PREDICT: Predicting locations and seasons of top predator interactions with offshore wind farms

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With the increase of planned large-scale offshore wind developments in the North Sea, there is a growing need to understand where top-predator distributions will have heightened probability of interaction with windfarms. The seasonal distributions of top predators such as seabirds and marine mammals are driven by the movements of their principal prey, fish. The daily, weekly, and annual migration patterns of fish result in highly predictable seasonal changes in foraging and spawning grounds that are driven by environmental variables [1]. Characterising the environmental predictors of fish aggregations between seasons and years could enable calibration and validation of regional models, thereby providing robust forecasts of top predator distributions, which in turn can inform siting and operations of offshore windfarms.

The PREDICT project is a multi-disciplinary collaboration between the University of the Highlands and Islands, the University of Aberdeen, and industry partner Ørsted that aims to improve understanding of fish migration patterns and the environmental drivers of these in the North Sea throughout the annual cycle. The project will identify years, regions, oceanographic and finer-scale features (e.g. frontal and highly stratified areas) to predict mechanisms driving variability in annual fish migrations that are the most likely cause of high variation in seabird and marine mammal distributions [2]. Appropriate low-carbon and low-cost technologies will also be determined, including combinations of novel sensors and platforms, to facilitate simultaneous collection of data on fish and environmental drivers. The design and development of processing techniques for the temporal and spatial data generated from such instrumentation will likewise be conducted [3]. The bottom-up approach employed in this study will add to the evidence base, thereby helping to address knowledge gaps in regional offshore wind environmental characterisation while simultaneously providing a vision for next-generation monitoring techniques to reduce variance and uncertainty in assessments of top predator distributions.

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Hydrodynamic drivers fish school behavior in high energy tidal sites

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Tidal stream environments are areas characterised by extremely fast currents and a range of turbulent features that vary considerably over short temporal and spatial scales and are known foraging hotspots for highly mobile marine predators due to increased prey availability. On the other hand, such areas are ideal for marine renewable energy extraction, introducing the potential for conflict, due to planned increases in the use of coastal seas for the extraction of renewable energy. For this reason, there is an urgency to understand the effects of tidal devices on seabirds' behaviour, both direct and indirect, through changes in their prey behaviour and availability.

Using fish school and hydrodynamic data collected simultaneously in a tidal stream area and a mediation analysis framework, this study aimed to characterise the drivers behind prey availability in tidal stream areas. Specifically, we focused on characterising the direct and/or indirect effect of velocity and turbulent kinetic energy (TKE) on fish school depth and cohesion, to test the hypothesis that fish schools are closer to the surface and less cohesive in the water column during periods of fast velocities and therefore more accessible to foraging seabirds.

Results showed that fish schools moved closer to the surface and became less cohesive as velocity increased, thus more accessible to foraging seabirds. However, as TKE increased, so did fish school cohesion, suggesting that velocity and TKE have opposite effects on fish school cohesion. Given that the effect of velocity on fish school cohesion is higher than the effect of TKE, during baseline conditions with high velocity and high TKE, we would likely observe a decrease in school cohesion. However, as other studies have shown, TKE is likely to increase downstream of tidal devices while velocity decreases. Under this scenario, an increase in school cohesion is expected downstream of devices, consequently affecting predator foraging behaviour.

This study brings us a step further to identifying the underlying mechanisms which can influence seabird foraging, as well as other marine predators targeting similar prey species.

PELAgIO: Physics-to-Ecosystem Level Assessment of Impacts of Offshore Wind Farms

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By 2050 it's estimated >400 GW of energy will be gathered by offshore wind in the North Sea alone. How will this increased anthropogenic use of our coastal seas impact already stressed marine ecosystems? And how will that same production of renewable energy offset risks of extreme climate change that, left unchecked, will increase the risk of biodiversity declines. There are many complex changes to ecosystems linked to Offshore Wind Farms (OWFs) that we need to understand, so that the extent of increasing wind energy extraction further offshore is managed in the most sustainable way. An important effect of large wind energy extraction will be to reduce the amount of energy that would normally go into local ocean currents via surface stress, altering sea state and mixing. Conversely, there will be local increases in turbulence around turbine structures and seabed scouring near fixed foundations. Any change in ocean mixing may change the timing, distribution and diversity of phytoplankton primary production, the base of the food chain for marine ecosystems, to some degree. This has knock-on-effects on the diversity, health and locations of pelagic fish that are critical prey species of commercial fish, seabirds and marine mammals. Observed changes caused by operational OWFs in the southern North Sea include local surface temperature rise and the displacement of seabirds and fishing fleets from the OWF footprint, whereas seals often appear to be feeding near turbines. All of these changes have a linked component, important prey fish species, which are likely to aggregate near structures (as seen at other offshore platforms). Seabirds and fishing fleets subsequently have less space to hunt, with potentially increased competition for fish. However, if OWFs are also de facto marine protected areas and so positively affect local primary production, they may provide good habitat for fish population growth.

So, what are the cumulative effects of current OWF developments and the thousands of additional planned structures? Do the physical, biogeochemical and ecosystem changes exacerbate or mitigate those resulting from climate change? As OWFs migrate further offshore as floating structures, how can current knowledge based on shallow, coastal fixed turbines be suitably extrapolated to understand the impacts on ecosystems dependent on seasonal cycles that are typical of deeper waters?

The new PELAgIO project will address all of these questions through an inter-disciplinary, multi-scale observation and modelling framework that spans physical mixing through to plankton production, on to the response of fish and whole ecosystems. We will present how we will collect fine-scale data using the latest multi-instrumented acoustic platforms set beside and away from OWFs, complemented by autonomous submarine robots. The new approach to capture continuous and coincident data from physics to fish, over multiple scales and seasons will allow understanding of the changes to mixing and wind deficit impacts and what is 'different' inside an OWF as well as the size of its footprint. This bottom-up, comprehensive approach will enable true calibration and validation of 3D ocean-biogeochemical modelling systems, from the scale of turbine foundations up to the regional and even cross-shelf scales. These new data will also help to understand and quantify how OWF expansion might change prey fish availability to seabirds and mammals with the identified changes integrated into Bayesian ecosystem models. The outcomes of these models, run under different scenarios chosen by stakeholders, will enable the cumulative effects of ecological, social and economic trade-offs of different policy approaches for OWFs to be quantifiably assessed for present day conditions, during extreme events and under climate change.

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The potential of wind farms to affect primary production

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The rapid growth of renewable energy development in the shelf seas has raised the need to assess the direct and indirect impacts of these new infrastructures on the marine ecosystem. Very large-scale windfarms (fixed and floating) are going to be deployed in Scottish shelf seas (Scottish Government, 2022) under different hydrodynamic conditions (Leeuwen et al., 2015) where will change physical and biological processes (Carpenter et al., 2016). The extent in space and time of these variations are partially unknown and are likely to affect the trophic layers relying upon primary producers and physical drivers.

To investigate the possible effects of wind energy extraction, we need to start exploring areas with good long-term baseline data. The region of Firth of Forth and Tay Bay (Scotland, UK) has extensive wildlife and physical surveys and exemplifies an ecological and economic area of interest for top predators (seabirds, mammals) and the fishing industry. The area is targeted for future floating and static wind farm deployments. Seasonal variations occurring at and around wind farms were investigated by comparing two modelled scenarios, with and without windfarms, using FVCOM coupled to ERSEM. A first parametrization of the effects of wind farms on primary production is applied in this region following Christiansen et al. (2022).

Comparing the two models from March to July 2003 showed an overall decrease in primary production before the bloom, with a daily maximum decrease of up to 6% after wind farm deployments. Variations in Chl-a higher than 0.2 mg/m^3 at the depth of maximum concentration were recorded up to 80 km away from the wind farms. The size and location of each wind farm appeared correlated to the spatial extension of their effects. Shallow and highly concentrated patches develop in coastal waters (< 25 km), while the primary productivity changed over time close to the wind farms (< 20 km). The resulting change in the vertical distribution of food resources is likely to affect the distribution of upper trophic layers, influencing their vulnerability or sensitivity to turbines (e.g. seabirds and fish).

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