ICES Journal of Marine Science, 2023, Vol. 0, Issue 0, 1–17
https://doi.org/10.1093/icesjms/fsad191
Received: 7 May 2023; **revised:** 26 September 2023; **accepted:** 27 October 2023
Review Article

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

A synthesis review of nature positive approaches and coexistence in the offshore wind industry

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Abstract

Offshore wind is one of the major fast-growing renewable energy industries, and sustainable implementation of offshore wind farms (OWF) is desired. Nature positive approaches have been proposed to promote biodiversity gain and improve ecosystem resilience. At the same time, coexistence has been considered a way to mitigate the race for ocean space and better integrate the development of the OWF industry. Here, we provide a systematic narrative synthesis review on nature positive approaches and coexistence in OWFs. We observed an increased interest in the topics over the last 5 years, with most of the documents coming from the northern hemisphere, in particular Europe and the North Sea. Literature is mostly related to bottom-fixed turbines, with relatively fewer documents available regarding floating offshore wind, which is a nascent industry. There is a lack of long-term *in situ* assessments of the impact of nature positive approaches. Whilst there are various biodiversity impacts of OWFs, the literature highlights the artificial reef effect and biodiversity protection and gain (diversity and abundance) for ecological and economically relevant groups. Coexistence strategies with OWF, such as fisheries, aquaculture, and marine-protected areas, bring positive and negative outcomes for the environment, and further investigation on their integration should be explored.

Keywords: renewables; offshore wind farm; nature positivity; nature inclusive design; coexistence

Highlights:

- Nature positive approaches and terminology in the offshore wind industry were reviewed.
- Nature-based solutions and nature-inclusive design can be considered nature positive approaches.
- Need for additional data collection, testing and *in situ* experimentation (long-term).
- Literature mostly related to bottom-fixed structures, limited in the nascent floating offshore wind industry.

List of abbreviations

OWF:	Offshore wind farms
NbS:	Nature-based solution
NiD:	Nature-inclusive design
MPAs:	Marine-protected areas
IUCN:	International Union for Conservation of Nature
COP:	Conference of the Parties

Introduction

The combination of climate change and biodiversity loss is among the greatest challenges ever faced by humankind (Rogers et al. 2020, Pettorelli et al. 2021, Habibullah et al. 2022). The efforts required to meet the global climate goals of the Paris Agreement should not be underestimated. Focus on achieving both climate and biodiversity goals jointly has in turn increased the interest in sustainable solutions, and recent efforts to implement solutions to contemporary societal challenges are involving the environment (IPBES 2019, Kousky 2022). As highlighted by the United Nations Sustainable Development Goals, it is important to promote synergy between the different economic, social, and environmental advances and goals.

A premise to achieving the climate goals is a shift towards renewable energy production, and recent global projections show renewables accounting for 80%–90% of power generation by 2050 (McKinsey 2022). Offshore wind power will be a critical component of the renewables mix and already makes a significant contribution in several countries. The scale of ambition for both bottom fixed and floating wind farms is without precedence, with a predicted 316 GW installed globally by 2030 (GWEC—Global Wind Energy Council 2022). However, offshore wind requires large areas, which conflict with the needs of other marine users (Christie et al. 2014). Indeed, OWFs have been associated with a range of negative impacts on biodiversity; potential impacts are presented in all phases of offshore wind development, including the construction, operational, and decommission phases, due to e.g. changes in the seafloor sediment structure, noise, and vibration, electromagnetism, and others (Snyder and Kaiser 2009, Bergström et al. 2013, 2014, Degraer et al. 2020, Peschko et al. 2020, Galparsoro et al. 2022, Lloret et al. 2022, Maxwell et al. 2022, McLean et al. 2022). The infrastructure supporting OWFs is substantial and interacts directly with both terrestrial and aquatic environments, causing debates on the trade-offs between environmental impacts and ecosystem diversity, structure, and function (Petersen and Malm 2006, Popescu et al. 2020, Daewel et al. 2022). Within this context, Bennun et al. (2021) provided a comprehensive guideline for project developers during all phases of OWFs development, outlining a mitigation hierarchy that covers avoiding, minimizing, restoring, and, if needed, offsetting biodiversity impacts including potential additional actions.

Due to the tight link between energy and environment, moving towards a nature positive industry has been in the spotlight in recent policy recommendations (Grodsky 2021, Locke et al. 2021). The G7 2030 nature compact agreement aims to halt and reverse biodiversity losses by 2030 aiming for a full recovery and a resilient environment by 2050, having the so-called nature positive approaches as a way to promote these changes. Nature positivity expands on what has been defined as *net positive impact* and *no net loss of biodiversity* corporate strategies adding integrated actions across the different dimensions of nature (e.g. climate and biodiversity) and social aspects (zu Ermgassen et al. 2022). Nature positive is now a widely used concept, and caution on its application has been pointed out, since efficiently implemented nature positive approaches must show a quantitative overall net gain, according to the most accepted definitions (Bull et al. 2020, Milner-Gulland 2022). However, there is not yet a consensus on the definition of nature positive approaches; here, we have considered natural positive approaches systematical initiatives aiming biodiversity gain and improve ecosystem resilience related to OWFs. Yet, proposed definitions to the broader term nature positive can be classified as conceptual (aspirational, mostly observed in broad, business-related organizations), process-based (operational steps, but with no criteria to successfully implement it), or target/outcome-based (specific biodiversity outputs) (see zu Ermgassen et al. 2022 for a broader review of the term). However, the International Union for Conservation of Nature is currently working on a common methodology to address and measure nature positive outcomes, proposing a definition to avoid potential greenwashing and align interests among companies, governments, and civil society, under a science-based system (see Table 1 for proposed definition) (IUCN 2022).

Several major companies and organizations state a goal to be nature positive following available guidelines ("Get Nature Positive"; Get Nature Positive 2022, Bull et al. 2022, Finance for Biodiversity 2022), and nature positive concepts are also guiding the sustainability goals of the renewable industry (European Environmental Bureau 2022). In order to support a sustainable offshore wind industry, nature-based solutions (NbSs) (Table 1 for definition) are proposed as achieving a nature positive industry (Stephenson et al. 2016, Lukic et al. 2021). The underwater physical structures associated with the turbines offer a substrate for colonization and are thus known to act as artificial reefs, enhance fish and macrofauna diversity, and support other biodiversity-related changes (Reubens et al. 2013, Coates et al. 2014, 2016, Hooper and Austen 2014, Kramer et al. 2015, Stenberg et al. 2015, Krone et al. 2017, van Hal et al. 2017). Nature-inclusive design (NiD) approaches (e.g. stable scour protection design, *fish hotels*—shelters, reef fields), also called nature-based design, are a type of NbS used to enhance ecological functioning (Table 1 for definition) (Degraer et al. 2020, Peschko et al. 2020, Maxwell et al. 2022, McLean et al. 2022). Nevertheless, the application of NiD on OWFs to achieve nature positive impacts is still in its infancy.

Access to a suitable area is key for most ocean-based industries. Due to the high pressure on land and coastal areas, more activities will move offshore. This global race for space will require solutions that alleviate the spatial conflicts, and marine spatial planning (MSP) (Table 1 for definition) recommendations for offshore wind consider coexistence with other sectors such as aquaculture and fishing, as well as environmental protection measurements. Some studies highlight that offshore wind farms (OWFs) can also contribute as conservation areas when restricting fisheries (e.g. no-take zones) and support biodiversity gain, although considering as *de facto* protection areas is a debatable topic in the literature (see the section "Marine protected areas"). In the European Union, policy is pushing the sustainable development of OWF, whilst at the same time suggesting to increase in the number of Marine Protected Areas (Goriup 2017). Although commercial multiuse practices may not be considered nature positive approaches *per se* according to our interpretation of the term, the knowledge involved in the practices can be better interpreted and applied towards a gain in ecosystem functioning. However, data from relevant documents in the field remains sparse and guidance is lacking. In our narrative systematic synthesis review, we aim to (i) evaluate the current knowledge and progress of approaches referred to as nature positive (including meaning and use of the term nature positivity) and coexistence for the offshore wind industry for both fixed and floating structures, and verify (ii) which coexistence strategies and initiatives from other aquatic-related activities and habitats are relevant to the offshore wind industry. In addition, we provide a narrative synthesis of potential nature positive-related effects (e.g. reef effect) and coexistence practices in the offshore wind industry, providing perspectives and future directions, highlighting synergies and potential next steps in the field.

Methods

Systematic search strategy

Documents were searched systematically and reported under the preferred practices for systematic reviews proposed by O'Dea et al. (2021) [see Figure S1 (Supplemental Material) for the step-by-step searching strategy]. We have selected relevant studies and documents published until September, 2022. We have only included papers (i) exploring nature positive approaches in OWFs (fixed and floating structures), including NbSs (e.g. NiD) and (ii) coexistence related to OWFs, for both fixed and floating structures. Searches were conducted in the Web of Science, Google Scholar, ProQuest, and Tethys (Department of Energy, PNNL) databases with the following combination of keywords and strings (adapted to Google Scholar, ProQuest, and Tethys due to the platform searching engines, as detailed in the Supplemental Material):

First string (nature positive and offshore wind): TS = {["nature-based solution*" OR "nature-positive solution*" OR ("nature" NEAR/1 "positive" OR "inclusive design" OR "based design" OR "based solution*")] AND ["offshore wind" OR ("offshore" AND "wind")]}

Table 1. Definition and concepts of the main terms related to nature positive approaches and coexistence. Associated terms used in the study and searches are mentioned in parentheses.

Terms	Definition	Additional information
Nature positivity-related terms: nature positive solution, approach, development, future	A nature positive future means that we, as a global society, halt and reverse the loss of nature measured from its current status, reducing future negative impacts alongside restoring and renewing nature, to put both living and nonliving nature measurably on the path to recovery (IUCN 2022).	The term is also used at different organizational levels, such as a nature positive project or nature positive organization.
Nature-based solutions (NbS)	Actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal, and marine ecosystems, which address social, economic, and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience, and biodiversity benefits (United Nations Environment Programme 2022).	Nature-based solutions would contribute to nature positivity.
Nature-inclusive design (NiD) (nature-based design)	Options that can be integrated in, or added to, the design of an anthropogenic structure with the aim to enhance ecological functioning (Hermans et al. 2020).	NiDs and nature-based design are used interchangeably. NiDs are a type of NbS.
Marine spatial planning (MSP)	The public process of analyzing and allocating the spatial and temporal distribution of human activities to achieve ecological, economic, and social objectives that are usually specified through a political process (Ojo and Charlton 2009).	–
Other effective area-based conservation measures (OECMs)	A geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the *in situ* conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values (CBD 2018)	–
Coexistence	Placement of multiple activities or uses within the same marine area, including safety zones where applicable (MMO 2013)	–
Multiuse (multiple sector use, cross-sectorial use, and co-use)	Ocean multiuse is the joint use of resources in close geographic proximity by either a single user or multiple users. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources and space by one or more users (Schupp et al. 2021)	–
Colocation	Two or more activities with overlapping footprints or occupying the same spatial footprint (MMO 2013)	–
Integrated social–ecological assessment	An integrated social–ecological assessment and monitoring tool has the potential to incorporate the components of a hazard impact assessment and also to include a health and livelihoods component to the assessment (Bronen 2015)	–
Integrated management	Integrated (Marine) Management is a broad, overarching approach that coordinates planning and management across sectors to better understand and address the range of pressures on the ecosystem by rationalizing management of marine uses for long-term ocean health (Stephenson et al. 2019)	–
No-take zones (no-go areas)	A No Take Zone is a Marine Protected Area permanently set aside from direct human disturbance, where all methods of fishing and extraction of natural materials, dumping, dredging, or construction activities are prohibited, from which the removal of any resources, living or dead is prohibited ('UK Marine Protected Areas Centre' 2007)	–
Marine protected area (MPA)	A protected area is a clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Day et al. 2012)	–

Second string (coexistence and offshore wind): TS = [("multi-use" OR "co-use" OR "co-location" OR "colocation" OR "co-operation" OR "integrated social–ecological assessments" OR "integrated social ecological assessments" OR "multisector planning" OR "integrated management" OR "cross-sectorial use" OR "multiple sector use" OR "multi-sector-use" OR "no-go areas" OR "no-take zones" OR "marine protected area") AND "offshore wind"].

Whilst the review focused on approaches within the OWFs, knowledge from other aquatic-related activities and infrastructures may complement our understanding of nature positive approaches in estuarine, coastal and marine areas. Offshore wind industry activities impact both land and aquatic areas, where nature positive implies going beyond the impacts of own activities. An additional and broader search was then conducted to extract information on nature positive approaches and related terms (not conducted in Tethys searching engine due to their focus on the offshore wind industry): "Third string: TS = {["nature-based solution*" OR "nature-positive solution*" OR ("nature" NEAR/1 "positive" OR "inclusive design" OR "based design" OR "based solution*")] AND ("marine" OR "coast*" OR "estuar*" OR "ocean")}."

Relevant documents from the author's personal archive were included in the list. Searches were followed by checking the studies' reference list (i.e. backward scanning) for additional missing studies. Search in the relevant languages in terms of number of publications per country was also nonextensively conducted. Reports and commissioned documents from institutes, governmental bodies, renewable energy-related initiatives (i.e. grey literature) on the topic are included, but not conference abstracts and introduction papers to Special Issues. Documents focusing on the negative impacts of OWF on specific group species and environmental assessments were also not included. Studies on general positive biodiversity impact in OWFs without reference to nature positivity (e.g. Coates et al. 2014, Stenberg et al. 2015) were not included in the list but explored throughout the text in the narrative synthesis. The review also focuses on biodiversity-related topics and does not look into social acceptance and factors of OWFs.

A PRISMA diagram is provided for all string searches summarizing the number of documents included and excluded in the identification, screening and eligibility process (Fig. 1). Information (i.e. data) from the selected documents (all three strings) were extracted and summarized in the different criteria and categories (Table S1, Supplemental Material). Since we have followed a narrative systematic synthesis review approach, more recent literature is discussed throughout the review, but not included in the systematic search results.

Nature positive approaches in offshore wind development: narrative synthesis and knowledge status

We have compiled 23 documents exploring nature positive approaches in the offshore wind industry (1st string) (Fig. 2a; Table S1, Supplemental Material). All documents are either peer-reviewed research articles (11) or reports (12), and the majority of studies are from or focused on the Northern Hemisphere, especially Europe and the North Sea, which is a global hotspot for offshore wind. Documents were categorized based on the general terms explored (potentially more than one per document), and NiD was well represented in the first string, followed by nature positive solutions and NbSs within the offshore wind industry (Fig. 2a).

Early studies indicated the potential environmental net effect of monopiles without linking it to the term nature positive. More recently, the term has expanded its uses and the positive outcomes of resilience and biodiversity gain have been more extensively explored in the literature. The topic, and related terms including NbSs and NiD, have gained more attention from the early 2000s, and most of the documents found were published in the last 5 years (i.e. 2017–2022; Fig. 2b).

The (artificial) reef effect

The most comprehensive and described environmental outcome from OWFs is the (artificial) reef effect (Sayer et al. 2005, Langhamer 2012, Firth et al. 2016, Degraer et al. 2020, Hermans et al. 2020, Evans et al. 2021, Komyakova et al. 2022, Sella et al. 2022) (see Table S1, Supplemental Material). The reef effect is obtained directly from the physical structures and foundations (monopiles, scour protections, moorings, and floaters) associated with OWFs and it is known that the structural complexity, and even the material of the structures, can cause significant changes in species settlement and community composition (Komyakova et al. 2022). Concrete foundations, for example, show the higher richness of certain groups of species (e.g. barnacles and tunicates) as compared to steel structures (Andersson et al. 2009).

The nature of the interactions between fauna and flora organisms and OWFs differs depending on the species traits (sessile and mobile), life stage (larvae, juvenile, and adult), and habitat (shallow or deep waters and location), as well as the physical extent of the interaction (e.g. single monopile and entire farm area) (De Mesel et al. 2015, Hammar et al. 2016). Offshore wind structures acting as artificial reefs tend to influence biodiversity by increasing the abundance and diversity of certain benthic and pelagic groups (Lengkeek et al. 2017, Degraer et al. 2020, Glarou et al. 2020), but changes are site-specific and should not be completely generalized (Annelies et al. 2021). Communities also change over time, highlighting the need for a good taxonomical understanding of the local communities, communities' succession stages, and environmental features prior to implementation. Experiments testing succession over long periods are rare. Yet, a 10-year experiment in the North Sea showed significant changes in species composition during the six first years after implementation, thus illustrating the potential of short-term assessments to overlook important stages of colonization and succession (Kerckhof et al. 2019).

Long-term assessments are also important to properly monitor the establishment of potential opportunistic invasive species. Offshore wind structures can be used as stepping stones to nonindigenous epifauna and benthic and pelagic larvae and adults from several groups [e.g. barnacles (*Megabalanus coccopoma*, *Perforatus perforatus*, and *Austrominius modestus*), limpets (*Crepidula fornicata*), crustaceans (skeleton shrimp—*Caprella mutica*, and hairy crab—*Pilumnus hirtellus* for European waters)] (De Mesel et al. 2015, Lengkeek et al. 2017). Three out of the four recommendations from Lengkeek et al. (2017) (Lengkeek et al. 2017) on how to avoid the establishment of nonindigenous species can be applied for all OWFs: (i) prevent the transportation of living material; (ii) prevent the installation of floating artificial substrates near the coast or in shallow waters; and (iii) use of natural materials such as rocks over artificial resources. A more specific recommendation, which can be used as an example for other shellfish groups, is to avoid the establishment of invasive Pacific oyster (*Crassostrea gigas*), which has invaded large-scale reefs in many locations replacing the native European flat oysters (*Ostrea edulis*) (Lengkeek et al. 2017).

NbSs and NiD

Initiatives to enhance ecological functioning with NbSs are regularly described for coastline and estuarine areas (e.g. rocky shores and salt marshes) (Stephenson 2022) and, along with fixed oil and gas platforms, form part of the theoretical framework of the knowledge available for application to the offshore wind (see the section 'Useful information from other habitats and aquatic-related business and infrastructures'). NbSs are often described as an umbrella term where approaches benefit ecosystem services and biodiversity (Stephenson 2022). We have obtained just a single document strictly referring to NbSs within OWFs, but some reports and peer-reviewed studies on the implementation and effects of artificial reefs and restoration could be classified as a NbS (Fig. 2a; Table S1, Supplemental Material). As a practical example, the European flat oyster communities were previously extensive biogenic reefs in the North Sea and have been an over-

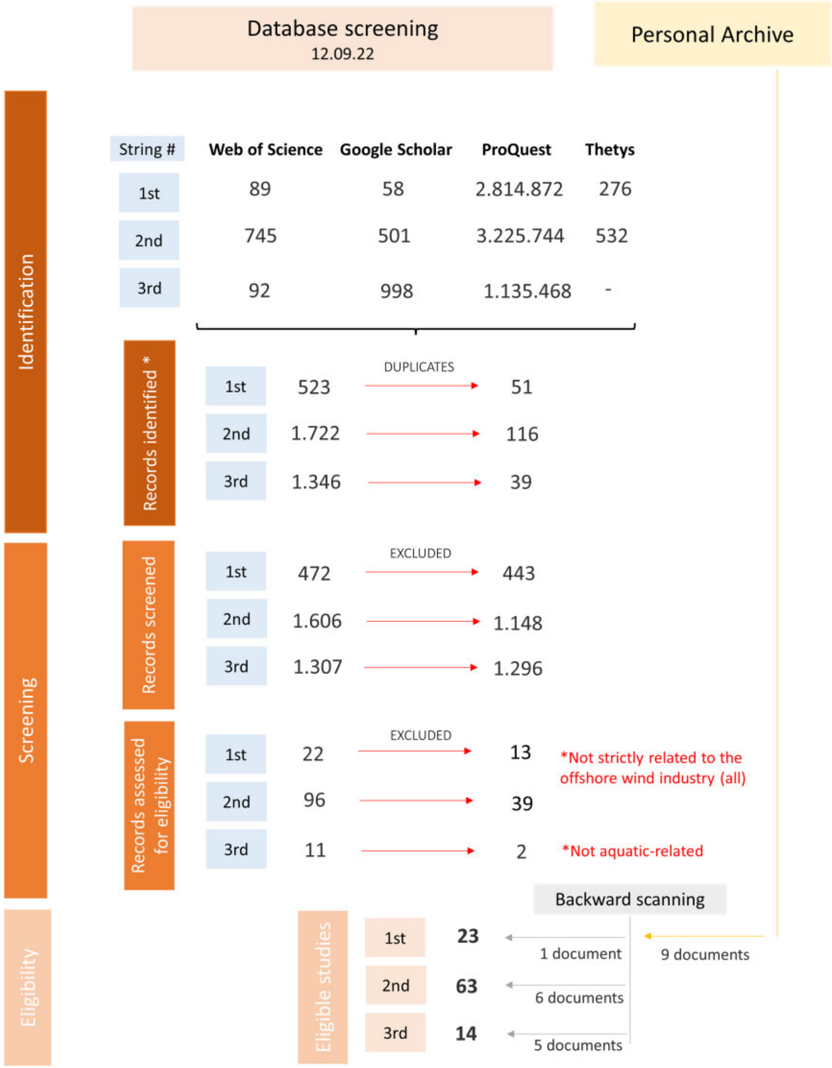

Figure 1. PRISMA diagram and steps followed to include scanned documents in the systematic analysis. All records assessed for eligibility had their full text retrievable. *Documents following our systematic searching strategy criteria.

exploited resource targeted by trawl fisheries. Several studies have reported their importance as a foundation and ecosystem engineer (i.e. species that directly or indirectly modulate the availability of resources to other species), highlighting potential positive outcomes in restoring these historical oyster settlement areas (Lengkeek et al. 2017, Kamermans et al. 2018, Robertson et al. 2021).

Nature-inclusive design structures support nature enhancement and resilience between and within offshore wind areas and turbines, both fixed and floating—the latter being much less explored and experimentally tested (Hermans et al. 2020, Stephenson 2022). Based on Hermans et al. (2020), NiD measures for monopile OWFs can be classified into three different types, depending on where they are established and their interaction with the foundations of offshore wind turbines. (i) The optimized scour protection layers are improved versions of ordinary scour protection for monopiles (i.e. foundations consisting of a single fixed structural element) or substation. Such additional rocks and adapted grading armour layers with little or no movement have been shown to provide habitat and increase the biomass of important commercial fish and crustacean species such as the Atlantic cod (*Gadus morhua*) and the European lobster (*Homarus gammarus*) (Rozemeijer and Van De Wolfshaar 2019) (Fig. 3a). (ii) Optimized cable protection layers for subsea power cables or cable crossings are reported; e.g. basalt bags, flexible structures, which cover the cables and provide microhabitats and shelter through the crevices, increasing biomass and creating an artificial reef, and Reef Cube® filter bags, which are cages which act as a shelter for mobile and sessile species (Fig. 3b). (iii) The add-on options are designed structures attached to the actual monopile or offshore substation. For instance, NiD measures designed to house the Atlantic cod include the Biohut®, an adjustable system of cages to be used on offshore jackets, and Cod hotels (Cotels), which are cage structures filled with steel tubes and funnels (Fig. 3c). The list of products available to the offshore wind industry is vast (see Hermans et al. 2020, The Nature Conservancy/Inspire Environmental 2021) for a catalogue and detailed list of NiD products), but there is still a lack of long-term *in situ* assessments to confirm their efficiencies.

In the North Sea, several pilot projects for NiDs are being conducted or are in the early stage of development (see Table S1, Supplemental Material). Reports are rich in informa-

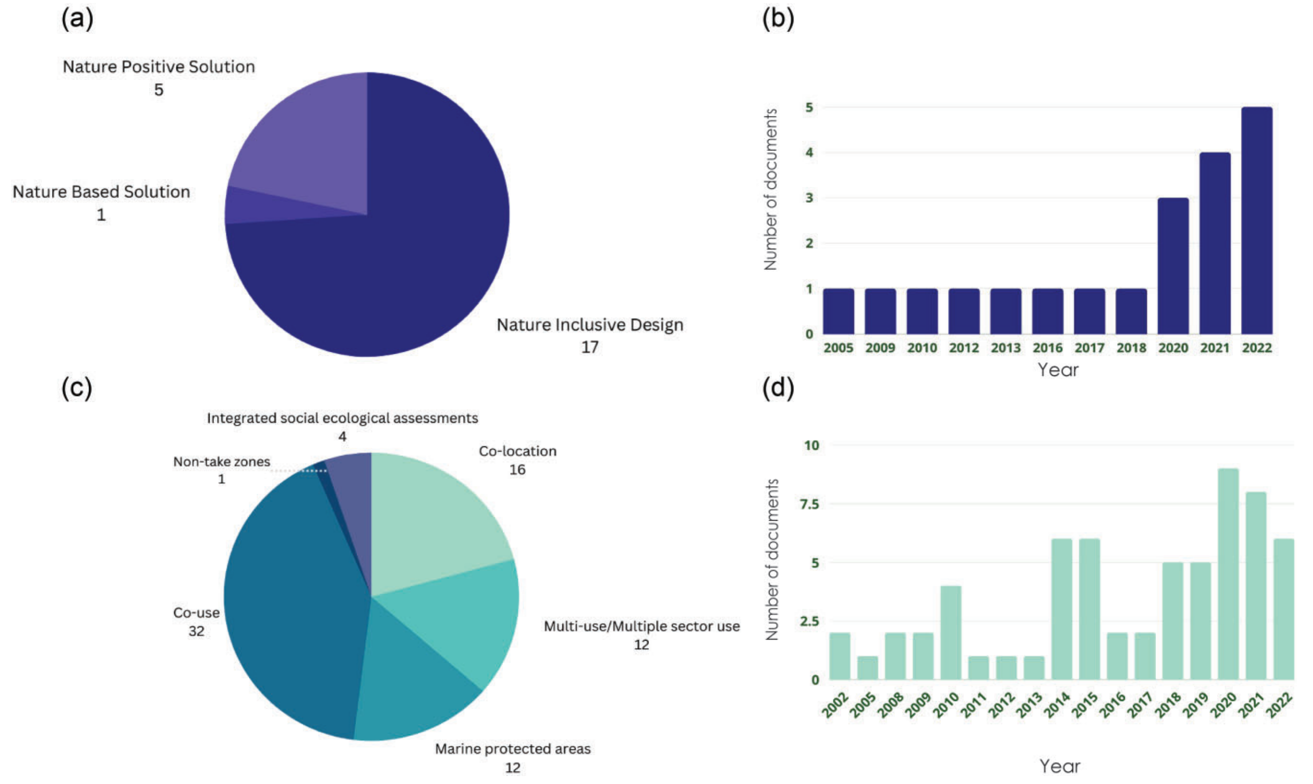

Figure 2. Categories of relevant documents related to offshore wind obtained in the first (a) and second (c) string and the total number of documents obtained in both strings, with the year of publication (b) and (d).

tion on NiD applications and implementation guidelines, focusing on the scour protection zones around foundations and soft sediment areas between the structures (e.g. Waardenburg 2020). A broad consultation with OWF actors (academic, industry, and suppliers) highlighted the advantages, both technical and ecological, along with the risks and costs for each of the NiD measures promoted (Hermans et al. 2020). The type of NiD material (natural versus synthetic and steel versus concrete), potentially impacting the structure of the turbines, and changes in the environmental dynamics (e.g. currents and extreme events) are some of the key points to be taken into consideration prior to implementation (Hermans et al. 2020). The consultation also suggested adding a different type of NiD measure into classification, namely standalone units (artificial reefs, not part of the actual turbine structure). This may include 3D-printed units with varied shapes designed to provide shelters with a large surface area within a small space, and fish hotels, which are connected and stacked concrete tubes to home fish and crustacean species (design by Wageningen University & Research; Hermans et al. 2020) (Fig. 3d) (see Fig. 4 for an overview of all NiDs *in situ*).

The application of NiD measures on offshore wind is, however, still in the initial stages of development on a global scale (Lukic et al. 2021), and there is a need for more pilot studies aiming at long-term monitoring of the composition, structure, and function of biological communities associated to NiDs, especially for floating wind farms in deeper water. There are risks involving NiDs that should be taken into consideration, such as settlement and migration of nonindigenous species, lack of ecological success, and impairments for the target species (i.e. ecological and policy-relevant species) (De Mesel et al. 2015, The Nature Conservancy/Inspire Environmental 2021). The report from Hermans et al. (2020) highlights that nonproven NiDs may bring uncertainties in the design process, technical and ecological risks, and may also increase project costs. Thus, baseline studies and site-specific social–environmental assessments, including oceanographic measurements and biodiversity impacts, are needed to better evaluate the efficiency of the various NiD measures. Defining the target groups and species (fauna and flora) as well as a systematic analysis of the ecological enhancement is essential to reduce the risk and enhance the cost-effectiveness of NiD measures (Hermans et al. 2020).

Coexistence in the offshore wind industry

The use of marine space for offshore wind, and the interplay between business and actors, encompass several concepts (Bonnevie et al. 2019, Schupp et al. 2019), despite different definitions (see Table 1), sharing space and resources brings opportunities to identify synergies and align towards mutual growth (Turschwell et al. 2022). As we observed in our search using the second string, 63 documents explored the different coexistence activities specifically with the offshore wind industry. Following the trend observed in the first string, most of the documents are recent (past 5 years), from Europe and the North Sea, with many of the studies being conducted in UK waters (14) (Fig. 2c and d; Table S1, Supplemental Material). Offshore wind is a relatively new business, sometimes implemented in spaces used and managed by different societal and commercial sectors. So far, OWFs have largely been bottom-fixed monopile structures deployed close to shore ($<$ 20 km) in shallow waters (depth of $<$ 30 m). The emergence of floating OWFs may create spatial conflicts with tra-

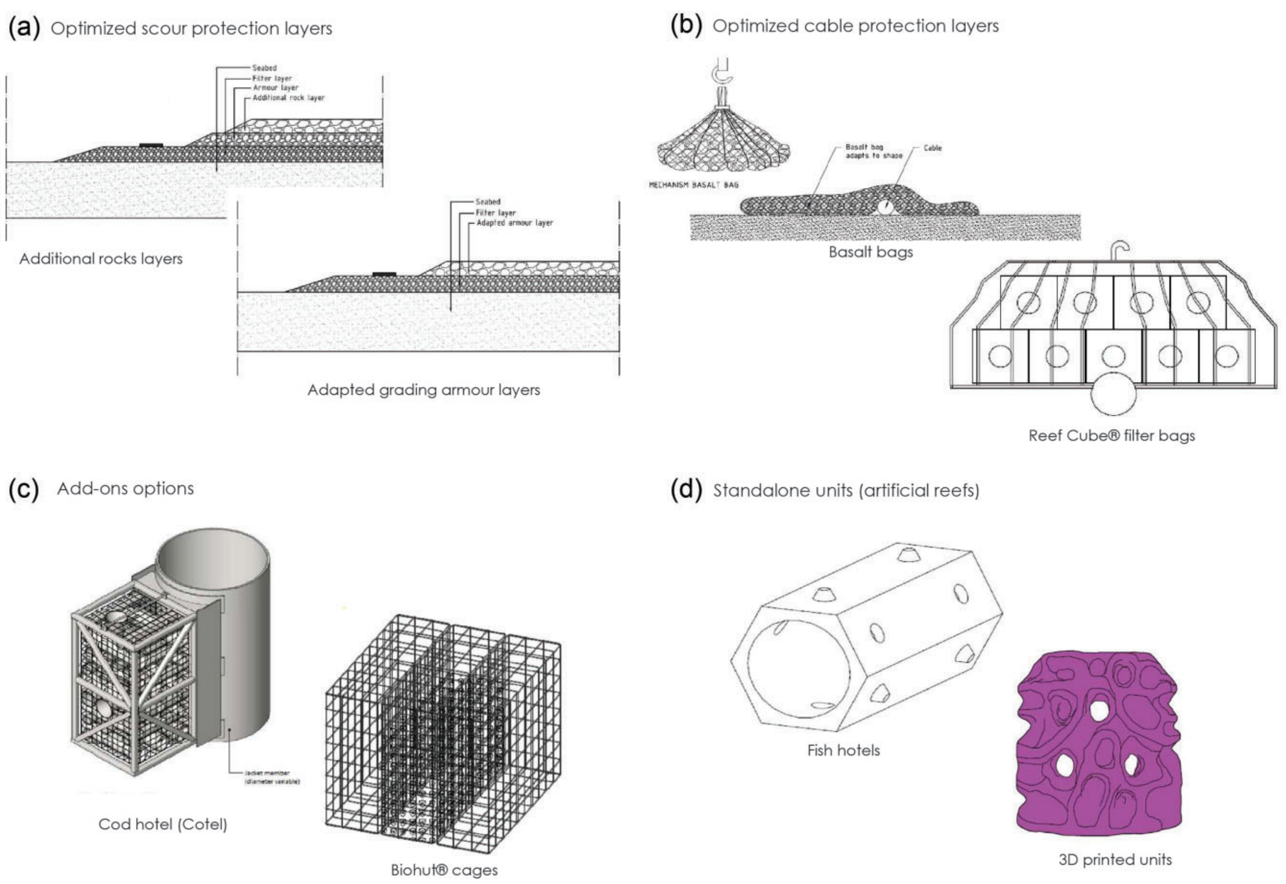

Figure 3. NiD structures and their classification based on Hermans et al. (2020). (a) Optimized scour protection layers: additional rocks and adapted grading armour layers, (b) optimized cable protection layers: basalt and Reef Cube® filter bags, (c) add-on options: cod hotel (cotel) and Biohut® cages, and (d) standalone units (artificial reefs): fish hotels and 3D printed units.

ditional and coming users of the open ocean (Gusatu et al. 2020, Nøland et al. 2022). In order to share space and resources, solutions to the race for space in busy coastal and marine environments require coexistence among the different companies and actors. Different tools are used to identify and prioritize businesses to achieve sustainable development, but the lack of adequate and mutual communication between the OWF industry, researchers, and other stakeholders is an impairment to an offshore blue economy and positive development (Steins et al. 2021, Turschwell et al. 2022). By analysing the different offshore wind coexistence activities [Table S2 (Supplemental Material) for a complete overview of obtained resources, and Fig. 4 for an overview of coexistence strategies for the offshore wind industry], we can potentially identify synergies, learn from the interplay among different industries and foster nature positivity.

Fisheries

Fishing vessels tend to avoid fishing within OWFs due to various reasons such as health and safety issues caused by the difficulties to manoeuvre the vessels inside the farms, particularly under challenging weather and current conditions (Blyth-Skyrme 2011, Christie et al. 2014, Dunkley and Solandt 2022). Moreover, the use of certain types of active fishing gear (e.g. bottom trawl) represents a risk to infrastructure associated with OWFs, including power cables (Christie et al. 2014). In practice, commercial fishing activities are therefore often displaced by the OWFs and are consequently forced to be conducted elsewhere, typically reducing the number of trips and consequently reducing the revenues (e.g. Scheld et al. 2022). Also, whereas some European countries prohibit fishing inside and around OWFs (e.g. in German waters), others (e.g. the UK) allow fishing in such areas (Krone et al. 2017, Stelzenmüller et al. 2021). Interview-based studies confirm that the fishing community are concerned about further OWF developments (Hooper et al. 2015). When floating OWF are being developed, a constructive dialogue between wind farm developers and the fishing industry is proposed as a prerequisite to identify coexistence solutions, promote constructive engagement and thereby minimize their conflict level (Haggett et al. 2020). Several frameworks for MSP have been developed, aiming to identify priority areas based on optimal coexistence trade-offs, for instance between OWFs and fisheries (e.g. Yates et al. 2015, Gusatu et al. 2020). Yet, floating wind farms represent a relatively new technology that is recently implemented in practice, in which differences between floating and fixed wind farms concerning coexistence issues are largely yet to be identified (e.g. ORE Catapult & Xodus Group 2022).

Nevertheless, submerged artificial structures in the marine environment, including OWFs and oil and gas platforms, are associated with multiple ecological effects (Lindeboom et al. 2011, Wright et al. 2020). Regarding OWFs, these effects include enhanced hard-bottom benthic diversity and attraction of other species, including benthos, fish, and marine mammals (Lindeboom et al. 2011 and references therein). For in-

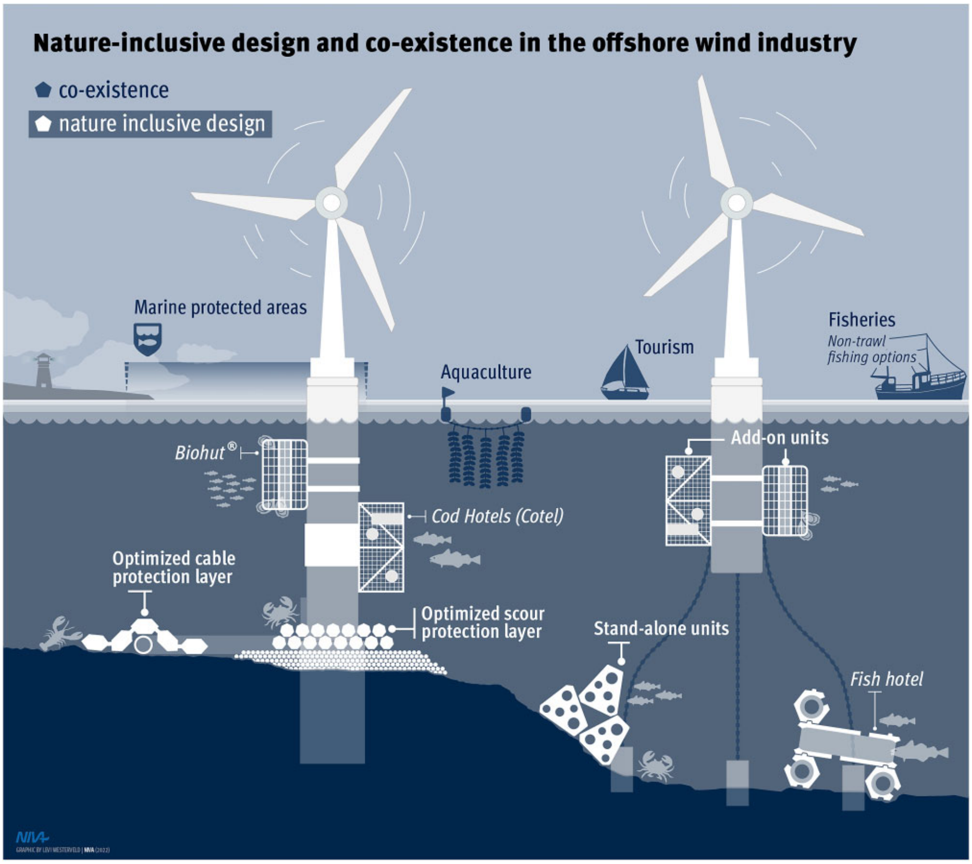

Figure 4. Conceptual illustration of NiD approaches (categorized in optimized cable and scour protection layer and stand-alone and add-on units) and coexistence strategies (marine protect areas, aquaculture, tourism, and fisheries) for fixed and floating OWFs.

stance, commercially attractive fish species such as Atlantic cod (*G. morhua*), pouting (*Trisopterus luscus*), and whiting (*Merlangius merlangus*) tend to aggregate close to OWFs (Vandendriessche et al. 2013, Reubens et al. 2014). Such dense aggregations of commercially attractive species would normally promote efficient and profitable fisheries with a low environmental footprint, but within OWF's, conventional fisheries with active gear remain challenging.

Alternative coexistence options for OWFing and fisheries have therefore been assessed. In particular, the combination of species attraction and challenges associated with the use of active fishing gear suggests that OWFs may constitute suitable areas for fisheries using passive, selective gear such as fishing traps (Letschert et al. 2021, Stelzenmüller et al. 2021). For example, studies from the German Bight (North Sea) showed that the brown crab (*Cancer pagurus*), a species typically harvested with traps, may utilize wind turbine foundations as nursing areas (Krone et al. 2013, 2017). Moreover, the reef effect associated with such foundations had a strongly positive effect on the local crab abundance (Krone et al. 2017). Indeed, a positive development of crab fisheries was observed in UK waters, likely resulting from the recent expansion of OWFs (Stelzenmüller et al. 2021).

Whereas some fisheries can plausibly be displaced to areas outside OWF areas without major negative economic effects on the fishing industry, other target species are dependent upon particular areas or habitats and must consequently be harvested there. For example, the sandeel (*Ammodytes* spp.), a highly valuable fish resource inhabiting the North Sea, depends on sandy habitats and avoids sediments with > 10% silt/clay content (Wright et al. 2020). Being harvested with active gear such as bottom trawl, coexistence of sandeel fisheries and OWF is plausibly challenging. On the other hand, the nephrops (*Nephrops norvegicus*), a commercially important crustacean caught in the North Sea, depend on muddy sediments (Letschert et al. 2021). If fishing vessels targeting the nephrops are displaced, for instance resulting from offshore wind developments, there is a risk that fishing opportunities may be lost (Letschert et al. 2021, Roach et al. 2022). However, as the nephrops are trawled and harvested with traps, coexistence of nephrops fisheries and OWF is considered feasible (Letschert et al. 2021). Therefore, knowledge of the type of fisheries (e.g. target species and gear) that can potentially be colocated with OWF is therefore vital and should be expanded (RSPB 2022).

Aquaculture

In response to area limitations, which become increasingly severe in coastal waters, some offshore aquaculture farms have recently been developed (Langan and Horton 2003, Morro et al. 2022). The concept is promising, but being exposed to harsh open-ocean conditions, offshore aquaculture involves high operational costs and challenging maintenance procedures (Gjuka 2017). Yet, provided allocation in spots with appropriate oceanographic conditions, the concept may also offer benefits including reduced organic and nutrient load on vulnerable fjord and inshore locations (Lindahl et al. 2005), low parasite pressure, and appropriate oxygen saturation (Morro et al. 2022). Recently, attention has been paid to the coexistence of OWF and aquaculture farming of various species including seaweed, bivalves, and fish, as a means of area-efficient, profitable, sustainable, and technologically feasible food production (Buck et al. 2010, Gimpel et al. 2015, Soma et al. 2019). Since areas within OWF are imposed by restricted access, they are characterized by a low level of disturbance (e.g. from shipping and tourism) and therefore emerge as suitable areas for coexistence with aquaculture (Buck et al. 2008). Furthermore, such coexistence may facilitate shared logistics and maintenance among the colocated industries (Buck et al. 2010).

Technical solutions supporting the offshore development of aquaculture have been developed in recent years. In terms of environmental conditions, several fish species including European sea bass (*Dicentrarchus labrax*), cod (*G. morhua*), and haddock (*Melanogrammus aeglefinus*) could be feasible to farm in coexistence with OWF (Gimpel et al. 2015). However, offshore fish farms are typically characterized by extensive physical structures, and they require close attention from operators (Buck 2007, Christie et al. 2014). In contrast, offshore farming of seaweed and bivalves typically rely on simpler designs such as longline systems (Buck et al. 2010, Christie et al. 2014, Tullberg et al. 2022). In addition, they share a feature that is presumably crucial with regard to cultivation in the harsh and often remote offshore environment: unlike fish, they do not require daily attention or feeding (Buck 2007, Christie et al. 2014). Nevertheless, in order to realise coexistence of OWF and aquaculture, various regulatory aspects as well as technological, economic, and biological issues are needed to be solved (Wever et al. 2015).

Seaweed cultivation combines CO_2 capture and food production and has been highlighted as a promising option for OWF coexistence (Moreira and Pires 2016, Koch et al. 2021). Seaweed sinking has been recently suggested as a NbS to mitigate climate change (carbon removal), however, the practice still lacks scientific knowledge and needs further investigation prior to the application (Ricart et al. 2022). Many seaweed species are also suitable as food for humans or feed for animals (van der Spiegel et al. 2013). Yet, when cultivated in coexistence with OWF, numerous technical and food safety-related factors need to be accounted for in order to produce healthy seaweed for food and feed purposes (Banach et al. 2020, van den Burg et al. 2020). For instance, to avoid the uptake of harmful substances, the farmed seaweed should not be exposed to pollution caused by vessel operation or accidents, or contaminants leaching from OWF structures (e.g. heavy metals from antifouling; Banach et al. 2020). Numerous seaweed species, including the sugar kelp (*Saccharina latissima*), are suitable for offshore farming (e.g. Van Den Burg et al. 2013). The seaweed production process typically involves two phases: a seedling laboratory production phase and a growout phase in the ocean (Taelman et al. 2015). The seedling production process is laborious, ultimately resulting in long, seeded cultivation strings (Taelman et al. 2015). In the growout phase, these cultivation strings are wrapped around offshore longlines (this deployment typically occurs in December), and high-quality seaweed is harvested in May the following year (Taelman et al. 2015). Although the production process of seaweed is well-established, uncertainty is still being induced in the planning of OWF and seaweed cultivation coexistence, as legal regulations for such coexistence are often immature (Soma et al. 2019)

Successful coexistence of OWF and bivalve cultivation depends on the environmental conditions in the coexistence area (Di Tullio et al. 2018). Biological and physical–chemical factors including seawater temperature, salinity, nutrient concentration, oxygen level, and the concentration of chlorophyll *a* in the water masses flowing through the mussel farm influence mussel growth, and these factors may also be altered by the presence of physical structures such as OWF`s (Benassai et al. 2014, Cazenave et al. 2016, Di Tullio et al. 2018). For instance, model studies indicate that physical structures may enhance vertical mixing and thereby induce a local increase in dissolved inorganic nitrogen available to biota at higher trophic levels (e.g. Cazenave et al. 2016). One of the bivalve species that are suitable for cultivation in coexistence with OWF is the blue mussel (*Mytilus edulis*; Griffin et al. 2015), a species that is both a food resource and an important filtration feeder. The cultivation of the blue mussel is typically carried out over a 15–18-month period, with spat collection in May–June during the first year, maintenance of longlines from August the first year until May the second year, and subsequent harvesting of consumption-size mussels (> 5.5 cm) in August–November (Buck et al. 2010). Given the relatively simple technology and limited requirements regarding daily attention, it is therefore evident that certain bivalve and seaweed species (e.g. *M. edulis* and *S. latissima*) emerge as good candidates for cultivation in coexistence with OWF (Buck 2007, Christie et al. 2014).

Marine protected areas

One of the most effective ways to restore marine biodiversity and functioning is by implementing areas where extractive activities are reduced or prohibited (Sala and Giakoumi 2018). As summarized by the High Level Panel for a Sustainable Ocean Economy (Ocean Panel), there is a need for more protected areas (an increase to 30% of fully protected MPAs) and renewables (an increase of 40 times more renewable energy by 2050) to support a sustainable ocean economy and healthy ocean (Stuchtey et al. 2021). The Kunming–Montreal Global Biodiversity Framework (GBF), followed by the Biodiversity Beyond National Jurisdiction (BBNJ) treaty, also emphasizes the significance of conserving and protecting marine areas to prevent biodiversity loss (CBD 2022, UN General Assembly 2023). Since OWFs in practice may act as no-take zones in most of the implemented countries, mainly European ones (Krone et al. 2017, Stelzenmüller et al. 2021), the area effectively turns into a fisheries reserve, bringing similar positive benefits as MPAs. Overall, today’s size of OWFs is in accordance with MPAs recommended size regulations, and the overall positive effect can be considered similar in terms of refuge for benthic habitats, benthos, fish, and marine mammals (Ashley et al. 2014). Marine protected areas, however, have different levels of protection thus requiring regional and detailed MSP assessments when considering colocation with OWFs.

In a global systematic review and meta-analysis, Ashley et al. (2014) broke down the question ‘*Can offshore windfarms act as marine protected areas?*’, and concluded that overall OWFs as nontake zones may indeed positively affect commercial species (e.g. fish and crustacean) with a minimum negative impact on commercial fishing. A detailed MSP framework for the Canary Islands also highlighted the benefits of colocating OWFs and MPAs, contributing to socioecological and economic development of the region (Abramic et al. 2021). However, there is a lack of offshore wind-focused studies and long-term monitoring to compare the negative and positive outcomes from OWFs and MPAs, such as the spill-over effects (net movement of individuals from marine reserves to surrounding fishing grounds) (Stelzenmüller et al. 2021). A recent report on European offshore renewable energy also highlighted offshore renewables as potential Other Effective Conservation Measures (OECMs) (Table 1 for definition) (Soukissian et al. 2023), but their consideration requires more research and it is debatable (Lloret et al. 2022). Knowledge of the efficiency of implementing OWFs inside protected areas, especially for floating structures, is even more scarce and questioned (Sanders et al. 2017, Lloret et al. 2022). *Les Éoliennes Flottantes du Golfe de Lion* (EFGL) project, located at the Natural Park of the Gulf of Lion, will be the first floating OWF to be implemented inside an MPA. The implementation of OWFs changes the baseline environmental features of the MPA, such as sediment and diversity of certain groups, highlighting the need for a historical ecological assessment of the area to evaluate potential restoration and colocation activities (Dunkley and Solandt 2022).

Useful information from other habitats and aquatic-related business and infrastructures

Coastal adaptation management initiatives involving sustainable restoration projects, and the use of eco-engineering designs, have been in practice to substitute or complement traditional civil engineering solutions and solve a range of environmental problems (e.g. coastal erosion and reef restoration) (O’Shaughnessy et al. 2020, Cohn et al. 2022, van der Meulen et al. 2022). Due to the social–ecological complexity of coastal and estuarine areas, there is a range of methods involving NbSs and NiDs varying in space and time, from micro (e.g. 3D-printed units) to macro (e.g. costal stretch) approaches to support biodiversity gain and ecosystem functioning (see reviews in Table S3, Supplemental Material). Although we cannot expect direct applications of the knowledge built from other marine based industries, the adaptation management and concepts could be evaluated, adapted, and applied to approaches within OWFs. However, OWF has a significant impact on the estuarine and coastal zones, and to achieve a nature positive industry, nature positive approaches—thus including NbSs and NiDs—should be included in OWF projects (Stephenson 2022 and literature within).

Climate change adaptation and mitigation represent increasingly important considerations in current and future marine research and industrial development (Bulleri et al. 2018, Kuwae and Crooks 2021). The impacts of anthropogenic climate change affect individuals to ecosystem levels, and some unprecedented changes are minimized or mitigated through NbSs (Wijsman et al. 2021, Moraes et al. 2022, van der Meulen et al. 2022). The knowledge acquired for beach erosion and coastal flood protection, e.g. brings an important catalogue of efficient natural and artificial material to be implemented, and how to evaluate sediment grains deposit and behaviour when in contact with physical structures and faunal communities (Wijsman et al. 2021, Moraes et al. 2022, van der Meulen et al. 2022).

Different designs and hydrodynamics influencing floating structures may affect settlement patterns of fauna and macroalgae differentially when compared to fixed foundations, and the information available from floating structures is still scarce. In the coastal zone, some studies show floating pontoons (hollow structures made either of concrete or fiberglass) affecting local biodiversity and facilitating species settlement, with a potentially negative effect from colonization of nonindigenous species and shading to the benthic compartment (O’Shaughnessy et al. 2020, van der Meulen et al. 2022). Additionally, wave energy farms mostly encompass floating structures and are often suggested as a business that can be colocated with offshore wind. Short- and long-term studies on wind farms suggested a higher abundance of fish and crabs on the foundations through time and highlighted the importance of habitat complexity on abundance and diversity of colonizing species (Langhamer and Wilhelmsson 2009, Bender et al. 2020), similarly to some results observed in association with OWFs (e.g. 26 119). Manipulating the complexity and structure of NiD is a well-explored topic on coastal artificial reefs and protection enhancement measures (Dahl et al. 2015, Kramer et al. 2015, Howie and Bishop 2021). By manipulating crevices and structural components of NiDs, structures can act more efficiently to attract and increase the density of certain groups of species or communities. However, habitat complexity is modified by the communities’ dynamics through time, and their establishment also promotes habitat change (e.g. oyster after settling create a different spatial structure to other living organisms), highlighting the importance of long-term monitoring of the community development (Smith et al. 2014). For example, the intrinsic complexity of oil and gas platforms and associated fixed structures recruits and attracts a large number of species, turning these structures into highly productive marine habitats (Claisse et al. 2014, Reeves et al. 2018). As such, we argue that biological patterns observed in association with related marine industries may also be relevant to the OWF industry.

Perspectives

As the use of the term nature positive grows, a joint and ambitious definition and accounting methodology will be useful to halt the loss of biodiversity where needed, provide transparency, and enable flow of capital to truly nature positive OWF projects. A way to implement efficient nature positive approaches, thus including NbSs and NiDs, is the collaboration between the stakeholders, industry, and research community (natural and social scientists), in establishing collaboration on *in situ*, long-term experiments and monitoring.

Relevant research and monitoring data is sparse, in particular for the nascent floating OWFs. Floating turbines have different physical and environmental footprints when compared to bottom-fixed structures, with a major part of the structure floating in deeper waters, and the anchoring system consists of typically three mooring lines anchored in the seafloor (James and Costa Ros 2015). These features, and the lack of an intertidal zone, may bring different effects to the biodiversity establishment, marine connectivity, and interaction with the surrounding environment. For instance, floating devices mimicking the turbine installation coupled with NiDs showed tracked fishes accessing these structures and moving back to the coastal shore (Lecaillon et al. 2022), evidencing an effect on their behaviour and potential influence on the community structure and dynamics. Also, NiDs should be implemented based on local environmental characteristics and needs; as example, there is an important difference between the use of NiDs to restore depleted reefs (e.g. oyster restoration in the

North Sea) and the use of artificials in areas where reefs are absent. The gain in species richness and consequent changes in habitat complexity and food-web structure should be a key decision factor while evaluating the need and relevance of implementing NiDs, or any other nature positive approach. As an example, seabirds may be drawn to the OWFs due to the availability of prey species, which have been established through the use of NbS designed for the aquatic environment. This may lead to extra unwanted interactions and associated risks between seabirds and OWFs. For seabirds in UK waters, a list of recommendations is provided to support nature positive development aligned to the group needs, such as the highlighting the importance of proper MSP and improvement of monitoring and mitigation measures in fisheries (Royal Society for the Protection of Birds, RSPB 2022).

Integrated planning and management are needed to achieve a holistic sustainability plan for OWFs (Stephenson et al. 2019). Co-use strategies (offshore wind combined with aquaculture, fisheries, and so on) are suggested as an economic and ecological benefit for all businesses (areal use and reduced costs), to mitigate the race for ocean space. Although not being nature positive approaches in the strict sense, positive outcomes from coexistence activities (e.g. kelp farming and carbon-storing) should be carefully evaluated. Ideally, colocated businesses could combine efforts to build a mutual implementation of nature positive approaches and strategies to reducing the overall impact on the environment. Other social–economic activities could also contribute to the development of the offshore wind industry. Tourism on OWFs has been considered an economic activity and a way to promote outreach and increase public awareness of renewables in general and OWFs in particular (Lukic et al. 2021). However, public and community perception is context-dependent and directly affects the local economy (Westerberg et al. 2013, Smythe et al. 2020, Degraer et al. 2021). As highlighted in Smythe et al. 2020, there is an interest to promote offshore wind tourism, but a potential short-lived interest and difficulties in implementing it on larger farms should be taken into consideration. The implementation of any multiuse strategy, however, should be planned from the early design phase of the project and in order to reach a consensus, they should be developed in close collaboration with stakeholders, including public consultations.

Successful upscaling of nature positive offshore wind and coexistence solutions will require cost-effective nature positive approaches, stakeholder support, as well as regulatory incentives. Research collaboration across disciplines, which have not traditionally worked together, is required to develop solutions that are both technologically and ecologically feasible. Research and pilot projects focusing on technology and services supporting colocation, can also reduce biodiversity pressure outside of the OWFs and ensure cost-effective nature positive approaches. This includes, e.g. technical solutions for aquaculture and fisheries within OWFs, as well as monitoring of biodiversity impacts and maintenance needs. The offshore wind industry also has a significant impact on the estuarine and coastal zones, requiring cables and connections to the grid, transformers, storage of turbine components, and use of industrial harbours. In order to be net nature positive, measures could also be considered in these areas, where restoration projects, and the use of eco-engineering designs and rewilding, is more developed (see examples in Table S1, Supplemental Material). Stakeholders, however, should be included at an early stage to ensure that nature positive approaches support coexistence and are perceived as acceptable to relevant users of the sea.

Numerous companies state the implementation of nature positive initiatives but there is a gap between what is needed in order to achieve a resilient environment and what has been provided by the industry so far (zu Ermgassen et al. 2022). Most of the initiatives are indeed relevant to the offshore wind industry, but due to the novelty and complexity of the industry and lack of some knowledge on the interactions between offshore wind and ecosystems, a specific evaluation of the needs to be nature positive in offshore wind should be provided, where the information presented here in the review could be used as a relevant resource. Yet, there is still an overall lack of operational and regulatory guidance to achieve nature positive outcomes (zu Ermgassen et al. 2022). The ways to measure and estimate efficacy of nature positive approaches are still under development and are mostly explored in the grey literature. However, it is suggested that we can effectively understand the impacts (positives and negatives) of a certain industry and propose measurements to achieve a positive net gain (Milner-Gulland 2022). The Nature Positive (2022) report gives a broad framework and guidelines to measure nature positive outcomes. As of interest to OWFs, the natural processes (carbon sequestration and storage, migration patterns, sediment transport, and the integrity of estuaries and integrity of tidal zones), ecosystems (extent of habitat, the function of species in their habitats, and ecological integrity of the habitat), and species (extent and abundance of species, extinction risk of species, and genetic diversity) are the main metrics highlighted to quantify nature positive outcomes.

In some countries, such as the Netherlands, the use of NiDs is already encouraged through tender requirements (Hermans et al. 2020). Moving forward, regulatory incentives via spatial planning and tenders will be important to foster nature positive approaches and coexistence. Also, in several countries OWFs structures must be removed at the end-of-life of the OWF (i.e. in the decommission phase; Mauricio Hernandez C et al. 2021, Hall et al. 2022). Removing the structures and associated NiDs could potentially outweigh long-term ecological benefits of NiDs. As applied in some decommissioning of oil and gas platforms (e.g. Gulf of Mexico and California, Kaiser and Pulsipher 2005), developers apply to leave a portion of each structure in place to continue functioning as an artificial reef (Mauricio Hernandez C et al. 2021, Hall et al. 2022). Similar research and pilots are needed for OWFs to investigate the advantages and disadvantages of partial decommission, allowing successful NiDs to be left behind at end of turbine life. This is especially important as OWFs can have several generations of turbines. Also, environmental impact assessments for offshore wind typically focus on reducing negative impacts, not on positive impacts, which may impede the development of NiDs.

There is a significant and concerning knowledge gap regarding OWF in the southern hemisphere and (sub)tropical areas, potentially due to a combination of lack of investments in research and less offshore wind development. Large offshore wind developments are being considered in regions holding rich biodiversity, such as Brazil, Vietnam, and Colombia, as well as world leading ambitions in China (GWEC—Global Wind Energy Council 2022). Biodiversity and environmental dynamics in (sub)tropical areas are significantly different from those in temperate environments, where most of the knowledge on nature positive approaches, and associated approaches (NbS and NiD), have been established. Thus, there is a need for regional assessments to decide the best practices for target groups. We are also aware that our searching strategy may cause a potential bias due to the lack of other bibliographic languages apart from English (Rockliffe 2022), an issue that is likely most relevant regarding the grey literature. Follow-up reviews using languages from countries where most of the knowledge is coming from (published in documents in English) (e.g. Northern European countries—Netherlands, Belgium, and Denmark) and areas with developing and established offshore wind industry (e.g. China) would be of great relevance.

Nontarget macrofauna species and meiofauna community changes are also less explored in the offshore wind literature. Both have key roles in marine benthic biogeochemistry (including carbon pathways) and serve as food for several target species (e.g. fish and crustaceans) in association with nature positive measures (Griffiths et al. 2017, Solan et al. 2020). Additionally, the review process revealed that additional scientific and monitoring efforts should be taken considering the functional diversity and different trophic levels within OWFs.

Conclusion

The global decarbonization of the energy sector requires a feasible and effective approach of nature positive approaches aiming for biodiversity net gain and resilience. It is consensus across publications and reports on the need for additional data collection, testing, and experimentation (long-term) on nature positive approaches in OWFs, especially *in situ* NiD experiments from floating wind turbines. There is still a strong need for a definition for the offshore wind industry and common guidelines and framework on how to achieve and measure positive outcomes in general, and aquatic systems in particular. Nature positive approaches should be carefully implemented, followed up with *in situ* experiments and science-based systematic monitoring. Coexistence practices support the multiuse of marine space and bring positive and negative impacts to the environment, and their evaluation and potential integration in the OWF industry should be considered.

Acknowledgements

We thank Witteveen + Bos and Gilles Lecaillon (Ecocean) for image authorization (Fig. 3), Sara Clarke (UiO, Library) for evaluating our research strings, Camilla Fagerli and Paul R. Berg (NIVA) for their valuable suggestions and manuscript proofreading, and Levi Westerveld for the illustration (Fig. 4). We also thank Editor Dr Mark Gibbs and the anonymous reviewer for their valuable comments.

Supplementary material

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Author contributions

Pardo, J.C.F. Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing—original draft, Writing—review and editing. Aune, M.: Conceptualization, Data curation, Investigation, Methodology, Writing—original draft, Writing—review and editing. Harman, C.: Conceptualization, Methodology, Supervision, Writing—review and editing. Walday, M.: Conceptualization, Methodology, Supervision, Writing—review and editing. Skjellum, S.F.: Conceptualization, Methodology, Project administration, Supervision, Writing—review and editing

Conflict of interest: None declared.

Funding

This review is part of a commissioned work requested by Equinor (Norway) on nature positive practices and coexistence in the offshore wind industry. Both parts agreed to have the work freely available following open access guidelines

Data availability

The data underlying this article are available in the article and in its online supplementary material.

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Handling Editor: Mark Gibbs