Offshore Wind Farm Site Location/Effort Displacement

Bibliography

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Background & Scope

This bibliography is a representative sample of relevant literature on offshore wind farm site location and its impact on marine species and the fishing community. References are from 2003-2021, with the focus on the last 10 years. Please find all references listed alphabetically.

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; EconLit; ProQuest's Science and Technology including Aquatic Science Fisheries Abstracts; Elsevier's Science Direct; JSTOR; EBSCO's Academic Search Complete and Environment Complete; NOAA's Institutional Repository; the Biodiversity Heritage Library; BioOne Complete; and Google Scholar.

References

Abhinav, K. A., Collu, M., Benjamins, S., Cai, H. W., Hughes, A., Jiang, B., . . . Zhou, B. Z. (2020). Offshore Multi -Purpose Platforms for a Blue Growth: A Technological, Environmental and Socio-Economic Review. *Science of The Total Environment, 734* https://doi.org/10.1016/j.scitotenv.2020.138256

"Blue Growth" and "Blue Economy" is defined by the World Bank as: "the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, while preserving the health of ocean ecosystem". Multi-purpose platforms (MPPs) can be defined as offshore platforms serving the needs of multiple offshore industries (energy and aquaculture), aim at exploiting the synergies and managing the tensions arising when closely co-locating systems from these industries.

Despite a number of previous projects aimed at assessing, from a multidisciplinary point of view, the feasibility of multipurpose platforms, it is here shown that the state-of-the-art has focused mainly on single-purpose devices, and adopting a single discipline (either economic, or social, or technological, or environmental) approach. Therefore, the aim of the present study is to provide a multidisciplinary state of the art review on, whenever possible, multi-purpose platforms, complementing it with single-purpose and/or single discipline literature reviews when not possible. Synoptic tables are provided, giving an overview of the multi-purpose platform concepts investigated, the numerical approaches adopted, and a comprehensive snapshot classifying the references discussed by industry (offshore renewables, aquaculture, both) and by aspect (technological, environmental, socio-economic). The majority of the multi-purpose platform concepts proposed are integrating only multiple offshore renewable energy devices (e.g. hybrid wind-wave), with only few integrating also aquaculture systems. MPPs have significant potential in economizing CAPEX and operational costs for the offshore energy and aquaculture industry by means of concerted spatial planning and sharing of infrastructure.

Alexander, K. A., Meyjes, S. A., & Heymans, J. J. (2016). Spatial Ecosystem Modelling of Marine Renewable Energy Installations: Gauging the Utility of Ecospace. *Ecological Modelling, 331*, 115-128 https://doi.org/10.1016/j.ecolmodel.2016.01.016

The deployment of offshore structures for renewable energy generation (wind/wave/tidal) will lead to the alteration of access to the area of installation for several users of the sea including: shipping, fishing, tourism and recreational users. Arguably, the largest impact will be upon the fishing industry where access loss may lead to displacement and reduced catch per unit effort in turn leading to conflict. To prevent conflict, it is important to understand mitigating factors. Marine renewable energy devices (MREDs) and associated infrastructure will be placed on the seabed, affecting benthic infauna and epifauna, important sources of food for many species including those of commercial importance, potentially providing benefits to the fishing industry and mitigating the causes of conflict. Two key plausible benefits of MREDs are the 'artificial reef effect' and the 'exclusion zone effect'. This study investigated the utility of the Ecopath with Ecosim and Ecospace modelling software to address the implications of these 'effects'. Two case study models were developed, one at the whole west coast of Scotland shelf scale and one at a smaller single installation scale. Our results suggested that the Ecospace model could potentially predict the effects of MRED installations, but revealed that there are a number of considerations which should be taken into account before attempting to do this. Key considerations include data availability (an issue in all modelling), spatial scale and resolution. Other limitations to this particular study such as the ability to make changes over time are currently being

addressed by ongoing developments of the software. Despite the considerations and limitations, these case studies reveal the usefulness of spatial ecosystem modelling, particularly Ecospace, to investigate this issue.

Avery, J. (2014). *Evaluation of Interactions between the Fishing Industry and the Offshore Renewable Energy Industry in the UK: A Consideration of Suitable Mitigation Strategies.* Plymouth University, No Available URL

The rapid developments in the offshore renewables sector in the UK pose numerous threats to local fishing communities. However, due to the considerable amount of space taken up by such developments, offshore renewables possess a unique opportunity to benefit fisheries. A survey questionnaire was designed to assess attitudes amongst the UK fishing industry towards the development of offshore renewables. Whilst attitudes towards the development of offshore renewable varied significantly, the majority of fishermen surveyed described negative impacts on their fishing activities. There was also a strong consensus that dialogue between the fishing industry and offshore renewables developers needs to be strengthened. These results of the survey were then compared with fisheries data from the MMO and wind farm data from 4C Offshore. Based on the combinations of this information, and the reviewed scientific literature, two main mitigation options were suggested and discussed. The first mitigation option is to designate existing and future offshore wind farms as marine protected areas; with site-specific conservation objectives to benefit local fisheries. The second mitigation option is to provide an alternative livelihood to commercial fishermen by implementing aquaculture projects into existing offshore wind farms, with an emphasis on co-use management.

Bastardie, F., Nielsen, J. R., Eigaard, O. R., Fock, H. O., Jonsson, P., & Bartolino, V. (2015). Competition for Marine Space: Modelling the Baltic Sea Fisheries and Effort Displacement under Spatial Restrictions. *ICES Journal of Marine Science, 72*(3), 824-840 https://doi.org/10.1093/icesjms/fsu215

Maritime spatial planning (MSP) and fishery management may generate extra costs for fisheries by constraining fishers activity with conservation areas andnew utilizations ofthe sea. Moreenergy-efficient fisheries are also likely to alter existing fishing patterns, which already vary from fisheryto fishery and from vessel to vessel. The impact assessment ofnew spatial plans involving fisheries should be based on quantitative bioeconomic analyses that take into account individual vessel decisions, and trade-offs in cross-sector conflicting interests.Weuse a vessel-oriented decision-support tool (the DISPLACE model) to combine stochastic variations in spatial fishing activities with harvested resource dynamics in scenario projections. The assessment computes economic and stock status indicators by modelling the activity ofDanish, Swedish, and German vessels (.12 m) in the international western Baltic Sea commercial fishery, together with the underlying size-based distribution dynamics ofthe main fishery resources of sprat, herring, and cod. The outcomes of alternative scenarios for spatial effort displacement are exemplified by evaluating the fishers's abilities to adapt to spatial plans under various constraints. Interlinked spatial, technical, and biological dynamics ofvessels and stocks in the scenarios result in stable profits, which compensate for the additional costs from effort displacement and release pressure on the fish stocks. The effort is further redirected away from sensitive benthic habitats, enhancing the ecological positive effects. The energy efficiency of some of the vessels, however, is strongly reduced with the new zonation, and some ofthe vessels suffer decreased profits. The DISPLACE model serves as a

spatially explicit bioeconomic benchmark tool for management strategy evaluations for capturing tactical decision-making in reaction to MSP.

Bastardie, F., Brown, E. J., Andonegi, E., Arthur, R., Beukhof, E., Depestele, J., . . . Reid, D. (2021). A Review Characterizing 25 Ecosystem Challenges to Be Addressed by an Ecosystem Approach to Fisheries Management in Europe. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2020.629186

The impacts of fisheries on ocean resources are no longer considered in isolation but should account for broader ecosystem effects. However, ongoing ecosystem-wide changes added to the inherent dynamics of marine ecosystems, create challenges for fisheries and fisheries management by affecting our ability to ensure future fishing opportunities and sustainable use of the seas. By reviewing a corpus of fisheries science literature, we contribute to informing policymakers with considerations of the various threats to fisheries and the marine ecosystems that support them. We identify and describe 25 ecosystem challenges and 5 prominent families of management options to address them. We capture the challenges within three broad categories: i) fishing impacts on the marine environments and future fishing opportunities, ii) effects of environmental conditions on fish and fishing opportunities, and iii) effects of socioeconomics, fisheries management and institutional set-up on fisheries. Our review shows that, while most EU fisheries are facing a similar array of challenges, some of them are specific to regions or individual fisheries. We reflect this in selected regional cases to exemplify the challenges along with fishery-specific cases, among the dramatic Baltic cod situation facing an array of cumulative pressures, moving ecosystem interactions that rely on the North Sea forage fish facing climate change, fishing interactions in a fluctuating mixed fishery in the Celtic Sea, bycatch and habitat degradation in the Bay of Biscay, undercapacity and lack of knowledge on some features of the EU Outermost Regions. We conclude by recognizing knowledge gaps regarding the direction of causality, nonlinear responses and confounding effects. All of the challenges we identify may guide further data collection and research coordination to improve our understanding and to monitor real changes, both of which are required to inform an Ecosystem Approach to Fisheries Management (EAFM). An European EAFM could build upon an array of management measures currently tailored for fisheries management only, including promoting funding interdisciplinary research and ecosystem monitoring. Such integrative management should reduce uncertainties in environmental, social and economic trends, and lower the risk for disruptive events or ecosystem effects with far-reaching consequences, including a shift toward less productive marine ecosystems.

Berkenhagen, J., Döring, R., Fock, H. O., Kloppmann, M. H. F., Pedersen, S. A., & Schulze, T. (2010). Decision Bias in Marine Spatial Planning of Offshore Wind Farms: Problems of Singular Versus Cumulative Assessments of Economic Impacts on Fisheries. *Marine Policy, 34*(3), 733-736 https://doi.org/10.1016/j.marpol.2009.12.004

The current approval procedure for wind farm proposals in the German EEZ only considers site specific conflict analysis between the wind farm and fisheries. Due to the relatively small spatial coverage of the sites potential opportunity losses to the fisheries are always considered as low or negligible. Cumulative effects on fisheries that will occur once all proposed wind farms are in place are not yet considered adequately. However, those cumulative effects will be quite substantial because, in particular, opportunities to catch such valuable species as flatfish will be considerably reduced.

Buck, B. H., Ebeling, M. W., & Michler-Cieluch, T. (2010). Mussel Cultivation as a Co-Use in Offshore Wind Farms: Potential and Economic Feasibility. *Aquaculture Economics and Management, 14*(4), 255-281 https://doi.org/10.1080/13657305.2010.526018

More than 50% of the annual worldwide harvest of mussels is produced in Europe. The mussel cultivation in Germany is based on an extensive on-bottom culture and depends entirely on natural resources for food, spat and space. Due to stakeholder conflicts and a lack of spat availability, mussel farmers tend to move offshore where space is not limited and adequate settlement guaranteed. Newcomers--the offshore wind farmers--are covering large areas in the German Bight which in contrast give the opportunity to use these areas in a multifunctional way by accepting mussel cultivation within the wind farms. This study compiles the basic data for offshore mussel cultivation in close vicinity to a designated offshore wind farm in the open sea of the German Bight and employs different case-scenario calculations to illustrate the impact of changing parameter values on overall profitability or non-profitability of this activity. Primary focus is placed on the production of consumer mussels but seed mussel cultivation is also taken into consideration. We show that production of consumer mussels with longline technology is sufficiently profitable even under the assumption of substantial cost increases. This is especially true, if existing capacities could be used. The cultivation of seed mussels depends on the possibility of using existing equipment. A substantial increase of seed mussel prices to at least 0.6 euros, given the main cost categories remaining constant, turns this alternative into substantial profitability. This study concludes with providing some recommendations on how favorable terms or actions could further improve profitability of offshore mussel cultivation. Altogether, our results are intended to shed some light on business management topics that future offshore mariculture operators such as traditional mussel farmers should follow in order to be efficient.

Campbell, M. S. (2017). *Fisheries, Marine Conservation, Marine Renewable Energy and Displacement: A Fresh Approach.* University of Plymouth, Retrieved from http://hdl.handle.net/10026.1/8336

Fishers are among the biggest commercial resource users in the marine environment. In order to meet international, national and local policies, the UK has to designate a suite of marine protected areas (MPAs) and reach marine renewable energy (MRE) targets. Inevitably, there will be conflict between these two industries and marine conservation. This study uses a multi-disciplinary approach to examine evaluate the suitability of various sources of data, which could be used to detect, assess, and ultimately predict, fishing effort displacement within the different sectors of the > 15 m fleet in the South West of the UK. Gear-specific Vessel Monitoring System (VMS) data from 2005-2008 was used to assess potential effort displacement due to Haig Fras, a proposed MPA and Wave Hub, a marine renewable energy installation (MREI). The spatial distribution of fishing activity was highly heterogeneous and distinct areas of intense fishing could be identified for all gear-types. A closure of Haig Fras would have the greatest impact on gillnetters. Scallop dredgers also occasionally use the area. The current closure at Wave Hub has the greatest impact on potters and whelkers whose geographic specialisation is most pronounced and who use the area extensively. Longliners also use the area disproportionately would be affected. A simple index of variability was developed in order to determine baselines and two other sources of data were used. High resolution seabed data and low resolution catch data. A semi structured interview was conducted with forty fishers to elicit further information on the challenges, barriers to progress and priority issues in relation to MRE those fishers face. The theme of discontent with the consultation process scored highly throughout. Fishers' Knowledge (FK) another source of data also

scored highly, although further work must be carried out to identify what aspects of this data are useful in assessment of fishing effort displacement.

Campbell, M. S., Stehfest, K. M., Votier, S. C., & Hall-Spencer, J. M. (2014). Mapping Fisheries for Marine Spatial Planning: Gear-Specific Vessel Monitoring System (Vms), Marine Conservation and Offshore Renewable Energy. *Marine Policy, 45*, 293-300 https://doi.org/10.1016/j.marpol.2013.09.015

Vessel Monitoring System (VMS) data from 2005 to 2008 in ICES Divisions VIIe-h were used to assess the distribution and intensity of fishing activity in and around the western English Channel, one of the most intensively used marine areas on the planet. The distribution of the UK fleet of large (> 15 m length). fishing vessels was analysed and clear gear-specific temporal and spatial differences in activity were found. Mobile demersal gears had the highest intensity and widest distribution of activity in the study area, and so might be expected to have the most widespread ecosystem-level impacts. The potential effects of two proposed fisheries closures; a planned wave energy testing facility (Wave Hub) and a candidate offshore Marine Protected Area (Haig Fras) are described. Maps indicate that mobile demersal gear fleets would be little affected if they were excluded from these proposed closures, but if the static gear fleets were excluded this would likely result in displacement of certain vessels, increasing fishing pressure on other rocky grounds and other fishers. Predictions concerning the effects of fisheries displacement can be improved through the use of high-resolution gear-specific activity data. This study shows that VMS can provide an invaluable source of such data, provided that gear information is made available to fisheries managers and scientists. (C) 2013 Elsevier Ltd. All rights reserved.

Carrella, E., Bailey, R. M., & Madsen, J. K. (2019). Repeated Discrete Choices in Geographical Agent Based Models with an Application to Fisheries. *Environmental Modelling & Software, 111*, 204-230 https://doi.org/10.1016/j.envsoft.2018.08.023

Most geographical agent-based models simulate agents through custom-made decision-making algorithms. This makes it difficult to assess which results are general and which are contingent on the algorithm's details. We present a set of general algorithms, applicable in any agent-based model for choosing repeatedly from a set of alternatives. We showcase each in the same fishery agent-based model and rank their performance under various scenarios. While complicated algorithms tend to perform better, too much sophistication lowers performance. Further, while some algorithms perform well under all scenarios, others are optimal only in specific circumstances. It is therefore impossible to produce a single, unequivocal performance ranking even for simple general algorithms. We advocate then a heuristic zoo approach where multiple algorithms are implemented in the same model; this allows us to identify its best algorithm and test sensitivity to misspecifications of the decision-making component.

Chagaris, D., Allen, M., & Camp, E. (2019). Modeling Temporal Closures in a Multispecies Recreational Fishery Reveals Tradeoffs Associated with Species Seasonality and Angler Effort Dynamics. *Fisheries Research, 210*, 106-120 https://doi.org/10.1016/j.fishres.2018.10.018

Seasonal closures are commonly used to reduce fishing mortality in recreational and commercial fisheries, but they may be less effective when effort is merely displaced to the open season or in

multispecies fisheries that allow for discarding to continue while other species are targeted. The latter is especially true for the valuable multispecies recreational reef fish fishery in the Gulf of Mexico, where discard mortality is high and it can be difficult to avoid catching one species while fishing for others. We evaluated the utility of complete bottom fishing closures (in addition to already mandated harvest closures) that would temporarily prohibit recreational reef fishing as a means to control effort, reduce the amount of dead discards, and improve stock status of multiple species. In this study we developed age-structured population models for six Gulf of Mexico reef fish species that dominate the recreational catch, with each model linked to a monthly effort dynamic model for the recreational fishery. The effect of closing any given month(s) varied across species and resulted in tradeoffs, such that some closures may result in positive effects on biomass of one species and negative effects on others. For example, a spring closure was predicted to have positive effects on Red Snapper Lutjanus campechanus spawning stock biomass but negative effects on Gag grouper Mycteroperca microlepis due to the contrasting patterns in harvest rates during those months. These tradeoffs were associated with seasonal availability patterns and the degree to which anglers might shift effort to the open season. The closure scenarios that were most likely to reduce dead discards without negatively impacting harvest, spawning biomass, or total effort occurred in late winter and early spring (March & April). In evaluating seasonal fishing closures, the gains in biomass and reductions in dead discards must be weighed against the socio-economic tradeoffs, in terms of lost effort-generated revenue at various spatial and temporal scales and angler dissatisfaction.

Clements, A., & Service, M. (2016). *Alternative Marine Conservation Zones in Irish Sea Mud Habitat: Assessment of Habitat Extent and Condition at 'Queenie Corner' and Assessment of Fishing Activity at Potential Mcz Sites.* Prepared by AFBI Fisheries and Aquatic Ecosystems Branch for Seafish, Edinburgh. Retrieved from http://www.seafish.org/media/Publications/Evidence_base_mud_MCZs_IrishSea_v1_2-FINAL.pdf

27 Marine Conservation Zones (MCZs) in Secretary of State and English waters were designated by the UK government, acting through Defra, in a first tranche in 2013, followed by a second tranche of 23 MCZs designated in 2016. Consultation of a third tranche is planned for early 2017, including potentially a number of sites of particular concern to the Northern Ireland fishing industry (Slieve Na Griddle, South Rigg and Mud Hole). Defra previously identified that these three sites, which were originally suggested through the Irish Sea Conservation Zones project, require further consideration due to their location within important fishing grounds, and that their designation "could have a significant impact on the fishing sector, particularly within Northern Ireland". Defra has encouraged the fishing industry to develop alternative site proposals for protecting subtidal mud habitats in the Irish Sea region, and that all available options will be then be considered in the third tranche of designations (Defra, 2015). Alternative sites were proposed following stakeholder engagement in a report for Seafish by AFBI in 2015 (AFBI, 2015); this concluded that the "least worst" options in terms of potential fishery displacement, yet representing the key habitat of interest, subtidal mud, were West of Walney in the eastern Irish Sea and a new site, "Queenie Corner", in the western Irish Sea. West of Walney was included in Tranche 2 of the MCZ designations, and this included a co-location zone with wind farms which had held up its submission in Tranche 1. It passed through consultation and was designated in January 2016. The site proposed as "Queenie Corner" in AFBI (2015) was formally proposed to Defra for consideration in October 2015, with support of both the Anglo-North Irish Fish Producers' Organisation Ltd. and Northern Ireland Fish Producers' Organisation Ltd. However, due to the introduction of the Welsh Fishery Zone, the site had to be re-drawn to avoid overlap with this zone, which reduced the

original site area proposed. During 2014 and 2015 additional surveys were completed by AFBI aboard the RV Corystes to provide the habitat evidence required for full consideration of Queenie Corner by Defra. Seafish provided funding for processing of samples and work up of these data to evaluate the presence, extent and condition of the habitat at Queenie Corner, and compare this to similar evidence at the remaining potential sites of Slieve Na Griddle, South Rigg and Mud Hole. This work is reported here, along with a comparison of fishing effort between 2006 and 2014 over each of these sites, and also West of Walney, to provide an overview of how these sites compare in terms of potential fisheries displacement should designation occur and management measures require banning of mobile gear fisheries.

Coates, D. A., Kapasakali, D.-A., Vincx, M., & Vanaverbeke, J. (2016). Short-Term Effects of Fishery Exclusion in Offshore Wind Farms on Macrofaunal Communities in the Belgian Part of the North Sea. *Fisheries Research, 179*, 131-138 https://doi.org/10.1016/j.fishres.2016.02.019

With the wide scale construction of offshore wind farms (OWFs) throughout the entire North Sea, large areas are permanently being closed to beam trawl fisheries. Beam trawling has affected macrobenthic assemblages for centuries, especially the fragile and long-lived species. Due to the prohibition of bean trawling in many OWFs, opportunities are being provided to investigate the potential recovery of vulnerable species and the creation of de-facto Marine Protected Areas (MPAs). The soft-substrate macrobenthic community was investigated from 2008 to 2012, before and after the construction of an OWF in the Belgian part of the North Sea, situated on the Bligh Bank. The fishery enclosed area (±21km2) within the OWF (No Fishery area) was compared with a surrounding control area (±30km2) where regular fishing activities were registered through vessel monitoring system (VMS) data throughout the period 2010–2011. Three years after the exclusion of beam trawl fisheries, subtle changes within the macrobenthic community were observed in the No Fishery area. The benthic mysid shrimp Gastrosaccus spinifer (30±15indm−2), tube-building polychaetes Terebellidae sp. (196±151indm−2) and the echinoderm Echinocyamus pusillus (73±71indm−2), sensitive to trawling activities, showed increased abundances within the No Fishery area. With an expansion of the wind farm concession area to 238km2 in the future, the likely increase of dense Terebellidae patches (e.g., Lanice conchilega reefs) within the No Fishery area could create an ecological important large-scale refugium for higher trophic levels. This study creates a baseline for the evaluation of long-term changes due to the fishing impacts and effects related to the presence of OWFs and highlights the importance of executing long-term monitoring programs in combination with targeted research.

Copping, A., Hanna, L., Brie Van, C., Blake, K., & Anderson, R. M. (2015). Environmental Risk Evaluation System—an Approach to Ranking Risk of Ocean Energy Development on Coastal and Estuarine Environments. *Estuaries and Coasts, 38*(1), 287-302 https://doi.org/10.1007/s12237-014-9816-3

The pressure to develop new and renewable forms of energy to combat climate change, ocean acidification, and energy security has encouraged exploration of sources of power generation from the ocean. One of the major challenges to deploying these devices is discerning the likely effects those devices and associated systems will have on the marine environment. Determining the effects each device design and deployment system may have on specific marine animals and habitats, estimating the extent of those effects upon the resiliency of the ecosystem, and designing appropriate mitigation measures to protect against degradation all pose substantial challenges. With little direct observational or experimental data available on the effects of wave, tidal, and offshore wind devices on marine

animals, habitats, and ecosystem processes, researchers have developed the Environmental Risk Evaluation System (ERES) to provide preliminary assessments of these risks and to act as a framework for integrating future data on direct interactions of ocean energy devices with the environment. Using biophysical risk factors, interactions of marine animals and seabirds, with ocean energy devices and systems, are examined; potential effects on habitats, and changes in processes such as sedimentation patterns and water quality, are also considered. The risks associated with specific interactions for which data are more readily available are explored including interactions between ocean energy devices and surface vessels, toxicity of anti-biofouling paints, and potential for harm to animals from turbine blade strike. ERES also examines the effect that environmental regulations have on the deployment and operation of ocean energy devices.

Cucknell, A. C., Boisseau, O., Leaper, R., McLanaghan, R., & Moscrop, A. (2017). Harbour Porpoise (Phocoena Phocoena) Presence, Abundance and Distribution over the Dogger Bank, North Sea, in Winter. *Marine Biological Association of the United Kingdom. Journal of the Marine Biological Association of the United Kingdom, 97*(7), 1455-1465 https://doi.org/10.1017/S0025315416000783

An area in the central North Sea was surveyed in November 2011 in order to estimate the abundance and density of harbour porpoises (Phocoena phocoena). A total of 2833 km of pre-determined trackline were acoustically surveyed, of which 28% included visual effort. The poor sighting conditions during the survey limited visual effort and demonstrated the advantage of using acoustic techniques for studying harbour porpoise in winter months. Absolute abundance and density estimates were calculated from acoustic encounter rates using estimates of probability of detection and mean group size. The density of harbour porpoises in the west of the survey area was almost double that in the east, with UK waters to the south-west of the Dogger Bank having the highest density of the area surveyed. The overall acoustic encounter rate was higher than most other surveys in the North Sea. The mean density across the survey area of 0.63 (95% CI 0.27-1.52) individuals km-2 and distribution of porpoises was similar to that documented in the summer suggesting that high abundance of harbour porpoises in the west of the North Sea is not confined to summer months. This information is particularly relevant given plans for the construction of a large offshore wind farm on the UK section of the Dogger Bank; the resulting impacts, including acoustic disturbance from pile driving, will potentially affect substantial numbers of harbour porpoises.

Dannheim, J., Bergstrom, L., Birchenough, S. N. R., Brzana, R., Boon, A. R., Coolen, J. W. P., . . . Degraer, S. (2020). Benthic Effects of Offshore Renewables: Identification of Knowledge Gaps and Urgently Needed Research. *ICES Journal of Marine Science, 77*(3), 1092-1108 https://doi.org/10.1093/icesjms/fsz018

As the EU's commitment to renewable energy is projected to grow to 20% of energy generation by 2020, the use of marine renewable energy from wind, wave and tidal resources is increasing. This literature review (233 studies) (i) summarizes knowledge on how marine renewable energy devices affect benthic environments, (ii) explains how these effects could alter ecosystem processes that support major ecosystem services and (iii) provides an approach to determine urgent research needs. Conceptual diagrams were set up to structure hypothesized cause-effect relationships (i.e. paths). Paths were scored for (i) temporal and spatial scale of the effect, (ii) benthic sensitivity to these effects, (iii) the effect consistency and iv) scoring confidence, and consecutively ranked. This approach identified

prominent knowledge gaps and research needs about (a) hydrodynamic changes possibly resulting in altered primary production with potential consequences for filter feeders, (b) the introduction and range expansion of non-native species (through stepping stone effects) and, (c) noise and vibration effects on benthic organisms. Our results further provide evidence that benthic sensitivity to offshore renewable effects is higher than previously indicated. Knowledge on changes of ecological functioning through cascading effects is limited and requires distinct hypothesis-driven research combined with integrative ecological modelling.

de Groot, J., Campbell, M., Ashley, M., & Rodwell, L. (2014). Investigating the Co-Existence of Fisheries and Offshore Renewable Energy in the UK: Identification of a Mitigation Agenda for Fishing Effort Displacement. *Ocean & Coastal Management, 102*, 7-18 https://doi.org/10.1016/j.ocecoaman.2014.08.013

The increased demand for sea space for renewable energy developments and marine conservation will have impacts on the fishing sector. As a consequence, it is imperative to understand the ways in which fisheries and renewable energy interact and explore the potential for co-existence. In this paper we investigate the challenges for co-existence between the two sectors, and explore a mitigation agenda for fishing effort displacement in the UK. Data were collected through stakeholder questionnaires and two stakeholder workshops. Thematic analysis was carried out to identify the key challenges faced by stakeholder groups. The research identifies as three key priority areas for this agenda: developing efficient and cost-effective mechanisms for overcoming data issues for assessment of fishing effort displacement; the development of appropriate methods of assessment; and the development of an acceptable consultation protocol between MRE and fishing sectors agreed on by all stakeholders.

de Jong, K., Forland, T. N., Amorim Maria Clara, P., Rieucau, G., Slabbekoorn, H., & Sivle, L. D. (2020). Predicting the Effects of Anthropogenic Noise on Fish Reproduction. *Reviews in Fish Biology and Fisheries, 30*(2), 245-268 https://doi.org/10.1007/s11160-020-09598-9

Aquatic animals use and produce sound for critical life functions, including reproduction. Anthropogenic noise is recognized as a global source of environmental pollution and adequate conservation and management strategies are urgently needed. It becomes therefore critical to identify the reproductive traits that render a species vulnerable to acoustic disturbances, and the types of anthropogenic noise that are most likely to impact reproduction. Here, we provide predictions about noise impact on fish reproduction following a two-step approach: first, we grouped documented effects of noise into three mechanistic categories: stress, masking and hearing-loss, and test which type of noise (continuous vs intermittent and regular vs irregular) was most likely to produce a significant response in each category with either a meta-analysis or a quantitative review, depending on data availability. Second, we reviewed existing literature to predict which reproductive traits would render fish most sensitive to stress, masking and hearing-loss. In step one, we concluded that continuous sounds with irregular amplitude and/or frequency-content (e.g. heavy ship traffic) were most likely to cause stress, and continuous sounds were also most likely to induce masking and hearing-loss. From step two we concluded that the vulnerability of a species to noise-induced stress will mainly depend on: (1) its potential to reallocate reproduction to more quiet times or locations, and (2) its vulnerability to masking and hearing-loss mainly on the function of sound communication in its reproductive behaviour. We discuss in which stages of reproduction fish are most likely to be vulnerable to anthropogenic noise based on these findings.Graphic abstract

Degraer, S., Carey, D. A., Coolen, J. W., Hutchison, Z. L., Kerckhof, F., Rumes, B., & Vanaverbeke, J. (2020). Offshore Wind Farm Artificial Reefs Affect Ecosystem Structure and Functioning: A Synthesis. *Oceanography, 33*(4), 48-57 https://doi.org/10.5670/oceanog.2020.405

Offshore wind farms (OWFs) are proliferating globally. The submerged parts of their structures act as artificial reefs, providing new habitats and likely affecting fisheries resources. While acknowledging that the footprints of these structures may result in loss of habitat, usually soft sediment, we focus on how the artificial reefs established by OWFs affect ecosystem structure and functioning. Structurally, the ecological response begins with high diversity and biomass in the flora and fauna that gradually colonize the complex hard substrate habitat. The species may include nonindigenous ones that are extending their spatial distributions and/or strengthening populations, locally rare species (e.g., hard substrate-associated fish), and habitat-forming species that further increase habitat complexity. Functionally, the response begins with dominant suspension feeders that filter organic matter from the water column. Their fecal deposits alter the surrounding seafloor communities by locally increasing food availability, and higher trophic levels (fish, birds, marine mammals) also profit from locally increased food availability and/or shelter. The structural and functional effects extend in space and time, impacting species differently throughout their life cycles. Effects must be assessed at those larger spatiotemporal scales.

Dépalle, M., Sanchirico, J. N., Thébaud, O., O'Farrell, S., Haynie, A. C., & Perruso, L. (2021). Scale-Dependency in Discrete Choice Models: A Fishery Application. *Journal of Environmental Economics and Management, 105*, 102388 https://doi.org/10.1016/j.jeem.2020.102388

Modeling the spatial behavior of fishers is critical in assessing fishery management policies and has been dominated by discrete choice models (DCM). Motivated by the widespread availability of micro-data on fishing vessel locations, this paper examines the complexity associated with the choice of the spatial scale in a DCM of fishing locations. Our empirical approach estimates the standard DCM at varying spatial resolutions using both simulated data and vessel monitoring system data from the Gulf of Mexico longline fishery. We assess model performance using goodness-of-fit, predictive capacity, parameter estimates, and the assessment of the fishery response to a hypothetical marine protected area. Results show that, even when the specification of the decision-making process is correct, models can be structurally biased because of the aggregation of spatial scale that neglects the value of many fishing locations. The extent of such biases can only be detected by considering various spatial aggregation levels.

Dolder, P. J., Minto, C., Guarini, J.-M., & Poos, J. J. (2020). Highly Resolved Spatiotemporal Simulations for Exploring Mixed Fishery Dynamics. *Ecological Modelling, 424*, 109000 https://doi.org/10.1016/j.ecolmodel.2020.109000

To understand how data resolution impacts inference on mixed fisheries interactions we developed a highly resolved spatiotemporal discrete-event simulation model MixFishSim incorporating: i) delay-difference population dynamics, ii) population movement using Gaussian Random Fields to simulate patchy, heterogeneously distributed and moving fish populations, and iii) fishery dynamics for multiple fleet characteristics based on population targeting under an explore-exploit strategy. We applied MixFishSim to infer community structure when using data generated from: commercial catch, a fixed-

site sampling survey design and the true (simulated) underlying populations. In doing so we thereby establish the potential limitations of fishery-dependent data in providing a robust characterisation of spatiotemporal distributions. Different spatial patterns were evident and the effectiveness of a simulated spatial closure was reduced when data were aggregated across larger spatial areas. The simulated area closure showed that aggregation across time periods has less of a negative impact on the closure success than aggregation over space. While not as effective as when based on the true population, closures based on high catch rates observed in commercial data were still able to reduce fishing on a protected species. Our framework allows users to explore the assumptions in modelling observational data and evaluate the underlying dynamics of such approaches at fine spatial and temporal resolutions. From our application we conclude that commercial data, while containing bias, provides a useful tool for managing catches in mixed fisheries if applied at the correct spatiotemporal scale.

Dunlop, E. S., Reid, S. M., & Murrant, M. (2016). Limited Influence of a Wind Power Project Submarine Cable on a Laurentian Great Lakes Fish Community. *Journal of Applied Ichthyology, 32*(1), 18-31 https://doi.org/10.1111/jai.12940

Previous research has identified the generation of electromagnetic fields (EMFs) emanating from renewable energy project transmission cables to be a potential stressor to aquatic communities. In this study, we investigated whether the presence of a high voltage submarine transmission cable affected the spatial pattern and composition of nearshore and offshore fishes at a Laurentian Great Lakes site. The transmission cable investigated in this study runs 7.8 km along the lakebed of Lake Ontario, carrying electricity from the Wolfe Island wind power project to the city of Kingston, Ontario. In autumn of 2011, both nearshore electrofishing and deeperwater fisheries acoustic surveys were conducted along transects at varying distances to the cable. For both habitat types, no detectable effects of the cable on the fish community were found. Local habitat variables, including substrate or depth, were more important in explaining variation in fish density than proximity to the cable. Common species encountered during the surveys were round goby (Neogobius melanostomus) in the nearshore and alewife (Alosa pseudoharengus) in the deeper channel. American eel (Anguilla rostrata), thought to be an electromagnetically sensitive species, was also encountered during the surveys including in close proximity to the cable. More robust impact assessments require sampling fishes before a cable installation, over greater time frames (additional seasons or years), and habitats that support more diverse native assemblages.

Dwyer, J., & Bidwell, D. (2019). Chains of Trust: Energy Justice, Public Engagement, and the First Offshore Wind Farm in the United States. *Energy Research and Social Science, 47*, 166-176 https://doi.org/10.1016/j.erss.2018.08.019

Public acceptance of renewable energy technologies (RETs) is critical to the broader adoption of these technologies and reducing the role of fossil fuels in electricity generation. Recent investigations into the public engagement processes surrounding RET projects reveal certain procedural deficits, especially concerning procedural fairness and stakeholder trust. With this in mind, we analyze two engagement processes that led to the Block Island Wind Farm, the first operational offshore wind farm in the United States. Through semi-structured interviews we identify certain procedural techniques that allowed process leaders to first build public trust in themselves, then in the process, and ultimately in the outcome. This chain of trust was fostered through informal efforts of process leaders to meet

stakeholder expectations concerning process leaders' ability to work for the public interest, provide meaningful engagement opportunities, and to produce non-discriminatory outcomes. This case study highlights the potential of such informal actions to meet stakeholder expectations and build trust, while also empirically demonstrating specific techniques that future process leaders could employ to increase stakeholder acceptance of RETs.

Erbe, C., Dähne, M., Gordon, J., Herata, H., Houser, D. S., Koschinski, S., . . . Janik, V. M. (2019). Managing the Effects of Noise from Ship Traffic, Seismic Surveying and Construction on Marine Mammals in Antarctica. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2019.00647

The Protocol on Environmental Protection of the Antarctic Treaty stipulates that the protection of the Antarctic environment and associated ecosystems be considered in the planning and conducting of all activities in the Antarctic Treaty area. One of the key pollutants created by human activities in the Antarctic is noise, primarily caused by ship traffic (from tourism, fisheries, and research), but also by geophysical research (e.g., seismic surveys) and by research station support activities (including construction). Arguably, amongst the species most vulnerable to noise are marine mammals since they specialise in using sound for communication, navigation and foraging, and therefore have evolved the highest auditory sensitivity among marine organisms. Reported effects of noise on marine mammals in lower-latitude oceans include stress, behavioural changes such as avoidance, auditory masking, hearing threshold shifts, and—in extreme cases—death. Eight mysticete species, 10 odontocete species, and six pinniped species occur south of 60OS (i.e., in the Southern Ocean). For many of these, the Southern Ocean is a key area for foraging and reproduction. Yet, little is known about how these species are affected by noise. We review the current prevalence of anthropogenic noise and the distribution of marine mammals in the Southern Ocean, and the current research gaps that prevent us from accurately assessing noise impacts on Antarctic marine mammals. A questionnaire given to 29 international experts on marine mammals revealed a variety of research needs. Those that received the highest rankings were 1) improved data on abundance and distribution of Antarctic marine mammals, 2) hearing data for Antarctic marine mammals, in particular a mysticete audiogram, and 3) an assessment of the effectiveness of various noise mitigation options. The management need with the highest score was a refinement of noise exposure criteria. Environmental evaluations are a requirement before conducting activities in the Antarctic. Because of a lack of scientific data on impacts, requirements and noise thresholds often vary between countries that conduct these evaluations, leading to different standards across countries. Addressing the identified research needs will help to implement informed and reasonable thresholds for noise production in the Antarctic and help to protect the Antarctic environment.

Farr, H., Ruttenberg, B., Walter, R. K., Wang, Y.-H., & White, C. (2021). Potential Environmental Effects of Deepwater Floating Offshore Wind Energy Facilities. *Ocean & Coastal Management, 207*, 105611 https://doi.org/10.1016/j.ocecoaman.2021.105611

Over the last few decades, the offshore wind energy industry has expanded its scope from turbines mounted on foundations driven into the seafloor and standing in less than 60 m of water, to floating turbines moored in 120 m of water, to prospecting the development of floating turbines moored in ~1,000 m of water. Since there are few prototype turbines and mooring systems of these deepwater, floating offshore wind energy facilities (OWFs) currently deployed, their effects on the marine environment are speculative. Using the available scientific literature concerning appropriate analogs,

including fixed-bottom OWFs, land-based wind energy facilities, wave and tidal energy devices, and oil and gas platforms, we conducted a qualitative systematic review to estimate the potential environmental effects of deepwater, floating OWFs during operation, as well as potential mitigation measures to address some of the effects. We evaluated six categories of potential effects: changes to atmospheric and oceanic dynamics due to energy removal and modifications, electromagnetic field effects on marine species from power cables, habitat alterations to benthic and pelagic fish and invertebrate communities, underwater noise effects on marine species, structural impediments to wildlife, and changes to water quality. Our synthesis of 89 articles selected for the review suggests that many of these potential effects could be mitigated to pose a low risk to the marine environment if developers adopt appropriate mitigation strategies and best-practice protocols. This review takes the necessary first steps in summarizing the available information on the potential environmental effects of deepwater, floating OWFs and can serve as a reference document for marine scientists and engineers, the energy industry, permitting agencies and regulators of the energy industry, project developers, and concerned stakeholders such as coastal residents, conservationists, and fisheries.

Fayram, A. H., & de Risi, A. (2007). The Potential Compatibility of Offshore Wind Power and Fisheries: An Example Using Bluefin Tuna in the Adriatic Sea. *Ocean & Coastal Management, 50*(8), 597-605 https://doi.org/10.1016/j.ocecoaman.2007.05.004

Given the increasing competition for marine resources, regulatory strategies that benefit multiple stakeholders are increasingly important. Offshore wind power generating facilities are becoming more common in the marine environment and alter the characteristics of the fisheries in the surrounding area. Floating wind turbines can act as fish aggregating devices (FAD), thereby increasing the catchability for some species. Many marine recreational fisheries are open access without effort restrictions; therefore, control of total harvest is difficult. Creating a limited entry recreational fishery and excluding commercial fishing from the area surrounding offshore wind turbines may aid in controlling total harvest and may benefit several important stakeholder groups: (1) recreational and commercial fishermen in terms of higher recreational catch rates and potentially higher overall yield, (2) fisheries managers in terms of more precise control of recreational fisheries harvest, and (3) owners of offshore wind power facilities in terms of reduced risk of damage to infrastructure due to fishing activity. We discuss the compatibility of wind power facilities and fisheries, conditions conducive to this compatibility, and provide an example from a proposed offshore wind power facility in the Adriatic Sea and its potential to affect the fisheries management there, particularly for bluefin tuna (Thunnus thynnus).

Fraschetti, S., Pipitone, C., Mazaris, A. D., Rilov, G., Badalamenti, F., Bevilacqua, S., . . . Katsanevakis, S. (2018). Light and Shade in Marine Conservation across European and Contiguous Seas. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2018.00420

As a response to increasing human pressures on marine ecosystems, the legislation aimed at improving the conservation and management of marine coastal areas in European and Contiguous Seas (ECS) underwent crucial advances. ECS, however, still remain largely affected by increasing threats leading to biodiversity loss. Here, by using emblematic case studies and expert knowledge, we review current conservation tools, comparing their application in different areas to assess their effectiveness, potential for synergies, and contradictions. Despite regional differences in their application, the existing legislative frameworks have the potential to regulate human activities and to protect marine biodiversity. However, four challenges remain to be addressed to fully achieve environmental policy goals: 1) Lack of

shared vision representing a limitation in transboundary collaboration. Although all EU countries are committed to fulfil EU Directives and other binding international legislative acts, a remarkable heterogeneity exists among countries in the compliance with the common legislation on conservation and in their degree of implementation. 2) Lack of systematic procedures for the selection of protected marine sites. Regional and national approaches in designating Natura 2000 sites and nationally designated Marine Protected Areas (MPAs) reflect varying conservation targets and importance of conservation issues in political agendas. 3) Lack of coherent ecological networks. Natura 2000 sites and other MPAs are still far from reaching the status of effective networks in all considered case studies. 4) Hotspot of conflicts with private economic interests prevailing over conservation aims. Recommendations are given to overcome the fragmented approach still characterizing the conservation and management of coastal marine environments. Holistic, integrated, ecosystem-based, cross-cutting approaches can avoid conflicts among institutions so as to provide effective and timely solutions to current and future challenges concerning the conservation and management of marine ecosystems and associated goods and services.

Gaichas, S. K., DePiper, G. S., Seagraves, R. J., Muffley, B. W., Sabo, M. G., Colburn, L. L., & Loftus, A. J. (2018). Implementing Ecosystem Approaches to Fishery Management: Risk Assessment in the Us Mid-Atlantic. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2018.00442

Fishery managers worldwide are evaluating methods for incorporating climate, habitat, ecological, social, and economic factors into current operations in order to implement Ecosystem Approaches to Fishery Management (EAFM). While this can seem overwhelming, it is possible to take practical steps towards EAFM implementation that make use of existing information and provide managers with valuable strategic advice. Here, we describe the process used by the U.S. Mid-Atlantic Fishery Management Council (Council) to develop an ecosystem-level risk assessment, the initial step proposed in their recently adopted EAFM guidance document. The Council first defined five types of Risk Elements (ecological, economic, social, food production, management) and identified which management objectives aligned with each element. Based on an existing ecosystem status report for the region and other existing sources (including expert opinion), potential ecological, social, economic, and management indicators were identified for each risk element. Finally, low, low-moderate, moderate-high, and high risk criteria were defined for each indicator, and the indicator data were used to score each risk element using the criteria. The ultimate outcome is a ranked risk assessment in order to focus on the highest risk issues for further evaluation and mitigation. The risk assessment highlights certain species and certain management issues as posing higher cumulative risks to meeting Council management objectives when considering a broad range of ecological, social, and economic factors. Tabular color coded summaries of risk assessment results will be used by the Council to prioritize further EAFM analyses as well as research plans over the coming five years. As ecosystem reporting and operational EAFM continue to evolve in future years, the Council foresees integrating these efforts so that ecosystem indicators are refined to meet the needs of fishery managers in identifying and managing risks to achieving ecological, social, and economic fishery objectives. Overall, ecosystem indicator-based risk assessment is a method that can be adapted to a wide range of resource management systems and available information, and therefore represent a promising way forward in the implementation of EAFM.

Gill, A. B., Degraer, S., Lipsky, A., Mavraki, N., Methratta, E., & Brabant, R. (2020). Setting the Context for Offshore Wind Development Effects on Fish and Fisheries. *Oceanography, 33*(4), 118-127 https://doi.org/10.5670/oceanog.2020.411

Changes to fisheries that result from offshore wind farm (OWF) installations may be considered good or bad depending on various stakeholders' perspectives. OWFs can act as artificial reefs that may benefit secondary fish production, but such effects may also have ecological consequences. The fisheries exclusion effect that turns some OWFs into no-go areas, hence effectively no-take zones, could provide resource enhancements or redistribution. However, the displacement of fishing effort may have consequences to fisheries elsewhere. Changes in the sensory environment related to sound, as well as electromagnetic fields and physical alterations of current and wind wakes, may have as yet unknown impacts on fisheries resources. Understanding the interactions among effect type, OWF development phase, and spatiotemporal population dynamics of commercial and recreational species remains challenging, exemplified by the commercial fishery lobster genus Homarus in European and North American waters. While knowledge of the interactions between resource species and OWFs is improving, there remain questions on the wider interaction between and consequences of OWFs and fisheries. Studies of this wider relevance should aim to improve understanding of the economic and societal impacts of OWFs linked to ecosystem services that support fisheries. Furthermore, assisting fisheries management and providing advice requires monitoring and survey data collection at appropriate spatiotemporal scales. This information will help to determine whether OWFs have any meaningful impact on regional fisheries, and increased investments will be needed to target scientifically appropriate monitoring of OWFs and fisheries, which is supported by better integrated policy and regulation.

Glarou, M., Zrust, M., & Svendsen, J. C. (2020). Using Artificial-Reef Knowledge to Enhance the Ecological Function of Offshore Wind Turbine Foundations: Implications for Fish Abundance and Diversity. *Journal of Marine Science and Engineering, 8*(5) https://doi.org/10.3390/jmse8050332

As the development of large-scale offshore wind farms (OWFs) amplifies due to technological progress and a growing demand for renewable energy, associated footprints on the seabed are becoming increasingly common within soft-bottom environments. A large part of the footprint is the scour protection, often consisting of rocks that are positioned on the seabed to prevent erosion. As such, scour protection may resemble a marine rocky reef and could have important ecosystem functions. While acknowledging that OWFs disrupt the marine environment, the aim of this systematic review was to examine the effects of scour protection on fish assemblages, relate them to the effects of designated artificial reefs (ARs) and, ultimately, reveal how future scour protection may be tailored to support abundance and diversity of marine species. The results revealed frequent increases in abundances of species associated with hard substrata after the establishment of artificial structures (i.e., both OWFs and ARs) in the marine environment. Literature indicated that scour protection meets the requirements to function as an AR, often providing shelter, nursery, reproduction, and/or feeding opportunities. Using knowledge from AR models, this review suggests methodology for ecological improvements of future scour protections, aiming towards a more successful integration into the marine environment.

Gray, T., Haggett, C., & Bell, D. (2005). Offshore Wind Farms and Commercial Fisheries in the UK: A Study in Stakeholder Consultation. *Ethics, Place & Environment, 8*(2), 127-140 https://doi.org/10.1080/13668790500237013

This paper is an exploration of a current environmental issue dividing two industries in the UK. The issue is offshore wind farms, and the industries are commercial fishing and wind energy. The controversy over offshore wind farms highlights three core issues of conflict: the adequacy of stakeholder consultation processes; the right to compensation for loss of livelihood; and the lack of adequate data. We find that the characterisations that developers, regulators, and fishers hold of each other critically inform their positions on these issues. We examine the weak bargaining position of fishers, and the 'power game' that is played out between them and developers. We conclude that offshore wind farm development would be better managed if stakeholder consultation was more extensive, compensation claims were standardised, and scientific data were more readily available, but that in the meantime, fishers could improve their bargaining power by mobilising potential allies.

Haggett, C., ten Brink, T., Russell, A., Roach, M., Firestone, J., Dalton, T., & McCay, B. J. (2020). Offshore Wind Projects and Fisheries: Conflict and Engagement in the United Kingdom and the United States. *Oceanography, 33*(4), 38-47 https://doi.org/10.5670/oceanog.2020.404

A just transition to renewable energy requires accounting for the effects of offshore wind projects (OWPs) on the fishing industry. Research on the interaction of OWPs with coastal communities and fisheries in the United Kingdom and the United States offers insights into minimizing conflict and enhancing constructive engagement between fishers and wind energy developers. Recent innovations include earlier and more meaningful inclusion of fisheries representatives in planning and decision-making, involving fisheries liaisons in the process, and conducting more cumulative studies and taking collaborative approaches to considering the effects of OWP on fishing.

Hall, D. M., & Lazarus, E. D. (2015). Deep Waters: Lessons from Community Meetings About Offshore Wind Resource Development in the Us. *Marine Policy, 57*, 9-17 https://doi.org/10.1016/j.marpol.2015.03.004

Meeting the United States' offshore renewable-energy goals for 2030 necessitates deploying approximately 9000 wind turbines along U.S. coastlines. Because siting bottom-mounted turbines in most nearshore coastal zones is either impractical or politically difficult, turbine developers are testing floating-platform turbine technologies for deeper waters. Deepwater, floating-platform turbines have the advantages of being sited in the highest quality winds farther offshore, movable if desired, and located beyond the horizon, out of sight from shore. This paper reports on conversations with 103 coastal stakeholders at community meetings regarding development and testing of floating turbines off the coast of Maine, U.S.A. Using naturalistic field methods, this essay reports common questions and concerns of commercial lobstermen, fishermen, and coastal civic leaders. Early-stage conversations suggest that once coastal community members understand the benefits and impacts of wind farm development on their quality of life, many share specific preferences for where offshore developments could be located. Citizens' remarks are sophisticated, nuanced, and innovative and include robust ideas for pairing turbine siting with fishery conservation. Findings imply that when looking to site offshore turbines in public, multiple-use ocean spaces, developers, planners, and coastal communities should engage early and often in two-way conversation rather than one-way outreach.

Halouani, G., Villanueva, C.-M., Raoux, A., Dauvin, J. C., Ben Rais Lasram, F., Foucher, E., . . . Niquil, N. (2020). A Spatial Food Web Model to Investigate Potential Spillover Effects of a Fishery Closure in an Offshore Wind Farm. *Journal of Marine Systems, 212*, 103434 https://doi.org/10.1016/j.jmarsys.2020.103434

There is a growing interest in the development of offshore wind farms to provide a sustainable source of renewable energy and contribute to the reduction of carbon emissions. In parallel, there is a need to better understand the effects of these installations on coastal marine ecosystems and identify potential sea use conflicts, especially when the area is subject to access restrictions. This study investigated the effects of a spatial closure during the exploitation phase of an offshore wind farm in the extended Bay of Seine (English Channel, France) using Ecospace, a spatially and temporally explicit module of Ecopath with Ecosim. To address this question, simulations were conducted through the evaluation of "what-if scenarios" to assess the effectiveness of a fishing exclusion zone inside and surrounding the offshore wind farm. Several biomass, catch and trophic level-based indicators were calculated to evaluate how the exclusion zone could affect fishing activities and main components of the food web. All the indicators were estimated in the extended Bay of Seine and summarized by sub-area. Findings suggested that the spillover effect could mitigate the negative impact of access loss on fishing activities, in a scenario of simulated closure of the area of the wind farm. The Ecospace model predicted an increase of catches (up to 7% near the wind farm) and a slight increase in the proportion of high trophic level species. However, the influence of spillover effects is limited in space and the expected increase of biomass and catches are highly localized in areas around the offshore wind farm installations. At the scale of the Bay of Seine, further analysis of the spillover effects revealed a spatial pattern and suggested that the implementation of an exclusion zone inside the offshore wind farm could concentrate highly mobile predators.

Haraldsson, M., Raoux, A., Riera, F., Hay, J., Dambacher, J. M., & Niquil, N. (2020). How to Model Social-Ecological Systems? - a Case Study on the Effects of a Future Offshore Wind Farm on the Local Society and Ecosystem, and Whether Social Compensation Matters. *Marine Policy, 119* https://doi.org/10.1016/j.marpol.2020.104031

Models of social-ecological systems (SES) are acknowledged as an important tool to understand human-nature relations. However, many SES models fail to integrate adequate information from both the human and ecological subsystems. With an example model of a future Offshore Wind Farm development and its effects on both the ecosystem and local human population, we illustrate a method facilitating a "balanced" SES model, in terms of including information from both subsystems. We use qualitative mathematical modeling, which allows to quickly analyze the structure and dynamics of a system without including quantitative data, and therefore to compare alternative system structures based on different understandings of how the system works. By including similar number of system variables in the two subsystems, we balanced the complexity between them. Our analyses show that this complexity is important in order to predict indirect and sometimes counterintuitive effects. We also highlight some conceptually important questions concerning social compensations during developmental projects in general, and wind farms in particular. Our results suggest that the more project holders get involved in various manner in the local socio-ecological system, the more society will benefit as a whole. Increased involvement through e.g. new projects or job-opportunities around the windfarm has the capacity to offset the negative effects of the windfarm on the local community. These benefits are enhanced when there is an overall acceptance and appropriation of the project. We suggest

this method as a tool to support the decision-making process and to facilitate discussions between stakeholders, especially among local communities.

Hattam, C., Hooper, T., & Papathanasopoulou, E. (2015). *Understanding the Impacts of Offshore Wind Farms on Well-Being.* The Crown Estate Retrieved from www.thecrownestate.co.uk

This review aims to explore the positive and negative impacts arising from the UK offshore wind industry in terms of well-being. The emphasis is placed on objective measures of wellbeing relating to material living conditions, such as personal income and jobs, and issues relating to quality of life, such as health (OECD 2011).

Haynie, A. C., & Layton, D. F. (2010). An Expected Profit Model for Monetizing Fishing Location Choices. *Journal of Environmental Economics and Management, 59*(2), 165-176 https://doi.org/10.1016/j.jeem.2009.11.001

We develop and analyze the properties of a new type of discrete choice model which jointly estimates the expected value of catch and location choice. This model implicitly monetizes location choices and can be used to predict costs and effort redistribution of creating marine protected areas or of implementing other policy changes that either increase travel costs or alter expected revenue. We illustrate our approach by considering the closing of the Steller sea lion conservation area in the United States Bering Sea to pollock fishing.

Ho, L.-W., Lie, T.-T., Leong, P. T. M., & Clear, T. (2018). Developing Offshore Wind Farm Siting Criteria by Using an International Delphi Method. *Energy Policy, 113*, 53-67 https://doi.org/10.1016/j.enpol.2017.10.049

Previous research on offshore wind farm (OWF) siting has been dominated by studies centred on energy resources and profitability, human activities and acceptance. Recently, studies on environmental impacts of OWFs have emerged. Few studies have been carried out to discuss the issues comprehensively. This study develops a set of comprehensive OWF siting criteria; including the profitability, social, security and environmental considerations. It solicits expert opinions from academia and industry through an international Delphi method. Contrary to the typical consensus seeking in Delphi studies, it focuses on understanding the dissensus through a comprehensive discussion. We find that profitability and social considerations are the most commonly agreed siting criteria among the experts whereas environmental and security criteria receive less agreement. As OWFs move further offshore, we are concerned about the understanding of the associated environmental impacts, and how energy and marine policy affect the marine spatial planning and consenting process. Research must get ahead of the developments to provide a better understanding of the potential impacts and to guide the consenting and monitoring processes.

Hoagland, P., Dalton, T. M., Jin, D., & Dwyer, J. B. (2015). An Approach for Analyzing the Spatial Welfare and Distributional Effects of Ocean Wind Power Siting: The Rhode Island/Massachusetts Area of Mutual Interest. *Marine Policy, 58*, 51-59 https://doi.org/10.1016/j.marpol.2015.04.010

Coastal and marine spatial planning (CMSP) involves characterizing the potential socioeconomic consequences of locating one or more human uses in place of others in the coastal ocean. Most commonly, the focus of CMSP is on the siting of alternative uses across ocean space. This article examines the broader economic and distributional effects of the potential siting of a renewable energy facility (wind power) in a southern New England offshore area that also is used intensively for commercial fishing. For a leading siting alternative, a counterfactual involving the complete displacement of commercial fishing would result in estimated direct output impacts to the regional economy of $5 million, leading to $11 million in direct, indirect, and induced impacts and a corresponding loss of about 150 jobs. Total economic welfare losses were estimated at $14 million, reflecting not only output reductions but also the effects of price increases in the relevant markets. The welfare losses would be progressively distributed, such that households in mid-to high-income categories would likely bear the most significant impacts. Adjusting these welfare losses for society's aversion to income inequality, inequality-adjusted impacts would be more pronounced in areas that are not necessarily located in close proximity to the coastline. Individual low-income households located in five non-coastal census tracts would bear estimated median impacts (>= $140/year), which would be an order of magnitude larger than those borne by the next group of impacted households. When implementing CMSP, it is critically important to characterize not only the distribution of effects over the coastal ocean but also the distribution of impacts on coupled human communities onshore, including those communities that may not be considered strictly coastal.

Hooper, T., & Austen, M. C. (2014). The Co-Location of Offshore Windfarms and Decapod Fisheries in the UK: Constraints and Opportunities. *Marine Policy, 43*, 295-300 https://doi.org/10.1016/j.marpol.2013.06.011

The offshore wind sector in the UK is expanding rapidly and is set to occupy significant areas of the coastal zone, making it necessary to explore the potential for co-location with other economic activities. The presence of turbine foundations introduces hard substrates into areas previously dominated by soft sediments, implying that artificial reef effects may occur, with potential benefits for fisheries. This review focuses on the possibilities for locating fisheries for two commercially important decapods, the brown crab Cancer pagurus and the European lobster Homarus gammarus, within offshore wind farms. Existing understanding of habitat use by C. pagurus and H. gammarus suggests that turbine foundations have the potential to act as artificial reefs, although the responses of these species to noise and electromagnetic fields are poorly understood. Offshore wind farm monitoring programmes provide very limited information, but do suggest that adult C. pagurus associate with turbine foundations, which may also serve as nursery areas. There was insufficient deployment and monitoring of rock armouring to draw conclusions about the association of H. gammarus with offshore wind farm foundations. The limited information currently available demonstrates the need for further research into the ecological and socio-economic issues surrounding fishery co-location potential.

Hooper, T., Ashley, M., & Austen, M. (2015). Perceptions of Fishers and Developers on the Co-Location of Offshore Wind Farms and Decapod Fisheries in the UK. *Marine Policy, 61*, 16-22 https://doi.org/10.1016/j.marpol.2015.06.031

The predicted expansion of the global offshore wind sector is likely to increase conflicts as users of the coastal zone compete for space, and the displacement of fisheries is of particular concern. It is therefore important to explore opportunities that could support the co-existence of offshore wind farms (OWFs)

and fishing activity. In addition to ecological evidence on the effects of OWFs on commercially exploited species, the co-location issue requires understanding of the perceptions of fishers and OWF developers on key constraints and opportunities. Interviews were carried out in 2013 with 67 fishers in South Wales and Eastern England and with 11 developers from major energy companies, to discover experiences and opinions on the co-location of OWFs with crab and lobster fisheries. Developers expressed broad support for co-location, perceiving potential benefits to their relationship with fishers and their wider reputation. Fishers had more mixed opinions, with geographical variation, and exhibited a range of risk perception. The lack of reported experience of potting within OWFs was not related to stock concerns but to uncertainty around safety, gear retrieval, insurance and liability. Clear protocols and communication to address these issues are essential if co-location is to be feasible. Scale may also limit the potential benefits to fishers, especially in that large offshore OWFs are likely to be inaccessible to much of the inshore fleet. There remains the potential to enhance the artificial reef effects of OWFs by deploying additional material between the turbines, but options to finance such schemes, and how investment by OWF developers could be offset against compensation paid to displaced fishers, require further investigation.

Hooper, T., Hattam, C., & Austen, M. (2017). Recreational Use of Offshore Wind Farms: Experiences and Opinions of Sea Anglers in the UK. *Marine Policy, 78*, 55-60 https://doi.org/10.1016/j.marpol.2017.01.013

The expansion of offshore wind farms (OWFs) is likely to increase conflict with other marine users as different sectors compete for space. There may also be positive interactions, as the artificial reef effects from energy infrastructure have the potential to sustain and enhance fishing opportunities. Recreational sea angling is an important sector within the UK but the experiences and opinions of UK sea anglers with respect to OWFs have not been documented. To address this, an online survey was undertaken with recreational anglers around the UK (n=199). Respondents represented a range of sodo-demographic and angling characteristibs, although male, more frequent and older fishers as well as club members were over-represented compared to a 2012 national survey. One quarter of the respondents had fished around the perimeter of or within an OWF, most on multiple occasions, and 73% of those who had not expressed a willingness to do so in future. Anglers reported both positive and negative effects on catch success when fishing near or within OWFs compared to their experiences of the same site prior to OWF development. Outcomes for individual species were also mixed. Anglers recognised the potential artificial reef effects of OWFs and their role as a "safe haven", particularly due to the exclusion of commercial fishers. Negative perceptions included restricted access, harm to marine wildlife, and visual impact. There is little evidence that OWFs will have a significant economic impact on recreational fishing, as most anglers are unlikely to change their behaviour in response to future developments.

Hooper, T., Ashley, M., & Austen, M. (2018). Capturing Benefits Opportunities for the Co-Location of Offshore Energy and Fisheries. In *Offshore Energy and Marine Spatial Planning.* K. L. Yates & C. J. A. Bradshaw (Eds.), (pp. 189-213): Routledge Retrieved from https://www.taylorfrancis.com/chapters/edit/10.4324/9781315666877-11/capturing-benefits-tara-hooper-matthew-ashley-melanie-austen

The infrastructure required for offshore energy creates new substrata that provide settlement surfaces for a range of benthic species. These artificial reef effects are well-documented, and there is growing evidence that the enhanced prey availability and shelter can attract species of interest to commercial

and recreational fishers, creating potential co-location opportunities. The exclusion of towed bottom gears from the proximity of energy installations due to concerns about safety and infrastructure damage creates further opportunities for static gear and small-scale fishers. However, even for these groups, taking advantage of fishing opportunities might not be straightforward in practice. We review the ecological evidence supporting the potential for energy infrastructure to enhance fisheries, considering which target fish and shellfish species appear to benefit, at which stage in their lifecycle, and whether there is evidence for any contribution to fisheries production, as opposed to the simple attraction of individuals from elsewhere. We also discuss the socio-economic issues related to the potential exploitation of any enhanced fishery resource, considering the attitudes, opinions, and existing practice of fishers, boat skippers and developers with respect to such factors as the feasibility, safety, and economic viability of co-location. We also review the possibilities for the co-location of aquaculture as an alternative to capture fisheries. We conclude by considering how this information on the potential for fishery and aquaculture co-location might be incorporated into future marine spatial planning.

Hutniczak, B., & Münch, A. (2018). Fishermen's Location Choice under Spatio-Temporal Update of Expectations. *Journal of Choice Modelling, 28*, 124-136 https://doi.org/10.1016/j.jocm.2018.05.002

Information acquired by individuals over time plays a crucial role in their decision-making process. Gained experience updates beliefs on expected payoffs and is used in a range of decisions each individual is facing. In this paper, we focus on the formation of beliefs about the payoffs associated with spatial choices set in an uncertain environment. We task ourselves with better understanding of day-to-day flexibility of actions as a result of continuous update of prior expectations. We built a model where private and common knowledge on expected economic returns blend and lead to divergence of expectations between individuals. This innovation expands the frontiers of spatio-temporal modeling of micro-behavior to offer a new insight on decay of information relevance with increasing spatial and temporal separation. Application to fishermen harvest location choices demonstrates the use of the model. Successful fisheries management must be able to accurately predict the response of fishermen to regulations with particular attention paid to flexible technologies which allow individuals to adjust effort and alter behavior. Good understanding of fishing locations choice and location adjustment flexibility can contribute substantially to a design of management practices with spatial components.

Hutton, T., Mardle, S., Pascoe, S., & Clark, R. A. (2004). Modelling Fishing Location Choice within Mixed Fisheries: English North Sea Beam Trawlers in 2000 and 2001. *ICES Journal of Marine Science, 61*(8), 1443-1452 https://doi.org/10.1016/j.icesjms.2004.08.016

Numerous studies have proposed methodologies to model fisher behaviour with the aim of predicting the outcomes of decision-making on board a fishing vessel. Both short- and longterm processes (e.g. investment) impact fleet dynamics. The proposed structure of the models has tended to depend upon the nature of the fishery and the control variables (technical restrictions, quotas, effort control, and/or closed areas). For example, within the context ofmulti-stock, multi-fleet fisheries (mixed fisheries), a skipper will allocate effort (as input to the production process) to harvest a range ofspecies. Spatial complexity is normally excluded in models of behaviour. In this paper, two spatial analyses are presented for modelling location choice: an analysis based on a random utility model (RUM), and a simplified simulation model of individual vessels that depends on the results of the RUM. These models are applied to the English beam-trawl fleet operating in the North Sea in 2000. The results from the

RUM indicate that the number of trips, the average trip length, and the average effort in each ICES rectangle are significant variables affecting location choice, in addition to catch rate for the previous year (1999), weighted by value. The last result is used as an assumption in a simulation model offishing effort, i.e. fishers make decisions on spatial location ofoperation on the basis ofpast catch rates. The simulation model is used to predict the distribution of the same fleet for one month during the temporary closure in the North Sea in 2001. The predicted values for effort relate well to the fishing patterns observed.

Hynes, S., Gerritsen, H., Breen, B., & Johnson, M. (2016). Discrete Choice Modelling of Fisheries with Nuanced Spatial Information. *Marine Policy, 72*, 156-165 https://doi.org/10.1016/j.marpol.2016.07.004

Temporary marine area closures or more permanent Marine Protected Areas are being proposed as potential options in ecosystem-based marine spatial management. These policy options are known to displace fishing effort. In this paper, EU Vessel Monitoring System (VMS) data is combined with other site and vessel information and used to model the fishing site choice decision of Irish demersal otter trawlers. Uniquely, the fishing ground options used in the analysis reflect the actual seabed contours trawled by the fleet. The fishing site choice model, based on this natural site definition is compared to an alternative destination choice model where the fleet decision is specified using a grid based site definition as employed in previous work. It is argued that the natural site specification is a more realistic specification of the fisher site choice decision. Using the preferred natural fishing site choice model, a policy scenario involving the hypothetical closure of one of the fishing ground options is then simulated to examine the possible redistribution of fishing effort.

Jentoft, S., & Knol, M. (2014). Marine Spatial Planning: Risk or Opportunity for Fisheries in the North Sea? *Maritime Studies, 12*(1), 1-16 https://doi.org/10.1186/2212-9790-12-13

The North Sea is one of the busiest marine areas in the world. It is also a major fisheries ground. Bordered by seven countries with their own spatial uses and claims, the stage is set for complex and demanding governance challenges. Recent decades have also seen user groups multiply, competition for space and resources increase, and the pressure on the marine environment and its living natural resources grow. As governments strive to balance conservation and economic development needs, they also have to deal with inter-as well as intra-national user conflicts. Marine Spatial Planning (MSP) has arrived as a new approach to these issues. It is argued that for North Sea fishing people and their communities MSP holds risks as well as opportunities, depending on which institutions are formed and what role they are allowed to play in the planning process.

Kafas, A., Donohue, P., Davies, I., & Scott, B. E. (2018). *Displacement of Existing Activities*: Taylor & Francis Group. Retrieved from https://www.taylorfrancis.com/chapters/edit/10.4324/9781315666877-7/displacement-existing-activities-andronikos-kafas-penelope-donohue-ian-davies-beth-scott

The introduction of a new marine activity in marine spatial planning often imposes spatial restrictions on existing marine users. This chapter describes the potential effects of offshore energy developments on established widespread marine users, using the commercial wild-capture fishing sector as an example.

The potential for fishing effort displacement is a concern amongst stakeholders and has a range of direct and indirect, positive and negative, economic, social, and environmental effects on individual fishers, the fishing industry, fishery-dependent coastal communities, and wider society. We present methods for assessment of possible impacts, as well as management recommendations for prevention and mitigation.

Kastelein, R. A., Huijser, L. A. E., Cornelisse, S., Helder-Hoek, L., Jennings, N., & de Jong, C. A. F. (2019). Effect of Pile-Driving Playback Sound Level on Fish-Catching Efficiency in Harbor Porpoises (Phocoena Phocoena). *Aquatic Mammals, 45*(4), 398-410 https://doi.org/10.1578/AM.45.4.2019.398

The foundations of offshore wind turbine parks are often constructed by means of percussion pile driving. Broadband impulsive sounds generated by pile driving may disturb and distract marine mammals such as harbor porpoises (Phocoena phocoena); their concentration may be reduced, affecting the skills they need for foraging (e.g., timing and precision) or reducing their ability to catch prey and, thus, their foraging efficiency. The resulting reduction in fitness may eventually lead to population declines. Therefore, it is important to understand the effects of these anthropogenic sounds on the ability of harbor porpoises to catch fish. Two captive harbor porpoises (porpoise F05 and porpoise M06) performed a fish-catching task (i.e., retrieving dead fish from a net feeding cage) while they were exposed to low ambient noise (quiet conditions) and impulsive pile-driving playback sounds at three (porpoise M06) or four (porpoise F05) mean received single-strike sound exposure levels (SELss) between 125 and 143 dB re 1 gPa2s. The two study animals differed in their fish-catching success rate at all noise levels, including under quiet conditions: Porpoise F05 was less likely to catch fish than porpoise M06. They also responded differently to increasing SELss: Only porpoise F05 was significantly more likely to terminate trials and less likely to catch fish as SELss increased above 134 dB, but her trial failure rate remained unaffected by increasing SELss. The time taken to catch a fish did not vary with SELss but was slightly longer for porpoise F05 than for porpoise M06. Results suggest that high-amplitude pile driving sounds are likely to negatively affect foraging in some harbor porpoises by decreasing their catch success rate and increasing the termination rate of their fish-catching attempts; the severity of the effects is likely to increase with increasing pile driving SELss. However, individual differences in responses to sound, termination rates, and fish-catching success (even in ambient conditions) may complicate the quantification of the impacts of pile driving sounds on harbor porpoises.

Kleinschmidt, B., Burger, C., Dorsch, M., Nehls, G., Heinänen, S., Morkūnas, J., . . . Quillfeldt, P. (2019). The Diet of Red-Throated Divers (<I>Gavia Stellata</I>) Overwintering in the German Bight (North Sea) Analysed Using Molecular Diagnostics. *Marine Biology, 166*(6), 1-18 https://doi.org/10.1007/s00227-019-3523-3

In Europe, the German Bight is one of the most important non-breeding areas for protected red-throated divers (Gavia stellata). It is unclear what attracts the birds to this area, especially as the food composition of seabirds outside the breeding season is notoriously difficult to study. To obtain information on prey species composition of red-throated divers in this area, faecal samples from 34 birds caught alive were analysed using DNA metabarcoding. Prey DNA was detected in 85% of the samples with a mean number of 4.2 ± 0.7 taxa per sample (n = 29). Altogether, we found a broad prey spectrum with 19 fish taxa from 13 families dominated by five groups: clupeids, mackerel, gadoids, flatfish and sand lances with clupeids being the most frequently detected prey. Our results indicate that

red-throated divers are generalist opportunistic feeders in the German Bight, but pelagic schooling fish that aggregate at frontal zones and have a high energetic value might be favoured. Atlantic mackerel appears to be a more important prey for red-throated divers in this area than previously thought. The precision achievable using metabarcoding has revealed a number of prey species that are consumed by red-throated divers in the German Bight, which helps to explain the selection of this area by divers in winter and spring.

Krone, R., Dederer, G., Kanstinger, P., Kramer, P., Schneider, C., & Schmalenbach, I. (2017). Mobile Demersal Megafauna at Common Offshore Wind Turbine Foundations in the German Bight (North Sea) Two Years after Deployment - Increased Production Rate of Cancer Pagurus. *Marine Environmental Research, 123*, 53-61 https://doi.org/10.1016/j.marenvres.2016.11.011

Within the next decades the construction of thousands of different types of large wind turbine foundations in the North Sea will substantially increase the amount of habitat available to reef fauna. To gain first insights which effect these substantial changes in habitat structure and diversity might have on faunal stocks settling on hard substrata, we compared the mobile demersal megafauna associated with the common types of wind turbine foundations ('jacket', 'tripod' and 'monopile with scour protections of natural rock') in the southern German Bight, North Sea. Monopiles with scour protection were mostly colonized by typical reef fauna. They were inhabited by an average of about 5000 edible crabs Cancer pagurus (per foundation), which is more than twice as much as found at the foundation types without scour protection. Strong evidence was found that all three foundation types not only function as aggregation sites, but also as nursery grounds for C. pagurus. Assuming equal shares of the three foundation types in future wind farms, we project that about 27% of the local stock of C. pagurus might be produced on site. When, for example, comparing the existing fauna at 1000 ship wrecks and on the autochthonous soft substrate with those which probably will establish at the foundations of 5000 hypothetically realized wind turbines, it becomes clear that the German Bight in the future will provide new artificial reef habitats for another 320% crabs (C. pagurus) and 50% wrasse (Ctenolabrus rupestris) representing substrata-limited mobile demersal hard bottom species. Further research is urgently required in order to evaluate this overspill as it would be an important ecological effect of the recent offshore wind power development.

Lapena, B. P., Wijnberg, K. M., Hulscher, S., & Stein, A. (2010). Environmental Impact Assessment of Offshore Wind Farms: A Simulation-Based Approach. *Journal of Applied Ecology, 47*(5), 1110-1118 https://doi.org/10.1111/j.1365-2664.2010.01850.x

Assessing and monitoring the impact of offshore wind farms on marine fauna is vital if we want to achieve ecologically sustainable development of this renewable energy resource. Given the complexity of the marine environment, a method capable of accommodating spatio-temporal behaviour of specific species and their interrelation with other marine phenomena is an essential prerequisite for investigating whether or not there has been any measurable impact to date. This paper presents a method based on geostatistical simulation to assess whether pre- and post-construction collected bird count data suggest displacement of birds due to the wind farm. The method takes into account spatial autocorrelation in species abundance at various scales, pre- and post-construction differences in environmental conditions and in survey effort and design. We demonstrate that taking these factors into account influences the conclusions about a wind farm's impact on bird life. In particular, incorporating spatial autocorrelation in seabird numbers is an important factor in reducing the risk of

wrongly identifying an effect of a wind farm on bird abundance. Synthesis and applications. The development of offshore wind farms is often in conflict with nature conservation interests. Environmental impact assessment and monitoring is essential to protect and manage the marine environment. The method described here will allow scarce data to be utilized effectively as a basis for well-informed environmental decisions. In addition, the method will assist in the design of optimal monitoring procedures at a given site, balancing costs and effectiveness in detecting potentially harmful impacts.

Leach, R., White, R., McTaggart, K., & Clyne, F. (2005). *Mind Games: Cognitive Mapping of Fishers' Knowledge and Perceptions on the Impacts of Wind Farms on Fisheries*. Paper presented at the ICES. https://www.ices.dk/sites/pub/CM%20Doccuments/2005/V/V0405.pdf

The development of offshore wind farms around the coasts of England and Wales could make a significant contribution to securing energy supplies for future generations. However, while knowledge of wind farm impacts is developing all the time, there are still some uncertainties about the impacts of wind farms on the environment and specific industries whose activities may be affected by their development. Cognitive mapping was used as a tool in the dialogue between fishers and researchers in a study that investigates the socio-economic impacts and opportunities arising from wind farm developments. Cognitive mapping helped fishers to express their knowledge and perceptions of impacts in a structured way that facilitated a comprehensive and transparent understanding of the issues and concerns of fishers. Specific consideration of possible options to minimise the impacts of developments during construction and operation phases highlight some factors that shape fishers' adaptation to management actions.

Mackinson, S., Curtis, H., Brown, R., McTaggart, K., Taylor, N., Neville, S., & Rogers, S. (2006). A Report on the Perceptions of the Fishing Industry into the Potential Socio-Economic Impacts of Offshore Wind Energy Developments on Their Work Patterns and Income. *SCIENCE SERIES TECHNICAL REPORT-CENTRE FOR ENVIRONMENT FISHERIES AND AQUACULTURE SCIENCE, 133* Retrieved from https://www.cefas.co.uk/publications/techrep/tech133.pdf

Offshore wind farms in the Greater Wash, Thames estuary and North West could make a significant contribution to the UK's commitment to renewable energy. However, the extent of proposed 'Round 2' wind farms will affect a range of marine users and environmental resources. Defra commissioned this Investigation to seek the views of the UK fishing Industry Into the potential Implications of proposed Round 2 offshore wind farm developments on their work patterns and Income. The project was intended only to gather the views of the fishing Industry In the three Strategic Areas, not those of the wind farm developers or the government departments responsible for the licensing and consenting process.

Mangano, M. C., Mieszkowska, N., Helmuth, B., Domingos, T., Sousa, T., Baiamonte, G., . . . Sarà, G. (2020). Moving toward a Strategy for Addressing Climate Displacement of Marine Resources: A Proof-of-Concept. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2020.00408

Realistic predictions of climate change effects on natural resources are central to adaptation policies that try to reduce these impacts. However, most current forecasting approaches do not incorporate

species-specific, process-based biological information, which limits their ability to inform actionable strategies. Mechanistic approaches, incorporating quantitative information on functional traits, can potentially predict species- and population-specific responses that result from the cumulative impacts of small-scale processes acting at the organismal level, and can be used to infer population-level dynamics and inform natural resources management. Here we present a proof-of-concept study using the European anchovy as a model species that shows how a trait-based, mechanistic species distribution model can be used to explore the vulnerability of marine species to environmental changes, producing quantitative outputs useful for informing fisheries management. We crossed scenarios of temperature and food to generate quantitative maps of selected mechanistic model outcomes (e.g. Maximum Length and Total Reproductive Output). These results highlight changing patterns of source and sink spawning areas as well as the incidence of reproductive failure. This study demonstrates that model predictions based on functional traits can reduce the degree of uncertainty when forecasting future trends of fish stocks. However, to be effective they must be based on high spatial- and temporal resolution environmental data. Such a sensitive and spatially explicit predictive approach may be used to inform more effective adaptive management strategies of resources in novel climatic conditions.

Marchal, P., Bartelings, H., Bastardie, F., Batsleer, J., Delaney, A., Girardin, R., . . . Jouanneau, C. (2014). Mechanisms of Change in Human Behaviour. Retrieved from www.marine-vectors.eu

The scope of this report is to present the science developed within the VECTORS project to improve the understanding of the key processes driving the behaviour of human agents utilising a variety of EU maritime domains. While particular attention has been paid to the spatial interactions between fishing activities and other human uses (e.g., maritime traffic, offshore wind parks, aggregate extractions), the behaviour of nonfishing sectors of activity has also been considered. Various quantitative and semi-qualitative approaches have been pursued to gain better insight into behavioural drivers based on past data, and also forecast how human agents would react if access was constrained by either management (e.g. Marine Protected Areas – MPA), or the installation of a new operator. This report covers the North Sea and Eastern Channel, and also one area of the Baltic Sea: the Gdansk Bay.

Methratta, E. T. (2020). Monitoring Fisheries Resources at Offshore Wind Farms: Baci Vs. Bag Designs. *ICES Journal of Marine Science, 77*(3), 890-900 https://doi.org/10.1093/icesjms/fsaa026

Offshore wind farms often co-occur with biodiverse marine ecosystems with high ecological, economic, and cultural value. Yet there are many uncertainties about how wind farms affect marine organisms and their environment. The before-after-control-impact (BACI) design, an approach that compares an impact location with an unaffected control both before and after the intervention, is the most common method used to study how offshore wind farms affect finfish. Unfortunately, this design has several methodological limitations that undermine its ability to detect effects in these studies. An alternative approach, the before-after-gradient (BAG) design, would sample along a gradient with increasing distance from the turbines both before and after the intervention, and could overcome many of the limitations of BACI. The BAG design would eliminate the difficult task of finding a suitable control, allow for the assessment of the spatial scale and extent of wind farm effects, and improve statistical power by incorporating distance as an independent variable in analytical models rather than relegating it to the error term. This article explores the strengths and weaknesses of the BACI and BAG designs in the context of offshore wind development and suggests an approach to incorporating the BAG design into existing fisheries surveys and a regional monitoring framework.

Methratta, E. T., & Dardick, W. R. (2019). Meta-Analysis of Finfish Abundance at Offshore Wind Farms. *Reviews in Fisheries Science & Aquaculture, 27*(2), 242-260 https://doi.org/10.1080/23308249.2019.1584601

Offshore wind farms are becoming increasingly common in the coastal margins of marine ecosystems worldwide. Yet, the effects that wind farm structures have on fish populations remain unclear. To explore potential effects, a meta-analysis of studies that have examined the abundance of finfish inside of wind farms compared to nearby reference sites was conducted. Using well-established meta-analytic methods, the overall effect size across all studies was calculated, and then changes in effect size for soft-bottom and complex-bottom oriented species were explored in association with several covariates including characteristics of the wind farm (depth, distance from shore, wind farm age), the sampling design (season, gear type, and distance from the turbine sampled), and ecosystem level characteristics (functional feeding group and fishing presence/absence). The overall effect size was positive and significantly different from zero, indicating greater abundance of fish inside of wind farms. Likewise, positive and significant effect sizes were noted for several covariates for both soft-bottom and complex-bottom species. The findings of this study underscore the need for regional, national, and international collaboration on monitoring approaches and data sharing in order to develop a more holistic understanding of how offshore wind farms affect living marine resources.

Michler-Cieluch, T., & Kodeih, S. (2008). Mussel and Seaweed Cultivation in Offshore Wind Farms: An Opinion Survey. *Coastal Management, 36*(4), 392-411 https://doi.org/10.1080/08920750802273185

German coastal regions and adjacent offshore waters are claimed for a variety of different, and often overlapping, uses. Conflicts ofinterest are expected to increase due to the planned construction of offshore wind farms. The development of an integrated approach combining different commercial activities, such as open ocean aquaculture and wind farming, could be a possible solution to overcome these conflicts. To illuminate existing perception and opinions on this multiple-use idea, this study examines the attitudes ofrepresentatives ofeight different actor groups toward potential offshorewind farm–mariculture integration in the German North Sea. Results from our questionnaire survey show that the respondents' attitudes toward the suggested multiple-use setting seem to be largely influenced by their general opinion toward offshore wind farms. The Fisheries actor group differs from the other questioned groups in that negative attitudes are overall predominant. This case study points to the need for a credible mechanism that more successfully integrates key actor groups, such as fisheries, into future planning and research issues.

National Academies of Sciences, E., and Medicine,. (2018). *Atlantic Offshore Renewable Energy Development and Fisheries: Proceedings of a Workshop in Brief* The National Academies Press. https://doi.org/10.17226/25062

The production of offshore renewable energy is in its early stages in the United States. The development of offshore energy on the U.S. Outer Continental Shelf (OCS) is overseen by the Bureau of Ocean Energy Management (BOEM). In support of its mission to conduct its activities in an environmentally and economically responsible way, BOEM engaged a steering committee of the National Academies of

Sciences, Engineering, and Medicine to facilitate a workshop about the research and monitoring needed to assess potential impacts from offshore wind turbine installation and operation on fisheries on the Atlantic OCS. This activity is specifically focused on fisheries resources, and is one part of a suite of efforts by BOEM to understand the potential impact of offshore renewable energy on the environment. This workshop was held on November 8–9, 2017, in New Bedford, Massachusetts. The steering committee focused its activities on southern New England, where several offshore wind leases are progressing toward construction. Representatives from research institutions, the fishing and wind industries, and state and federal governments were invited to share their perspectives and experiences to help inform and advance guidelines for monitoring impacts on fisheries from offshore wind projects. In her introductory remarks, Bonnie McCay from Rutgers University, who chaired the steering committee, explained that the purpose of the workshop was to have a forum for engagement of the range of stakeholders in the wind energy development process. The workshop included presentations and panel discussions, as well as open discussion among all workshop participants. A summary of the prepared presentations and panel discussions, including some clarifications and additional remarks that arose during the discussions with the audience, is described in this document.
To introduce participants to the status of offshore wind in the United States, James Bennett, Chief of BOEM's
Office of Renewable Energy Programs, described BOEM's ongoing leasing activities in the Atlantic. To date, 13 competitive leases covering 1.4 million acres in the OCS have been sold, generating $68 million in sales. If fully utilized, these leases have the potential to generate more than 15 gigawatts of energy, sufficient to power 5 million homes. Leases are in place in every state from Massachusetts to North Carolina, with further lease sales to occur in the future. Three site characterizations—surveys of the lease area conducted by the lessees—have been approved by BOEM. Construction and operation plans are forthcoming and construction may occur as soon as 2020 for a research lease in Virginia and 2021 for commercial projects in southern New England. In his remarks, Bennett highlighted the need to balance the environmental and economic benefits offshore wind can bring through renewable energy and job creation, while conserving valuable existing ocean uses.

Negro, V., del Campo, J. M., Frades, J. L., Martin-Anton, M., Esteban, M. D., Lopez-Gutierrez, J. S., & Soukissian, T. (2020). Impact of Offshore Wind Farms on Marine Ecosystems, Pelagic Species and Fishing. *Journal of Coastal Research*, 118-122 https://doi.org/10.2112/si95-023.1

The evolution of the clean energies is one of the targets of the Sustainable Development Goals (SDG) of the United Nations (UN 2015 - 2030). However, the increase in the number of marine wind farms (gravity based structures < 10%; piles < 82% and jackets, tripod, tripile and floating installations 7%) with a progressive growth in depth, distance from shore, power and diameter, requires a deep reflection. The marine growth in piles and GBS structures would be studied if it is beneficial for marine ecosystems and fish species, displacement and colonization of new ones. After the installation, new substrates became colonised by a wide variety of benthic organisms. The objective of this research manuscript is to pose this challenge and the analysis in countries like Spain and the Mediterranean Countries where tourism is one of the main sources weath and the environment and landscape are essential in the preservation of the territory and the harmony with nature.

Nieland, D. L., & Wilson, C. A. (2003). Red Snapper Recruitment to and Disappearance from Oil and Gas Platforms in the Northern Gulf of Mexico. In *Fisheries, Reefs, and Offshore Development.* D. R.

Stanley & A. ScarboroughBull (Eds.), (Vol. 36, pp. 73-81) Retrieved from https://fisheries.org/bookstore/all-titles/afs-symposia/x54036xm/

The red snapper Lutjanus campecbanus is a potentially large and long-lived species that can achieve ages approaching 60 years and weights of more than 22 kg. In the northern Gulf of Mexico, oil and gas platforms provide the preponderance of both vertical relief and hard substrate habitat for red snapper and other reef-associated fishes. In July 1998, we collected morphometric data and sagittal otoliths from 300 red snapper randomly selected from among the mortalities manifested subsequent to the explosive removal of an obsolete gas platform. Ages estimated from counts of otolith annuli ranged from 1 to 9 years among these specimens. The virtual absence of age-1 red snapper (0.68%) and the preponderance of age-2 red snapper (53%) at the platform demonstrate that red snapper recruit to platforms sometime during their second year. Truncation of the age distribution results from natural mortality, fishing mortality and emigration to other habitats after several years of residency. Assuming this population to be typical, the age distributions of the commercial and recreational harvests suggest that oil and gas platforms serve as essential habitats for younger red snapper. Conversely, platforms may make red snapper at ages 4, 5, and 6 years more vulnerable to fishing mortality as they are perhaps being harvested in proportions greater than their numbers in the population at large.

Peng, B. (2019). Application of Marine Remote Sensing Technology in the Development of Fishery Economy. *Journal of Coastal Research, SI*(94), 783-787 https://doi.org/10.2112/SI94-155.1

More than two-thirds of the surface of the Earth's surface is the ocean. These areas are not only the space in which the species live, but also the provider of resources. Only from the perspective of marine Fishery, marine Fishery not only provide an important source of food for humans, but also provide a large number of jobs for the society. When using the traditional method to study the ocean, if it is not supplemented by a relatively macroscopic angle, it is easy to be partial, and the ocean remote sensing technology can realize the long-term, large-scale and high-precision simultaneous monitoring of ocean information. Therefore, more and more applications have been applied in research on fishery distribution and fishery environment monitoring. This paper will use marine remote sensing technology to systematically analyze the fishing of marine Fishery, which will be of guiding significance for the actual operation of fishermen in the future.

Perry, R. L., & Heyman, W. D. (2020). Considerations for Offshore Wind Energy Development Effects on Fish and Fisheries in the United States a Review of Existing Studies, New Efforts, and Opportunities for Innovation. *Oceanography, 33*(4), 28-37 https://doi.org/10.5670/oceanog.2020.403

The energy system in the United States has a significant opportunity to meet society's needs for reliable, affordable, and clean energy by utilizing offshore wind. Development is moving quickly in the Atlantic Ocean, with the first large-scale utility project approval anticipated in December 2020. Offshore wind will have positive and negative impacts on existing ocean resources and ocean users, yet there is no precedent in the United States for evaluating effects on fisheries and fishers from utility-scale development. US regulations stipulate that wind developers conduct extensive surveys and impact monitoring for the approximate 30-year life of each project. This requirement creates an unprecedented and exciting opportunity for regional-scale, multi-decade, and cooperative monitoring and research that can inform decision-making for US regulators managing wind development and fisheries. This paper

offers a vision for creating collaborative science partnerships designed to help build trust and transparency among two important US industries-fishing and offshore wind.

Peschko, V., Mercker, M., & Garthe, S. (2020). Telemetry Reveals Strong Effects of Offshore Wind Farms on Behaviour and Habitat Use of Common Guillemots (<I>Uria Aalge</I>) During the Breeding Season. *Marine Biology, 167*(8) https://doi.org/10.1007/s00227-020-03735-5

Seabirds have increasingly encountered offshore wind farms (OWFs) in European waters in the past 10 years, resulting in potential conflicts with offshore foraging areas. During the breeding season, seabirds are restricted in their choice of foraging habitat and are under increased pressure to find enough prey to raise their offspring. However, information on the individual reactions of seabirds towards OWFs during the breeding season is lacking. Three OWFs located 23–35 km north of the island of Helgoland have operated since October 2015. We studied their possible effects on locally breeding common guillemots (Uria aalge) using GPS tracking. GPS tags were deployed on 12 breeding guillemots from Helgoland for 8–26 days during 2016–2017. Most individuals avoided the OWFs, but one individual in each year briefly entered the OWFs on two or three occasions. Using a point process model, we revealed a 63% reduction in the resource selection of the OWF areas compared with the surroundings (lower confidence interval (CI) = 79% reduction, upper CI = 36% reduction). Furthermore, OWF avoidance was increased to 75% when the turbine blades were rotating (lower CI = 93% reduction, upper CI = 11% reduction). Guillemots mainly approached the OWFs from their eastern edge when resting or diving, and rarely approached the areas when commuting. These results provide a detailed description of guillemot reactions to OWFs during the breeding season, and the first comprehensive analysis of OWF effects on this species based on telemetry data. The strong avoidance effect for guillemots during the breeding season indicates the need to consider the presence of OWFs when interpreting future trends in the abundance and breeding success of this species.

Piwetz, S., Jefferson, T. A., & Würsig, B. (2021). Effects of Coastal Construction on Indo-Pacific Humpback Dolphin (Sousa Chinensis) Behavior and Habitat-Use Off Hong Kong. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2021.572535

Construction-related loss of habitat, degradation of existing habitat, noise pollution, and vessel activity are growing issues for Indo-Pacific humpback dolphins (Sousa chinensis) that occur in the shallow, near-shore, highly industrialized waters off Lantau Island, Hong Kong. We studied the occurrence of dolphins in discrete locations, fine-scale movement patterns, and dolphin behavioral activity states. Potential explanatory variables varied and included year, season, time of day, dolphin group size and behavioral activity state, proximity to construction activity, and vessel type and number. Land-based observations and theodolite tracking of dolphins and vessels were conducted from seven locations to the north of Lantau Island, Hong Kong, and marine construction activities near survey sites were identified. A total of 636 groups of dolphins were recorded, totaling 150.91 hours of tracking, from 405 days of observation effort. Hurdle models were used to analyze dolphin occurrence, multivariate generalized additive models (GAMs) were used to analyze fine-scale movement patterns, and log-likelihood ratio and binomial z score post hoc tests were used to analyze behavioral activity states. Dolphin occurrence was lower in historically important areas near long-term, low-intensity construction activity and dolphin swimming speed was higher in response to vessel presence. Overall, foraging and traveling were the most frequently observed behavioral activity states and resting behavior was observed off only one location that was not in proximity to construction activities. Temporal overlap in adjacent marine

construction areas may displace animals for extended periods and nearby ecologically similar habitats should be identified and designated as marine protected areas to mitigate effects of such disturbance.

Punt, M. J., Groeneveld, R. A., van Ierland, E. C., & Stel, J. H. (2009). Spatial Planning of Offshore Wind Farms: A Windfall to Marine Environmental Protection? *Ecological Economics, 69*(1), 93-103 https://doi.org/10.1016/j.ecolecon.2009.07.013

Wind farms are often planned offshore where wind conditions are favourable and the visual impact is less important. Wind farms have both positive and negative effects on the marine environment. Negative effects include bird collisions, underwater sounds and electromagnetic fields, whilst positive effects constitute functioning as artificial reef and acting as no-take zones for fish, with possible spill-over effects. This paper presents a spatially explicit framework to analyze effects of wind farms on the marine environment and aims to evaluate how wind farms can contribute to protection of the marine environment through strategic and economically viable location choices. The functioning and the applicability of the model are demonstrated in a numerical example for the Dutch exclusive economic zone. We find that the careful spatial planning of wind farms is a key factor for profitability and environmental protection, and that, if carefully planned, the environment can benefit from offshore wind farms.

Qu, Y., Hooper, T., Swales, J. K., Papathanasopoulou, E., Austen, M. C., & Yan, X. (2021). Energy-Food Nexus in the Marine Environment: A Macroeconomic Analysis on Offshore Wind Energy and Seafood Production in Scotland. *Energy Policy, 149*, 112027 https://doi.org/10.1016/j.enpol.2020.112027

The rapid development of offshore wind farms (OWFs) has stimulated debate about its overall socioeconomic impacts. Expanding the scale of OWFs increases the availability and affordability of electricity but could displace existing fishing activities and reduce food supply. To evaluate these impacts from a macroeconomic perspective, a computable general equilibrium (CGE) model is developed, using Scotland as a case study. A particular focus is placed on the disaggregated electricity and seafood sectors, their interconnectedness from an energy-food nexus perspective, and the distributional effects across household groups. This paper explores, from macroeconomic perspective, the trade-offs in the energy-food nexus between expanding OWFs and the seafood sectors, together with the impacts on food and energy security. The results suggest that, through economic linkages, increasing the number of OWFs would have a negative, but limited, effect on seafood production sectors. However, the falling cost of electricity from OWFs would have a positive impact on the economy overall and benefit lower income households, contributing to a reduction in fuel poverty. The model results raise the awareness of nexus linkages between OWFs and seafood production and are applicable to policies involving the development of other offshore renewables.

Rademacher, K. R., & Render, J. H. (2003). Fish Assemblages around Oil and Gas Platforms in the Northeastern Gulf of Mexico: Developing a Survey Design. In *Fisheries, Reefs, and Offshore Development.* D. R. Stanley & A. ScarboroughBull (Eds.), (Vol. 36, pp. 101-122) Retrieved from https://fisheries.org/bookstore/all-titles/afs-symposia/x54036xm/

A pilot survey was conducted in 1995 by the National Marine Fisheries Service, Mississippi Laboratories to develop a survey design for assessing fishes associated with the offshore oil and gas platforms in the Gulf of Mexico. Eight platforms of various sizes, configurations, and depths were sampled with a pan and tilt video camera, stationary video cameras, and a remotely operated vehicle (ROV). Differences in fish species observed, and their abundances as measured by the different gear types, were evaluated to determine an optimal sampling design for large-scale surveys. Forty-four taxa from 19 families were observed over all platforms and all gears. More taxa were observed within the confines of the platforms and in close proximity to the platforms than were observed away from the platforms. Camera orientation was important in detecting some species (e.g., groupers were only observed within the confines of the platforms). The number of taxa observed did not vary with depth or among platforms; however, there were differences in fish density with depth and among platforms. More red snapper Lutjanus campechanus were seen at depths greater than 25 M, while more gray snapper Lutjanus griseus were found at depths less than 20 in. Total fish densities were lower at platforms with barnacles as the dominant attached fauna and higher at platforms with higher relief epifauna (octocorals, sponges, and bryozoans). Red snapper densities were higher at platforms with higher relief epifauna, and gray snapper densities were higher at barnacle-dominated platforms. There was no difference in fish density with platform age nor any relationship between platform age and attached faunal types.

Rambo, H. (2017). *From Fish Biodiversity Indicators to Spatial Risk Assessments: Towards the Integration of Blue Growth and Conservation Objectives in the German Bight.* Staats-und Universitätsbibliothek Hamburg Carl von Ossietzky, Retrieved from https://ediss.sub.uni-hamburg.de/handle/ediss/7347 Retrieved from https://ediss.sub.uni-hamburg.de/handle/ediss/7347

Spatial management measures are increasingly implemented in the Southern North Sea which is one of the most intensively used marine areas in the world. Various human activities are competing for space while exerting chronic pressures on marine habitats and the associated fauna. The most dominant spatial conflict exists between the development of offshore wind farms (OWF), conservation interests and the fishing sector. The effects of spatial allocations such as for OWF development or the designation of Natura 2000 sites as well as resulting displacement of fishing effort on benthic systems are riddled with uncertainties. The policy landscape governing spatial management processes is likewise highly complex. One of the future governance challenges in European seas will be to align economic growth from the sea ("Blue Growth") with conservation of biodiversity and ecosystem health. Amongst the key policies that members states of the European Union need to conform to is the Marine Strategy Framework Directive (MSFD) which requires achieving good environmental status (GES) of European seas. In addition, member states need to implement maritime spatial plans under the Maritime Spatial Planning (MSP) Directive to achieve sustainable use of marine resources. Both instruments aim at implementing an ecosystembased spatial management approach. However, a current gap is the lack in spatially explicit indicators and associated management targets that could describe the achievements towards multi-objective planning. In addition, holistic assessment procedures are lacking which facilitate information needs of policy objectives and allow evaluating risks, opportunities and uncertainties of spatial management options on the ecosystem. The aim of this dissertation is thus i) to perform such an assessment by operationalising spatially explicit indicators of fishing pressure and ecosystem state and ii) to synthesise information in a risk based probabilistic approach (Bayesian Belief Networks) that allows testing trade-offs and uncertainties of planned spatial management measures. The analysis is performed in the German Bight, specifically the Exclusive Economic Zone (EEZ) of the North Sea, focussing on benthic communities, mostly demersal fish.

Raoux, A., Tecchio, S., Pezy, J.-P., Lassalle, G., Degraer, S., Wilhelmsson, D., . . . Niquil, N. (2017). Benthic and Fish Aggregation inside an Offshore Wind Farm: Which Effects on the Trophic Web Functioning? *Ecological Indicators, 72*, 33-46 https://doi.org/10.1016/j.ecolind.2016.07.037

As part of the energy transition, the French government is planning the construction of three offshore wind farms in Normandy (Bay of Seine and eastern part of the English Channel, northwestern France) in the next years. These offshore wind farms will be integrated into an ecosystem already facing multiple anthropogenic disturbances such as maritime transport, fisheries, oyster and mussel farming, and sediment dredging. Currently no integrated, ecosystem-based study on the effects of the construction and exploitation of offshore wind farms exists, where biological approaches generally focused on the conservation of some valuable species or groups of species. Complementary trophic web modelling tools were applied to the Bay of Seine ecosystem (to the 50 km 2 area covered by the wind farm) to analyse the potential impacts of benthos and fish aggregation caused by the introduction of additional hard substrates from the piles and the turbine scour protections. An Ecopath ecosystem model composed of 37 compartments, from phytoplankton to seabirds, was built to describe the situation " before " the construction of the wind farm. Then, an Ecosim projection over 30 years was performed after increasing the biomass of targeted benthic and fish compartments. Ecological Network Analysis (ENA) indices were calculated for the two periods, " before " and " after " , to compare network functioning and the overall structural properties of the food web. Our main results showed (1) that the total ecosystem activity, the overall system omnivory (proportion of generalist feeders), and the recycling increased after the construction of the wind farm; (2) that higher trophic levels such as piscivorous fish species, marine mammals, and seabirds responded positively to the aggregation of biomass on piles and turbine scour protections; and (3) a change in key-stone groups after the construction towards more structuring and dominant compartments. Nonetheless, these changes could be considered as limited impacts of the wind farm installation on this coastal trophic web structure and functioning.

Reilly, K., O'Hagan, A. M., & Dalton, G. (2015). Attitudes and Perceptions of Fishermen on the Island of Ireland Towards the Development of Marine Renewable Energy Projects. *Marine Policy, 58*, 88-97 https://doi.org/10.1016/j.marpol.2015.04.001

The expansion of the marine renewable energy (MRE) sector will increase pressure on sea space and existing maritime users which could potentially lead to conflict. Commercial fishing has been identified by many as the industry most likely to be affected by the development of MRE. In order to reduce the risk of spatial conflict and to enable decision-making based on the co-existence of the two sectors, it is important to gain a better understanding of the attitudes of fishermen towards the development of MRE projects in their locality. A survey was designed to provide quantitative information on fishermen's attitudes to marine renewable energy and the perceived impacts and opportunities. Three MRE developments which have been proposed around the island of Ireland (comprising Republic of Ireland and Northern Ireland) were chosen as case study sites in which to carry out the survey. The sites represent offshore wind, wave and tidal energy respectively and are in differing stages of development. In total, 104 complete surveys were conducted with fishermen located at ports in the vicinity of the case study sites. 40% of those surveyed agreed that it is important to develop marine renewable energy in their locality. A further 15% were neutral on this matter. It is encouraging for developers and policy

makers that the majority of respondents (70%) were of the opinion that fisheries and MRE projects can co-exist.

Reilly, K., O'Hagan, A. M., & Dalton, G. (2016). Developing Benefit Schemes and Financial Compensation Measures for Fishermen Impacted by Marine Renewable Energy Projects. *Energy Policy, 97*, 161-170 https://doi.org/10.1016/j.enpol.2016.07.034

Commercial fishermen are arguably the stakeholder group most likely to be directly impacted by the expansion of the marine renewable energy (MRE) sector. The potential opposition of fishermen may hinder the development of MRE projects and the provision of benefit schemes could to enhance acceptance. Benefit schemes refer to additional voluntary measures that are provided by a developer to local stakeholders. The aim of this study is to explore the issue of the provision of benefit packages to local fishing communities and financial compensation measures for fishermen who may be impacted by MRE projects. Semi-structured interviews were conducted with fourteen fishermen from three separate case study sites around the island of Ireland where MRE projects were being developed. In addition, ten company fisheries liaison officers (CFLOs) who have worked on MRE projects in the UK and Ireland were also interviewed. The interviews were analysed under the headings of local employment, benefits in kind, compensation and community funds and ownership of projects. Analysis shows that there is uncertainty among fishermen over whether they would benefit or gain employment from MRE. Provision of re-training schemes and preferential hiring practices could be used by MRE developers to reduce this uncertainty. There was also agreement between fishermen and CFLOs on the need for the provision of an evidence-base and a standard approach for the calculation of disruption payments. A formal structure for the provision of benefit schemes for fishermen would be useful. Furthermore, schemes that provide a range of benefits to fishermen and other stakeholders over the lifetime of a MRE project are more likely to be successful at enhancing acceptance.

Reilly, K., O'Hagan, A. M., & Dalton, G. (2016). Moving from Consultation to Participation: A Case Study of the Involvement of Fishermen in Decisions Relating to Marine Renewable Energy Projects on the Island of Ireland. *Ocean & Coastal Management, 134*, 30-40 https://doi.org/10.1016/j.ocecoaman.2016.09.030

The development of the marine renewable energy (MRE) will impact traditional users of the marine resource, such as commercial fishermen. This could potentially lead to opposition and spatial conflict. The successful development of the MRE sector will heavily depend on the acceptance of projects by fishing communities. Effective stakeholder engagement is crucial to enhancing acceptance among fishermen. The consultation process is one of the key ways in which to engage fishermen and enable them to participate in decision-making. There is agreement among experts in the field that despite its importance, the consultation process is not effective and it is often carried out from the top down with little opportunity for real participation. A mixed methods research approach was used to examine the experiences of fishermen on their level of involvement in consultations and decision-making on marine renewable energy projects. In total, 104 surveys and 14 in-depth interviews were carried out with fishermen operating from ports at three case study sites around the island of Ireland where MRE projects were being developed. Just over half (56%) of those surveyed felt that they had been involved in consultations, while only 22% felt that they had been involved in decisions made on the projects. The use of participatory mapping tools in the selection of sites for MRE development provides an

opportunity for fishermen to influence decisions. Designing and implementing marine spatial plans could also help to provide clarity and transparency over how trade-offs in the use of sea space are dealt with.

Reubens, J., Degraer, S., & Vincx, M. (2011). Aggregation and Feeding Behaviour of Pouting (Trisopterus Luscus) at Wind Turbines in the Belgian Part of the North Sea. *Fisheries Research, 108*(1), 223-227 https://doi.org/10.1016/j.fishres.2010.11.025

A substantial expansion of offshore wind farms in the North Sea has been planned, inducing a growing interest in the effects of these artificial habitats on the marine environment. Numerous researches have been done to consider the possible effects of wind farms. However, to date little research investigated actual effects on the ichthyofauna. This study provides the first insights into the use of the artificial hard substrates by Trisopterus luscus (pouting) at the Thorntonbank wind farm in the Belgian part of the North Sea. Scuba diving operated visual surveys around one wind turbine revealed a distinctly higher pouting population size and biomass (i.e. 22 000 individuals yielding a total biomass of 2700 kg) as compared to the population size present at the soft sediments surrounding the wind turbines. Stomach content analyses further demonstrated the dietary preference for prey species that lived on the turbines (i.e. Jassa herdmani and Pisidia longicornis). Yet, the present study clearly demonstrates that wind turbines built at sea may attract fish populations considerably, possibly related to the enhanced provision of resident food items on the turbines.

Reubens, J., Degraer, S., & Vincx, M. (2014). The Ecology of Benthopelagic Fishes at Offshore Wind Farms: A Synthesis of 4 Years of Research. *Hydrobiologia, 727*(1), 121-136 https://doi.org/10.1007/s10750-013-1793-1

In the next 10–20 years, thousands of wind turbines will be present in the North Sea. In this paper, we investigate the impact of these windmill artificial reefs (WARs) on the ecology of benthopelagic fish. More specifically we will try to resolve the attraction-ecological trap-production issue for Atlantic cod and pouting at WARs and link the information to opportunities for fisheries activities. From 2009 until 2012 the behavioural ecology of Atlantic cod and pouting was investigated at WARs in the Belgian part of the North Sea (BPNS). Information on length-frequency distribution, diet, community structure and movements were combined to gain insights on the behavioural ecology and to unravel whether production occurs. We demonstrated that specific age groups of Atlantic cod and pouting are seasonally attracted towards the WARs, that they show high site fidelity and feed upon the dominant epifaunal prey species present. Growth was observed throughout the period the fishes were present. Production on a local scale can be assumed. On a regional scale however, no changes were observed yet. Based on the acquired knowledge we judged that no fisheries activities should be allowed inside the offshore wind farms in the BPNS.

Reubens, J. T., Braeckman, U., Vanaverbeke, J., Van Colen, C., Degraer, S., & Vincx, M. (2013). Aggregation at Windmill Artificial Reefs: Cpue of Atlantic Cod (Gadus Morhua) and Pouting (Trisopterus Luscus) at Different Habitats in the Belgian Part of the North Sea. *Fisheries Research, 139*, 28-34 https://doi.org/10.1016/j.fishres.2012.10.011

Intensive exploitation of the marine environment by mankind can alter the natural habitat of marine organisms drastically. The addition of artificial hard substrates (e.g. shipwrecks and wind turbine foundations) to soft-sediment sandy bottoms is a pervasive example of an anthropogenic habitat change. To investigate the importance of hard substrate habitats for demersal fish species, we studied the spatio-temporal variability for two commercially important species, Atlantic cod (Gadus morhua) and pouting (Trisopterus luscus), from 2009 to 2011 at three different habitats in the Belgian part of the North Sea (BPNS), i.e. windmill artificial reefs (WARs), shipwrecks and sandy bottoms. Our results showed that population densities of both species were highly enhanced at the hard substrate habitats in comparison to the sandy sediments. The highest catch-per-unit effort values for both species were recorded around the WARs, which indicated distinct aggregation around the wind turbine foundations. In addition, the observed aggregation at the hard substrates differed between seasons. Highest population densities were observed in summer and autumn, i.e. the most intensive feeding period for both fishes. We conclude that the distribution and behaviour of Atlantic cod and pouting is affected by the presence and complexity of artificial hard substrates on the seabed.

Roach, M., Cohen, M., Forster, R., Revill, A. S., & Johnson, M. (2018). The Effects of Temporary Exclusion of Activity Due to Wind Farm Construction on a Lobster (Homarus Gammarus) Fishery Suggests a Potential Management Approach. *ICES Journal of Marine Science, 75*(4), 1416-1426 https://doi.org/10.1093/icesjms/fsy006

Offshore wind farms (OWF) form an important part of many countries strategy for responding to the threat of climate change, their development can conflict with other offshore activities. Static gear fisheries targeting sedentary benthic species are particularly affected by spatial management that involves exclusion of fishers. Here we investigate the ecological effect of a short-term closure of a European lobster (Homarus gammarus(L.)) fishing ground, facilitated by the development of the Westermost Rough OWF located on the north-east coast of the United Kingdom. We also investigate the effects on the population when the site is reopened on completion of the construction. We find that temporary closure offers some respite for adult animals and leads to increases in abundance and size of the target species in that area. Reopening of the site to fishing exploitation saw a decrease in catch rates and size structure, this did not reach levels below that of the surrounding area. Opening the site to exploitation allows the fishery to recuperate some of the economic loss during the closure. We suggest that our results may indicate that temporary closures of selected areas may be beneficial and offer a management option for lobster fisheries.

Rodríguez, A., Arcos, J. M., Bretagnolle, V., Dias, M. P., Holmes, N. D., Louzao, M., . . . Chiaradia, A. (2019). Future Directions in Conservation Research on Petrels and Shearwaters. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2019.00094

Shearwaters and petrels (hereafter petrels) are highly adapted seabirds that occur across all the world's oceans. Petrels are a threatened seabird group comprising 120 species. They have bet-hedging life histories typified by extended chick rearing periods, low fecundity, high adult survival, strong philopatry, monogamy and long-term mate fidelity and are thus vulnerable to change. Anthropogenic alterations on land and at sea have led to a poor conservation status of many petrels with 49 (41%) threatened species based on IUCN criteria and 61 (51%) suffering population declines. Some species are well-studied, even being used as bioindicators of ocean health, yet for others there are major knowledge gaps regarding their breeding grounds, migratory areas or other key aspects of their biology and ecology. We

assembled 38 petrel conservation researchers to summarize information regarding the most important threats according to the IUCN Red List of threatened species to identify knowledge gaps that must be filled to improve conservation and management of petrels. We highlight research advances on the main threats for petrels (invasive species at breeding grounds, bycatch, overfishing, light pollution, climate change, and pollution). We propose an ambitious goal to reverse at least some of these six main threats, through active efforts such as restoring island habitats (e.g. invasive species removal, control and prevention), improving policies and regulations at global and regional levels, and engaging local communities in conservation efforts. The clear message that emerges from this review is the continued need for research and monitoring to inform and motivate effective conservation at the global level.

Schupp, M. F., Kafas, A., Buck, B. H., Krause, G., Onyango, V., Stelzenmuller, V., . . . Scott, B. E. (2021). Fishing within Offshore Wind Farms in the North Sea: Stakeholder Perspectives for Multi-Use from Scotland and Germany. *Journal of Environmental Management, 279* https://doi.org/10.1016/j.jenvman.2020.111762

Offshore wind power generation requires large areas of sea to accommodate its activities, with increasing claims for exclusive access. As a result, pressure is placed on other established maritime uses, such as commercial fisheries. The latter sector has often been taking a back seat in the thrust to move energy production offshore, thus leading to disagreements and conflicts among the different stakeholder groups. In recognition of the latter, there has been a growing international interest in exploring the combination of multiple maritime activities in the same area (multi-use; MU), including the re-instatement of fishing activities within, or in close proximity to, offshore wind farms (OWFs). We summarise local stakeholder perspectives from two sub-national case studies (East coast of Scotland and Germany's North Sea EEZ) to scope the feasibility of combining multiple uses of the sea, such as offshore wind farms and commercial fisheries. We combined a desk-based review with 15 semi-structured qualitative interviews with key knowledge holders from both industries, regulators, and academia to aggregate key results. Drivers, barriers and resulting effects (positive and negative) for potential multi-use of fisheries and OWFs are listed and ranked (57 factors in total). Factors are of economic, social, policy, legal, and technical nature. To date, in both case study areas, the offshore wind industry has shown little interest in multi-use solutions, unless clear added value is demonstrated and no risks to their operations are involved. In contrast, the commercial fishing sector is proactive towards multi-use projects and acts as a driving force for MU developments. We provide a range of management recommendations, based on stakeholder input, to support progress towards robust decision making in relation to multi-use solutions, including required policy and regulatory framework improvements, good practice guidance, empirical studies, capacity building of stakeholders and improvements of the consultation process. Our findings represent a comprehensive depiction of the current state and key stakeholder aspirations for multi-use solutions combining fisheries and OWFs. We believe that the pathways towards robust decision making in relation to multi-use solutions suggested here are transferable to other international locations.

Schupp, M. F., Bocci, M., Depellegrin, D., Kafas, A., Kyriazi, Z., Lukic, I., . . . Buck, B. H. (2019). Toward a Common Understanding of Ocean Multi-Use. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2019.00165

The ‘open ocean’ has become a highly contested space as coastal populations and maritime uses soared in abundance and intensity over the last decades. Changing marine utilization patterns represent a

considerable challenge to society and governments. Maritime spatial planning has emerged as one tool to manage conflicts between users and achieve societal goals for the use of marine space; however single-sector management approaches are too often still the norm. The last decades have seen the rise of a new ocean use concept: the joint 'multi-use' of ocean space. This paper aims to explain and refine the concept of ocean multi-use of space by reviewing the development and state of the art of multi-use in Europe and presenting a clear definition and a comprehensive typology for existing multi-use combinations. It builds on the connectivity of uses and users in spatial, temporal, provisional, and functional dimensions as the underlying key characteristic of multi-use dimensions. Combinations of these dimensions yield four distinct types of multi-use with little overlap between them. The diversity of types demonstrates that there is no one-size-fits-all management approach, but rather that adaptive management plans are needed, focusing on achieving the highest societal benefit while minimising conflicts. This work will help to sharpen, refine and advance the public and academic discourse over marine spatial planning by offering a common framework to planners, researchers and users alike, when discussing multi-use and its management implications.

Slijkerman, D., & Tamis, J. (2015). *Fisheries Displacement Effects Related to Closed Areas: A Literature Review of Relevant Aspects.* IMARES Retrieved from https://edepot.wur.nl/366172

The implementation of the Marine Strategy Framework Directive (MSDF) is rapidly progressing. In 2015 a programme of measures needs to be defined and reported to DG Environment. In this programme, the Frisian Front (FF) and Central Oystergrounds (CO) are designated as search areas for fisheries management, targeting the conservation and possibly recovery of biodiversity of the local seafloor fauna.
A likely effect of installing protected areas is displacement of fisheries: fisheries are (partially) banned, and fishers will have to fish elsewhere. Fisheries displacement, or "fishing effort displacement" refers to the redistribution of the fishing effort formerly in closed areas to remaining fished areas (Grüss, 2014). This displacement of fishing effort may have economic effects, because steaming to and from the fishing grounds may take longer, new fishing grounds have to be explored, and competition for resources may increase.
Fisheries displacement is therefore an important aspect within the context of protecting the FF and CO. However, little is known about displacement of fisheries and the ecological and economic consequences in general, let alone for the fisheries operating in the FF and CO.
In the process of developing measures within the context of the MSFD, the ministry of Economic Affairs assigned a study to IMARES to explore displacement of fishing effort in the Dutch North Sea. The aim of this study was to gain knowledge on fisheries displacement and to put this knowledge in perspective of future measures under MSFD. It is a first attempt to obtain more information, and this study provides a broad and general overview of relevant aspects regarding displacement. This overview was obtained by a literature quick scan. Furthermore, a workshop with fishers was held for a first estimate of displacement related to the MSFD measures.

Smith, M. D. (2005). State Dependence and Heterogeneity in Fishing Location Choice. *Journal of Environmental Economics and Management, 50*(2), 319-340 https://doi.org/10.1016/j.jeem.2005.04.001

To explore the distinction between state dependence and heterogeneity in repeated decisions, this paper combines a Mixed Logit model witha state dependence parameterization from the marketing

literature to study fishing location choices of commercial sea urchin divers in California. It examines implications of ignoring either effect and finds in all cases that true state dependence is an important determinant of location choice. Consequently, spatial policies like marine reserves can lead to differences in the short- and long-run behavioral responses of the fishing fleet. Under some specifications, random preference parameters are statistically significant when state dependence is excluded from the model, but when it is included, random preference parameters are not significant. In other specifications, including state dependence only dampens the variability in preference parameters. These results highlight the importance of gathering and analyzing diary-type data for commercial fisheries as well as for similar choice problems in recreation demand.

Smith, M. D., & Wilen, J. E. (2003). Economic Impacts of Marine Reserves: The Importance of Spatial Behavior. *Journal of Environmental Economics and Management, 46*(2), 183-206 https://doi.org/10.1016/s0095-0696(03)00024-x

Marine biologists have shown virtually unqualified support for managing fisheries with marine reserves, signifying a new resource management paradigm that recognizes the importance of spatial processes in exploited systems. Most modeling of reserves employs simplifying assumptions about the behavior of fishermen in response to spatial closures. We show that a realistic depiction of fishermen behavior dramatically alters the conclusions about reserves. We develop, estimate, and calibrate an integrated bioeconomic model of the sea urchin fishery in northern California and use it to simulate reserve policies. Our behavioral model shows how economic incentives determine both participation and location choices of fishermen. We compare simulations with behavioral response to biological modeling that presumes that effort is spatially uniform and unresponsive to economic incentives. We demonstrate that optimistic conclusions about reserves may be an artifact of simplifying assumptions that ignore economic behavior.

Smythe, T., Bidwell, D., & Tyler, G. (2021). Optimistic with Reservations: The Impacts of the United States' First Offshore Wind Farm on the Recreational Fishing Experience. *Marine Policy, 127*, 104440 https://doi.org/10.1016/j.marpol.2021.104440

The expansion of offshore wind farms (OWF) has given rise to increased concerns about potential use conflicts with ocean and coastal users and attempts to mitigate these conflicts through marine spatial planning. Whereas scholars and managers often focus on the impacts of OWF on commercial fishing, members of the public also raise concerns about impacts on recreational fishing. Despite these concerns, relatively few empirical studies have been conducted to assess the impact of OWFs on recreational anglers. This study fills this gap. We conducted a mixed-methods study, comprising interviews and a survey, to assess the impacts of the United States' first OWF on recreational anglers' experiences. Interview findings revealed anglers' enjoyment of the OWF as an enhanced fishing location, due to catch and non-related aspects of the experience. Anglers also reported concerns about increased crowding around the OWF and raised concerns about potential fishing access restrictions around this and future projects. Survey data confirms that anglers, particularly those who fished at the wind farm, believe the wind farm has benefitted fishing. Respondents also value the wind farm as symbolic of progress towards green energy. Overall, results suggest that wind farms do not necessarily conflict with angling; to the contrary, our research shows that this OWF is viewed as an enhanced fishing destination. Results underscore the importance of understanding angler behavior and experiences in managing conflicts with OWF and other ocean uses. Recommendations include conducting social science research

to enhance understanding of ocean users, managing issues like crowding and access, and considering the benefits of nearshore OWFs for anglers and other stakeholders.

Spijkers, J., Merrie, A., Wabnitz, C. C. C., Osborne, M., Mobjörk, M., Bodin, Ö., . . . Morrison, T. H. (2021). Exploring the Future of Fishery Conflict through Narrative Scenarios. *One Earth, 4*(3), 386-396 https://doi.org/10.1016/j.oneear.2021.02.004

Summary Recent studies suggest that the pervasive impacts on global fishery resources caused by stressors such as overfishing and climate change could dramatically increase the likelihood of fishery conflict. However, existing projections do not consider wider economic, social, or political trends when assessing the likelihood of, and influences on, future conflict trajectories. In this paper, we build four future fishery conflict scenarios by considering multiple fishery conflict drivers derived from an expert workshop, a longitudinal database of international fishery conflict, secondary data on conflict driver trends, and regional expert reviews. The scenarios take place between the years 2030 and 2060 in the North-East Atlantic ("scramble for the Atlantic"), the East China Sea ("the remodeled empire"), the coast of West Africa ("oceanic decolonization"), and the Arctic ("polar renaissance"). The scenarios explore the implications of ongoing trends in conflict-prone regions of the world and function as accessible, science-based communication tools that can help foster anticipatory governance capacity in the pursuit of future ocean security.

Steins, N. A., Veraart, J. A., Klostermann, J. E. M., & Poelman, M. (2021). Combining Offshore Wind Farms, Nature Conservation and Seafood: Lessons from a Dutch Community of Practice. *Marine Policy, 126*, 104371 https://doi.org/10.1016/j.marpol.2020.104371

Large-scale development of offshore wind farms implies an increase in marine resource use conflicts. Managing potential impacts on marine ecosystems and on resource access for traditional and prospective users is key. Multi-use scenarios are a solution but are often approached as a 'design question' that can be settled through Marine Spatial Planning. In practice, regulatory, technical and socio-economic factors often hinder multi-use. Overcoming such barriers requires active collaboration between all stakeholders, yet meaningful participation in MSP processes often is a challenge. This paper explores the role of Communities of Practice as a participatory tool for developing multi-use. The Netherlands set up a 'Community of Practice North Sea' to stimulate the development of multi-use pilots by bringing interested parties together, sharing experiences and learning from each other in a context of existing and developing spatial and social claims. This development is part of the government's strategy aimed at finding a balance between offshore wind energy development, nature conservation and seafood production. The paper shows that by (partly) decoupling policy from practice and creating a positive learning environment, Communities of Practice have potential as a participatory tool for encouraging cooperation between stakeholders in an informal setting and facilitating a transition towards multi-use of marine resources. The paper proposes ten guidelines for using Communities of Practices as an action-oriented tool for salient multi-use practices.

Stelzenmuller, V., Diekmann, R., Bastardie, F., Schulze, T., Berkenhagen, J., Kloppmann, M., . . . Kraus, G. (2016). Co-Location of Passive Gear Fisheries in Offshore Wind Farms in the German Eez of the North Sea: A First Socio-Economic Scoping. *Journal of Environmental Management, 183*, 794-805 https://doi.org/10.1016/j.jenvman.2016.08.027

Worldwide the renewable energy sector is expanding at sea to address increasing demands. Recently the race for space in heavily used areas such as the North Sea triggered the proposal of co-locating other activities such as aquaculture or fisheries with passive gears in offshore wind farms (OWFs). Our interdisciplinary approach combined a quantification of spatial overlap of activities by using Vessel Monitoring System and logbook data with a stakeholder consultation to conclude and verify on the actual feasibility of co-location. In the German Exclusive Economic Zone (EEZ) of the North Sea up to 90% of Danish and 40% of German annual gilinet fleet landings of plaice overlapped with areas where OWFs are developed. Our results indicated further that the international gilinet fishery could lose up to 50% in landings within the North Sea German EEZ when OWF areas are closed entirely for fisheries. No spatial overlap was found for UK potters targeting brown crab in the German EEZ. We further identified a number of key issues and obstacles that to date hinder an actual implementation of co-location as a measure in the marine spatial planning process: defining the legal base; implementation of safety regulations; delineation of minimum requirements for fishing vessels such as capacities, quotas, technical equipment; implementation of a licensing process; and scoping for financial subsidies to set up business. The stakeholder consultation verified the scientific findings and highlighted that all those points need to be addressed in a planning process. In the German EEZ we have shown that the socioeconomic importance of spatial overlap varies within planning boundaries. Therefore we recommend an interdisciplinary bottom-up approach when scoping for suitable areas of co-location. Hence, an informed marine spatial planning process requires comprehensive and spatial explicit socio-economic viability studies factoring in also ecological effects of OWFs on target species.

Stelzenmüller, V., Gimpel, A., Haslob, H., Letschert, J., Berkenhagen, J., & Brüning, S. (2021). Sustainable Co-Location Solutions for Offshore Wind Farms and Fisheries Need to Account for Socio-Ecological Trade-Offs. *Science of The Total Environment, 776*, 145918 https://doi.org/10.1016/j.scitotenv.2021.145918

The spatial expansion of offshore wind farms (OWFs) is key for the transition to a carbon free energy sector. In the North Sea, the sprawl of OWFs is regulated by marine spatial planning (MSP) and results in an increasing loss of space for other sectors such as fisheries. Understanding fisheries benefits of OWFs and mitigating the loss of fishing grounds is key for co-location solutions in MSP. For the German exclusive economic zone (EEZ) of the North Sea we conducted a novel socio-ecological assessment of fisheries benefits which combines exploring potential spill-over from an OWF with an experimental brown crab (Cancer pagurus) pot fishery and an economic viability analysis of such a fishery. We arrayed a total of 205 baited pots along transects from an OWF located near the island of Helgoland. After a soaking time of 24 h we retrieved the pots and measured the carapace width (mm), weight (g), and sex of each individual crab. To conclude on cumulative spill-over potentials from all OWFs in the German EEZ and drivers of passive gear fisheries we analysed vessel monitoring system (VMS)-data and computed random forest regressions. Local spill-over mechanisms occurred up to distances of 300 to 500 m to the nearest turbines and revealed an increasing attraction of pot fishing activities to particular OWFs. This corresponds to the observation of constantly increasing fishing effort targeting brown crab likely due to both a growing international demand and stable resource populations at suitable habitats, including OWFs. Our break-even scenarios showed that beam trawlers have the capacities to conduct during summer an opportunistic but economically viable pot fishery. We argue that particularly in the North Sea, where space becomes limited, integrated assessments of the wider environmental and socio-economic effects of planning are crucial for a sustainable co-location of OWFs and fisheries.

ten Brink, T. S., & Dalton, T. (2018). Perceptions of Commercial and Recreational Fishers on the Potential Ecological Impacts of the Block Island Wind Farm (Us). *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2018.00439

Offshore wind is gaining momentum in the United States as a viable source for meeting domestic energy needs. Although offshore wind farms have been developed in Europe and Asia, the Block Island Wind Farm (BIWF) is the first offshore wind farm built in North America. To improve marine resource management, it is critical to understand the impacts of the wind farm on marine resource users in context. Little is known about the impacts of offshore wind farms on marine resource users in the United States. This study investigates recreational and commercial fishers' perceptions of the impacts of the BIWF on the local marine ecosystem. Semi-structured interviews were conducted with 25 fishers, mostly based out of Block Island or Point Judith, Rhode Island (US), in the summer and fall of 2017. During the interviews, fishers were asked about their perceptions of changes in the marine ecology of the wind farm area during and after the offshore wind turbines were constructed, and how their activities in the area have changed since the wind farm was installed. Results indicate that there were perceived impacts of the BIWF on the local ecosystem and the behavior of the marine resource users. For some recreational fishers, the wind farm functioned as a destination or target and served as an artificial reef for spearfishing. For some commercial fishers, the increase in recreational fishing due to the establishment of the BIWF crowded out commercial fishers in these areas. As the offshore wind farm industry expands within US waters, findings from this study and others like it provide valuable insights on the potential impacts of these wind farms on marine resource users.

Tidd, A. N., Hutton, T., Kell, L. T., & Blanchard, J. L. (2012). Dynamic Prediction of Effort Reallocation in Mixed Fisheries. *Fisheries Research, 125-126*, 243-253 https://doi.org/10.1016/j.fishres.2012.03.004

A discrete choice model is applied to determine how fishing effort is allocated spatially and temporally by the English and Welsh North Sea beam trawl fleet. Individual vessels can fish in five distinct areas, and the utility of fishing in an area depends on expected revenue measured as previous success (value per unit effort) and experience (past fishing effort allocation), as well as perceived costs (measured as distance to landing port weighted by fuel price). The model predicts fisher location choice, and the predictions are evaluated using iterative partial cross validation by fitting the model over a series of separate timeperiods (nine separate time-periods). Results show the relative importance of the different drivers that change over time. They indicate that there are three main drivers throughout the study, past annual effort, past monthly effort in the year of fishing, and fuel price, largely reflecting the fact that previous practices where success was gained are learned (i.e. experience) and become habitual, and that seasonal variations also dominate behaviour in terms of the strong monthly trends and variable costs. In order to provide an indication of the model's predictive capabilities, a simulated closure of one of the study areas was undertaken (an area that mapped reasonably well with the North Sea cod 2001 partial closure of the North Sea for 10 weeks of that year). The predicted reallocation of effort was compared against realized/observed reallocation of effort, and there was good correlation at the trip level, with a maximum 10% misallocation of predicted effort for that year.

Valcic, B. (2009). Spatial Policy and the Behavior of Fishermen. *Marine Policy, 33*(2), 215-222 https://doi.org/10.1016/j.marpol.2008.06.001

Fishery policy makers would often benefit from information on how a policy might change fishermen behavior before the policy is implemented. This paper contributes to the literature by comparing simulated behavioral response with actual response to a spatial policy using a discrete choice model of fishing location choice. The results point to the inherent problem of the simulation's inability to capture the fundamental change in the nature of the choice problem that occurs with the change in policy. Addressing this problem will be important as these models continue to be used to inform policy makers.

Vanermen, N., Onkelinx, T., Courtens, W., Van de walle, M., Verstraete, H., & Stienen, E. W. (2015). Seabird Avoidance and Attraction at an Offshore Wind Farm in the Belgian Part of the North Sea. *Hydrobiologia, 756*(1), 51-61 https://doi.org/10.1007/s10750-014-2088-x

Issue Title: Environmental impacts of offshore wind farms - Learning from the past to optimise future monitoring programmes Through before-after control-impact designed ship-based seabird surveys, seabird displacement occurring after the installation of an offshore wind farm at the Belgian Bligh Bank in 2010 was studied. Results demonstrate that northern gannet (Morus bassanus), common guillemot (Uria aalge) and razorbill (Alca torda) avoided the wind farm area, and decreased in abundance with 85, 71 and 64%, respectively. Lesser black-backed gull (Larus fuscus) and herring gull (Larus argentatus) were attracted to the wind farm, and their numbers increased by a factor 5.3 and 9.5. Other gull species too were found to frequent the turbine-built area, most notably common gull (Larus canus), black-legged kittiwake (Rissa tridactyla) and great black-backed gull (Larus marinus). The ecological incentives behind the observed attraction effects are still poorly understood, but on top of the increase in roosting possibilities it is plausible that offshore wind farms offer enhanced feeding opportunities. Importantly, attraction of seabirds to offshore wind farms implies an increased collision risk.

Vanermen, N., Onkelinx, T., Verschelde, P., Courtens, W., Van de walle, M., Verstraete, H., & Stienen, E. W. (2015). Assessing Seabird Displacement at Offshore Wind Farms: Power Ranges of a Monitoring and Data Handling Protocol. *Hydrobiologia, 756*(1), 155-167 https://doi.org/10.1007/s10750-014-2156-2

Issue Title: Environmental impacts of offshore wind farms - Learning from the past to optimise future monitoring programmes Prior to the construction of an offshore wind farm at the Belgian Thorntonbank, local seabird abundance was studied by means of ship-based surveys. 'Seabirds at sea' count data, however, exhibit extreme spatial and temporal variation, impeding the detection of human impacts on seabird abundance and distribution. This paper proposes a transparent impact assessment method, following a before-after control-impact design and accounting for the statistical challenges inherent to 'seabirds at sea' data. By simulating a broad range of targeted scenarios based on empirical model coefficients, we tested its efficacy in terms of power and investigated how the chance of statistically detecting a change in numbers is affected by data characteristics, monitoring period and survey intensity. Because of high over-dispersion and/or zero inflation, the power to detect a 50% decrease in numbers was generally low, but did reach 90% within less than 10 years of post-impact monitoring for northern gannet (Morus bassanus) and common guillemot (Uria aalge).

Walsh, H. J., & Guida, V. G. (2017). Spring Occurrence of Fish and Macro-Invertebrate Assemblages near Designated Wind Energy Areas on the Northeast Us Continental Shelf. *Fishery Bulletin, 115*(4), 437-450 https://doi.org/10.7755/fb.115.4.1

Fish and macro-invertebrate assemblages were examined in the vicinity of 5 wind energy areas on the northeast U.S. continental shelf by using 2 sampling gears. Collections of fish and macro-invertebrates during the spring of 2014 with a 2-m beam trawl and a standard bottom trawl were compared. Correspondence analysis of proportions of taxa in the catch at sampling stations and estimated individual weights, averaged by taxon, were used to describe the composition of assemblages, and composition of the catch was compared between collections made with the 2 different gears and among different wind energy areas. These comparisons indicated that the 2 gears collected different fish and macro-invertebrate communities. Analysis of the collections by gear type indicated that assemblages varied across several spatial scales. Canonical correspondence analysis was used to examine the relationship between assemblages, sampling programs, and environmental variables to determine which variables and Correspondence analysis dimensions were aligned with stations and were related to the assemblages. Environmental variables explained 20.5% of the variation for the beam trawl stations and assemblages and 28.8% of variation for the bottom trawl stations and assemblages. Our results indicate that assessments of wind energy areas on the northeast U.S. shelf should be conducted by using multiple gear types across multiple spatial and temporal scales.

Weaver, A. (2021). An Ethology of Adaptation: Dolphins Stop Feeding but Continue Socializing in Construction-Degraded Habitat. *Frontiers in Marine Science* https://doi.org/10.3389/fmars.2021.603229

Adaptation is a biological mechanism by which organisms adjust physically or behaviorally to changes in their environment to become more suited to it. This is a report of free-ranging bottlenose dolphins' behavioral adaptations to environmental changes from coastal construction in prime habitat. Construction was a 5-yr bridge removal and replacement project in a tidal inlet along central Florida's Gulf of Mexico coastline. It occurred in two consecutive 2.5-yr phases to replace the west and east lanes, respectively. Lane phases involved demolition/removal of above-water cement structures, below-water cement structures, and reinstallation of below+above water cement structures (N = 2,098 photos). Data were longitudinal (11 years: 2005-2016, N = 1,219 surveys 2-4 times/week/11 years, n = 4,753 dolphins, 591.95 hours of observation in the construction zone, 126 before-construction surveys, 568 during-construction surveys, 525 after-construction surveys). The dependent variable was numbers of dolphins (count) in the immediate construction zone. Three analyses examined presence/absence, total numbers of dolphins, and numbers of dolphins engaged in 5 behavior states (forage-feeding, socializing, direct travel, meandering travel, and mixed states) across construction. Analyses were GLIMMIX generalized linear models for logistic and negative binomial regressions to account for observation time differences as an exposure (offset) variable. Results showed a higher probability of dolphin presence before construction, more dolphins before construction, and significant decreases in numbers of feeding but not socializing dolphins. Significant changes in temporal rhythms revealed finer-grained adaptations. Conclusions were that the dolphins adapted to construction in two ways, by establishing feeding locations beyond the disturbed construction zone and shifting temporal rhythms of behaviors that they continued to exhibit in the construction zone to later in the day when construction activities were minimized. This is the first study to suggest that the dolphins learned to cope with coastal construction with variable adjustments.

White, C., Halpern, B. S., & Kappel, C. V. (2012). Ecosystem Service Tradeoff Analysis Reveals the Value of Marine Spatial Planning for Multiple Ocean Uses. *Proceedings of the National Academy of Sciences, 109*(12), 4696-4701 https://doi.org/10.1073/pnas.1114215109

Marine spatial planning (MSP) is an emerging responsibility of resource managers around the United States and elsewhere. A key proposedadvantage ofMSP is that itmakes tradeoffs in resource use and sector (stakeholder group) values explicit, but doing so requires tools to assess tradeoffs. We extended tradeoff analyses from economics to simultaneously assess multiple ecosystem services and the values they provide to sectors usinga robust, quantitative, and transparent framework. We used the framework to assess potential conflicts among offshore wind energy, commercial fishing, and whalewatching sectors in Massachusetts and identify and quantify the value from choosing optimal wind farm designs that minimize conflicts among these sectors. Most notably, we show that using MSP over conventional planning could prevent >$1 million dollars in losses to the incumbent fishery and whale-watching sectors and could generate >$10 billion in extra value to the energy sector. The value of MSP increased with the greater the number of sectors considered and the larger the area under management. Importantly, the framework can be applied even when sectors are not measured in dollars (e.g., conservation). Making tradeoffs explicit improves transparency in decision-making, helps avoid unnecessary conflicts attributable to perceived but weak tradeoffs, and focuses debate on finding the most efficient solutions to mitigate real tradeoffs and maximize sector values. Our analysis demonstrates the utility, feasibility, and value of MSP and provides timely support for themanagement transitions needed for society to address the challenges of an increasingly crowded ocean environment.

Wiersma, B., & Devine-Wright, P. (2014). Public Engagement with Offshore Renewable Energy: A Critical Review. *Wiley Interdisciplinary Reviews-Climate Change, 5*(4), 493-507 https://doi.org/10.1002/wcc.282

Offshore renewable energy, including offshore wind, tidal and wave energy, has sometimes been represented as opposition-free alternatives to controversial technologies such as onshore wind turbines, and has received increasing attention from social scientists in recent years. A fragmented literature has emerged investigating public engagement with these technologies and the determinants of public acceptance, comprising 59 key studies-the majority investigating offshore wind energy (59%). This literature review argues that while the ways in which public actors engage with offshore renewable energy are to some extent similar to onshore energy infrastructure, there are also important differences. These include the generally lower levels of public knowledge about the technologies, a changing role for visual impacts, a fundamentally different, marine, spatial context, and different sets of stakeholders in different decision-making arenas. There is a need to explore as yet unasked and unanswered questions-going beyond 'established' variables identified in the onshore wind-based 'beyond NIMBY' literature-especially regarding the role of the marine location of these technologies, and the cross-technology and cross-disciplinary applicability of findings. In order to more fully understand public responses to energy infrastructures, future research needs to move beyond case studies of onshore wind developments, adopting more diverse and ambitious research designs and methodologies. (C) 2014 John Wiley & Sons, Ltd.

Wilhelmsson, D., & Langhamer, O. (2014). The Influence of Fisheries Exclusion and Addition of Hard Substrata on Fish and Crustaceans. In *Marine Renewable Energy Technology and Environmental Interactions.* M. A. Shields & A. I. L. Payne (Eds.), (pp. 49-60). Dordrecht: Springer Netherlands https://doi.org/10.1007/978-94-017-8002-5_5

Offshore renewable energy development (ORED) could induce local ecological changes and put species assemblages of conservation interest at risk. If well planned and coordinated, however, ORED could be beneficial to the local subsurface marine environment in several aspects. Acknowledging the scale of ORED, there is increasing interest in the opportunities offered by the resulting changes in fishing patterns, such as exclusion or limitation of bottom trawling, in wind and wave farms. Areas encompassing several square kilometres may in some important aspects resemble Marine Protected Areas, and wind and wave-energy foundations and other associated structures can function as artificial reef modules and enhance the local abundance of marine organisms, including commercially important fish and crustaceans. It is also possible that floating offshore energy devices can function as fish aggregation devices for pelagic fish. Here, the potential influence of offshore wind and wave farms on fish and commercially important crustaceans is described, mentioning the uncertainties with regard to positive and negative effects on benthic and pelagic assemblages and specific species.

Zhang, Y., Zhang, C., Chang, Y. C., Liu, W. H., & Zhang, Y. (2017). Offshore Wind Farm in Marine Spatial Planning and the Stakeholders Engagement: Opportunities and Challenges for Taiwan. *Ocean & Coastal Management, 149*, 69-80 https://doi.org/10.1016/j.ocecoaman.2017.09.014

Taiwan has advantages in the development of offshore wind power, as it has abundant wind energy resources at the seas. The local government has developed a series of measures to promote the development of wind power generation industry. The development of offshore wind farm in Taiwan, however, has to solve the problems that offshore wind farms are overlapping with some traditional fishing grounds and are unable to reach consensus with relevant stakeholders. This paper starts from the great potential of offshore wind power in Taiwan and the active promotion of the government, and analyses the impact and possible opportunities brought by offshore wind farm development to local fisheries, from the perspective of Zhanghua Area, a key area of development of offshore wind farm in Taiwan. This paper proposes that the local government in Taiwan should use marine spatial planning as a tool, through the comprehensive participation of government, developers, fishermen and other bodies, seeking the coexistence and prosperity of offshore wind farm and fisheries. Avoidance, compensation, and feedback, as well as communication and collaboration will be an important strategy to solve the conflicts of multiple use of the sea and to promote the development of marine renewable energy.