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Recommendations for coexistence between offshore wind and fisheries

Strategic Sector Cooperation between Brazil and Denmark for a just and inclusive energy transition

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The consultants can declare no conflict of interest and state full compliance with the good scientific practices and standard expected from a Danish University.

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Credits

Photos by Elisabeth Baden, Erika Akariguame and Esther Savina.

We also reproduce pictures from the Instagram account of local fisher “reginaldo.ryan9”.

Executive summary and key takeaways from the site visit

This report addresses the coexistence of fisheries and offshore wind (OSW) development in Brazilian coastal zones. The goal is to utilize knowledge from other OSW markets to facilitate coexistence. The report focuses on the pilot project off the coast of Areia Branca, but we also consider the potential effects of future larger buildouts. Observations are based on visits to two fishing communities, available scientific literature and expert opinions.

The pilot project uses water-filled gravity-based foundations, which can be towed by conventional tugboats and assembled inshore, minimizing construction time and noise. The survey of successful coexistence in other OSW sites has focused on the operational phase, given the limited scale and duration of the construction phase of the Areia Branca OSW.

The survey of best practices for stakeholder involvement focuses on fisheries' coexistence with offshore wind in the context of the concertation process, where adjustments and tradeoffs are most easily clarified and implemented. The main points of concern from all stakeholders are currently:

- Compatibility with commercial fishing gears,
- Environmental effects on fish resource (noise, blade shade),
- Data collection and monitoring in an ecosystem-based approach.

Early return of experience in Europe and the US shows that stakeholder involvement in the planning processes can result in successful coexistence between OSW and fisheries, especially with passive gears. However, implementation also depends on the specific characteristics of the site and the integrated management approach in force at the national level. The site visit indicates good chances of compatibility of local commercial fishing practice in proximity to wind turbines, if the potential drift of gillnets and the penetration depth of mooring anchors is sufficiently considered.

A barrier to coexistence may be that fishers remain cautious and/or do not use the OSW due to safety, legality and insurance concerns. Fishers' engagement in the renewable energy transition and development of OSW can be facilitated by:

- Early and Continuous Engagement, i.e. starting before environmental evaluations and throughout the project.
- A Fisheries Liaison Officer in charge of easy-to-understand communication through the fishers preferred channels e.g. face-to-face meetings and adaptable methods (e.g., Facebook) between fishers and developers.

- Building Trust, e.g. by recognizing fishers' daily issues, share experiences and data, visualize gear, participate in trials.
- Consultations and involvement with respect to e.g. micro-siting, boulder displacement, and phased construction.
- Participatory Tools and inclusive practices: Ensure participation, trust, gender equity, and co-ownership models.

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Abbreviations

CNPA	National Confederation of Fishers and Aquaculture (in Portuguese: Confederação Nacional dos Pescadores e Aquicultores)
DEA	Danish Energy Agency
EIA	Environmental Impact Assessment
IBAMA	Brazilian Institute of the Environment and Renewable Natural Resources (in Portuguese: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Ranováveis)
ICES	International Council for the Exploration of the Sea
MMA	Ministry of Environment and Climate Change (in Portuguese: Ministério do Meio Ambiente e Mudança do Clima)
MME	Ministry of Mines and Energy (in Portuguese: Ministério de Minas e Energia)
MPA	Ministry of Fisheries and Aquaculture
OSW	Offshore Wind
SENAI	National Service for Industrial Training (in Portuguese: Serviço Nacional de Aprendizagem Industrial)
USA	United States of America

1. Introduction and disclaimer

1.1. Context and objective of the study

The report is to the attention of the Danish Energy Agency (DEA) and partner institutions in Brazil:

- the Ministry of Mines and Energy (MME),
- the Ministry of Environment and Climate Change (MMA),
- the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)
- and SENAI Innovation Institute for Renewables Energy.

The Government of Brazil and the Government of Denmark are currently engaged in a strategic sector cooperation for a **just and inclusive energy transition**. The assignment is intended to address the concerns towards **coexistence between fisheries and offshore wind** (OSW) development in Brazilian coastal zones with a strong fishing tradition. The objective of the cooperation is to provide knowledge and inspiration from the participation processes, regulatory mechanisms, and technical solutions that have been applied in other offshore wind markets to mitigate disputes.

More specifically, the following contribution is aimed at supporting the ongoing development of a **pilot OSW project in Areia Branca**. The pilot project consists of two bottom-fixed turbines at 6-8 m depth. The turbines will be connected to a salt production facility offshore, and thus there will be no export cable to shore. Following an invitation from one of the main partners, IBAMA, the DEA attended two public hearings conducted in connection with the impact assessment of the pilot project.

The National Service for Industrial Training (SENAI) in Rio Grande is in charge of the preparation of the **Environmental Impact Assessment** (EIA) report, which includes consideration of commercial fisheries (see standard terms of reference by IBAMA). The development team at SENAI is thus in the process of meeting with artisanal fishers[1] for **mapping fishing activities**, including fishing grounds, target species, gears, seasonality, and value chain through the local fishers' organization.

We first report observations of the site visit, highlighting similarities and differences with scenarios encountered in Europe and the United States of America (USA), and suggest points of attention based on return of experience and expert opinion.

We then present a general overview of the topic of coexistence between offshore wind and commercial fisheries, based on the most recent scientific literature and examples in Europe and the USA.

[1] We use the gender-neutral word "fisher" instead of e.g. "fisherman" (Branch & Kleiber, 2017).

Recommendations for coexistence are discussed for the pilot project and the potential future larger OSW buildout off the coast of Rio Grande.

1.2. Disclaimer

The Danish Energy Agency ("DEA") is a state agency of the Government of the Kingdom of Denmark, which, within the framework of its institutional mission, implements the Strategic Sectoral Cooperation program, sponsored and funded by the Danish Ministry of Foreign Affairs. The program aims to promote the exchange of knowledge and strengthen cooperation between a Danish public authority and its counterparts in growing economies of strategic relevance, with a focus on the implementation of sustainable policies and advanced technical solutions in the energy sector.

The government-to-government cooperation relationship between Denmark and Brazil, in a strictly constructive spirit, presents some observations and suggestions to the topic of coexistence between offshore wind and fisheries. These suggestions are in line with international standards and best practices in the matter, with the aim of contributing to the sustainable development of the energy sector and facilitating the implementation of solid and efficient regulatory frameworks.

It is important to emphasize, however, that the opinions and comments expressed in this document are for guidance purposes only and do not represent a binding commitment, a definitive official position, or the assumption of legal, financial or any other obligations on the part of the Kingdom of Denmark, its agencies, ministries, government departments or members of their staff.

Furthermore, the absence of observations in certain sections of the document should not be interpreted as tacit approval, conformity or agreement with the content of the terms of reference. The DEA reserves the right to issue additional considerations in the future, if it deems it pertinent, within the framework of its collaboration with the Brazilian authorities.

1.3. Site visit

A site visit took place from October 23rd to 31st 2024. It included a day of public meetings steered by SENAI, with two local fishing communities (*Colonias*) close to the pilot project site (Areia Branca) in Ponta do Mel (

Figure 1) and Cristovão (

Figure 2).

Figure 1. Meeting with the fishers' local organization in Ponta do Mel

Figure 2. Meeting with the fishers' local organization in Cristovão

Each meeting was complemented by a visit to the harbor with members of the fishers' local organization, where it was possible to see gears and enquire about fishing practices (

Figure 3).

Figure 3. Harbor visit with the President of the fishers' local organization in Ponta do Mel

1.4. Overview of how OSW can impact commercial fisheries

OSW can impact commercial fisheries in different ways (Figure 4), and it is thus important to consider the **environmental** but also the **socio-economics effects**.

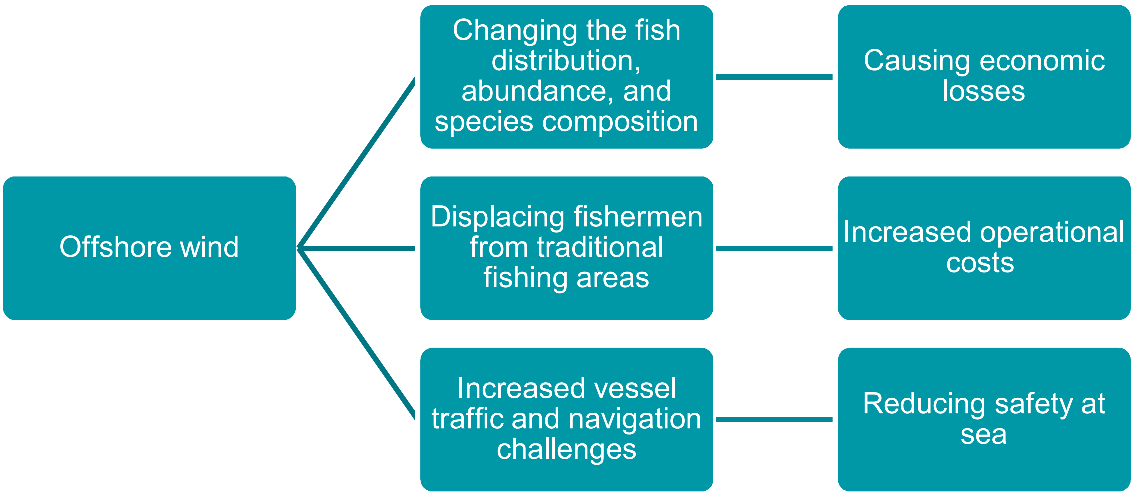

Figure 4. A simplified diagram on the different ways offshore wind can impact commercial fisheries.

The main **risks associated with fishing in OSW** areas are:

- the risk of **hooking** a cable (inter-array or export cable) by a bottom-towed gear or a mooring anchor, which can lead to loss of the fishing gear or capsizing of the fishing vessel,

- the risk of **collision** between two vessels, for example a fishing vessel and an operation and maintenance vessel, or two fishing vessels,
- the risk for a fishing vessel to hit a fixed infrastructure of the OSW such as a turbine (**allision**[2]),
- the risk of a fishing gear **drifting** in the water column, which can then get entangled in a fixed infrastructure of the OSW or the engine of an operation and maintenance vessel.

Not all gears present the same risks. **Active or mobile gears** are those being towed behind a vessel, catching fish by filtering or encirclement. Because of the dynamic fish capture process, vessels with this type of gear may have to significantly change their fishing behaviors to avoid interacting with turbines and underwater cables, which can include complete displacement from traditional fishing grounds. **Passive gears** are stationary and rely on the movements of the fish in the catch process. Vessels with passive gears are likely to be less affected, although the gears may be deployed as long fleets (i.e., a succession of multiple individual gears attached together) and are likely to drift, which makes it challenging to operate between turbines.

Fishers can use the same overarching gear type to target different species, with different gear specifications, seasonality and fishing grounds, which together define a fishing **métier**.

1.5. Limitations of the study

Due to the nature of the pilot-scale project, and the characteristics of the Brazilian shelf, we focus the present work on **bottom-fixed technologies** of OSW. Bottom-fixed technology results in a smaller spatial footprint and potential exclusion zone around the turbines than floating technology. Consequently, bottom-fixed technologies have larger potential for coexistence with commercial fisheries.

It is planned that the foundation for the turbines of the pilot project will be **water-filled gravity-based** such as the Elisa 5MW prototype used in the Canary Islands[3]. The advantage of this technology is that it allows the foundations to be towed to the construction site using conventional tugboats instead of heavy-lift vessels. The telescopic configuration of the tower was designed to be able to use the platform as a self-stable floating barge from which the crew can pre-assemble the entire system inshore. The construction phase at sea is thus expected to be limited in time. The system is also noiseless (no pile driving). There might be an effect of the seabed preparation process, which often involves dredging and laying a layer of gravel to ensure a stable base, but with limited footprint due to the small size of the pilot project. Due to the limited scale and

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[2] While the term “collision” is commonly used, maritime incidents in the context of risk analysis are described as collision if it involves moving ships, and allision if it involves a moving ship and a stationary object.

[3] https://esteyco.com/projects/elisa/tech.html

time of the construction phase of the pilot project, we focus the coexistence objectives on the **operational phase of the OSW site**.

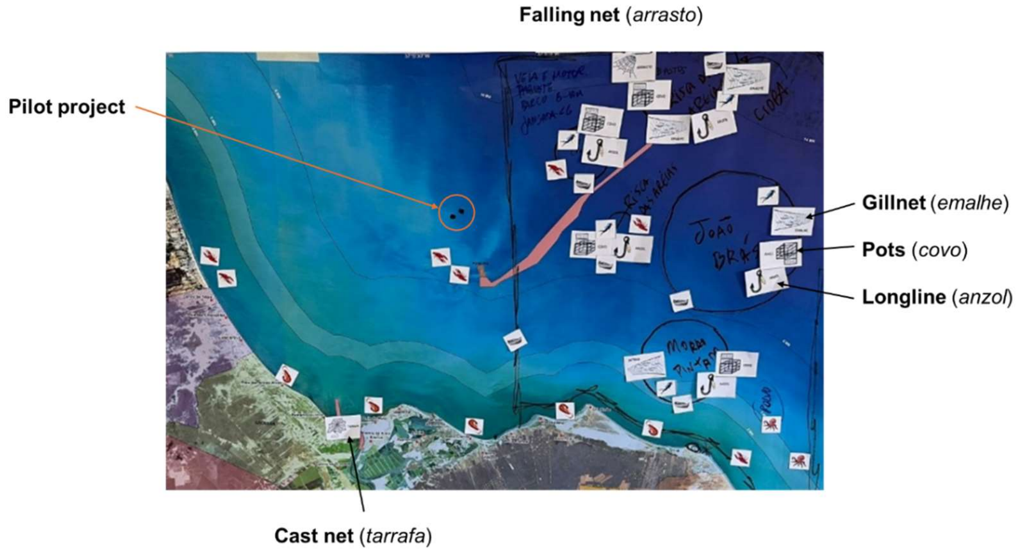
The two communities visited represent 320 members of a group of about 2000 commercial fishers in Ponta do Mel and Cristovão. For context, there are 82 fishing communities in Rio Grande do Norte (Santos de Vasconcelos et al., 2003). Expert observations and conclusions from this visit are thus **not meant to be representative of other cases**.

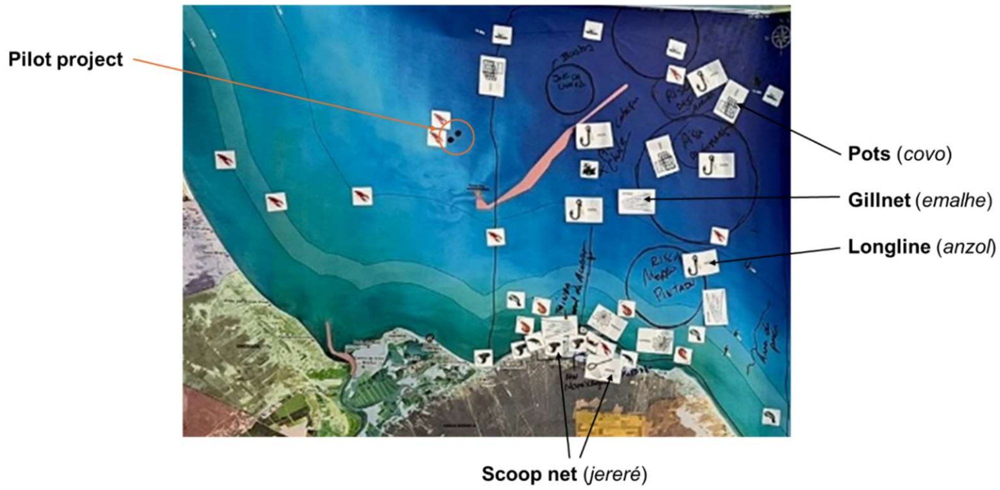
The topic of coexistence between offshore wind and fisheries is relatively new, with a limited number of peer-reviewed publications that mostly focus on passive gear fisheries. The following observations are thus largely based on the **return of experience and expert opinion** from discussions with colleagues in academia, but also with the fishing and wind industry from Europe and the USA as part of the International Council for the Exploration of the Sea (ICES) working groups and informal meetings.

2. Site visit observations

2.1. Types of fisheries

The pilot site is close to shore and the main segment of the fleet of interest is the **small-scale fisheries**[4], i.e., fishing vessels **below 12 m** using **passive fishing gear**[5] (Figure 5, Figure 6).





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[4] Also known as “artisanal”, “local”, “coastal”, “traditional”, “subsistence”, “non-industrial”.

[5] Fishing gears are classified based on the behavior of the target species and the gear for capture. Passive gears are left in place, i.e. static and rely on the movements of the fish in the catch process, sometimes bait is used to attract fish. Active or mobile gears are towed behind the vessel and catch fish by filtering or encirclement.

Figure 5. Map of fishing grounds by fishing gear and target species discussed with the fishers in Ponta do Mel (top) and Cristovão (bottom). The pilot project is represented by the two black dots circled in orange in the middle of the map. Portuguese gear name is in brackets in italics.

Figure 6. Examples of fishing vessels in Ponta do Mel (left) and Cristovão (right).

This is in line with observations between 2011 and 2014 where artisanal fishing contributed up to 66% (47,046 tons) of landings in Rio Grande do Norte (Carvalho, 2016). Hand implements such as here spears, cast and scoop nets are small-scale fishing gears often used in subsistence fisheries (He et al., 2021).

2.1.1. Fleets: main gear and vessel size

Fleets are defined according to main gear and vessel size. Most of the gear types are **passive and miscellaneous gears** (but not all) (Figure 7), including:

- Hand collection supplemented by spears, cast and scoop nets,
- Diving with surface air delivery,
- Pots,
- Gillnets,
- Long lines.

Figure 7. Passive gears in Ponta do Mel with two different traps (left) and a gillnet (right).

Small-sized **sailing and/or motorized** vessels made of wood are used (Figure 8, Figure 9). The smallest vessels have a flat bottom hull, whereas larger vessels have a V-shaped hull.

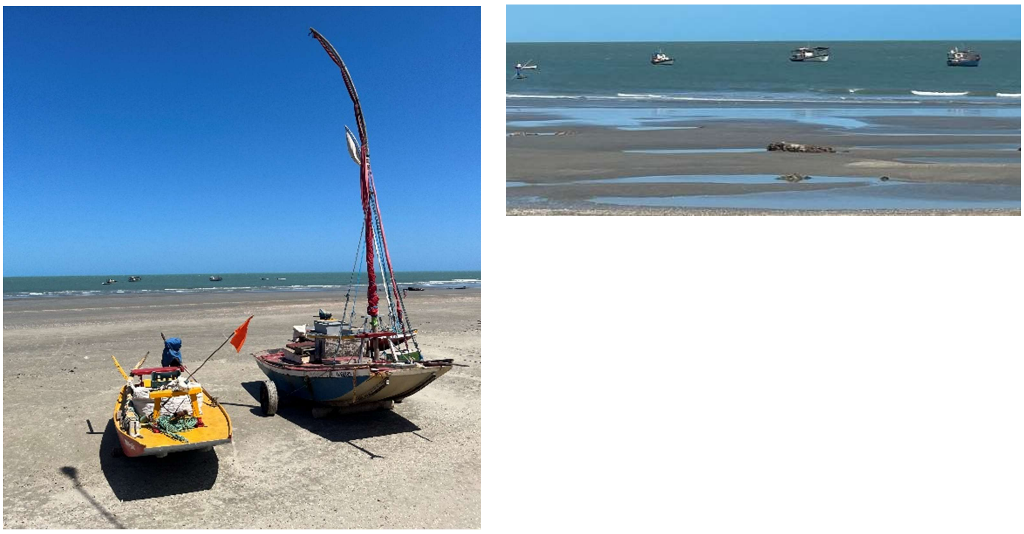

Figure 8. Small-sized sailing (left) and motorized (right) vessels observed in Ponta do Mel

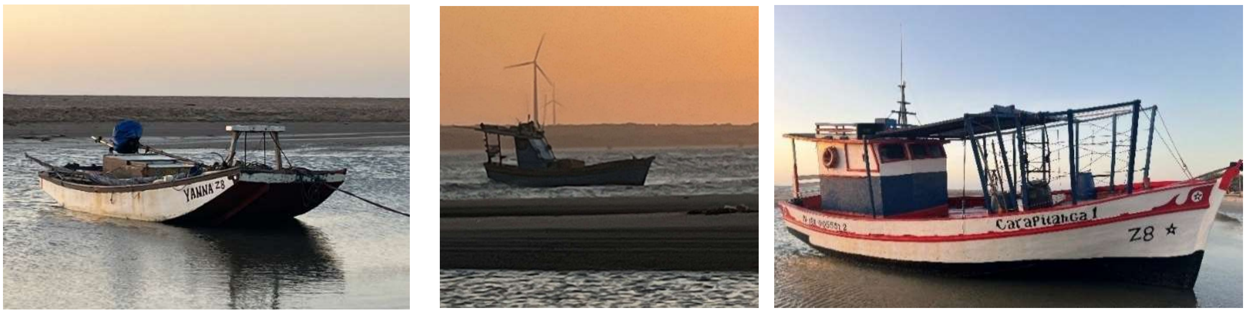

Figure 9. Small-sized sailing (left) and motorized (middle, right) vessels observed in Cristovão

Vessel size can also be reported in engine size, storage size and/or number of crew (Table 1).

Table 1. Fleet segmentation for the small-sized vessels adapted from Ivo et al. (2012) and DCF classification.

	By foot	Sailing vessels	Motorized vessels
Vessel length	-	0-5 m	6-11 m
Engine size	-	Complemented by sail	18-70 HP
Storage size		Ice in cooling box	
Number of crew	(women)	2-5 (men)	
Sea autonomy	1 day	1-3 days	5-11 days
Spatial range	Shore	Up to 5 nm	Up to 18 nm
Day or night	Day	Day (starting 4am) or night	

The **number of crew** is dependent on vessel size and gear type, but also on the number of days at sea, with up to 5 persons for daily trips, but no more than 2 for longer trips. When diving for lobster, compressors are connected to the engine of the boat and oxygen reaches the divers through a hose (Alencar et al., 2021). The crew is then usually composed of (Alencar et al., 2021):

- 1-2 divers,
- 1-2 hose men who control the air compressor and oversee loosening the rope and pulling it back (*mangueristas*),
- and eventually 1 leader, usually the oldest.

The **number of days at sea** is driven by ice availability to conserve catch, which depends on vessel storage size, but also air temperature for cooling boxes. **Larger motorized vessels** work further offshore, with refrigeration allowing for longer time at sea (Ivo et al., 2012).

The **range of operation** is driven by motorization and distance to fishing ground. For divers, operation is restrained to relatively shallow waters (10-40m) due to depth limitations (Alencar et al., 2021).

2.1.2. Exploitation patterns of the different métiers[6] : target species, gear specifications, seasonality and fishing grounds

Our understanding is that the main commercial activity of the fleet in Ponta do Mel and Cristovão is to spear fish for lobster by **diving** with surface air delivery (air compressor). The spear (in Portuguese: *arpão*) is described by Alencar et al. (2021) as a wooden handle of approximately 50cm with a sharp metal hook.

Lobsters are targeted on natural localized flat-bottom grounds (in Portuguese: *restingas*), where fishers position **artificial shelters** (in Portuguese: *marambaia*) acting as fish (shellfish) attraction devices. These are made of salvaged materials such as fridges or empty oil barrels hammered and attached to wood pallets (Alencar et al., 2021) (Figure 10). The diver removes the lobsters found in the *marambaia* with the spear. Each dive can cover 8 to 10 *marambaias* (Alencar et al., 2021). Fishers in these communities also use **pots** (in Portuguese: *covo*) to target lobsters (Figure 5, Figure 10), but it is unclear whether these are used to trap the lobster found by the diver for later collection or to directly target lobster as an alternative to diving. Alencar et al. (2021) also reports the use of 5 -7 mm mesh gillnets to trap the live lobster for further collection, and Ivo et al. (2000) mention that lobster may be targeted directly by gillnet in shallow waters (25m).

Figure 10. Pots for lobster (Instagram account of local fisher "reginaldo.ryan9" accessed October 2024) (left) and fridges which may be salvaged for use as artificial shelter (right)

As the fishery for lobster is closed annually for about 6 months (Figure 11), the fishing strategy accommodates for **selective supply at a specific time of the year**. Alencar et al. (2021) reports that larger lobsters are preferred in the initial months of the fishing season. Other métiers are reported on the study site, either as a commercial activity and/or to support own and community consumption (Figure 5, Figure

[6] Métiers characterize fishing operations sharing a similar exploitation pattern, with respect to e.g. target species, gear specifications, seasonality and fishing grounds.

11). The seasonality of these métiers does not seem to be as marked as the diving fishery for lobster (Figure 11).

Figure 11. Seasonality by fishing gear and target species discussed with the fishers in Ponta do Mel (top) and Cristovão (bottom).

The spear is not only used when diving for lobster but also to target octopus. Other hand-implements are used from the shore to target crustacean (shrimp, crab), and include:

- **Scoop net** (in Portuguese: *jereré*), a small net bag used to scoop or sieve the catch from the water, held open by a metal, plastic or wooden frame, and usually operated by one or more people (He et al., 2021),
- **Cast net** (in Portuguese: *tarrafa*), constructed from tailored netting sections joined together to produce a cone-shaped net with weights allowing the net to sink quickly and a drawstring at the bottom to prevent fish from escaping (He et al., 2021).

These gears can also catch small fish, but fish are mostly targeted using:

- **Pots** (in Portuguese: *covo*)**,** though it remains unclear whether the gear is actively used for capture or only to keep live catch.
- **Gillnet** (in Portuguese: *emalhe*), which are kept open vertically by floats attached to the head rope and by weights added to the footrope, set close to shore or in open water,
- **Longline** (in Portuguese: *anzol*), where hooks are connected to branch lines which are then attached to a long horizontal mainline, usually baited and set in open water (He et al., 2021).

One should note that the use of **falling net** (in Portuguese: *arrasto*) is mentioned by the fishers on the edge of the study area to target shrimp (Figure 5). Similarly to a cast net, the falling net is a cone-shaped net with weights and a drawstring on its perimeter. However, it is not cast but simply allowed to fall from above. When operated offshore, it is usually large in scale and operated at night from a boat with the use of lights to attract target species (He et al., 2021), but we do not know if this is representative of the practices in the study area. Even if this type of net is operated from a vessel, it is different from a trawl as the capture process does not involve towing the net behind the vessel.

2.2. Diving risk and licenses

Diving is dangerous, especially for communities far from a hyperbaric chamber. An informal study carried out by the regional labor department of the state of Rio Grande do Norte estimated that 86.4% of the divers have suffered at least one **hyperbaric accident** (Cavalcante et al., 2015). Two (out of 32) lobster fishing communities in Rio Grande do Norte registered 12 fatal cases of hyperbaric decompression in two years (Alencar et al., 2021).

Commercial fishing of lobsters (red lobster *Panulirus argus*, green lobster *Panulirus laevicauda* and spotted lobster *Panulirus echinatus*) is regulated by MMA and the Ministry of Fisheries and Aquaculture (MPA)[7] based on biological advice through (Madrid & Izquierdo 2013; Alencar et al., 2021):

- **Catch limits**, with a maximum limit of 6,192 tons for red and green lobster in 2024,
- **Minimum catch size**, based on tail/body[8] length,
- **Temporal closure**, with a 6-months closure to allow populations to recover,
- **Prohibited practices**, retaining egg-bearing females is prohibited and lobsters should be stored and transported alive,
- **Gear specifications**, the use of traps is allowed but the netting must be square and have at least 5 cm between consecutive knots, whereas gillnets, *marambaia* and diving is forbidden,
- **Vessel specifications**, which should be more than 4 meters long, may not carry any type of compressed air apparatus, and must have satellite tracking with regular signal emission if the vessel is motorized and larger than 10 m,
- **Effort limits,** each fisher can only deploy up to 100 traps,
- and **licenses**.

The **closing period** is supported by the payment of the minimum wage for licensed fishers (*Seguro Defeso*), and illegal fishing is punished by a fine.

Many vessels are currently not licensed. This is in line with Alencar et al. (2021) who registered that only 5 out of 16 vessels were licensed in the beach of Pirangi. We understand that divers may not be licensed because the regulation forbids this capture method. Discussion with fishers at the workshop also suggests that the lack of interest from local authorities may explain the limited licensing. Fishers also mentioned the **cost of the certification** for divers, but it is unclear whether this was for fishing or another activity (see diversification below).

2.3. Value chain

Commercial catch is **landed directly to an intermediary** and processed by specialized companies before export. In small-scale fisheries, it is common to find an intermediary (or “middleman”) between fishers and the market, facilitating the sale and distribution of fish, but also providing credit for e.g. operational costs.

About **80% of the landings are exported**. Artisanal fishing for export was encouraged by the Brazilian government and the fishing industry in several coastal regions, and lobster is one of the main items of the Brazilian balance of trade (Dias-Neto, 2008, Alencar et al., 2021). Only fish not fit for market is for own

[7] Ordinance SAP/MAPA Nº 221 (June 8, 2021); Ordinance MPA/MMA No. 11 (April 29, 2024)

[8] Cephalothorax

consumption or shellfish collected by women onshore. Alencar et al. (2021) report that the catch is separated into 3 size classes and thus price classes. The smallest size may be purchased by the community from the middleman at low prices and resold to the local tourist industry (tourists, owners of local bars, and restaurants) (Alencar et al., 2021).

The middlemen contribute to **running (fuel) and investment (boat) costs** (Alencar et al., 2021). The cost for purchasing a vessel is estimated at 15k R$, representing about 8 weeks of a fisher's income (up to 2k R$ a week). There seems to be a government subsidy for diesel since 2004[9]. The ice used on-board may be provided by the export companies (Alencar et al., 2021).

Indirect activities on land include a fish shop, construction of fishing boats (wood) and production and mounting of fishing gear (Figure 12).

Figure 12. A fish shop (left) and fishers repairing their nets (right) in Ponta do Mel.

2.4. Social composition and family structure

We observed **distinct gender roles**, with men fishing from vessels at sea while women and children may engage in harvesting shellfish by foot on the shore (Figure 13). Such gender roles are common in fisheries worldwide (Kleiber et al., 2015; de Andrade et al, 2017; Branch & Kleiber, 2017).

[9] https://www.gov.br/mpa/pt-br/assuntos/noticias/inscricoes-abertas-para-programa-de-subsidio-do-oleo-diesel

Figure 13. Clear gender composition of the fishing activities represented at the workshop in Cristovão with women and children harvesting by foot on the shore (left) and men sailing at sea (right).

Women also commonly support the family business by assisting to meetings, managing the households' finances and cleaning fish for the local market (Figure 14). One female participant was a business owner. Few children wish to continue fishing, and both men and women were interested in the diversification possibilities for the future generations.

Figure 14. A few women joined the workshop in Ponta do Mel on behalf of their husband or father, or as a business owner.

A summary of effort, catch, costs, and gender **by fleet segment** (by foot, vessels 0-5 m, and vessels 6-11m) is given in Appendix.

2.4.1. Comparable small-scale fisheries systems in Europe and points of attention

We present below an overview of the similarities and differences between the situation observed at the pilot site and comparable small-scale fisheries systems in Europe, i.e., small-scale (Figure 15), which we then detail with a focus on points of attention.

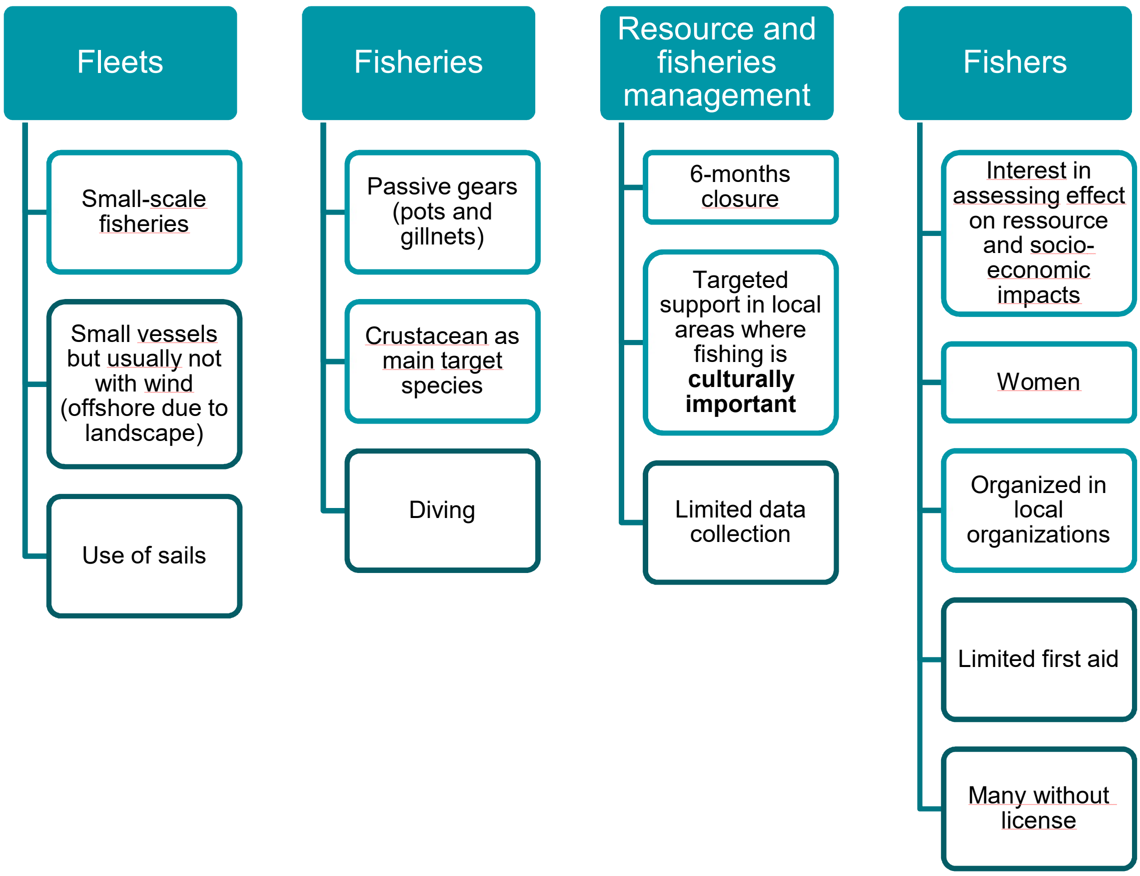

Figure 15. Overview of the similarities in blue and differences in red between the situation observed at the pilot site and comparable small scale fisheries systems in Europe, at the level of the fleets, fisheries, resource and fisheries management, and fishers.

2.4.2. Fleets and fisheries

The fleet segments encountered during the site visit were small-scale fisheries with sailing and/or motorized vessels. Small-scale fleets are still well represented in Europe, where they are generally considered as sustainable fisheries and benefit from targeted support in local areas where fishing is culturally important. Small-scale fisheries are a good candidate for coexistence with OSW, in Europe but also in Japan (Shimada et al., 2022), and sailing vessels are usually authorized in OSW areas. Additionally, small-scale fisheries tend to use **lighter gears**, which should limit the risk of hooking a cable, but they may be more prone to drift.

Local differences between communities but also between individual fishers make a mapping exercise challenging and implies **careful generalization**. Indeed, different types of fishing activities may have different concerns about energy projects, and fishers may be divided in their attitude to sharing commercially sensitive data (Alexander et al., 2013; Pita et al., 2013; de Groot et al., 2014; Reilly et al., 2016; Haggett et al., 2020). Additionally, it can be difficult for fishers to "frame" their activity as fishing grounds may change between years or seasons to follow the moving resource.

2.4.3. Resource and fisheries management

Fishers are generally concerned about the possible environmental effects, especially on the fish resource. It is the case here as well, with a focus on loss of habitat for lobsters.

Monitoring of effects is usually continued throughout the whole life cycle of the OSW, in Denmark for example there is a collaboration between the Danish Nature Agency and the Danish Centre for Environment and Energy at Aarhus University, who reports each year on the surveillance of marine areas in Denmark and specifically includes stations in OSWs. The current focus of research on the direct, indirect and cumulative effects of offshore wind on the marine environment is on electro-magnetic fields and underwater noise, including the effect of particle motion and vibration (Svendsen et al 2022). Overall, long-term monitoring in Europe indicates that mostly negative impacts are reported for birds, marine mammals, and ecosystem structure, whereas mostly positive effects are reported for fish (though potentially more severe effects for elasmobranchs) and macroinvertebrates (Galparsoro et al., 2022). Indeed, current knowledge indicates that most OSW areas are large enough to host fish species with a preference for rocky habitats, but small enough not to have adverse negative effects on species inhabiting the original seabed between the structures (Stenberg et al., 2015; Svendsen 2022). The OSW area can act as a shelter against currents and predators and provide food, stimulating aggregation behavior (**reef effect**) (Galparsoro et al., 2021). Hard substrates of OSW quickly become colonized by biofouling organisms such as barnacles, mussels, and algae, attracting small invertebrates and fish that feed on them[10]. The introduction of hard structures in soft seabed areas can however alter the habitat, potentially benefiting some species while those preferring soft substrates may find the new environment less suitable.

The **strong seasonality** of lobster fishing should be considered in the planning of temporary closures of the OSW area during construction, i.e., the potential environmental effects of building during stock recovery

[10] Offshore Wind Farm Artificial Reefs Affect Ecosystem Structure and Functioning: A Synthesis

versus potential socio-economics effects to close during the fishing season. In England, a collaborative study involving the fishing industry and the developer identified positive effects on the lobster population from temporary closures during construction (Roach et al., 2018),

Impact assessment should focus on the effects of the project itself, but it is not always easy to separate the effects of the OSW from e.g. seasonal/annual changes in resources and/or climate change. Identifying effort[11] and spatial displacement, economic losses, species impacts, social impacts, and cumulative effects is **data demanding** and might be especially difficult in a context where institutional responsibilities are not always clear (Shields et al., 2009; de Groot et al., 2014). Little to no investment in fisheries management in the last 10 years has left Brazil with limited data collection and monitoring, sometimes funded by private actors e.g. program of monitoring of the landings from Petrobrás (Dias-Neto, 2008; Carvalho, 2016; Alencar et al., 2021). In addition, income and costs are shared with a middleman with **little traceability** (cash-based transactions).

2.4.4. Fishers and fishers' organization

Overall, living and working conditions are rudimentary with limited access to communication and electricity, limited social benefits (licensing), limited first aid (difficult access through the road which is not paved in Cristovão, and long distance to a hyperbaric chamber). As observed in Europe and the USA, fishers are organized in local and regional organizations that support legalization of the activity (increase social benefits), raise environmental concerns (reduce illegal fishing) and aim for coexistence with OSW. National syndicates may also represent the fishers' interests, such as the National Confederation of Fishers and Aquaculture (CNPA) supporting the payment of the allocation when the fishery is closed (Figure 16). It is important to note that it can be difficult to identify the **community of relevance** (Gray et al., 2005; Rudolph et al., 2017; Haggett et al., 2020) and consequently, whom authorities and project developers should engage with. Even though fishers' organizations typically liaise with developers as the institutional stakeholders, they may represent only a specific segment of the fleet:

- Due to past experiences with ineffective or corrupt leadership, fishers may be skeptical about the benefits of joining organizations,
- There might be geographical barriers joining meetings for fishers in remote areas,
- Power struggles and social hierarchies within fishing communities can hinder the formation of cohesive organizations,

[11] Fishing effort is the amount of fishing gear of a specific type used over a given time period, e.g., number of hours trawled, or number of hooks set per day.

- Older fishers or those with a better economy will be able to attend meetings while the younger ones operating on a tighter budget will prefer going sailing.

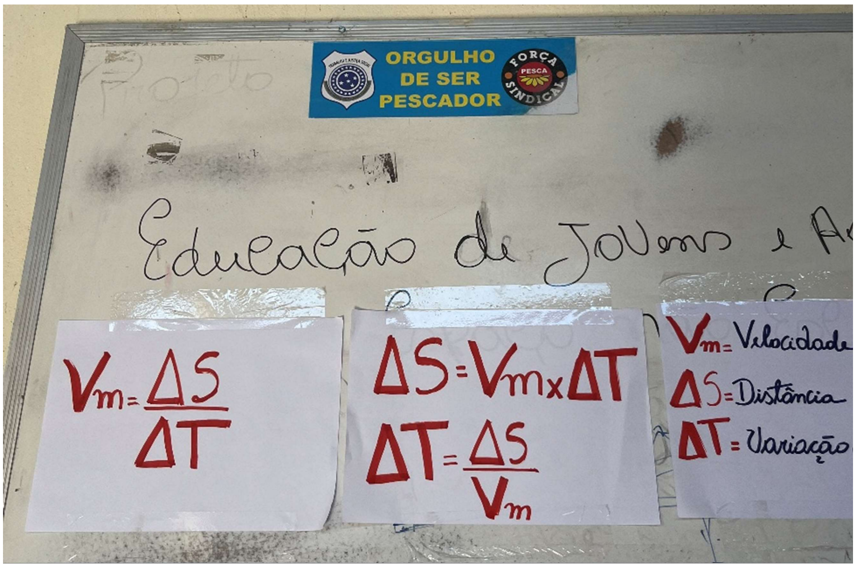

Figure 16. Sticker of the syndicates National Confederation of Fishers and Aquaculture (CNPA) and Força Sindical supporting fishers in Ponta do Mel.

As observed worldwide when faced with OSW development, fishers are interested in assessing the **resource and socio-economics impacts**. Environmental concerns mentioned during the workshop were related to noise, blade shade[12] and oil leaking from the nacelles. The latter has been observed with a few land-based turbines and caused concern for it to happen at sea. Addressing these concerns seems especially important in the communities visited, where **familiarity with onshore projects** may breed discontent and opposition (Soma and Haggett, 2015; Haggett et al., 2020). Indeed, Scottish fishers who knew of nearby offshore developments were five times more likely to have a negative attitude (Alexander et al., 2013).

In general, onshore wind requires a lot less maintenance than offshore wind, and hence offshore wind creates many more long-term jobs during the entire lifetime of the offshore wind farm. It is important to highlight, however, that diversification activities would require education efforts and re-skilling to be considered for long-term employment in a wind farm site office. Tenders for assisting in the OSW construction or operation and maintenance are usually requesting to follow specific technical or financial

[12] Under certain conditions, the sun may pass behind the rotor and cast a shadow. When the blades rotate, the shadow flicks on and off. There is so far limited evidence in the literature on the effect of shade flicker on aquatic organisms (Williamson et al., 2024).

standards, not to mention working in English, which may strongly challenge local diversification initiatives. In addition, as few children wish to continue fishing and due to the importance of a combined income, diversification programs are of interest and should **target all family members** and not only fishers.

3. Risk assessment of fishing with respect to wind farm operation

An analysis of incidents reported between 2010 and 2019 in the United Kingdom shows that incidents are more common during the OSW construction phase than during operation and involve a vessel working for the wind project in most cases (82%) (Rawson & Brito, 2022). Of the 69 reported incidents, **only 4 involved a fishing vessel** (2 allisions and 2 near misses) (Rawson & Brito 2022). Recorded incidents are still rare and studies are therefore based on risk modelling (Rutkowski & Kubacka, 2023) possibly including expert advice (Yu & Lui, 2019), with mixed results.

It is generally accepted that a small vessel (< 24-25 m) will be better suited to operate within an OSW-park than a large vessel, and that passive gears are more compatible with OSW (MMO, 2013; Gusatu et al., 2024). However, the size of fishing gear is not always proportional to the size of the vessel (Eigaard et al., 2016), and the different fisheries do therefore not present the same risks. In addition, a **lower probability of detecting the risk** due to insufficient training or lack of equipment might put fishing vessels more at risk than other types of vessels (Yu & Liu, 2019).

3.1.1. Drift and entanglement of light gears

Gillnets, pots and longlines are often fished in long fleets of individual gears. Gillnets and pots might also be used as a single unit, especially for lobster fishing, if pots are used to keep live catch. Depending on their design, they may be used to fish at the surface, in midwater or near the seabed. They may be anchored to the seabed or be allowed to drift freely with marker buoys or the boat attached to it. We do not know this level of operational detail for fishing practices in Ponta do Mel and Cristovão and will therefore share a general understanding about drifting of passive gears. Passive gears have **higher risk to drift** if they are:

- Light,
- Long,
- Positioned perpendicular to the current,
- Set for a long time.

In this case study, gillnet fleets are typically 150 m long, which can be considered **relatively short** in comparison to other fisheries where net fleets may measure several kilometers. They are soaked for 2 hours, which is **very brief** in comparison to other fisheries where the gear can be soaked for several days. The mounted gillnets that were observed during the site visit can be characterized as **relatively light** based on the size and material of floats and lead lines (Figure 17). Pots observed in the area was mounted with relatively light weights (Figure 17); an example of a casting net design from Santa Catarina informs a diameter of 85 cm and weights of Pb 20 g/m (Oliveira et al., 2020).

Figure 17. Light bottom-set gillnets observed during the site visit in Ponta do Mel (left and middle) and weight for pots (Instagram account of local fisher "reginaldo.ryan9" accessed October 2024) (right),

Drift of passive gears is currently the **hot topic for coexistence** in France. A local fishers' organization is launching a study to quantify gillnet drift at Dieppe Le Tréport OSW, where their fishery reports drifting up to 2 kilometers. Such drifts would seem to be on the higher range, as other fishers have reported drifts of about 200-300 m in e.g. Britany OSW development zone (pers. com.). Literature reports sweeping of about 2 meters for gillnets (Savina et al., 2018) and almost no movement (in the order of cm) for pots (Kopp et al., 2020), but there are very few studies in situ due to the challenges of this type of experimental work at sea. Until now, the interest in gill net drift has mostly focused on mitigating marine mammals' entanglement or the seabed impact, and the software tool for modelling net drift (FineLab) still needs to be validated with in situ data (Benoît Vincent, IFREMER, pers. com.).

Gear modifications to prevent drift may include technical alternatives like changing the anchoring solution, e.g., heavier weights or sinking ropes, or shortening the net fleets, but also operational adaptation such as soaking time.

A study for crab traps in the Netherlands (Prinses Amalia OSW) tested **different types of Bruce anchors** to prevent hooking risk into the inter-array and export cable. A Bruce anchor looks like a claw with three curved flukes[13] extending from a long and straight central part (shank). It is designed to self-right if it lands upside down, is effective for a sandy seabed like the Dutch coastal zone and affordable for fishers. Modified Bruce anchors included variants with bars, steel cables or ropes from each end point of a fluke to the shank to prevent the anchor from hooking on the cable. It was however concluded that the modified Bruce anchors did not dig in well and were thus deemed unsuitable to securely anchor crab-pot-strings (Rozemeijer et al.,

[13] The fluke is the pointed part of an anchor designed to dig into the seabed and provide holding power.

2022). In addition, the study identified that **elongating the buoy line**, i.e., between the buoy and anchor could reduce the pulling of waves and currents and thus the potential drift (Rozemeijer et al., 2022).

In some OSW in France, there are ongoing discussions for attaching the passive gears directly to turbines, but this of course would add to the navigation hazards and could result in reduced catch rates. In gillnets, the interaction between gear and target species is a complex process, and any gear modification is likely to lead to changes in catchability and selectivity. One should also think about health and safety at sea; using heavier weights implies **higher handling strain and risk on the vessel's stability**, which might be especially of concern for small-sized vessels.

3.1.2. Penetration depth of mooring anchor

Although cable failures caused by longlines have been reported (Drew and Hopper 2009), passive gears are generally not the most frequent gear type reported in **hooking incidents**. One should however mention that this can happen when trying to recover lost gear with the help of a grapple (Drew and Hopper 2009).

While the fishers dive for lobster, the vessel is anchored (Figure 18). The anchor used is a **grapnel anchor** with four arms. The design ensures that at least one arm hooks onto seabed structure such as rocks or reefs, regardless of how the anchor lands.

Figure 18. A vessel anchored at the shore in Cristovão (left) in Ponta do Mel (right)

It is usually not allowed to anchor in OSW areas in Europe due to the risk of hooking a cable. Burying the cable is the most common mitigation measure for **protecting a cable**. The burial depth is based on the greatest recommended minimum depth associated with different anthropogenic risks (fishing, navigation) multiplied by a safety factor, and an added margin of sediment mobility that depends on the substrate conditions of the site. The choice of security factors depends on the developer's risk versus price assessment. An overall minimum burial depth of 0.5 m is recommended, as lower values are difficult to achieve in practice. Based on experimental results with a 400mm safety margin, Moore (2017) concludes that the most significant factor that influences anchor penetration depth is the size of the anchor. Guidelines then suggest that a **burial depth of 1 m** is sufficient for an anchor fluke length of about 0.7 m. One should note that cable burial is also likely to provide mitigation for the possible impacts of the electromagnetic fields induced by the cables on sensitive fish species (CMACS, 2003).

When the seabed does not allow for burial, e.g., bedrock, very heavy clay or boulders, alternative protection can consist of **protective mats, sleeves or shells made of cast iron**, or piles of boulders and rocks. Fishers may tend to prefer mats to boulders and rocks to reduce hooking risk, but rocks might be of interest in Ponta do Mel and Cristovão for the lobster fishery with respect to its potential for artificial reef effects. Indeed, it was reported during the site visit that lobster habitats have allegedly disappeared in recent years due to more sand depositing in the coast off Areia Branca. The causes are not investigated in detail, but a possible explanation (by one fisher) is the establishment of hydroelectric dams limiting the discharge of rivers and hence changing the sediment dynamics in the coastal areas. The capability of the cable protection structures to function as artificial reefs will however be driven by the specific design chosen for protection (Werner et al., 2024).

3.1.3. Safety at sea

The flat bottom hulls observed in Ponta do Mel and Cristovão are usually well-suited for fishing in shallow waters (Yu et al., 2021; Khalid et al., 2021), but their use in rough weather may pose difficulties especially for the vessels without motorization within OSW areas.

In addition, the small size of the vessels leaves **limited handling space on deck**, especially when they are equipped with a sail for daily trips with up to 5 crew members (Figure 19). Even for longer trips further from shore, with only two men are onboard, working around the clock with alternated deck shifts. This might reduce “deck crowding” but also increase the crew reaction time in case of an accident related to construction or operation of OSW, e.g., man overboard.

Figure 19. Deck organization of a small-sized sailing vessel in Ponta do Mel (left) and view of a deck operation at sea from the Instagram account of local fisher "reginaldo.ryan9" (right)

Fishers use **navigational aids**, such as very high frequency (VHF) radio and the global positioning system (GPS) (Soares et al., 2018). Vessels may carry survival equipment such as personal flotation devices and throwable flotation devices, but fishing grounds remain far from any first-aid assistance to the fishers.

4. Expected impacts and recommendations for coexistence

4.1. Pilot project

4.1.1. Exclusion zones

For a given fishing gear, the orientation and distance between turbines will determine whether it is possible to fish in sites with OSW. The coexistence potential is, however, **not only driven by technical considerations**, but also:

- the "willingness" of the developer to support the cost for coexistence e.g. cable protection and layout, as well as the OSW site maps, and navigation initiatives recommended by the fishers
- Generally available facilities and systems at sea, e.g. control, tracking of boats and communication devices
- National framework and regulations e.g. non-price tender criteria supporting coexistence

The insurance cost for the developer is also a factor. Indeed, OSW are generally covered against physical damage, accidents and natural hazards, but increased risk of navigational hazard due to interaction with a fishing gear or vessel might increase the insurance cost. The insurance does not cover the fisher though, who also pays for his own insurance, which should limit the risk of moral hazard, i.e., increased exposure to risk because one does not bear the full cost of that risk. It is usually agreed that if fishing is allowed, then the insurance cost for the fisher should not increase as the OSW infrastructures are then considered as any other sea infrastructure such as, e.g., buoys, but there is little data available to support such trends.

Authorization to fish is usually initiated by negotiations between fishers and developers for each project, which are then ruled by the Navy. A range of **different policies towards coexistence** between fisheries and OSW is seen throughout Europe (Bonsu et al., 2024):

- not allowed e.g. Germany,
- only allowed for experimental passive fisheries e.g. the Netherlands,
- only allowed for passive fisheries e.g. Belgium,
- sometimes allowed for passive gears e.g. Denmark (except for the Horns Rev 2 export cable open to trawling),
- generally allowed, even for active gears e.g. UK and France.

When fishing is not allowed, an exclusion zone around the full OSW site can range from 50 to 500 m (Bonsu et al., 2024). When fishing is allowed, there is usually an exclusion of **50 m around each turbine** and **200**

m around the substation[14] and inter-array and export cables. The design and size of exclusion zones are still an ongoing point of negotiation. For example, the Danish Fishers Producer Organization is asking for a revision of the current protection zones for cables as specified in the Danish Fisheries Act.

In addition, access to the OSW can be restricted based on various parameters such as (Bonsu et al., 2024):

- time of the day,
- weather conditions,
- vessel speed,
- activated VHF and AIS systems,
- no cohabitation between active and passive gears, and if possible, using **existing agreements between fleets**.

Adapting fishing gear to be OSW-compatible is theoretically a good idea, but in practice, changing fishing gear design to suit the wind farm can be very difficult. First and foremost, the alternative method should secure efficient fish capture. Not all vessels can switch gear types because the licenses often specify what type of fishing is permitted based on the vessel's design and safety regulations. There is also a tipping point when changing gear becomes economically viable. Finally, if this implies a change in target species, one should consider how this will affect quotas and markets.

An alternative preventive measure may consist in **marking the fishing gear** using e.g. radar, GPS tracking or floating lines and markers (Mahoney, 2005). Monitoring should not add burden on authorities, and an easy setup can just be for fishers to share the position of their gears with their peers and the developer, e.g., French fishers use a special WhatsApp group.

Ultimately, even when fishing is allowed, fishers are cautious and reduced fishing effort within OSW areas has been reported in the UK (Dunkley et al., 2022). To facilitate operation in OSW, **feedback from commercial fishers** recommends the following initiatives and measures from the OSW developers:

- Map of the OSW online or on a USB key, e.g. Kingfisher[15] provides information on subsea structures and the seabed to the fishing industry,
- 4G antenna in the park area to be able to communicate between boats,
- Native speaker onboard the OSW vessels to facilitate communication on site.

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[14] The electricity from the wind turbines is collected at the substation, where it is converted to travel efficiently over long distances before being sent to land.

[15] https://www.seafish.org/safety-and-training/kingfisher-information-services/

If a **“Rigs-to-Reefs" strategy** is chosen, i.e., keeping the base of the turbine foundation to act as artificial reef after decommissioning, exclusion zones may remain (Lemasson et al., 2022).

4.1.2. Effect on the resource

Effects on benthic habitat can be considered relatively minor overall, but it is recommended to avoid sensitive features such as complex habitat. Depending on site-specific conditions and geographical locations, baseline disturbances, e.g. severe storms or seasonal changes in ocean currents, may have relatively larger effects than foundation installations on benthic habitats (ICF, 2020). There is documented evidence for **stepping-stone and local artificial reef effects** e.g. at the Block Island Wind Farm in the USA, and introducing hard structures can provide surfaces for colonization of sessile[16] benthic species (Bergström et al., 2014; De Mesel et al., 2015; Degraer et al., 2020; Haggett et al., 2020; Wilber et al., 2022). In this context it is important to note the limited size of the pilot project in Areia Branca, which may result in a localized reef-effect. A possibility could be to create additional artificial reefs for lobsters in the vicinity of the turbines.

Crustaceans such as lobsters are common target species for commercial fisheries in wind development areas, and in the UK long-term monitoring indicates no negative effect of OSW on the lobster population ecology (Roach et al., 2018). The effect of sound emitted by the OSW in operation is likely restricted to masking animal communication and orientation signals, rather than causing physiological damage or permanent avoidance reactions (Popper and Hawkins, 2019; Gill et al., 2020). Movement and behavioral changes in response to subsea cable electromagnetic fields are possible for species that migrate/orient using magnetic/electric cues (Gill et al., 2020). Other factors that can affect the different stages of aquatic organisms are the changes in hydrography and turbidity, especially for larval dispersal and distribution (Gill et al., 2020).

4.1.3. Adaptive capacity

Even small decreases in revenue and increases in cost can have implications to fishing **community livelihoods and well-being**, especially as in this case, for indigenous communities and persons without a high school diploma (Willis-Norton et al., 2024).

The greater the **dependence**, the more sensitive an individual may be to loss of fishing opportunity (Willis-Norton et al., 2024). Adaptive capacity is often higher for **fishers that can work out of multiple ports** and for members of a fishing cooperative that are working with partners.

[16] Fixed

Socio-cultural information documenting adaptive capacity and challenges for fishers at all levels of organization have informed (Kruse et al., 2024; MMO, 2024):

- difficulty finding competent staff,
- difficulty identifying successors willing to take over the family business,
- self-image and identification to fishing,
- innovative capacity and entrepreneurship e.g. new ways of fishing, technology and marketing,
- political support,
- accessing loans for investment.

4.1.4. Fishery compensation

Estimation of loss of fishing opportunities and indirect effects are usually part of the environmental impact assessment, but the government can request a separate socio-economic study on fisheries with a follow-up (e.g., French tenders) if the national framework for EIA is not specific enough to include all the relevant aspects of fisheries socio-economic systems. Generic EU guidelines can be found (van Hoey et al., 2021), but there is currently no common methodology across European countries. Assessing environmental and socio-economics effects requires a good understanding and monitoring of fisheries, usually based on VMS/AIS and log-book data, interviews with the fishers, ICES catch data and/or fish surveys. For small-scale fisheries however, it can be the case that there is no VMS/AIS, and some fishers' local organizations have developed **custom monitoring systems**[17].

When impact mitigation is not possible, fishers may receive **compensation for lost fishing opportunities**, i.e., disruption to fishing effort and fish stocks, in the form of (Hooper et al., 2015; Reilly et al., 2015; ten Brink & Dalton, 2018; Roach et al., 2018; BOEM, 2020; Haggett et al., 2020; Schupp et al., 2021; Bonsu et al., 2024):

- Individual financial compensations (preferred in Denmark in most cases),
- Funds and/or collective measures to support fisher navigational and safety equipment, deflect any increase in insurance costs and support research and innovation (preferred measures in the UK, France and the USA),
- 5% of funds from offshore bids are allocated to support environmentally friendly fishing (in Germany).

Collective measures may aim at a win-win solution not necessarily directly related to the OSW impact but customized to local needs, e.g., new cranes or tractors, or in relation to energy transition. In the context of the pilot project led by SENAI with a strong expertise in energy technologies, one could consider

[17] https://valpena.univ-nantes.fr/

decarbonated alternatives e.g. bio- or e-methanol for motorization of the sailing vessels, which appear to be good candidates based on the vessel size and the annual number of days at sea. Collective measures might be more efficient in the small communities due to the difficulty in monitoring the economy at the level of the different vessels and fleets. They might then support access to electricity, insurance, GPS equipment, and communication equipment to the fishing vessels to allow safe navigation around turbines.

4.1.5. Diversification and community-led initiatives

OSW can provide **opportunities for fishers to diversify or supplement income**, such as (Lilley et al., 2010; Alexander et al., 2013; Reilly et al., 2016; ten Brink & Dalton, 2018; Haggett et al., 2020):

- vessel guard or survey assistance,
- selling fuel to the developer,
- retrofitting or purchasing new vessels to work for the wind sector,
- developing offshore wind e.g. Fishermen's Energy Inc. in the USA,
- chartering for touristic purpose e.g. nature or fishing tours.

Fishers may tend to prefer diversification alternatives that will allow them to continue their activity at sea. Older fishers with a longer history of fishing and no other employment experience may have lower **capability of switching into alternative careers** (Willis-Norton et al., 2024).

This seems different in the context of the project in Ponta do Mel and Cristovão where other family members are not necessarily willing to continue fishing. The recent development in multi-uses focuses on offshore aquaculture (Koundouri et al., 2017), but on-land systems such as aquaponics[18] may be a significant/important **empowerment tool for small communities** (Muñoz-Euán et al., 2024).

It might be useful to collaborate and get support from already developed local initiatives. During the visit, the role of Bloomberg Philanthropies[19] in the energy transition was mentioned, and their Vibrant Oceans Initiative[20] aimed at community-led solutions for small-scale fisheries might be relevant for collaborations.

[18] Aquaponics couples aquaculture (raising aquatic animals such as fish, crayfish, snails or prawns in tanks) with hydroponics (cultivating plants in water with the nutrient-rich aquaculture water).

[19] https://www.bloomberg.org/

[20] https://www.bloomberg.org/environment/protecting-the-oceans/bloomberg-ocean/

4.2. Large-scale OSW buildout

4.2.1. OSW layout

OSW layout, and thus cable layout, are important factors that define coexistence options and thus impact for larger buildouts. Wind farms are designed so that one wind turbine doesn't block the wind flow from the next, to maximize production, currently at distances **between 6 and 10 rotor diameters apart**.

Straight rows of turbines organized in a grid usually facilitate coexistence, i.e., the safe operation of fishing gears but also search and rescue (Pol & Ford, 2020). This is especially true if there is a relatively **large distance between turbines**, i.e., about 1 km for today's turbines. With wind turbines becoming larger and therefore more spaced from each other to limit the wake effect, future wind farms should have a density of less than 3.5 MW/km² of installed capacity, which should allow more configurations of the turbine positions to facilitate fishing such as **corridors** (ABPmer, 2002). Indeed, a study in the UK suggests that the configuration of the turbines in two separate plots allows vessels to move and fish in the OSW without entering the rows of turbines (Dunkley et al., 2022). The Massachusetts and Rhode Island Port Access Study concluded that wind turbines should be positioned in **uniform grids**, preferably with a minimum of three differently oriented transit paths, but the recommendation for uniform grids has not always been approved by the fishing industry (on a case-by-case basis depending on the project) (NYSERDA, 2022).

It should be noted that the development of corridors must generally be accompanied by a **cable layout** limiting the risk of hooking in these corridors.

4.2.2. Conflict with active gears

A reduction in commercial fishing activity inside OSW can lead to a **spatial redistribution in fishing effort** to other areas (Gill et al., 2020). Because of the narrow continental shelf in the Areia Branca region (Short & Klein 2016), larger OSW parks in Areia Branca may force some vessels to change fishing ground, with potential **conflicts for space** between the different fisheries. As the industrial sector is growing (Carvalho, 2016), there might be a risk of overlap with the l**arger vessels working further offshore**. These larger vessels may deploy active gears such as trawl and seine. Active gears are usually larger vessels, which means that they can sail more easily to other fishing grounds than smaller vessels deploying passive gears and may thus more easily report their activities outside of the OSW areas. However, active gears are also less likely to comply with OSW coexistence requirements due to higher risk of hooking cables for trawls and a large spatial footprint for seines.

Planning OSW outside of the most profitable fishing areas can help mitigate user conflicts among sectors (Kruse et al., 2024). Choice of zones for wind project development should be **large enough to allow the possibility of designing** corridors / groupings of turbines or spacing between turbines to facilitate coexistence scenarios, especially for bottom-fixed installations. Mapping fishing activities and potential fleet conflicts from OSW can be addressed in the context of **Marine Spatial Planning** (Haggett et al 2020), in line with the current mapping research efforts in Brazil (Oliveira Leis et al., 2019; Silva, 2024).

4.2.3. Tender and Consent application

The **power balance** between the developer, the fishing industrial sector and the marginalized small-scaled communities, sometimes operating undeclared, should be considered and may call for careful regulation following international standards for public participation and early involvement.

The consent application to the authorities may include **specific requirements for coexistence** (van Hoey et al., 2021; Reilly et al., 2015):

- Inter-network cable configuration - reducing its spatial footprint
- Cable burial (depth / type recommendation)
- Consultation of the development of the wind farm with professionals, e.g., possibility of coordinating the work phase,
- Plans to recruit local residents or businesses.

To facilitate consultation with professionals on key technical decisions such as the configuration of the wind farm, the use of **envelope authorization**, i.e., EIA submitted with variable characteristics of the OSW, may be helpful (Anchustegui and Hunter, 2024).

Wind development in general can benefit from being accompanied by involving and encouraging the local community and stakeholders (Schupp et al., 2021):

- in situ device testing and research and development projects,
- Improving environmental and socio-economic assessment methods,
- Increasing stakeholder knowledge of available fishing practices and wind technologies, for coexistence (educational resources and funding for direct dialogue forums),
- Demonstrating the benefits of coexistence for developers in terms of e.g. corporate social responsibility, corporate reputation, faster consultation, should include cost, analysis of coexistence options compared to compensation schemes,
- Ship fittings and financial cost of adaptations incl. vessel licensing if relevant.

4.2.4. Direct, indirect and cumulative effects

In the perspective of large buildouts, the spatial and temporal aspects of impacts require the assessment of **cumulative impacts on the ecosystem**. Cumulative effects on physical processes from multiple turbines or adjacent wind projects are not expected to be perceptible because of the wide spacing between individual turbines (at least 500 m) (ICF, 2020). One should however be careful with respect to the regional-scale artificial reef effects that may occur when OSW are sited in proximity to each other. Indeed, the introduction of numerous new hard substrates such as turbines and scour protection over large regional areas dominated by fine sediments may act as a **steppingstone for non-indigenous species** (Dahl et al., 2023).

Before-after-Control-Impact (BACI) designs of OSW projects have commonly been used to make comparisons of post-construction with a reference condition. **Distance-based** methods, or a combination of distance-based with before-after design, are more recently considered for characterizing the spatial and temporal variance associated with OSW and fisheries (Methratta, 2021). There are also specific recommendations for the different compartments to be studied, e.g., underwater noise can be evaluated using the Population Consequences of Acoustic Disturbance model (Hawkins & Popper, 2017; Svendsen et al., 2022). If fisheries and environmental data are collected, **several years** of data should be included in the assessment.

Fish surveys are usually conducted using traditional capture techniques, but recent developments can allow alternative methods, e.g. fine-scale positional data from telemetry (Bicknell et al., 2025), underwater video or eDNA. It is our experience that including commercial fishing gears, though it might require additional sampling effort in parallel of the survey gears, can help fishers be more mindful and trustful of the assessment.

Overall, assessments rely heavily on existing knowledge about the OSW development area, and one can only recommend moving towards data collection and monitoring in an **ecosystem-based approach**[21].

[21] https://missionatlantic.eu/tools/

5. A few words on negotiation and effective community engagement towards a just transition to renewable energy

5.1. Fishers' engagement

Engagement should start early, i.e., before the environmental evaluation process and consent application, and be maintained through the life cycle of the project (Alexander et al., 2013; FLOWW, 2014; Aitken et al., 2016; Reilly et al., 2016; Haggett et al., 2020;). This implies **sufficient time and monetary compensation for representative participation** (van Hoey et al., 2021).

It is now common in the UK, USA and France, to hire a **Fisheries Liaison Officer** (FLO) who provides information to fishers, conveys their concerns and issues to the developer, and convenes meetings as appropriate (Moura et al., 2015; McCann et al., 2013; Haggett et al., 2020). The FLO is hired by the developer directly (e.g. Ørsted Sea Services) or through independent entities, such as consultants (e.g. Brown and May Marine Ltd) or commercial division of fishers' organizations (e.g. National Federation of Fishermen's Organisations Services). The latter is becoming more and more common and may facilitate compromises (Stelzenmüller et al., 2020).

The tendency is also for the fishing industry to form coalitions e.g. the Responsible Offshore Development Alliance (RODA) in the USA Atlantic coast with 170 fishing industry associations and companies (Haggett et al., 2020). This can favorize representative participation as it creates a single point of contact for different projects, **enhancing consistency, and minimizing disruption to the fishers' time.**

Sharing a **common understanding of terminology and constraints towards co-design** is key in establishing trust between fishers and developers, and can be supported by (Schupp et al. 2021):

- Return and sharing of experience from other fishers,
- 2D and 3D visualization of the gears in relation to the OSW,
- Participation in sea trials (use of commercial gears and / or vessels),
- Demonstration of different risk scenarios at sea with the fishers and the Navy,
- Sharing data across industries e.g. underwater images or bathymetric survey data by developers to demonstrate to fishers that fishing can take place safely at wind farms.

Consultations to limit the impact on fishing may then include:

- Micro-siting of the turbines and cables before construction,
- Choosing where to displace boulders during site preparation,
- Phasing of the construction and/or operation and maintenance.

5.2. Examples for tailoring communication with fishers

Few fishers are likely to read long technical reports, so outputs and communications from developers and authorities must be easily available and understandable (de Groot et al., 2014). Guidelines on how to provide easy-to-read information can be found here Inclusion Europe.

Face-to-face meetings and **personal interactions** are preferred (Gray et al., 2005; Haggett et al., 2020) but channels of communication may need to be adapted, depending on local fishing community preferences, e.g. Facebook (Reilly et al., 2016).

Difficult coexistence is often brought about by an accumulation of **other pressures** on the fishing activity, e.g., reduced fish stocks, competition for space at sea, and growing environmental and climate requirements. It is thus important to understand fishers' daily challenges. It is our experience that, especially in the beginning of the project, spending time at the harbour or on the vessels is very helpful. In addition, fishers may lack trust in developers, government, and other authorities, and it is therefore important to **deliver on promised outputs** (Mackinson et al., 2006; de Groot et al., 2014; Haggett et al., 2020; Alexander et al, 2013).

5.3. Participatory tools like SeaSketch

Decision support tools should aim at developing a collective understanding and discussion based on quantitative predictions of impacts and beneficial/detrimental effects on fishing activities of different OSW scenarios. Such a tool can be used for research purposes[22], but also on a **participatory platform** such as "SeaSketch" currently considered for the Brazilian MSP[23].

Return of experience from the public debate in France has however shown that use of online tools facilitated the extraction of results but were unable to facilitate the involvement of the public (Guyot-Téphany et al., 2024).

5.4. Good practices for human interaction

One of the key aspects to a just transition is to ensure that those affected are recognized and can participate in decision-making. (Haggett et al., 2020). Firestone et al. (2020) found perceptions of **developer openness and trustworthiness** to be the most important determinant of **process fairness** (Klain et al., 2017; Haggett et al., 2020).

[22] https://displace-project.org/blog/download/

[23] https://next.seasket.ch/brasil/app

As women are often marginalized from participation in fisheries governance, any efforts to develop new, or reform existing institutions, should reduce gendered power-inequities in participation (Gustavsson et al., 2021).

A just energy transition is also in debate in Denmark, where ongoing research maps how **society, market and policy** can lead to a just energy transition[24]. **Co-ownership models** for example can foster local support but also ensure that the economic benefits of renewable energy are shared more broadly.

[24] https://www.youtube.com/watch?v=rQFJj1mphio

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7. Appendix

Summary of fleet characteristics. Data gaps in grey.

		By foot	0-5 m	6-11 m
Fleet capacity	Number of vessels	-	-	-
Vessel effort	Engine size	-	Complemented by sail	18-70 HP
	Storage size		Ice in cooling box	
	Number of crew	(women)	2-5 (men)	
	Sea autonomy	1 day	1-3 days	5-11 days
	Spatial range	Shore	Up to 5 nm	Up to 18 nm
	Fishing grounds		Sometimes hard bottom with pots and traps, proximity to corals and canyon	
	Gear size		GNS: 150m long	
	Soak time		GNS: 2hrs	
Catch	Target assemblage	Shellfish and crustaceans	Mixed crustaceans and demersal fish	
	Composition	Target species	80% target species (lobster) 20% discard fish (not fit for market) used as bait or own consumption	
	Rates in kg	-	-	-
	Rates in value	-	-	-
Costs of the fishery	Running costs	-	Food and fuel R$ 100-150	-
	Fixed costs	-	1 vessel = 15k R$	-
	Market	Own consumption	Export	
	Income	-	Up to 2k R$ a week	
Social	Gender	Women	Men	Men