DIGEST

BIODIVERSITY AND OFFSHORE WIND POWER

The impacts of offshore wind power on biodiversity and recommendations for assessing the risks

Ever since the first deployment of offshore wind turbines, there has been controversy over the costs and alleged economic and environmental benefits of offshore wind power.

Numerous research studies have tried to assess the impacts, whether positive or negative, of these installations on biodiversity and marine ecosystems, generating a high volume of publications. These impacts are very variable and differ depending on the wind turbine's life stage, location, type, its foundation and anchoring technology, the associated infrastructure, and the species that interact with these installations. Turbines are generally grouped together in offshore wind farms (OWFs), over more or less large areas, and at a variable distance from the coast. However, coastal areas are highly biodiverse and culturally important areas where sharing the use of the land, the sea, and their resources is a real issue.

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The impacts of offshore wind power: what do we mean?

While renewable offshore energy production contributes to the overall increase in human activity in marine environments, it has both positive and negative effects on marine ecosystems. These effects, by their intensity, duration, or severity, cause significant changes to biodiversity.

Many research studies have tried to assess the impacts of offshore wind power on biodiversity and marine ecosystems.

Offshore wind installations impact the three major components of an ecosystem's ecological integrity, namely:

- its **composition** (the impact on different biological groups such as fish, birds, ...);
- its **structure** (the impact on habitats, biotic homogenization, ...);
- its **function** (the impact on species interactions, their adaptive capacity, ...).

The most frequent forms of pressure exerted by these installations include **biological disturbance, sound and physical disturbance, energy input** (including electromagnetic fields), **physical losses, loss of nutrients, loss of organic and inorganic matter, hydrological change, and non-indigenous species.**

The best-documented impacts are most often negative and affect species, especially seabirds and marine mammals, and ecosystem structure. The impacts on ecosystem functions can be both positive and negative, but are generally still poorly documented (see figure below).

The intensity and nature of the impacts of offshore wind power depend on:

- The **life stage of the installation**, its location, the **type of turbine, foundation** and **anchoring system**, and the **associated infrastructure**;
- The **species present**, their **vulnerability** (e.g. migratory birds), the **state of biodiversity** and its **resilience**;
- **The proximity (or not) of other OWFs, protected areas, and other human activities**, and **local planning strategies**;
- How natural environments are perceived by users and regulators of marine environments;
- The **adaptability of ecosystem service beneficiaries** to the impacts of wind farms;
- The potential **synergistic impacts** of other pressures.

All these elements must be considered and articulated.

Focus on less documented impacts

There are considerable gaps in our knowledge of the environmental impacts of offshore wind power. In general, the positive impacts of OWFs are the least documented. Precise information is also lacking regarding the impact of cumulative pressures, as well as the impact on fish, invertebrates and ecosystem services, which can be either positive or negative.

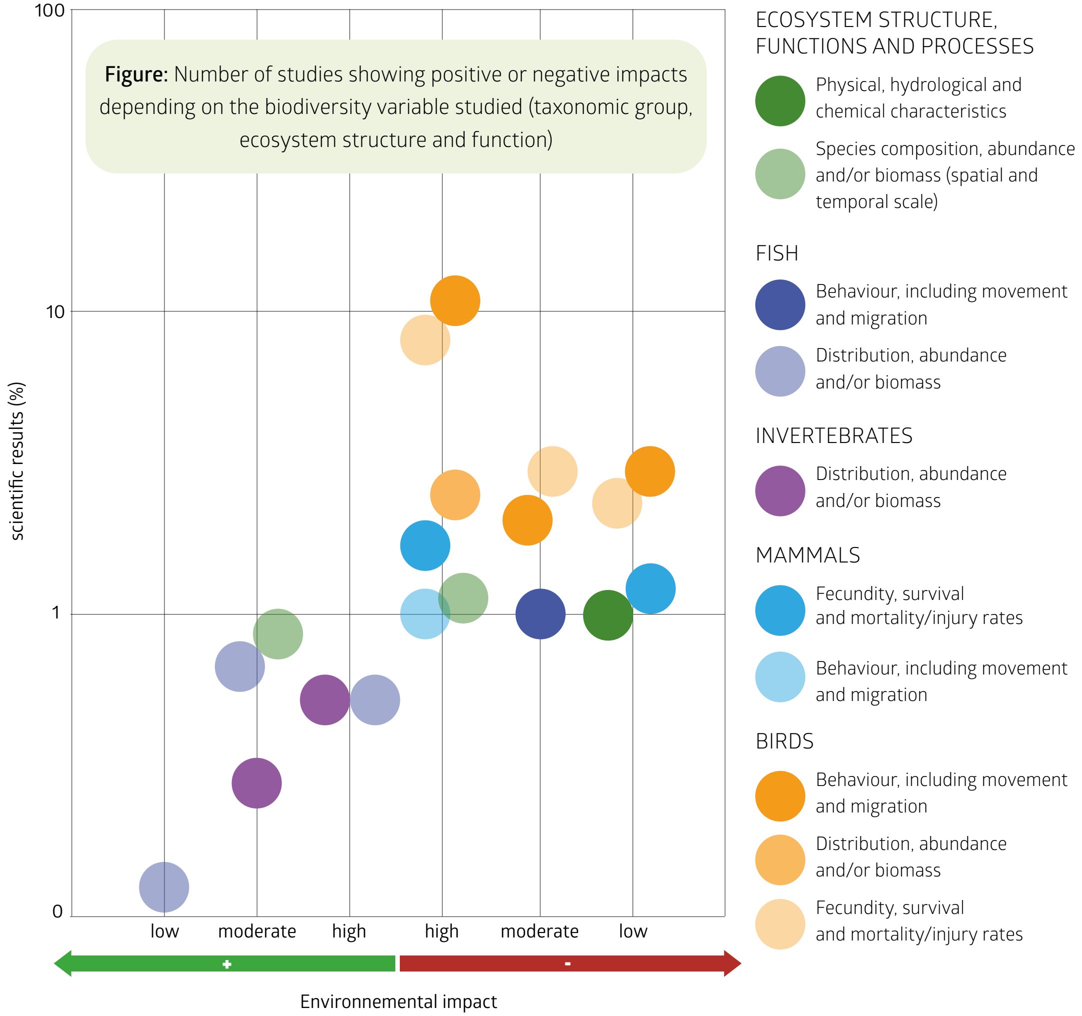

Figure: Number of studies showing positive or negative impacts depending on the biodiversity variable studied (taxonomic group, ecosystem structure and function)

IMPACTS ON SPECIES

OWFs have a negative impact during the construction phase, caused by the building site and its associated disturbances, but can subsequently have positive impacts on certain marine species. Indeed, they provide a substrate for mussels, amphipods, and sea anemones, which create secondary reefs that over time will attract increasingly large mobile predatory species such as cod, saurel, mackerel, pouting, harbour porpoises, harbour seals, and bottlenose dolphins, and even rare species such as barnacles, grey triggerfish, and coral. The group where impacts are the most frequently negative are birds (including guillemots, gannets, kittiwakes, little gulls, terns, black geese, ...), with causes of mortality that are similar to those from onshore wind installations. However, some birds, such as herring gulls and cormorants, also benefit from these installations.

Figure: Spatial extent of the pressures from OWFs

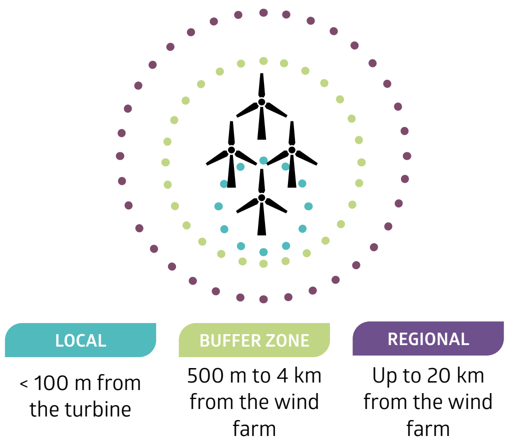

Table: Typology of the pressures on biodiversity during OWF construction and operation

CONSTRUCTION PHASE	
Pressures	**Impacts on species**
Rearrangement of the benthos, increased turbidity, alteration of organic matter and detritus fluxes: modification of the ecosystem	Possible benthic anoxia, i.e. a lack of oxygen on the seafloor, lowered light levels for primary producers, physical damage to filter and suspension feeders, and egg smothering for secondary and teriary consumers. Spatial extent: **Local**
Digging and crushing of the substrate during the installation of foundations and connecting cables: modification of the ecosystem	Mortality of infauna (animals living in the sediments) and sessile species (attached to a substrate) and loss of essential habitats. Stress and avoidance behaviours for species able to move away from the construction site. Over 27 % loss of primary producers and groups of primary producers. Spatial extent: **Regional**
Pile driving during the installation of foundations: sounds and vibrations	Behavioural effects in the most sensitive groups of species (top predators, particularly marine mammals, and to a lesser extent some species of fish and crustaceans): physical damage and stress, avoidance of the construction area and changes in distribution. Spatial extent: **Buffer zone**

OPERATIONAL PHASE	
Pressures	**Impacts on species**
Collisions with masts and blades	Bird and bat fatalities. Spatial extent: **Local**
Barrier effect: avoidance, exclusion	Behavioural effects in migratory species of fish, birds, and marine mammals: Changes in migration routes, reduction in feeding areas, loss of resting sites. Increased energy expenditure and risk of indirect mortality as these species seek to avoid farms by a long distance (up to 3 km). Spatial extent: **Regional**
Reef effect: new colonization substrates and new habitats for hard substrate species	Affects the entire trophic network: Changes in community structure, evolution towards a more complex ecosystem with an increase in the diversity and biomass of filter-feeding bivalves and pelagic fish, the aggregation of top predators and increased predation. A stepping stone effect for non-native hard substrate species can also be observed. Spatial extent: **Local**
Reserve effect due to fishing restrictions	Species targeted by fisheries will benefit, with, in the long term, an ecological spillover effect and increased fish biomass around the farm. Spatial extent: **Buffer zone**
Changes in functional habitats	Behavioural effects in some soft substrate species (infauna and certain primary producers) and some diving and surface birds. Spatial extent: **Local and buffer zone**
Sounds and vibrations from the rotation of wind turbine blades	Disturb some species of macroinvertebrates (crustaceans), fish, marine mammals, and birds. Spatial extent: **Local and regional**
Light pollution: Lights and flickering shadows	Behavioural effects in some species of fish, birds, and bats. Spatial extent: **Local and regional**

IMPACTS ON ECOSYSTEM SERVICES

It is recognized that the provision of ecosystem services is positively correlated with biodiversity.

Ecosystem services are the benefits that humans derive from ecosystems to ensure their well-being. They are classified into four main categories:

- **Provisioning services:** wood, food, fibres;
- **Cultural services:** landscapes, identity, well-being;
- **Regulating services:** regulation of air quality, water quality, climate change, extreme events, pathogens;
- **Supporting services:** creation of functional habitats, soil formation and fertility, pollination, chemical cycling, etc.

Scientists estimate that all ecosystem services are impacted by OWFs, during both the construction and the operation phase. These impacts can be positive (habitat creation, area protection, nursery effect, and the provision of resources for fisheries in adjacent areas) or negative, especially for cultural services, by altering the landscape.

The resulting changes in ecosystem production functions perturb trophic interactions. This can also impact species or genetic diversity and lead to a gain or loss of biomass, triggering beneficiaries like fishermen to adapt their practices.

Within the OWF context, the ecosystem service regime shift is mainly caused by the reef effect (i.e. the capacity of man-made structures to harbour living organisms), and the reserve effect. These effects, associated with the construction phase, will develop in the long term a richer and more complex ecosystem than the soft substrate ecosystem existing prior to construction.

Changes to ecosystem services occur *via*:

- The appearance of new practices (e.g. marine and coastal leisure tourism, educational, or museum exhibitions) or conversely, a loss or a limitation of practices for safety reasons (e.g. navigation restrictions, limitations on boat size, type of fishing gear, restricted access to wrecks and heritage features);
- Spatial shifts in new or established activities, linked to new uses (e.g. tourism) or restriction of established uses (e.g. no-fishing areas), or delayed uses;
- Changes in biomass and the ability to access this biomass;
- Changes in the social values of the marine environment, for example the loss of some essential qualities of the sea (e.g., the feeling of wilderness, open spaces, or freedom from anthropic structures) or conversely, the development of an image of a territory developing renewable energy;
- Losses or gains of knowledge or skills (e.g. fishing).

WHAT IMPACTS? WHICH SERVICES?

Legend:

- construction
- operational
- Positive impact
- Negative impact

PROVISIONING SERVICES

Loss of more than 27% of primary producers and primary consumer groups from digging and crushing of the substrate.

The reef effect, reserve effect and change of functional habitat result in a decrease in the abundance and diversity of flatfish due to the loss of soft substrate habitats.

Net emigration of species from OWFs to adjacent areas with an increase in the biomass of commercial species. This "spillover" effect is well documented for protected areas, but remains to be quantified for the smaller areas around OWFS where human activities persist and which, through the disturbance they cause to wildlife, can reduce or nullify this effect.

The reef effect, reserve effect and change of functional habitat result in the global increase in the abundance and diversity of pelagic fish within the farm and nearby, despite increased predation by top predators.

CULTURAL SERVICES

Marine megafauna and avifauna avoid the OWF area, which will negatively impact ornithology and observation activities.

In OWFs, increased secondary production associated with greater species and genetic diversity promotes the aggregation of top predators of heritage interest, and fisheries resources of recreational interest.

Increased water filtration contributes to a clearer and more attractive seascape. The coupling of these different effects has a positive effect on potential recreational uses.

REGULATING SERVICES

Reduction in water filtration, nutrient production and recycling services due to the rearrangement of benthos and increased mortality rate of filtering organisms.

Improvement in water filtration, nutrient production and recycling services due to an increase in abundance of filtering bivalves.

Access to ecosystem services and trade-offs

Changes in regulating services will affect the supply of both provisioning and cultural services. Likewise, changes in social values and associated shifts profoundly reconfigure the functioning of marine-coastal territories, potentially leading to conflicts between different maritime human activities.

RECOMMENDATIONS FOR MANAGEMENT AND DECISION-MAKING

The progressive expansion of offshore wind power to meet energy production objectives faces technical, economic, and social problems and environmental concerns worldwide.

Some challenges include:

- the sharing of ocean space between stakeholders: this must be taken into account in order to avoid, or at least minimize, conflicts.
- the development of tools for ecological risk assessment that need to be further integrated into decision-support tools to identify future deployment areas (avoiding high biodiversity areas), and inform the consent process.

In addition to checking that OWF projects will not cause significant environmental harm, new projects must also be assessed for their compliance with the targets of the Global Biodiversity Framework adopted in December 2022 in Montreal.

Table: Recommendations related to targets of the Global Biodiversity Framework

Targets of the Global Biodiversity Framework	Recommandations	Actors
Target 1 Spatial planning	A collaborative, integrated and inclusive concertation process for the spatial planning of maritime areas that integrates future generations and biodiversity.	Offshore wind energy industry; public decision-makers; Research community
Target 2 Restoration	Identify areas of high environmental interest to ensure their strict protection.	Research community
	Have the reef effect as one of the priority objectives of any offshore wind project.	Offshore wind energy industry
	Choose eco-design and nature-based solutions.	Offshore wind energy industry
	Consider the size of the OWF and the number of hard structures, to minimize the transformation of the area.	Offshore wind energy industry; Research community
Target 3 Protected areas	Aim to share the space with wildlife: have the reserve effect as one of the priority objectives of the project.	Offshore wind energy industry
Target 6 Invasive alien species	Reduce the attractiveness of habitats for invasive alien species.	Offshore wind energy industry; Research community
	Put measures in place to enhance biodiversity as much as possible, including of potential predators and competitors.	public decision-makers; Research community
	Restore habitats and reduce anthropogenic pressures.	Offshore wind energy industry; public decision-makers
Target 7 Pollution	Identifier et évaluer les risques de pollutions impactant la biodiversité pendant la phase d'installation et de fonctionnment des parcs éoliens afin de proposer des plans de réduction de ces pressions et des risques associés.	public decision-makers; Research community
Target 11 Regulating services	Take into account ecosystem and societal components when assessing the state of marine and coastal ecosystems.	Offshore wind energy industry; Research community
	Identify the environmental and socio-economic parameters that can be used for monitoring the global impacts of OWFs, including on ecosystem services.	Offshore wind energy industry; Research community
Target 14 Integration into policy making	Improve impact studies by following the avoid-reduce-compensate sequence, integrating scientific knowledge from the design process onwards, and developing mitigation measures to lower the impact over the project's lifetime.	Offshore wind energy industry; Research community
Target 15 Integration into businesses	Manage the impacts of the installations by regularly monitoring the sites and updating processes as new scientific evidence becomes available.	Offshore wind energy industry
	Assess the impacts over the entire value chain and use a systemic approach (composition, ecosystem structure and function).	Offshore wind energy industry
	Regularly communicate on the risks associated with the chosen management options.	Offshore wind energy industry
Target 16 Consmmation durable	Être transparent sur la participation du projet à l'empreinte écologique française, participer aux campagne de réduction des consommations d'énergie et aux projets de recherche caractérisant nos dépendances à la biodiversité.	Offshore wind energy industry
Target 17 Sustainable consumption	Participate in or fund the monitoring of invasive alien species.	Offshore wind energy industry
	Encourage the establishment or maintenance of rare or threatened species by reducing the pressures associated with offshore wind activity, and contribute to the acquisition of knowledge on these species (monitoring, studies, research projects).	Offshore wind energy industry; Research community
	Contribute to biodiversity conservation by setting up multi-activity areas and large strictly protected areas.	public decision-makers
Target 22 Equity, inclusion, participation	Take into account the impact of OWFs, including in terms of loss of ecosystem services and access to resources and maritime areas, that weigh on society (including future generations), biodiversity, and other human activities, when choosing the location and size of these installations.	Offshore wind energy industry; public decision-makers; Research community

Offshore wind energy industry, Managers and field operatives — public decision-makers — Research community

There are still important technical obstacles that prevent the precise quantification of the direct and indirect impacts of OWFs (e.g. counting bird carcasses at sea is nearly impossible), and many uncertainties and knowledge gaps, in particular in terms of quantifying the impacts of the cumulative pressures arising from the planned multiplication of OWFs in France and across Europe.

Other risks and impacts are less well documented but nonetheless real, such as an increased risk of the spread of non-indigenous species and the large-scale homogenization of habitats, as well as the loss of environmental, socio-cultural, and touristic value.

Even though the publication rate on this topic has grown, especially in the past eight years, reflecting the development of offshore wind power worldwide, the mid- to long-term impacts of the deployment of numerous OWFs on the functioning of marine ecosystems still remains to be determined.

This article was written within the framework of the "**Impact of Renewable Energy Sources on Biodiversity**" programme. This research funding programme led by the **French Foundation for Biodiversity Research (FRB)** and the **Mirova Research Center** aims to better assess the impact of renewable energy sources on biodiversity and deliver operational recommendations for best practice to those working in the renewable energy sector.

Read the full publication:

Reference: Quinard A., Dupuis L., Hette-Tronquart N., Besnard A., Jactel H., and Langridge J. (2024) The Effectiveness of Measures and Good Practices in Place for Minimizing the Impact of Onshore Wind Power on Biodiversity. Knowledge Synthesis. Paris, France : French Foundation for Biodiversity Research (FRB).

With the support of

mirova research center

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