ECOWind ECOFlow

Annual Impact Meeting Report 2024

Image Credit - Photo of the Kincardine Offshore Wind Farm project courtesy of Principle Power

Produced by:

Howell Marine Consulting

Funded by:

Department for Environment Food & Rural Affairs

UKRI Natural Environment Research Council

Offshore Wind Evidence + Change Programme | The Crown Estate | Crown Estate Scotland

ECOWind

ECOFlow

Contributors

This report was prepared by Howell Marine Consulting using evidence gathered by the contributing government, industry and academic speakers (below), as presented at the second Annual Impact Meeting held on the 20-21 November 2024.

Dr Alex Banks,
Principle Scientist
Natural England

Anna Tarbet
Strategic Compensation Project Manager
OWIC

Antonina Nazarova,
Senior Research Associate
University of East Anglia
BOWIE

Audrey Jones,
Principal consultant
Howell Marine Consulting

Prof Beth Scott,
University of Aberdeen,
PELAgIO PI

Prof Colin Moffat,
ECOWind Programme Advisory Group Chair

Dr Christopher A. Unsworth,
Bangor University,
ACCELERATE

Dr Connor McCarron,
HR Wallingford
ACCELERATE

Eleni Antoniou
Strategic Environment & Policy Manager
Orsted

Ellie-Mae Cook,
Aura Centre for Doctoral Training
BOWIE

Dr Emma Tyldesley,
Environment modeller
University of Strathclyde Glasgow
ECOWINGS

Prof Francis Daunt,
Centre for Ecology & Hydrology,
ECOWINGS PI

Gabriella Gilkes,
Senior Research and Evidence Manager,
The Crown Estate

Dr Henk van Rein,
Research Impact Lead
Howell Marine Consulting

Joanna Rzempoluch,
Research Assistant
University of Southampton
BOWIE

Jon Rees
Strategic consents specialist
The Crown Estate

Dr Jordan Burgess,
Postdoctoral research assistant
University of Hull
BOWIE

Dr Joshua Lawrence,
Research associate
Heriot-Watt University
ECOWINGS

Dr Julie Salvetat,
Postdoctoral researcher
University of the Highlands and Islands
PELAgIO

Prof Justin Dix
University of Southampton
eSWEETS3

Prof Katrien Van Landeghem,
Bangor University,
ACCELERATE PI

Dr Lisa Skein,
Research scientist
National Oceanography Centre
ACCELERATE

Prof Martin Solan,
University of Southampton, BOWIE PI

Prof Matthew Palmer,
Plymouth Marine Laboratory
EQUIFY PI

Dr Michela De Dominicis,
National Oceanography Centre
PELAgIO

Dr Neda Trifonova
The University of Aberdeen
PELAgIO

Dr Oliver Leedham,
UK Centre for Ecology & Hydrology
ECOWINGS

Dr Olivia Hicks,
Bangor University
ACCELERATE

Rachael Mills
Offshore Wind Evidence and Change Programme Lead

Prof Stephen Votier,
Heriot-Watt University
FRONTLINE PI

Dr Steve Gibson
Associate Director – Strategy
Howell Marine Consulting

Prof Tim Smyth,
Plymouth Marine Laboratory
PELAgIO

Dr Thomas Williams,
University of Southampton,
BOWIE

Tristan Bromley,
Whole of Seabed (WoS) lead
The Crown Estate

Dr Veerle Huvenne,
National Oceanography Centre,
ACCELERATE

Victoria Metheringham,
Head of Marine Biodiversity and Environment Science and Monitoring
Defra

Dr Vladimir Krivtsov
University of Strathclyde Glasgow
ECOWINGS

Dr Will Le Quesne
Principal Ecosystem Scientist
Cefas

Acronyms

ACCELERATE	Ecological Implications of Accelerated Seabed Mobility around Windfarms
AIM	Annual Impact Meeting
ANS	Artificial Nesting Structure
BOWIE	Benthic-Offshore Wind Interactions
Cefas	Centre for Environment, Fisheries and Aquaculture Science
Defra	Department for Environment, Food & Rural Affairs
ECOFlow	Ecological Consequences of Floating Offshore Wind programme
ECOWind	Ecological Consequences of Offshore Wind programme
ECOWINGS	Ecosystem Change, Offshore Wind, Net Gain and Seabirds
EIA	Environmental Impact Assessment
EMF	Electromagnetic Fields
EQUIFy	Establishing a Framework for Quantifiable Evidence and Impact of Ecosystem Change Throughout the Lifecycle of UK Floating Offshore Wind Farms
eSCARP	English Seabird Conservation and Recovery Pathway
eSWEETS3	Enabling Sustainable Wind Energy Expansion in Seasonally Stratified Seas
FOW	Floating Offshore Wind
FRONTLINE	Impacts of Floating Offshore Wind on Celtic Sea Ocean Fronts and Biodiversity
GES	Good Environmental Status
HV	High Voltage
MNG	Marine Net Gain
NE	Natural England
NERC	Natural Environment Research Council
OWEKH	Offshore Wind Evidence and Knowledge Hub
OWF	Offshore Wind Farm
OWIC	Offshore Wind Industry Council
PELAgIO	Physics-to-Ecosystem Level Assessment of Impacts of Offshore Windfarms
PI	Principal Investigator
POSEIDON	Planning Offshore Wind Strategic Environmental Impact Decisions
ReSCUE	Reducing Seabird Collisions Using Evidence
SAR	Synthetic Aperture Radar
SNCB	Statutory Nature Conservation Body
TCE	The Crown Estate
TKE	Turbulent Kinetic Energy
USV	Uncrewed Surface Vehicle

ECOWind

ECOFlow

Benthic ecosystem dynamics & interactions with OWFs

- **Seabed Turbulence and Mobility:** Increased turbulence and seabed mobility around monopiles can strip top sediments from the seabed and create new bedforms. Greater effects are predicted in low-energy, deeper waters.
- **Community Shifts:** Fixed Offshore Wind Farm (OWF) turbines have lower species diversity relative to seabed sediments but higher abundance and biomass. The altered community structures produce different local ecological functions.
- **Invertebrate Responses to OWF vibrations:** OWF vibrations may have significant lasting effects on invertebrates, such as decreasing their oxygen consumption, food intake, changes in glucose levels, and may impact larval survival and health.

Innovative data collection

- **Stratification:** Deeper water floating OWFs could alter the timing and magnitude of water-column stratification, affecting nutrient pathways, oxygen levels and plankton distribution. Preliminary results show decreases is stratification close to the windfarm and these changes are more prominent in the summer.
- **Uncrewed Surface Vehicle (USV) trials:** USV equipped with echosounders successfully detected surface fish and seabirds alongside concurrent aeroplane surveys (using video data).
- **Electromagnetic Field (EMF) Tool:** A tool was developed to calculate EMF values efficiently and accurately using cable parameters. No demonstrable ecosystem effects were observed unless within 0.5 m of a high voltage (HV) subsea-cable.
- **Synthetic Aperture Radar (SAR):** SAR Earth observation analysis shows a mix of wind speed deceleration and acceleration is present across OWFs.

Impacts of OWFs on prey & foraging opportunities

- **Zooplankton:** Under 2040 climate change scenarios (HADGEM, RECICLE IPSL and GFDL), all zooplankton in the North Sea, especially smaller groups, show a strong decline, driven by reduced circulation and salinity.
- **Acoustics for fish behaviour:** Integration of acoustics data with tide, current speed and time of day variables provides fine-scale insights into fish behaviour and distribution near OWFs.
- **Habitat to prey:** Analysis of multi-scale spatial and temporal data around Puffin Island, North Wales, shows sediment variables play a significant role in shaping seabird distribution. Ongoing work focuses on predicting how changes in physical environments impact marine top predators.

Cumulative effects of OWFs & climate change

- **Seabed mobility:** Projections for 2050 and 2090 reveal hotspots of bed shear stress in fast tidal flows, western coasts, and shallow waters, driven by storms.
- **Sea level rise and storm impacts:** Rising sea levels decouple seabed currents, reducing shear stress. Storms generate bed shear stress up to three times larger than natural tides.
- **Temperature:** Sea surface and seabed temperatures will rise in well-mixed areas, leading to marine heatwaves. Sea surface temperatures are projected to increase by 3.0°C (±1°C) by 2100 (~0.3°C per decade).
- **Marine use scenarios:** Under combined OWF and climate change scenarios, the changes in primary production will have consequences for seabirds. Stopping fishing with mobile gear results in improved outcomes for fish recruitment and seabird breeding success.

Poster Highlights

Effectiveness of compensatory measures for UK seabirds - an expert elicitation quantified potential gains across 14 measures for 11 species of bird.

Modelling the cumulative effects for compensation and marine net gain (MNG) - provides climate-resilient compensation measures and insights for fisheries management.

Assessing the impact of continuous and impulsive vibration on marine invertebrates: Sensitivity thresholds need to be better addressed in Environmental Impact Assessments (EIAs).

The scale of change for benthic communities: The disproportionate gain in habitat results in ecological functional shifts on both local and large landscape sized scales.

Turbulent wake of OWF monopiles can change seabed properties: by enhancing bed shear stress, changing seabed sediments.

Enhanced bed shear stress and mixing in the tidal wake of a monopile: tidal wake doubles the drag acting on the seabed, potentially enhancing sediment transport and vertical mixing.

Assessing the physiological and behavioural responses of marine invertebrates to vibration: sub lethal OWF impacts inform the health of populations.

A GIS tool to evaluate mussel cultivation in EU waters: A spatial multi-criteria evaluation was used to identify suitable OWF for multi-use with mussel farming in European waters.

All posters can be accessed on the ECOWind website:
https://ecowind.uk/

ECOWind Summary

The Ecological Consequences of Offshore Wind programme, ECOWind (2022-2026) is a co-designed partnership between the Natural Environment Research Council (NERC), The Crown Estate (TCE), Crown Estate Scotland and the Department for Environment, Food & Rural Affairs (Defra). ECOWind seeks to address critical gaps in understanding how large-scale expansion of OWF affects marine ecosystems. ECOWind includes four research projects, Ecological Implications of Accelerated Seabed Mobility around Windfarms (ACCELERATE), Ecosystem Change, Offshore Wind, Net Gain and Seabirds (ECOWINGS), Benthic-Offshore Wind Interactions (BOWIE) and Physics-to-Ecosystem Level Assessment of Impacts of Offshore Windfarms (PELAgIO).

ECOFlow Summary

The Ecological Consequences of Floating Offshore Wind programme, ECOFlow, (2025-2028) builds onto ECOWind, delivering impactful, policy-ready science, but to specifically understand the effects of Floating Offshore Wind (FOW) on marine ecosystems. ECOFlow includes two research projects, “Establishing a framework for quantifiable evidence and impact of ecosystem change throughout the lifecycle of UK FOW Farms” (EQUIFy) and “Impacts of FOW on Celtic Sea ocean fronts and biodiversity” (FRONTLINE). A closely-related NERC-funded project, “enabling Sustainable Wind Energy Expansion in Seasonally Stratified Seas” (eSWEETS3) has been incorporated into ECOFlow.

ECOWind and ECOFlow seeks to address three core challenges

- To understand the ecological effects of fixed / floating offshore wind infrastructure on different trophic levels across critical ecosystem drivers and within the context of climate change.
- To develop new ways to monitor and assess the environmental effects of fixed / floating offshore wind infrastructure.
- To utilise the robust evidence and tools developed to support the evolution of UK marine policy in adapting to the expansion of fixed / floating offshore wind.

Introduction

The urgency for addressing climate change and biodiversity loss has never been greater. With emissions increasing by 0.8% in 2023, the UK is projected to exceed the 1.5°C threshold within six years.[1] Offshore wind is already contributing enough electricity to power 14.2 million UK homes in 2023.[2] By 2030, 77–82% of UK electricity is predicted to originate from renewable sources, predominantly offshore wind, requiring ocean space equivalent to Italy's landmass.[3,4] Marine biodiversity assessments highlight poor ecological status across multiple descriptors in both the Greater North Sea and Celtic Seas, underscoring the need for strategic planning to combat these crises effectively.

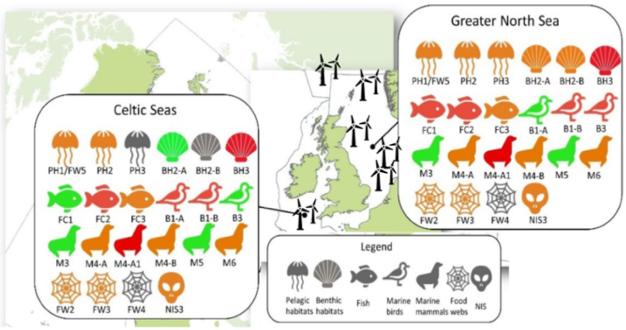

Figure 1. Good Environmental Status indicators across the UK. Adapted from McQuatters-Gollop et al., 2022.

The **Annual Impact Meeting (AIM)** serves as a platform uniting academia, policy and industry to overcome communication barriers, disseminate high-impact research, and foster collaboration. The meeting aims to translate cutting-edge research from ECOWind and ECOFlow into actionable solutions and identify opportunities for real-world applications.

The AIM 2023 highlights:

- Hosted 153 attendees from ECOWind, PrePARED, POSEIDON, government, Statutory Nature Conservation Body (SNCB) and industry representatives.
- Discussions addressed key opportunities for research alignment for seabed dynamics, seabirds, fish and cumulative ecological impacts. Participants compiled a research timeline, identifying pathways for translating findings into actionable strategies for key challenges such as compensation, ecological network and food web assessments and building the EIA evidence base.

The AIM 2024 highlights:

- AIM 2024 brought together a total of 238 participants from 89 organisations.

> *"ECOWind research is assisting with a live policy issue within government,"* ***Defra***
> *"The AIM has given me ideas on how to communicate science to policy and formed a route for impact,"* ***Academic researcher***

- The latest science from ECOWind was presented across four themes in relation to offshore wind: benthic ecosystem dynamics, impacts on prey, innovative methods and cumulative and climate change effects. Followed by a morning discussing the latest policy challenges including strategic evidence, strategic compensation and MNG.

---

[1] Global Carbon Budget Report, 13 Nov 2024
[2] The Crown Estate, Offshore wind report 2023.
[3] Clean Power 2030. Advice for achieving clean power for Great Britain. National Energy System Operator.
[4] INSITE https://insitenorthsea.org/

Science highlights

Benthic ecosystem dynamics and interactions with OWFs

Chaired by Prof Katrien Van Landeghem *(Principal Investigator (PI) of the ACCELERATE project)*

The interaction between the seabed and fixed turbines in OWFs has significant ecological and environmental implications. Understanding these processes is essential for:

- developing effective mitigation and compensation measures for undesirable effects;
- understanding how seabed changes affect habitats, prey availability and seabird populations, and consequent effects towards achieving good environmental status (GES);
- scoping the collection of high-quality temporal data to support meaningful monitoring;
- influencing policy and industry practices towards more nature-positive outcomes.

How the turbulent wake of offshore windfarm monopiles can change seabed properties via excess bed shear stress.

Dr Christopher A. Unsworth, Bangor University, ACCELERATE, christopher.unsworth@bangor.ac.uk

- Analysis of field data collected from Rhyl Flats wind farm in 2023 reveals that wind turbine monopiles induce seabed wake effects up to 200 m from the monopiles.
- The increased water column turbulence and accelerated seabed mobility in the turbine wakes can **strip finer sediments from the surface of the seabed** and **create new fields of bedforms** (Figure 2).
- Scaled laboratory experiments show that for a typical 15 m diameter monopile, the wake effects can lead to seabed changes to 15,000 m^2 of surrounding benthic habitats.
- **Larger wake effects are expected in lower-energy environments, that typically occur in deeper waters. This may affect the OWFs of the Round 5 and 6 leasing rounds[5].**
- Turbulent Kinetic Energy (TKE) modelling techniques used have shown improved accuracy in predicting bed shear stress and associated impacts, useful for estimating wakes effects in future OWF leasing rounds.

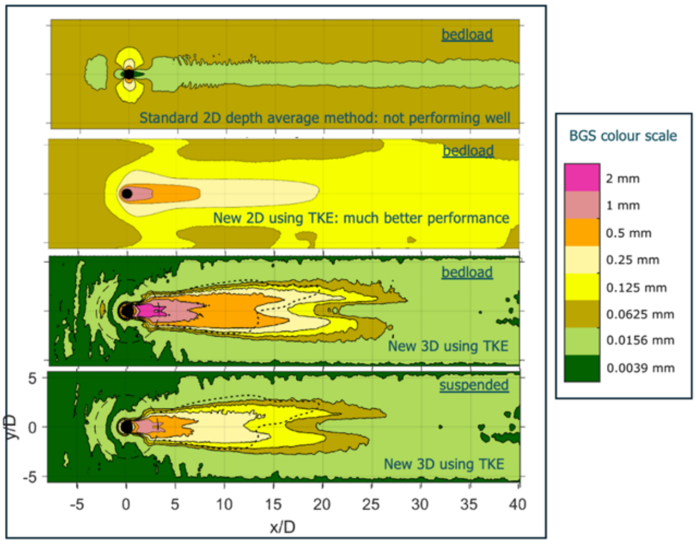

Figure 2. Sediment particle changes from monopiles (black dot) using TKE modelling. British Geological Society (BGS) scale shows sediment particle sizes in mm.
Image credit: Dr Christopher A. Unsworth, Bangor University

[5] https://www.datocms-assets.com/136653/1725984848-tce_future-offshore-wind.pdf

Species to habitat associations inside and outside Offshore Windfarms and a framework for modelling biodiversity and Ecosystem Services

Dr Lisa Skein and Dr Veerle Huvenne
National Oceanography Centre
lisa.skein@noc.ac.uk
vaih@noc.ac.uk

Project: ACCELERATE

- Benthic community data collected from both inside and outside OWFs in Eastern Irish Sea are being used to develop predictive models for forecasting future species associations, biotope distributions and ecosystem services in 2050 and 2090.
- Early results of current benthic community data show **differences between OWF-associated and natural hard substrate assemblages,** as well as dominance of different key benthic invertebrates across different habitat types.

Assessing the scale of change for benthic communities

Ellie-Mae Cook
Aura CDT
University of Hull
E.E.Cook-2015@hull.ac.uk

Project: BOWIE

- Comparison of **OWF data from over 50 EIAs** shows that when compared**, monopile-associated biodiversity was lower but biomass and abundance higher than with pre-construction sediment biodiversity.**
- Analysis suggests ecosystem impacts from introduced artificial substrata may be underestimated in real-life scenarios, with a net increase in habitat availability across all wind farms, with most projects experiencing a gain in habitat surface area of more than 100%.

How substrate vibrations influence benthic species

Jordan Burgess
University of Hull
Jordan.burgess@hull.ac.uk

Project: BOWIE

Laboratory mesocosm experiments focussing on invertebrates show that simulated OWF vibrations may have significant lasting effects on the invertebrates:

- **Impulsive Pile Driving: After 1 day, oxygen consumption decreased by 50%, and glucose levels dropped by 45%;**
- **Operational Continuous Vibration: Over 10 days, food intake reduced by 57%, while glucose levels increased by 46%,** reflecting a chronic stress responses;
- Potential **impacts to larvae survival and health** (results coming soon). Important for OWFs as they must account for critical breeding periods of invertebrates to minimise long-term ecological impacts.

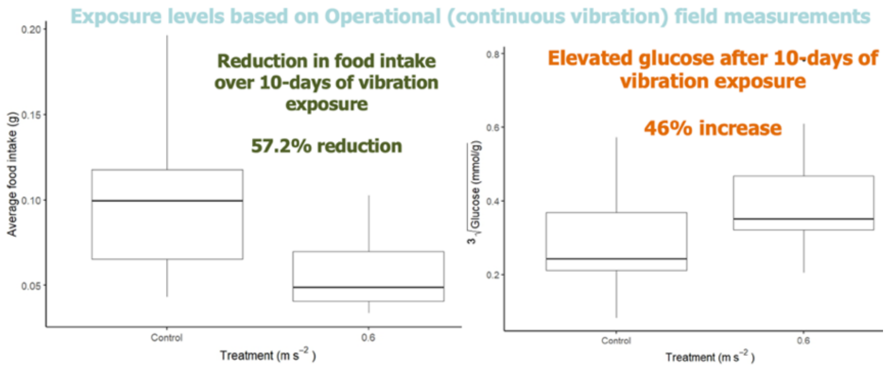

Figure 3. Continuous vibration effects on food intake of invertebrates in mesocosms. Image credit: Jordan Burgess, University of Hull

Impacts of OWFs on prey distribution, availability, and foraging opportunities

Chaired by Prof Francis Daunt (*PI of the ECOWINGS project)*

The interaction between OWFs and marine ecosystems has significant implications for predator-prey dynamics and food web stability. By examining the interactions between OWFs, prey distribution and predator behaviour, we can better predict environmental risks, inform future development scoping, and identify suitable compensation measures.

Climate projections of zooplankton and forage fish: a shifting baseline for seabird prey fields

Dr Emma Tyldesley
emma.tyldesley@strath.ac.uk

Dr. Vladimir Krivtsov
vladimir.krivtsov@strath.ac.uk

University of Strathclyde Glasgow

Project: ECOWINGS

Future projections of zooplankton groups, abundances and potential energy (kJ.m^3) to pass on to higher trophic levels were estimated alongside temperature changes to model the abundance of sandeel and sprat populations in areas of the North-West European continental shelf that are key for seabird foraging success.

- **Under three 2040 climate scenarios, HADGEM, RECICLE IPSL and GFDL, all zooplankton groups in the North Sea show a strong decline,** driven by reduced circulation and salinity (Figure 4).
- Model results also show regional variations in sandeel growth, e.g. higher growth at Dogger Bank compared to Wee Bankie.

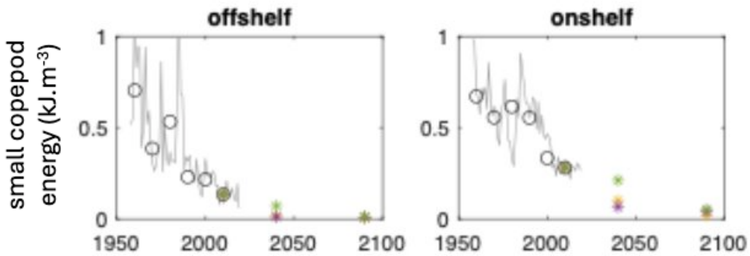

Figure 4. Copepod energy availability off and on the NW European shelf. Image credit: Dr Emma Tyldesley, University of Strathclyde Glasgow

This food web model will be refined to simulate future forage fish climate projections and relate findings to offshore wind development areas.

A multifaceted approach to monitoring fish behaviour and predator interactions around offshore wind farms

Dr Julie Salvetat
University of the Highlands and Islands
Julie.Salvetat@uhi.ac.uk

Project: PELAgIO

Integration of multi-frequency active acoustic data from survey vessels and seabed moorings **enables classification of three fin-fish groups, moving towards a non-invasive, cost-effective monitoring method for abundance and behaviour of these fish:**

- Mackerel and sandeel (no swim bladder);
- Gadoids (swim bladder for buoyancy control); and
- Clupeids (well-developed swim bladder, sensitive to sound and pressure).

The mechanistic link from the predictable physical environment to diving seabird distribution via their marine prey

Dr Olivia Hicks
Bangor University
o.hicks@bangor.ac.uk

Project: ACCELERTE

Using multi-scale spatial and temporal data around Puffin Island, North Wales, the study integrates fine scale sediment data, prey abundance and distribution, and seabird fine-scale movement and energy use. Results show that **sediment variables play a significant role in shaping seabird distribution**. Ongoing work focuses on modelling predator energy gain to understand relationship to habitat quality, and to strengthen predictions of how changes to the physical environment impact marine top predators (Figure 5).

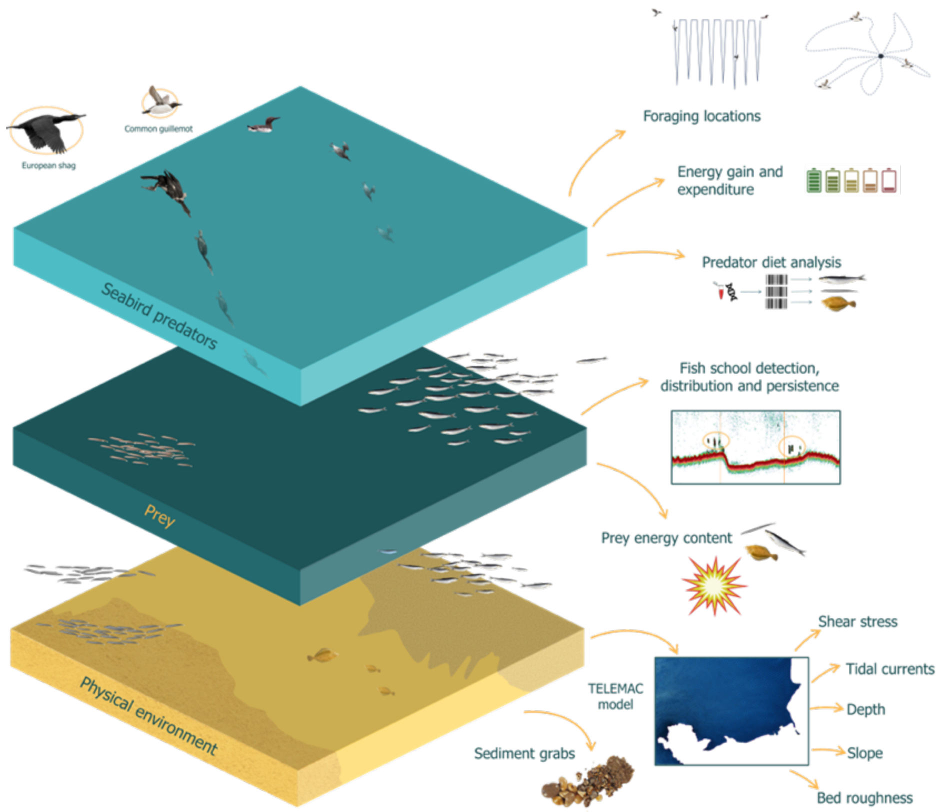

Figure 5. Data outputs from modelling and integration of physical environment, forage fish and seabird spatial distributions.
Image credit: Dr Olivia Hicks, Bangor University

Strategic monitoring and innovative data collection approaches

Chaired by Prof Martin Solin (*PI of BOWIE*)

Assessing environmental impacts requires a deeper understanding of **ecosystem interactions and functionality**—including reproduction, growth, and mortality. To address strategic questions effectively we need the right data at the right time—data that not only describes species abundance and distributions but also reveals the underlying interactions driving ecosystem responses.

Assessing the impact of offshore windfarms & climate change on the ocean biogeochemical state of the North Sea

Dr Rory O'Hara Murray
Marine Directorate Scotland
Rory.Murray@gov.scot

Dr Michela De Dominicis
National Oceanography Centre
micdom@noc.ac.uk

Project: PELAgIO

The North Sea water column is usually mixed in winter and stratified in summer. Physical and biogeochemical modelling of areas shows that **drag and mixing effects on the water surface and mid-water wakes of turbines in OWFs can lead to less stratification in the summer**, changing this regime. This effect showing less stratification, is more pronounced closer to the windfarm.

Changes to the timing and magnitude of seasonal stratification may affect nutrient pathways and oxygen availability as a result, especially at deeper sites, with knock on effects for planktonic production. **Preliminary results from gliders deployed east of a Scottish OWF showed enhanced chlorophyll a distribution in the wind wake of turbines.** Further investigation of these results is underway before findings can be confirmed. Different present and future OWF development scenarios will be also modelled to assess the bio-physical changes induced by the large-scale expansion of OWFs. The bio-physical changes will be compared with climate change effects (using RCP8.5 scenario).

Sampling challenges in offshore windfarms generate innovation in marine autonomous systems

Dr Joshua Lawrence, Heriot Watt University
joshua.lawrence@hw.ac.uk

Project: ECOWINGS

Trials using 360^0 video cameras and echosounder were successfully carried on the ECOWINGS USV in preparation for spring/summer deployments in 2025 (Figure 6). The USV will be used alongside concurrent aeroplane and AUV surveys to validate the detection of seabirds and surface fish respectively. **USVs offer a low-carbon, low-risk, low-cost alternative method to traditional ship- and aeroplane-based approaches.**

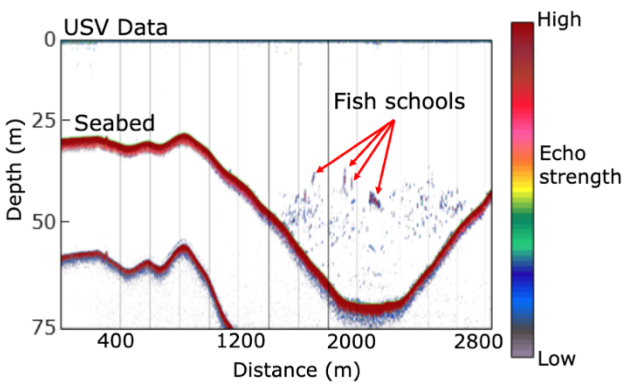

Figure 6. Echogram of fish schools detected from an Uncrewed Surface Vehicle in an OWF.
Image credit: Dr Joshua Lawrence, Heriot Watt University

Assessment of impacts associated with Electro-Magnetic Fields (EMF) produced by High-Voltage (HV) submarine cables

Joanna Rzempołuch
University of Southampton
jr9g20@soton.ac.uk

Project: BOWIE

Current EMF calculations are complex, computationally expensive, and often rely on simplified methods that reduce accuracy.

- The SCAMPI tool (MATLAB/Python) has been developed to calculate EMF values along HV cables.
- The tool requires only cable parameters as inputs and delivers EMF values at a low computational cost, with a good level of accuracy.
- **Analysis of realistic EMF impacts shows no demonstrable effects until within 0.5 m of HV subsea cables.**
- A device has been designed to recreate EMFs produced by HV cable systems, enabling controlled testing and further assessment of ecosystem impacts.

Quantifying the impact of offshore wind farm infrastructure using Earth Observation

Dr Tim Smyth,
Plymouth Marine Laboratory
tjsm@pml.ac.uk

Project: PELAgIO

Using SAR, Ocean Colour optical and Near Infrared wavelengths, the impacts of OWFs on key surface processes have been analysed, using data collected from the Seagreen OWF. Key findings are:

- SAR can measure sea surface roughness to determine windspeed at the sea surface;
- SAR produces high-resolution data (10–30 m horizontal resolution) that penetrates clouds, enabling improved remote sensing;
- **Wind speeds were observed to accelerate both within and downwind of the OWF.**

Further work will determine the net effects of changes in wind speed in a OWF by investigating the combined wind speed deceleration and acceleration (Figure 7), and whether certain wind combinations are linked to turbine operation.

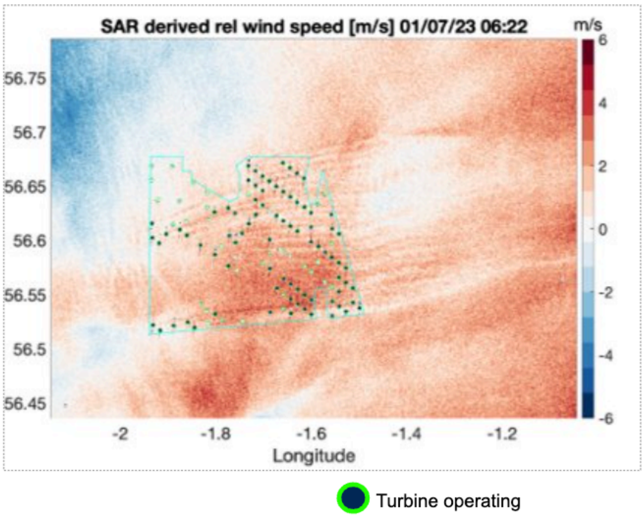

Figure 7. SAR data reveals wind speed variations across operating turbines.
Image credit: Dr Tim Smyth, Plymouth Marine Laboratory

A decision support system for marine management and planning

Dr. Antonina Nazarova
University of East Anglia
A.Nazarova@uea.ac.uk

Project: BOWIE

A balance sheet approach was applied to evaluate strategic policy, regional and local impacts, and trade-offs associated with OWF development. This approach informs a cost-benefit analysis across different scenarios, incorporating carbon valuations from OWF and ecosystem service assessments.

The Cumulative effects of OWFs and environmental drivers of change from climate change

Chaired by Prof Beth Scott *(PI of PELAgIO)*

To understand routes for MNG and compensation measures, we need models to analyse the complexity of cumulative effects down to population level at local scales and ecosystem service changes at regional scales, whilst also accounting for the counterfactual impacts of climate change.

Assessment of future UK Continental Shelf scale seabed vulnerability from different environmental drivers

Dr Connor McCarron,
HR Wallingford
c.mccarron@hrwallingford.com

Project: ACCELERATE

Seabed Mobility Projections for 2050 and 2090 highlight areas where bed shear stress is predicted to be higher than today, such as in **areas of fast tidal flows** and **along western coasts and shallow water areas.** Mapped projections show **larger areas of the seabed sediments begin to become mobilised**, identifying areas of vulnerability.

- Rising sea level projections show a decoupling of currents from the seabed that alters tidal flows. **In shallow water areas and estuaries,** however, **bed sheer stress increases** (Figure 8a).
- Storm modelling reveals **storms generate bed shear stresses three times larger than natural tide forces.** Projections suggest minimal change in storm severity by 2050, but significant increases by 2090, especially **along western coasts and shallow water areas.** (Figure 8b).
- Temperature models reveal a rising sea surface temperature and rising temperature at the seabed in well mixed areas, which translate to marine heatwaves. **Sea-surface temperatures are projected to increase by 3.0°C (±1°C) by 2100 (~0.3°C per decade)** (Figure 8c).
- Stratification in the Irish Sea remains largely unchanged but is driven primarily by temperature. **By 2100, thermal stratification duration will extend by approximately 2 weeks, with an increase in strength due to rising air temperatures, having implications for primary productivity.**

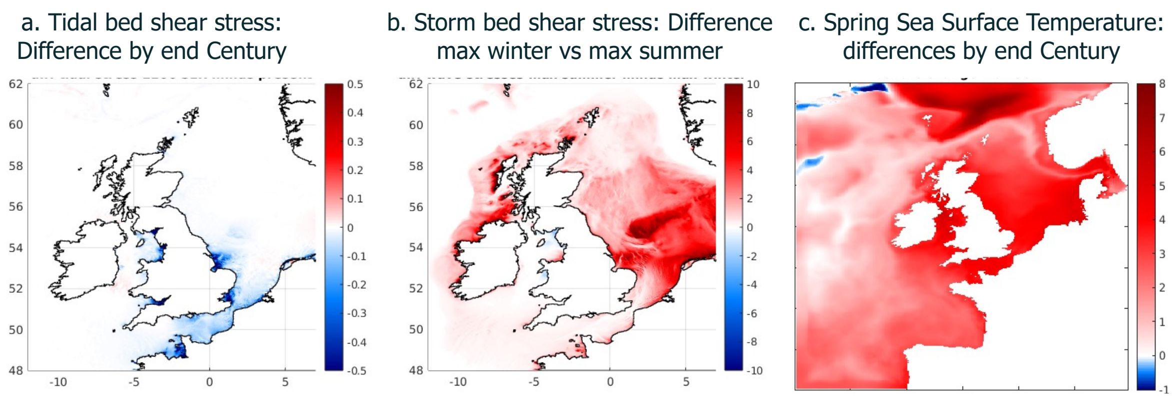

Figure 8. Predicted changes to bed-shear stress (N/m²) due to a. tidal forces, b. storm activity, and to c. sea surface temperatures by 2090
Image credit: Dr Connor McCarron, HR Wallingford

Estimating effects of displacement on seabirds via changes in prey consumption

Dr Oliver Leedham, UK Centre for Ecology & Hydrology
olilee@ceh.ac.uk

Prey consumption maps were created for kittiwake, guillemot, and razorbill using a novel method integrating species energetics, demography and population counts. Overlays of OWF locations identified areas where OWF development could lead to prey reductions. A **Seabird Prey Mapper Tool** has been developed to assess the foraging value of specific areas in the context of OWF development and will be publicly available soon (Figure 9).

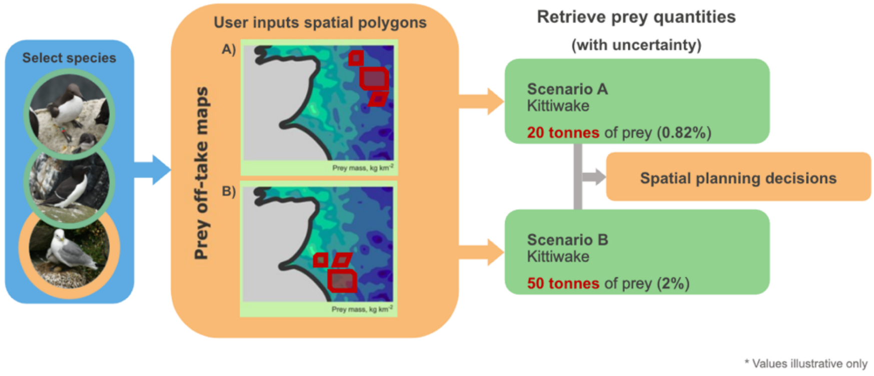

Figure 9. Seabird Prey Mapper Tool Image credit: Dr Oliver Leedham, UK Centre for Ecology & Hydrology

Cumulative expansion of "Ocean-Use" predicts seafloor functioning across the UKEEZ

Dr Thomas Williams
University of Southampton
t.williams@soton.ac.uk

Project: BOWIE

Between 2000 and 2020, up to 98% of UK Exclusive Economic Zone waters were exposed to at least one ocean-use driver (e.g. fishing, shipping, noise, cables). As ocean-use intensifies, variability in outcomes becomes more pronounced across different habitats:

- As ocean use increases, bioturbation generally declines but quickly plateaus or reverses, with trends varying temporally and by sediment type;
- Under low ocean uses, there are consistent effects on benthic functioning.

Dynamic Ecosystem models predictions of cumulative effects on populations

Dr Neda Trifonova
University of Aberdeen
neda.trifonova@abdn.ac.uk

Project: PELAgIO

Working collaboratively with the fishing industry and OWF developers, various marine use scenarios were modelled using a Bayesian ecosystem model to assess ecological outcomes:

- Under a scenario **where mobile fishing gear was excluded from OWFs and Marine Protected Areas, all changes to fish recruitment and seabird breeding success were positive;**
- Under the **scenario where OWFs are present and climate change occurs**, many seabirds declined, being particularly sensitive to resulting changes in primary production. With the **removal of mobile fishing gear from this scenario, however, positive increases occurred for kittiwake breeding success.**

The project is now using these outputs to assess changes in ecosystem goods and services and the resulting socio-economic value under alternative management and climate change scenarios.

Introduction to the ECOFlow projects and eSWEETS3

EQUIFy: Establishing a Framework for Quantifiable Evidence and Impact of Ecosystem Change Throughout the Lifecycle of FOW farms

Lead Principal Investigator: Prof Stephen Votier, Heriot-Watt University
s.votier@hw.ac.uk

EQUIFy aims to develop a flexible and evidence-based framework to quantify the ecological impacts of future FOW farms. Key objectives:

- Assess FOW-driven changes in mixing processes, primary productivity and the abundance and behaviour of fish, birds, and marine mammals;
- Evaluate the regional-scale effects of FOW on oceanic conditions, cascading effects on higher trophic levels and overall ecosystem functions, considering long term cumulative impacts;
- To understand how the expansion of FOW will interact with current marine use and the consequences of climate change.

Frontline: Impacts of Floating Offshore Wind on Celtic Sea Ocean Fronts and Biodiversity

Lead Principal Investigator: Prof Matthew Palmer, Plymouth Marine Laboratory
mpa@pml.ac.uk

Frontline aims to evaluate the effect of FOW on oceanography, as well as on commercial fisheries, within dynamic shelf-sea ecosystems, targeting the Celtic Sea as an example. Key objectives:

- Assess oceanographic processes to understand fish nursery effects and marine vertebrate distribution/behaviour in relation to FOW;
- Map the distribution, abundance and behaviour of Celtic Sea top marine predators and hotspots, and quantify the displacement effects and estimates of seabird collision risks for FOW;
- Determine the potential impact of changing fishery distribution patterns on marine predators and biodiversity, as well as the social and economic implications.

eSWEETS3: Enabling Sustainable Wind Energy Expansion in Seasonally Stratified Seas

Lead Principal Investigator: Prof Jonathan Sharples, University of Liverpool
Jonathan.Sharples@liverpool.ac.uk

eSWEETS3 aims to understand how ocean biogeochemistry might respond to mixing around floating offshore wind farms. Key objectives:

- Combine near- and far-field observations with numerical modelling to determine the short- and long-term impact of large-scale FOW deployments on shelf sea biogeochemistry;
- Develop a novel method for continuous, cost-effective monitoring of the shelf sea environment as the industry expands.

Policy highlights

Keynote: Gabriella Gilkes, Senior Research and Evidence Manager, TCE

The Marine Delivery Route map[6] outlines The Crown Estates strategies to support economic growth, halt biodiversity loss and promote nature recovery, all working towards achieving Net Zero ambitions for the seabed adjacent to England, Wales and Northern Ireland. Actions include sharing evidence, aligning science with policy for timely decisions, and fostering collaboration across policy, science, and industry to reduce consenting risks and restore habitats.

Advancing Marine Policy: Strategic Evidence

Victoria Metheringham, Head of Marine Biodiversity and Environment Science and Monitoring, Defra

- Evidence drives the policy cycle: building robust evidence bases, addressing gaps, and integrating ecological, social, and economic insights. The English Marine Natural Capital and Ecosystem Assessment programme[7] bridges language barriers to better inform decision-makers, including statisticians, socioeconomics, treasury, ministers, and legal teams, and will provide advice in the management of UK marine environments.
- Defra is adopting a strategic, holistic view across policy areas, enabling ECOWind and ECOFlow research to guide live policy decisions and strategic evidence plans. The UK Marine Strategy and GES descriptors serve as cross-cutting frameworks to unify evidence and policy efforts.

Whole of Seabed Update, Tristan Bromley, The Crown Estate

- Whole of Seabed scenario mapping serves as a central framework, and supports the creation of a robust evidence base to guide long-term strategic decision-making.

Dr Alex Banks, Natural England (NE)

- **Strategic evidence for EIAs:** NE is adopting a strategic approach to integrate new evidence into best practices for EIAs at both strategic and project levels. NE advocates shifting the current system of live-science interpretation by SNCBs for collaborative analysis of parallel evidence streams to reduce time constraints.
- **POSEIDON: Planning Offshore Wind Strategic Environmental Impact Decisions[8]:** developing integrated risk maps for 27 seabird species, 12 marine mammal species, benthic communities, and habitats. These maps, launching on Marine Data Exchange by Summer 2025, will feed into baseline characterisations and address uncertainties.
- **ReSCUE: Reducing Seabird Collisions Using Evidence:** creating a shared database of seabird flight height data and standardising data collection methods. Standards will be ready in Q1 2025, with the database completed by 2027.

---

[6] https://www.thecrownestate.co.uk/our-business/marine/Marine-Delivery-Routemap
[7] https://www.gov.uk/government/publications/natural-capital-and-ecosystem-assessment-programme/natural-capital-and-ecosystem-assessment-programme
[8] https://www.marinedataexchange.co.uk/content/stories/poseidon-planning-offshore-wind-strategic-environmental-impact-decisions

- **eSCARP: English Seabird Conservation and Recovery Pathway[9]:** presents 19 recommendations relating to seabird breeding, feeding, surviving and knowledge, forming a recovery handbook linked to offshore wind EIA compensation. This is specific to the waters around England.
- **Offshore Wind Seabird Assessment Tool:** integrates information for EIAs and cumulative effects frameworks, enabling more strategic assessments.

Developing a regional evidence base on impacts of OWF on marine natural capital and GES
Dr Will Le Quesne, Centre for Environment, Fisheries and Aquaculture Science (Cefas)
The challenge lies in transitioning:

- From topic-specific research to coordinated analysis;
- from local studies to national and regional evaluation;
- from single-sector to cumulative impact assessments; and
- from ecological assessments to policy-relevant analyses.

The proposed solution: modify the ecosystem-based approach by:

- Using a single, integrated tool for short-term tactical assessment and advice (applies to Management-Activity-Pressure assessment);
- Use multiple separate tools for long-term analysis and strategy (applies to Pressure-State assessments);
- Coordinate evidence to address multiple GES objectives.

Spatially Managed Marine Area Tool[10] – Developed to evaluate trade-offs and cumulative impacts of OWF and fisheries on GES ecological indicators.

Improving the EIA process – OWEKH: Offshore Wind Evidence and Knowledge Hub[11], Jon Rees, on secondment to TCE
Jon.Rees@thecrownestate.co.uk

Providing a sector wide online portal supporting access to the latest guidance and best practice created by Technical Topic Groups working on latest evidence from OWEC, ECOWind, ECOFLow, ScotMER, SUPERGEN, Tethys and other research programmes. Consolidating evidence into evidence notes starting with historic environment, shipping and navigation and seascape and visual impact. Initial evidence notes to be released throughout 2025.

Strategic Compensation & Marine Net Gain

MNG in England,
Audrey Jones, Howell Marine Consulting
Audrey@howellmarine.co.uk
A proposed model for the MNG Assessment Framework involves a structure aligned with the UK Marine Strategy. The model identifies how MNG could help achieve GES, through contributing to the delivery of measures within a strategic restoration plan which sets out the

---

[9] https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=20777
[10] https://randd.defra.gov.uk/ProjectDetails?ProjectId=21141
[11] https://owekh.com/home

opportunity, priority and need for nature restoration activities based on the UKMS status assessment and Programme of Measures. This is implemented through a regional programme of measures for each marine plan area, which then guides local delivery of nature restoration actions, including MNG. The residual loss from developments could be linked to the gain requirement through a GES Effects Assessment based on information collected for EIAs or EORs. This is a proposal and does not represent the government's preferred approach to a MNG Assessment Framework.

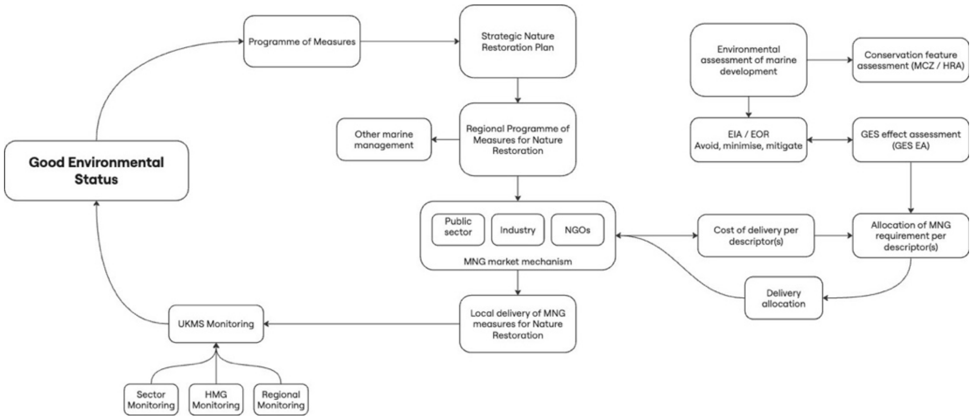

Figure 10. A Proposed framework for delivery of MNG using the UK Marine Strategy. HMG = His Majesty's Government; UKMS = UK Marine Strategy; MCZ = Marine Conservation Zone; HRA = Habitat Risk Assessment; EIA = Environmental Impact Assessment; EOR = Environmental Outcomes Report; GES = Good Environmental Status.
Image credit: Audrey Jones, Howell Marine Consulting

Strategic compensation: Offshore Wind Industry Council (OWIC[12]), Anna Tarbet, Renewable UK

Anna.tarbet@renewableUK.com

Three compensation measures have been approved and piloted:

- Designation/extension of marine protected areas (benthic);
- Offshore Artificial Nesting Structures for kittiwake (Round 4 - England only);
- Mammalian predator reduction (seabirds).

However, these measures are insufficient to address the entire OWF pipeline. To accelerate deployment and support the OWF pipeline, the Offshore Wind Champion report (Pick et al. 2023[13]) recommends enabling broader ecosystem improvements where like-for-like compensation is not feasible. This includes government-led initiatives to improve site conditions and accelerate marine recovery.

The OWIC strategic compensation study (£3.5 million, running until 2027) aims to close evidence gaps, test measures, and establish frameworks to ensure ecological cohesion and support OWF consent. Key research includes:

- Trialling artificial nesting structures (ANS) for multiple species;
- Enhancing monitoring and efficacy of control measures for predator reduction;

12 https://www.owic.org.uk/

13 https://www.gov.uk/government/publications/accelerating-deployment-of-offshore-wind-farms-uk-offshore-wind-champion-recommendations

- Studies that explore compensation options that aim to improve a conservation feature, habitat or species, that is different to the one under threat, called a "non-like-for-like" opportunities;
- Studies that explore compensation options focusing on ecosystem benefits and/or monitoring of habitat recovery, for example in sandbanks and reef habitats;
- Mapping defunct infrastructure in the Celtic Sea;
- Testing delivery frameworks and approaches;
- Supporting measures such as bycatch trials and measures that could support prey availability.

Areas ECOWind and ECOFlow research might be able to assist includes:

- Monitoring Kittiwakes and understanding kittiwake diets;
- Habitat creation/restoration and wider ecosystem benefits;
- Interconnectivity of seabird populations across the North Sea;
- Bycatch mitigation.

Compensation and Marine Net Gain: A need for more strategic approaches

Eleni Antoniou, Strategic Environment & Policy Manager, Ørsted
elean@orsted.com

Ørsted aims for all new renewable energy projects commissioned from 2030 onwards to achieve a net-positive biodiversity impact. Current biodiversity and compensation initiatives include the Wilder Humber Partnership, focusing on the restoration of seagrass, salt marshes, and native oysters, alongside Artificial Nesting Structures for kittiwakes.

Ørsted's biodiversity strategy emphasises:

- Identifying priority biodiversity features;
- Understanding offshore wind impacts;
- Developing a comprehensive biodiversity action plan;
- Ensuring transparent monitoring and reporting.

The strategy represents a shift toward a more strategic, forward-looking approach to biodiversity conservation.