: Representing fisheries' footprints in marine spatial planning suitability analyses for offshore wind energy development

Kelly Andrews[1], Blake Feist[1], J. Lilah Isé[2], Justin Ainsworth[3], Jessica Watson[3], Delia Kelly[3], Caren Braby[3]

Offshore renewable energy development is becoming a reality off the U.S. West Coast, and an important goal for selecting the locations of these new ocean-use sectors is to minimize overlap and conflict with current ocean user groups and marine natural resources. Two of the most important ocean user groups along the U.S. West Coast are commercial and recreational fisheries. The objective of this research was to identify fisheries data to be included in a comprehensive suitability analysis to identify locations within two planning areas that would be most suitable to offshore wind energy (OWE) development. Here, we describe the methodology used to characterize and calculate the relative importance of space within the OWE planning areas for nine fisheries sectors and then calculate the suitability of this space for OWE development relevant to the overlap with fisheries. We used fisheries' logbook and observer program data to summarize annual and cumulative fishing effort (hours fished or amount of gear used) and revenue across the entire planning area and within 2x2-km grid cells within the planning area across a range of years of available data for each fishery. We then ranked, normalized and combined effort and revenue data into a single metric ('ranked importance') for each fishery for each grid cell. Combining metrics allowed for the most important characteristic of each fishery (effort or revenue) to be captured for each grid cell. Finally, we used the ranked importance values for each fishery to calculate an overall suitability score for OWE development for each grid cell relevant to the overlap with fisheries. Results showed that annual commercial fishing effort and revenue varied widely across the last two decades for many fisheries; however, some fleets showed steadily increasing and decreasing trends in fishing effort across the planning areas. Spatially, the locations of the highest ranked importance values varied among individual fishing sectors, typically corresponding to specific bottom depth contours or habitat features associated with targeted species. Overall, large regions of the planning areas, particularly at depths between ~200 and ~500 m, were important to fisheries, while the western half of the southern planning area had the highest suitability scores for OWE development. Comprehensive marine spatial planning analyses will continue to be a critical component for minimizing conflict among ocean-user groups and impacts to species and their habitats, and for the responsible, sustainable development of new ocean-use sectors.

Keywords: fisheries, offshore wind energy development, marine spatial planning, suitability

Affiliation:

[1] Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic & Atmospheric Administration

[2] Western Regional Office, National Marine Fisheries Service, National Oceanic & Atmospheric Administration

[3] Marine Resources Program, Oregon Department of Fish & Wildlife

Contact information: kelly.andrews@noaa.gov

CM 488: A Bayesian framework using INLA for an ecosystem-based cumulative effect assessment of offshore windfarms

Morgane Declerck[1], Neda Trifonova, Arianna Zampollo, John Hartley, Beth Scott

To alleviate climate change consequences, UK governments are pioneering offshore wind farm (OWFs) to achieve the goal of 50 GW by 2030. The North Sea is a dynamic ecosystem with strong bottom-up/top-down natural and anthropogenic drivers facing rapid climate change impacts. Therefore, to ensure the compatibility of such large-scale developments with nature conservation needs, effects must be evaluated through cumulative impact assessments (CIA). By excluding climate change impacts, the current CIA procedures are failing to identify links between oceanic drivers and ecosystem components leading to high uncertainty in population-level predictions. This turns into highly uncertain ecosystem assessments with a limited understanding of impacts that manifest from fine-scale up through to ecosystem scales and therefore lacks the ability to inform future offshore wind leasing rounds.

This study will present a Bayesian framework using Integrated Nested Laplace Approximation (INLA). Firstly, we will use predicted drivers of population trends which are the outcomes of ecosystems models run over a 30-year time series. Secondly, we will use a fine-scale spatial modelling approach involving INLA allowing analysis of high-resolution spatial information to assess cumulative effects. The modelling framework will enable data-driven relationships between lower ecosystem components, such as oceanic drivers changing with both climate change and offshore energy extraction and their predicted effects across all trophic levels up to top predator populations (e.g., seabirds). The proposed methodology will assess the corresponding population trends under climate change and OWF scenarios across spatial scales.

As a case study, we will use the Firth of Forth in Scotland, UK, a location with internationally important seabird colonies where multiple OWFs (3.1 GW) have been consented. We will present results for Northern gannets (*Morus bassanus*), a generalist species whose population trends appear to be strongly linked to the oceanic driver: the Potential Energy Anomaly (PEA). PEA is an indicator of the levels of stratification and mixing and is predicted to change significantly with both climate change and the effects of introduced structures and wind energy extraction. The analysis will output ecosystem-level population trends and then finer-scale distributions with associated levels of uncertainty. Ultimately, our modelling framework will encapsulate the consequences of habitat change under climate change and OWFs from both colony level to regional population level for use in strategic CIAs, compensatory measures, and marine spatial planning.

Keywords: marine spatial planning, climate change, Northern gannets, potential energy anomaly, dynamic Bayesian network model

Affiliation: 1 - University of Aberdeen

Contact information: m.declerck.19@abdn.ac.uk

CM 496: Quantifying cumulative effects on the functional diversity of demersal fish communities under offshore wind farm expansion in the German North Sea

Jennifer Rehren[1], Maren Kruse, Rabea Diekmann, Matthias Hasenbein, Nikolaus W. Probst, Casper Kraan, Hermann Neumann, Shubham Krishna, Vanessa Stelzenmüller

The North Sea is facing increasing pressure from a multitude of expanding economic and cultural activities. Among them is the expansion of offshore wind farms (OWF) to reach the 2050 energy targets. OWFs do not operate in isolation but will exacerbate the impact of existing pressures on seabed ecosystems. Despite this, the cumulative effects of seabed-impacting activities on benthic and demersal communities remain poorly understood.

To address this gap, we developed a spatially-explicit Bayesian Belief Network describing the cause-effect pathways between major human activities, the pressures they exert, and key traits of demersal fish to quantify the impact of cumulative effects on the integrity of the fish communities using the German Bight of the North Sea as an example. The model identifies the contribution of OWFs to cumulative effects relative to other activities and estimates the probability of attenuation or amplification of effects. We also evaluated potential changes in the functional diversity of the demersal fish communities associated with the installation of the German expansion targets under different future scenarios of major human activities and identified areas of higher concern.

The Bayesian Belief Network developed here is a promising tool for informing decision-makers about key pressures and activities that potentially impair ecosystem functioning. It can also facilitate the identification of trade-offs between the provision of ecosystem services and management actions, such as climate change mitigation measures and the implementation of marine conservation areas.

Keywords: Cumulative effects, Bayesian Belief Networks, Offshore wind farms, North Sea, demersal fish, biological traits

Affiliation: 1 - Thünen-Institute of Sea Fisheries, Herwigstraße 31, 27572 Bremerhaven, Germany

Contact Information: jennifer.rehren@thuenen.de

CM 504: Offshore wind in the US Atlantic: pressing research needs and opportunities

Brendan Runde[1], Kate Wilke, Chris McGuire, Carl Lobue, Mike Pol

While there are currently zero commercial-scale wind farms operating in United States waters, over 30 are leased and planned to be built in the coming several years. Fisheries monitoring must occur for each project, which for most developers means funding one or more research studies in or near their wind area. In this talk, we highlight some outstanding research needs and make recommendations for how inter-project coordination might not only maximize our understanding of offshore wind's effects but also could improve coastwide fisheries management.

Keywords: monitoring, fisheries, management, surveys

Affiliation: 1 - The Nature Conservancy, 652 Peter Jefferson Parkway, Suite 190, Charlottesville, Virginia 22911, USA

Contact Author: Brendan.runde@tnc.org

CM 524: Race for ocean space- and reducing the burden on ecosystems

Solfrid Sætre Hjøllo, Sigurd Solheim Pettersen, Øivin Aarnes, Bjørnar Arnesen, Bente Petrove, Øivind Bergh, Anne D. Sandvik

The coming era for the blue economy will be shaped by humanity's pressing need for sustainable energy and food, but any industrial expansion must take place in a safe, secure, and equitable manner. This requires careful study of the impact each industry has on its environment and on local communities, considering the cumulative effects from all industries combined. The MARine CO-existence scenario building (MARCO) toolbox will combine spatial and temporal analysis to capture this complexity, and the combined analysis address key uncertainties, barriers, and opportunities to deal with future spatial conflicts and to safeguard ocean health. The spatial analysis will utilise GIS (Geographic Information System) technology for mapping out plausible development trajectories in selected regions to link and explore implications to marine ecosystems and vice versa. The temporal analysis using system dynamics (SD) modelling links economic development with impact on nature through clearly devised causal relationships and feedback loops. To account for the lack of knowledge about key effects on ecosystems from e.g. offshore wind and/or offshore aquaculture development, consideration of uncertainty will be important and will contribute to a reduction of the trust gap among ocean stakeholders. Examples of scenario building and incorporation of ecosystem- wide and socio-economic information will be presented.

Keywords: ocean space, scenario, offshore wind, offshore aquaculture, coexistence

Contact Information: solfrid.hjoillo@hi.no

<u>CM 567:</u> Ecological indicators of offshore wind interactions with marine ecosystems: Considerations for monitoring design

Elizabeth T. Methratta

Offshore wind development (OWD) is taking place in dynamic marine ecosystems that are facing multiple pressures including climate change, acidification, and fishing. There is a need to develop information-rich monitoring approaches that are able to disentangle OWD effects from other pressures and inform ameliorative solutions to unwanted OWD impacts. The objective of this project was to evaluate potential ecological indicators of OWD effects that could be considered for monitoring programs including indices of aggregate biomass, trophic dynamics, sensitive species, and size-based indices. Indicators were evaluated by comparing the direction and strength of their long-term temporal trends at two spatial scales: the scale of the Southern New England wind energy area (WEA) and the scale of the Southern New England Region in which the WEA is located. Several ecological indicators that are likely to be sensitive to OWD have significant temporal trends at either the WEA scale, the region scale, or both. This highlight the importance of addressing temporal variability in the design and duration of monitoring programs. Toward the goal of developing informative monitoring approaches, the following recommendations are made: 1). Identify clear research objectives and hypotheses; 2). Select a set of meaningful ecological indicators that can be sampled across projects within a region that link to stated hypotheses. 3) Collect indicator data using standardized methods across projects that are comparable to those used by long term regional and ecosystem wide surveys; 4) Use methodologies that enable cross-scale comparisons (project level, region level, shelf level) of temporal trends and allow the detection of divergence of project-level trends from broad scale trends if and when they occur; 5) Collect at least 3 years of project-level baseline indicator data in order to assess inter-annual variability and account for temporal structure in the data analysis phase; 6) Conduct post-construction project-level monitoring for the lifetime of the project; 7) Apply quantitative methods that allow for the analysis of trends in time series data, the ability to make causal inferences about the drivers of those trends, and the ability to determine if those drivers differ before vs. after construction; 8) Identify, vet with stakeholders, and choose meaningful decision criteria including thresholds at which action should be taken to ameliorate unwanted impacts; 9) Develop an IEA framework that incorporates relevant ecological indicators; 10) Provide open and transparent access to data and information to stakeholders.

Keywords: renewable energy, impact assessment, monitoring design, ecosystem function

Contact Information: elizabeth.methratta@noaa.gov

CM 578: Utilizing Bioclimate Modeling as a Technique to Understand Offshore Renewable Energy Effects Across Large Spatial Scales

Claire Ober[1], Yong Chen

Offshore wind power is poised to be one of the United States' next major energy sources, with several states and the federal government having released plans in the past few years to develop offshore wind programs. Given the interest in rapidly developing the scale, pace, and magnitude of offshore renewable energy installations, it is important to fully understand the complicated and intricate challenges that are emerging during this process. One such challenge is that large-scale wind operations will occupy sizable areas of marine space, and the ecosystem-wide effects of this perturbation is still largely unknown. Recent studies have demonstrated that offshore wind installations have a wide variety of localized effects ranging from trophic interactions to changes in localized currents, and as impacts may accumulate with time and location, it is important to consider potential impacts to the entire ecosystem rather than just focusing on the impacts within each individual wind energy area. Therefore, it is imperative to try and understand the consequences of offshore wind installations on a larger ecosystem-wide scale. This can be accomplished through the use of modeling techniques to upscale localized observations and relationships to an ecosystem-wide level in order to look at the broad changes across a region. Using longfin inshore squid (*Doryteuthis pealeii*) in the New York Bight region as a case study, this work describes the development and parameterization of a habitat suitability index (HSI) model to hind-, now-, and forecast key suitable habitat areas for longfin squid. An HSI model relies on quantified species-environment relationships to understand and predict spatial distributions of suitable habitat. This is a useful tool for exploring changes across a large spatial scale and forecasting potential responses under three defined future climate change scenarios, which is critical to both marine spatial planning efforts and for the scientific understanding needed in well-developed cumulative impact assessments. Understanding both species and habitat shifts within a large geographical area can help scientists, managers, developers, and other stakeholder groups to better address concerns relating to impacts from offshore wind energy areas to economically and ecologically important fisheries.

Keywords: bioclimate models, habitat suitability, offshore wind energy, ecosystem-wide effects

Affiliation: 1 - Stony Brook University, School of Marine and Atmospheric Sciences, Stony Brook, New York, 11790, USA

Contact Information: claire.ober@stonybrook.edu

CM 584: Impacts to Northeast US fishery-independent surveys and stock abundance indices due to offshore wind development

Angelia Miller[1], Catalina Roman, Catherine Foley, Kathryn Ford, Andrew Lipsky, Philip Politis, Gavin Fay

Offshore wind energy development is occurring throughout the Northeast Large Marine Ecosystem and will interact with many marine use sectors, including fisheries. Wind areas overlap spatially with the footprint of the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) multispecies bottom trawl survey, which has been conducted since the 1960s, and whose data are relied upon for the assessment and management of many fisheries stocks in the Northeast US. This fishery-independent survey is confronted by potential preclusion of trawl sampling efforts due to the spatial conflict arising from offshore wind energy development. There is a need to quantify the impacts of preclusion to monitoring and operations, and understand changes to species distributions and abundances within wind areas, which could jointly affect downstream data products, such as stock abundance indices, and fisheries management advice. Initial analyses serve as a proxy for expected losses for comparison to our species distribution modeling and suggest that, when accounting for reduced trawl samples, annual estimates of relative abundance are lower than those calculated when including all samples. Additionally, when compared to a random, null model of effort reduction, preclusion of wind areas resulted in lower abundance estimates. Applying summer flounder (*Paralichthys dentatus*) as a case study, we fit a spatiotemporal generalized linear mixed effects model (GLMM), generate simulated survey data, and calculate indices of abundance to compare survey outcomes with and without trawl samples inside proposed wind development areas. Finally, we extend the species distribution operating model to examine changes in species productivity, and to survey catch rates, as a function of offshore wind development. We find that loss of samples inside wind areas have a substantial impact on the abundance index. This study contributes directly to implementation of the Federal Survey Mitigation Strategy for the Northeast U.S. Region (Action 3.2.2) as a part of the Survey Simulation Evaluation and Experimentation Project , which aims to assess potential impacts to the bottom trawl survey operations and data products and identify mitigation strategies to maintain data integrity. Furthermore, we aim to improve upon the current knowledge surrounding the impacts that offshore wind energy development can have on fishery-independent surveys, which globally is scarce.

Keywords: survey effort reduction, preclusion, bottom trawl, species distribution modeling

Affiliation: 1 - University of Massachusetts Dartmouth, School for Marine Science and Technology, Department of Fisheries Oceanography

Contact Information: M.S. Student and Research Assistant, Angelia Miller, amiller7@umassd.edu

CM 628: Development of conceptual models to understand the interactions of offshore wind development and fisheries in the U.S. Gulf of Maine, Northwest Atlantic

Angela Silva[1,2], Abigail Tyrell[1,3], Sean M. Lucey[1], Fiona Hogan[4], Jen McCann[5]

In response to concerns voiced by fisheries stakeholders, we co-produced conceptual models to better understand the interactions between offshore wind, fisheries, and the environment in the Gulf of Maine (USA), a unique ecological region in the Northwest Atlantic. The development of conceptual models is the first step in a larger Integrated Ecosystem Assessment (IEA) process that will provide scientific advice for offshore wind development in the Gulf of Maine. Our interdisciplinary team is co-led by the NOAA Fisheries IEA program, the Responsible Offshore Development Alliance (RODA) and the University of Rhode Island. To develop the initial key nodes in the conceptual model, public comment letters from the fishing industry, submitted through the Bureau of Offshore Energy Management's (BOEM's) formal comment process, were analyzed through thematic coding analysis. We further developed the conceptual models through literature reviews and workshops held with fishing industry members, during which we (1) identified important linkages between fishing, the environment, and offshore wind development and operation in the Gulf of Maine, (2) discussed these linkages and identified data needed to measure the current conditions and potential future impacts from offshore wind. The next steps of the IEA process will be to gather data and existing indicators, identify gaps and limitations, and seek out means to develop new indicators. Among the many public comments voiced thus far, there has been near-universal agreement that fishing industry data, including local ecological knowledge (LEK) must be adequately considered when BOEM designates wind energy areas and assesses impacts of offshore wind projects. A wind-focused IEA can support that need and help ocean managers avoid, minimize, and mitigate, as well as monitor the impacts of offshore wind on the fishing industry. We will share lessons learned, including best practices for conceptual model development, collaborative stakeholder engagement, and effective strategies for assessing tradeoffs of multiple ocean uses.

Keywords: fisheries, offshore wind, conceptual model, stakeholder engagement

Affiliations: [1]National Oceanic and Atmospheric Administration, USA, [2] ECS Federal, Inc, USA, [3] IBSS Corporation, USA, [4] Responsible Offshore Development Alliance, USA, [5] Rhode Island SeaGrant, USA

Contact information: angela.silva@noaa.gov

CM 629: Improving analyses of the potential for fishing effort displacement caused by offshore development via integration of fishermen's ecological knowledge

Anne Hawkins[1], Fiona Hogan, Lane Johnston, Mike Conroy, Andrew Lipsky

The Responsible Offshore Development Alliance, in partnership with NOAA Fisheries, is examining the current state of knowledge regarding floating offshore wind energy (OSW) development and fisheries and the overlapping footprint between these industries. Because of the great speed and scope of OSW development in the United States, there is a need for greater comprehensive understanding of impacts -- both environmental and socioeconomic -- resulting from the interactions between these infrastructure projects and fisheries and marine ecosystems. A baseline of fishing effort patterns is required to understand the overlap of OSW and fishing and potential displacement, as well as to form the basis of mitigation and avoidance efforts aimed at minimizing impacts. Two primary sources of data may be informative to this effort: (1) proprietary fishing industry-held data; and (2) public or agency data sets. A major hurdle to inclusion of the former is the confidential nature of fishery-dependent data, which RODA is seeking to address through the creation of the Fisheries Knowledge Trust. Use of the public data sets in planning, meanwhile, will benefit from the perspectives of fishermen and inclusion of their knowledge gained at sea in order to improve presentation and interpretation of the underlying data. RODA is working directly with the fishing industry as part of its Synthesis of the Science II project to examine and improve publicly available maps of fishing effort. This follows on to a previous project conducted with Regional Ocean Partnerships to identify research recommendations and best practices for depicting fishery dependent data as determined by participants in those fisheries, this time with emphasis on regions where floating OSW technology is proposed.

Keywords: Responsible Offshore Development Alliance, RODA, Synthesis of the Science, commercial fisheries, offshore wind, floating, fishery dependent data

Affiliation: 1 - RODA, P.O. Box 66704 Washington, D.C. 20035

Contact information: annie@rodafisheries.org

CM 630: Fisheries and floating offshore wind energy: Synthesis of the Science II

Fiona Hogan[1], Anne Hawkins, Lane Johnston, Mike Conroy, Andrew Lipsky

The Responsible Offshore Development Alliance, in partnership with NOAA Fisheries, is examining the current state of knowledge regarding floating offshore wind development and fisheries. Offshore wind energy development (OSW) is progressing at a rapid pace in the United States in order to meet the national goals for this industry to produce 30 GW of power by the year 2030 and 15 GW generated from floating turbines by 2035. These ambitious goals have resulted in individual states recommending the installation of floating turbine technology in their deep, surrounding waters. Planning for floating technology OSW has begun in the Gulf of Maine, a semi-enclosed sea located in the northwest Atlantic, along the Pacific coast in the deep waters off California, Oregon, and Washington, and offshore the Mid-Atlantic region. Despite the large speed and scope of OSW development in the U.S., there is a need for greater comprehensive understanding of scientific research ongoing, and previously conducted, looking at the interactions between these infrastructure projects on fisheries and marine ecosystems. Our project focuses on floating turbine technology to provide a greater understanding of the technology, and its impact, to the fishing industry and general public, with a heavy focus on the integration of fishermen's ecological knowledge into planning exercises. The first phase involved a review of floating turbine technology to provide greater understanding of it to fishing industry members. The review will also include any unique impacts on the environment and local fishing communities that have been identified. Future work will involve convening two workshops to discuss floating OSW-related technology, potential adaptations and aim to build relationships between the two industries and explore opportunities for collaboration on engineering, materials, design, and other research and development activities.

Keywords: Responsible Offshore Development Alliance, RODA, Synthesis of the Science, commercial fisheries, offshore wind, floating offshore wind, fishermen's ecological knowledge

Affiliation: 1 - RODA**,** P.O. Box 66704**,** Washington, D.C. 20035

Contact information: fiona@rodafisheries.org

CM 636: Nature positive approaches in the offshore wind industry: a systematic review

Juan Pardo[1], Magnus Aune, Christopher Harman, Mats Walday, Solrun Skjellum

Renewables are important players in accelerating global de-carbonisation and support international environmental goals. Offshore wind is one of the major fast-growing renewable energy industries, and sustainable implementation of future offshore wind farms (OWF) is desired. Nature-positive approaches, thus including nature-based solutions and nature inclusive design, have been proposed to promote biodiversity enhancement and improve ecosystem resilience. Offshore wind farms interact with several other actors and activities, and the knowledge from these collaborations may support a nature positive OWF industry. In our study, we systematically reviewed the current knowledge and development of nature positive approaches in OWFs. We also review co-existence and activities that are relevant to OWFs, thus providing perspectives and recommendations regarding synergies among industries. We observed an increased interest in the topic over the last five years, and most of the studies included in the review focused on activities in the northern hemisphere, and in particular in European countries, and the North Sea. Nature positive-focused documents are still limited for floating OWFs, most of the literature being related to bottom-fixed turbines, and there is a lack of long-term in-situ assessments of the impact of nature positive approaches. Documents highlight the importance of the artificial reef effect and biodiversity protection and enhancement (diversity and abundance) for several ecological and economical relevant groups. Coexistence strategies with OWF, such as fisheries, aquaculture, and marine protected areas (MPAs), may bring positive and negative outcomes for the OWF industry, and further investigation on their integration to achieve positive outcomes should be explored.

Keywords: renewables, offshore wind farm, nature positivity, nature inclusive design, co-existence

Affiliation: 1 - Norwegian Institute for Water Research (NIVA), Centre for Coastal research (CCR), University og Agder (UiA), Jon Lilletuns vei 3, 4879 Grimstad, Norway

Contact author: PhD Research Fellow/Research Assistant, juan.pardo@ni.va.no