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# Environmental Compatibility of the Parc Tramuntana Offshore Wind Project in Relation to Marine Ecosystems

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**Abstract:** Parc Tramuntana is the first offshore wind project being promoted in the Catalonian waters, and due to this newness, it has generated a strong social debate surrounding expected environmental and socioeconomic impacts traditionally associated to marine wind farms, as there are no relevant references in this area. The objective of this report is to provide a specific analysis of some of the main potential impacts, based on detailed information and quantitative data, in order to place these impacts in a realistic context and determine their actual magnitude. This analysis is fed by diverse and detailed studies carried out over the last two years to assess the environmental impact of the project, in accordance with current regulations. According to environmental impact assessment, which is based on a standardized methodology, the impact of the project is objectively qualified as MODERATE on vectors such as turbidity and sedimentation, underwater noise, hydrodynamic circulation or the alteration of electromagnetic fields, and NOT SIGNIFICANT on aspects such as the proliferation of invasive exotic species. As this is an ongoing assessment process, this report presents initial conclusions that do not yet address all possible impacts. Nevertheless, the authors stress the importance of framing the debate on offshore wind in Catalonia in the context of the urgency of the climate emergency and its inevitable impacts on the natural environment.

**Keywords:** offshore wind impacts; turbidity; sediment dispersion; electromagnetic fields; acoustic impact; marine hydrodynamics; invasive species



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## 1. Introduction

Currently Catalonia, as well as the surrounding regions and countries, faces a situation of climate emergency, a situation that has been recognized both by the Generalitat de Catalunya [1], the Spanish Government [2], and the European Parliament [3].

It is hence a situation that involves the adoption of urgent measures to reduce the carbon emissions for which our energy and production model is responsible. It is therefore not only advisable, but essential, among other actions, to propose important changes in Catalonia's energy generation model, which involve the progressive replacement of non-renewable sources, which currently provide more than the 80% of the electricity generated, with renewable sources, including offshore wind. This strategy has been developed in Catalonia through the *Pacte Nacional per a la Transició Energètica de Catalunya* (National Agreement for the Energy Transition of Catalonia) and has been embodied in the Preliminary Draft of the Energy Transition Law, which contemplates large, medium, and small-scale renewable electricity generation, mainly by local sources (Strategy n° 12) [4].

According to the energy prospective studies for Catalonia with a 2050 horizon (PROENCAT 2050) [5], in order to meet the energy and environmental objectives Catalonia has been committed to comply, by 2030 it will be necessary to incorporate up to 12,000 MW of renewable production into the system (of which 1000 MW should correspond to offshore wind), a figure that should grow to more than 61,000 MW by 2050 (with a total contribution of 3500 MW from offshore wind). This new renewable capacity should make it possible to supply a demand characterized by a greater electrification of the economy, facing the expected closure of nuclear power plants and drastically reducing the current dependence on non-renewable sources, of foreign origin and with a high impact on greenhouse gas emissions.

Once the need to develop offshore wind energy in Catalonia has been assumed, its spatial development should be approached on the basis of criteria that incorporate and allow the complexity of the marine environment to be assessed, weighing the advantages and disadvantages of each area and the benefits and impacts of offshore wind farms on the whole of the territory and Catalan society.

Marine spatial planning plays an important role in this task. In recent years, the Spanish Ministry for Ecological Transition and the Demographic Challenge (*MITERD*) has been working, in coordination with many other Spanish state administrations and each of the autonomous communities of the Atlantic and Mediterranean arc, to develop Marine Spatial Management Plans (POEM) [6], which are currently under review following the presentation of their draft for public information and consultation, in order to incorporate the relevant modifications resulting from the allegations received, as a step prior to their approval by Royal Decree.

It should be noted that these plans are not arbitrary or based solely on economic or territorial interests, but that their approach responds to the assessment of a set of criteria that ensure that the combined pressure of activities in the marine environment is maintained at levels compatible with the achievement of good environmental status (GES), and that they do not compromise the capacity of marine ecosystems to respond to changes induced by human activity. An ecosystem approach has therefore been followed for its definition, considering both the interactions between land and sea, as well as the expected changes resulting from climate change.

Besides that, the challenges that the development of offshore wind in Catalonia and Spain face are not few, largely due to the newness of this type of project in Spain. One of these challenges is the adaptation of new projects to a constantly evolving regulatory framework to incorporate this new technology into the Spanish energy model, but also with a certain social rejection, characteristic of any change in strategy and implementation of new technologies for the first time in the country. The influence of this regulatory framework, especially regarding the environmental impact assessment process of this kind of project was already analyzed by Salvador et al. (2018) [7].

From the point of view of the possible social reticence to the development of offshore wind power in Catalonia by some economic stakeholders and some members of the scientific community, the social debate on this new technology is often justified on the basis of the lack of specific references of similar projects in operation in the Mediterranean that allow to accurately foresee the possible impacts that this type of projects can generate in the area of implementation, generating uncertainty.

While onshore and fixed founded offshore wind farms are quite widely installed around the world and provide relevant references on their impacts on the environment along their entire life-cycle (see e.g., Verma et al., 2022 [8] or Kouloumpis and Azapagic, 2022 [9]), and the adverse environmental impacts of different wind generation technologies have been already assessed (mainly in onshore context) [10], there are still many effects that cannot be directly extrapolated to floating offshore wind farms, producing a significant knowledge gap regarding the impacts of this technology in the environment.

This lack of applicable references means that some voices tend to assimilate as their own, without a rigorous analysis, other offshore wind experiences in the North Sea or the Baltic, where both the technological characteristics of wind farms (mostly with fixed foundations) and the environment (depth, dynamics, ecosystems, etc.) are very different from those of the projects proposed in Catalonia.

It should be noted in this regard that, although there are currently no floating offshore wind projects in operation, the French Government has already taken the first step to be the pioneers in the Mediterranean, approving the installation of a pilot floating offshore wind farm, called "*Eoliennes Flottantes du Golfe du Lion*" (EFGL), and two other pilot farms ("*Eolmed*" and "*Provence Grand Large*") are in progress.

The EFGL wind farm consists of three 10 MW turbines, to be installed 16 km off the coast of Leucate, and within the perimeter of a protected area of the Natura 2000 Network, the marine natural park of the Gulf of Lion, the due Environmental Impact Study having been carried out and its impact considered compatible with the conservation objectives of this protected area. The other two wind farms are also planned with three turbines each, with power ratings between 8 and 10 MW, and at a distance from the coast of between 14 and 18 km.

In addition, on 14 March 2022, the French government confirmed its intention to build an additional 500 MW of floating offshore wind power in the Mediterranean by 2030.

## 2. Motivation

In this context, given the urgency of developing new renewable generation projects, due to the limited time available to meet emission reduction targets, and the periods required for the processing and technical development of projects, several developers specialized in offshore wind have begun to work, both in Catalonia and in other regions of Spain, to respond in the imminent future to the demand for these types of facilities.

One of these developments, pioneered in Catalonia in terms of technical maturity and coordination with the territory, Parc Tramuntana, proposes the installation of a floating offshore wind farm off the coast of the Empordà.

This project is being developed with the premise of integrating the participation of the territory from the earliest stages of conception, applying all the way and in all aspects of the design the best existing practices at the state-of-the-art level to ensure compliance with the so-called Precautionary Principle, which supports the adoption of protective measures against the possibility of a technological risk to the environment, without yet having a definitive scientific proof of such risk.

Likewise, the project, which has not yet been submitted for environmental processing, will follow all the way the environmental and administrative procedures required under current legislation, which includes the preparation and processing of the due Environmental Impact Study, including the process of public information and consultation with all the competent administrations.

The process leading to the selection of the most suitable site and the design proposal of the offshore wind facility has been and will continue to be a living and evolving process. It has started from an initial approach, based on the energy demand, the availability of connection to the electricity grid, the conditioning factors imposed by the legislation in force (environmental, sectorial, town planning, etc.), maritime and airspace planning and the characteristics of the site, and has evolved (in size and technical solutions) through the incorporation of additional requirements and conditioning factors derived from the conversations held with different stakeholders of the territory and society.

This report analyzes some of the aspects and potential impacts of the project that have generated some debate in the scientific community. This is the case of the recent publication of the article by Lloret et al. (2022) in the journal Science of the Total Environment [11], intending to serve as a reference for the evaluation of environmental impacts related to floating wind technology in the western Mediterranean. This purpose is also oriented towards introducing accuracy in the data analysis and promoting the debate with some sectors who systematically express opposition to this type of renewable generation project without a detailed analysis of its impacts on the environment.

## 3. General Description of the Parc Tramuntana Project

The Tramuntana Floating Offshore Wind Farm Project consists of the installation of an offshore renewable energy generation farm on the continental shelf of the province of Girona, at a distance of approximately 24 km from the coast of the Bay of Roses, in a range of depths between 120 and 180 m and on thick silty and detritic seabed, with a total absence of rocky outcrops. The turbine closest to the coast is located 14 km from Cap de Creus.

The wind farm is located within the area designated in the draft of the *POEM* for the Levantine-Balearic demarcation as a priority area for offshore wind (LEBA-2, Figure 1), being the only area identified in Catalonia as suitable for this type of activity. This site also partially coincides with a permanent closed area for trawling and is located outside protected natural areas.

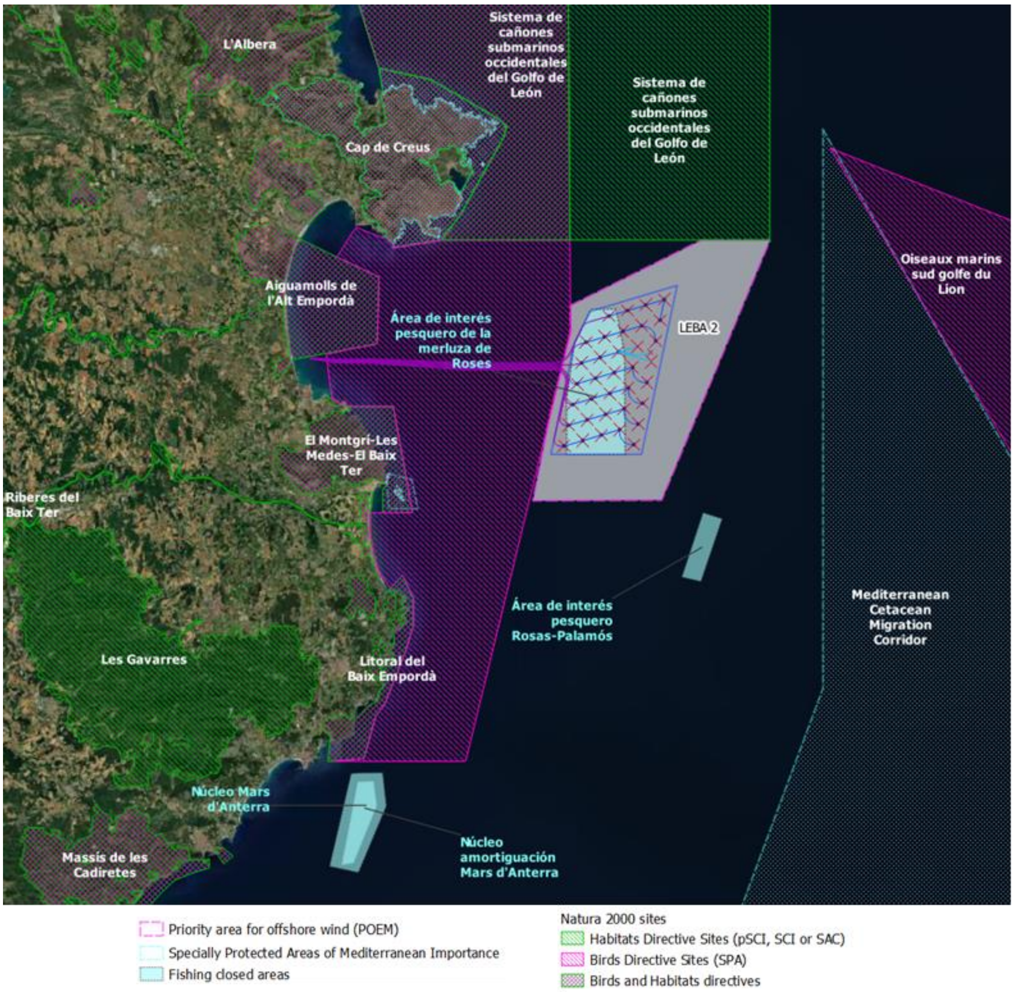



**Figure 1.** Location of the Tramuntana Floating Offshore Wind Farm Project in relation to environmental protected sites and other uses of maritime space.

The proposed solution consists of the following elements (Figure 2):

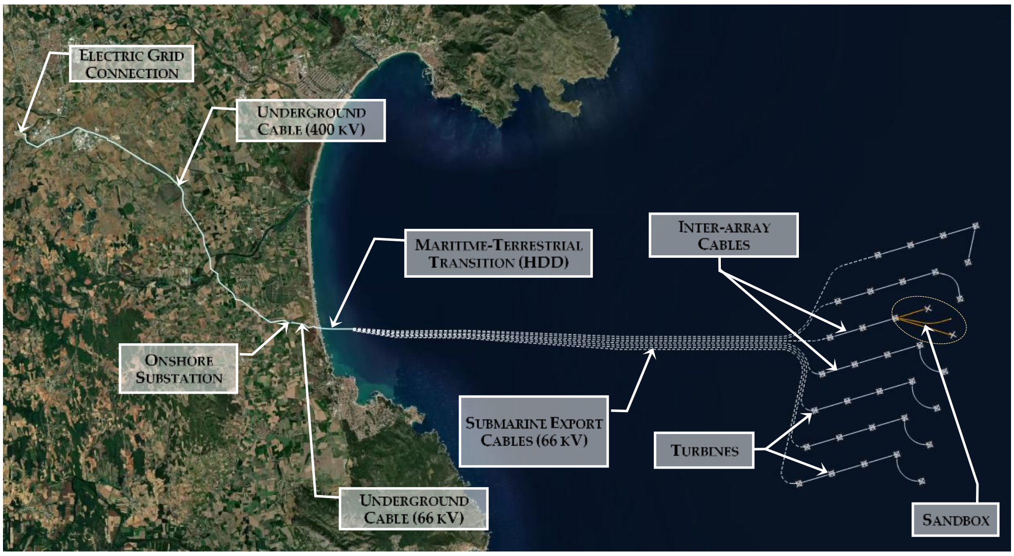



**Figure 2.** General layout of the Tramuntana Floating Offshore Wind Farm Project.

- Wind farm: it will have a total of 36 renewable energy generation positions, arranged in 7 rows perpendicular to the coast, in ENE direction (~N73° E). Initially, it will consist of 33 turbines of 15 MW and an R + D + i platform equipped with 3 positions for testing experimental devices (sandbox), with a total combined power of 500 MW. When fully developed, this sandbox will be replaced by 2 additional turbines of 15 MW each, with a maximum power of 525 MW;
- Submarine electrical cabling system for the interconnection of devices (inter-array cables) and subsequent export of the energy generated to shore (export cables). The export cables, which will be buried, run 24 km to the coast, in the municipality of Sant Pere Pescador;
- Maritime-terrestrial transition to the cable landing area on the coast, by means of HDD technique, and connection between the submarine cables and the terrestrial cables by transition boxes at the landing point;
- Terrestrial underground cabling (66 kV) for the connection between the transition boxes and the electrical substation, located approximately 1 km from the coast;
- Transformer substation, to raise the export voltage to 400 kV and provide the export electric circuit with the appropriate characteristics for connection to the onshore power grid.
- Terrestrial underground high-voltage conduction system (400 kV), to discharge the energy generated to the Spanish grid through the Santa Llogaia substation, near Figueres.

The estimated net energy production is approximately 1800 GWh/year, equivalent to 45% of the current consumption of the province of Girona, both household and industrial. The project includes a research platform, which will be developed in collaboration with the *Institut de Recerca d'Energia de Catalunya* (IREC) and will serve as a sandbox for different lines of R + D + i in the field of offshore renewable energy harnessing, as well as in other compatible uses of marine space such as aquaculture, fishing recovery, etc.

The wind farm takes up an area of approximately 95 km$^2$ where floating turbines and their anchoring systems are located. This area represents less than 0.12% of the surface of the Exclusive Economic Zone (EEZ) corresponding to Catalonia.

The 15 MW turbines have a total height of 261 m and a rotor diameter of 236 m, and are installed with a separation between turbines of between 1.2 and 2.5 km. They are attached to the seabed by 3 or 4 catenaries, each about 650 m long, attached to an anchor that remains buried about 14 m below the seabed.

The turbines are connected to each other by dynamic inter-array cables, which partially rest on the seabed, and from the end of each row of turbines comes an export cable, buried between 1.5 and 2 m below the seabed, which carries the generated energy to land. In the land–sea transition zone, a solution using small diameter perforations (Horizontal Directional Drilling or HDD) has been adopted to facilitate the landing of the cable without altering the seabed or the biological communities settled on it.

From the grounding point to the connection with the electrical grid, all the high voltage conduits are projected buried, to minimize the environmental and landscape impact.

Keeping this development proposal as an objective, since it is considered necessary to provide the Catalan system with this minimum capacity of marine renewable generation, the possibility of a phased development of the project is also proposed, so that a single array can be initially executed together with the sandbox facility. This would allow to advance in the installation of the general energy export infrastructures, and to have for a certain period of time a testing and demonstration facility to validate these types of wind farms in the Mediterranean and to verify their environmental and socioeconomic compatibility.

## 4. Methods of Analysis

In the analysis of impacts carried out in the Environmental Impact Study of the project, still under development, an identification and quantification methodology was used, which is based on the methodology proposed by *Conesa* (1995) [12], in accordance with the requirements included in Annex VI of Law 21/2013, modified by Law 9/2018, regarding the identification, quantification, and assessment of the foreseeable significant effects of the projected activities on the environment.

It is important to differentiate, regarding impacts, those occurring during the construction phase, which has a more limited duration in time, from those occurring during the operational phase, which may be prolonged throughout the service life of the facility. In addition, due to the nature of this project, which extends over both the marine and terrestrial areas, it is necessary to differentiate between the two areas when assessing the environmental factors affected.

In this report, a preview of the assessment of some of the main impacts on the marine environment, related to the conservation of biodiversity and the good environmental status of the area, is made in order to dispel doubts regarding some of the potential impacts that represent a major concern for the authors of the article of Lloret et al. (2022) [11]. It is important to mention that, for each of the potential impacts preliminarily identified by means of a Leopold matrix, each of the following attributes were characterized (Table 1).

**Table 1.** Impact classification table.

| Attribute | | Degree | Description | Value |
|---|---|---|---|---|
| Nature (Sign) | Beneficial (+) or detrimental (-) nature of the impact. | Beneficial impact | Improvement in the current situation | + |
| | | Detrimental impact | Loss in current situation | - |
| Extension (EX) | Theoretical area of influence of the impact in relation to the project's surroundings (% of area with respect to the surroundings in which the effect is manifested). | Isolated | | 1 |
| | | Partial | | 2 |
| | | Extensive | | 4 |
| | | Total | | 8 |
| | | Critical | | 12 |
| Persistence (PE) | Time of permanence of the effect from its appearance, after which the initial conditions prior to the action are recovered. | Sporadic | <1 year | 1 |
| | | Temporary | 1–10 years | 2 |
| | | Permanent | >10 years | 4 |
| Synergy (YES) | Reinforcement of two or more single effects caused by simultaneous actions. | No synergies | - | 1 |
| | | Synergist | Moderate synergism | 2 |
| | | Very synergist | Highly synergistic | 4 |
| Effect (EF) | Cause–effect relationship, form of manifestation of the effect on a factor as a consequence of an action. | Indirect | It has an immediate impact on the relationship of one environmental factor to another | 1 |
| | | Direct | With immediate effect on an environmental component | 4 |
| Recoverability (MC) | Possibility of total or partial reconstruction and return to the initial conditions prior to the action, by means of human intervention (introduction of corrective measures). | Short-term/immediately recoverable | <1 year | 1 |
| | | Recoverable in the medium term | 1–10 years | 2 |
| | | Mitigable | Alteration that can be reduced by corrective measures | 4 |
| | | Irrecoverable | Alteration impossible to repair | 8 |
| Intensity (IN) | Degree of impact of the action on the factor, in the specific area in which it acts. | Short | | 1 |
| | | Medium | | 2 |
| | | High | | 4 |
| | | Very high | | 8 |
| | | Total | | 12 |
| Moment (MO) | Manifestation period or time elapsing between the occurrence of the action and the beginning of the effect. | Long term | >10 years | 1 |
| | | Medium term | 1–10 years | 2 |
| | | Short term | <1 year | 3 |
| | | Immediate | 0 | 4 |

**Table 1.** *Cont.*

| Attribute | | Degree | Description | Value |
|---|---|---|---|---|
| Reversibility (VR) | Possibility of returning to the initial conditions prior to the action, by natural means, once the action ceases to act on the environment. | Short term | <1 year | 1 |
| | | Medium term | 1–10 years | 2 |
| | | Long term | 10–15 years | 3 |
| | | Irreversible | >15 years | 4 |
| Accumulation (AC) | Progressive increase in the manifestation of the effect, when the action that generates it persists continuously or repeatedly. | Simple | No side effects or cumulative effects | 1 |
| | | Cumulative | It increases in severity over time | 4 |
| Periodicity (PR) | Regularity of manifestation of the effect. | Irregular | Appears in and irregular manner | 1 |
| | | Periodic | Appears periodically | 2 |
| | | Continuous | Appears in a constant manner over time | 4 |

The combination of the valuation of the attributes described above for each analyzed impact was carried out in accordance with the methodology proposed by Conesa (1995) [12], according to the following formula:

$$I = 3IN + 2EX + MO + PE + RV + SI + AC + EF + PR + MC \quad (1)$$

results in a standardized and objective characterization of its significance, which may be COMPATIBLE, MODERATE, SEVERE, or CRITICAL impact. In order to properly understand how these impact categories are defined, their definitions are included below:

- Compatible Environmental Impact (C): impact whose recovery is immediate after the cessation of the activity, not requiring protective or corrective actions. $I \leq 25$;
- Moderate Environmental Impact (M): impact whose recovery does not require intensive protective or corrective practices, and in which the achievement of the initial environmental conditions requires a certain amount of time. $25 < I \leq 50$;
- Severe Environmental Impact (S): impact in which the recovery of environmental conditions requires the application of protective or corrective measures, and in which, even with these measures, recovery requires a long period of time. $50 < I \leq 75$;
- Critical Environmental Impact (Cr): impact whose magnitude is greater than the acceptable threshold. This results in a permanent loss of the quality of environmental conditions, with no possible recovery, even with the adoption of protective and corrective measures. $I > 75$.

It is worth noting that the analysis focused on a set of negative impacts, leaving in the background the more positive aspects of the project, mainly related to the contribution to the reduction of GHG emissions, which will indirectly help mitigate the serious deterioration of marine ecosystems associated with climate change.

## 5. Results and Discussion of the Analysis of the Main Impacts of Offshore Wind, Applied to Parc Tramuntana

### *5.1. Analysis of the Impact of the Project on Water Turbidity and Sedimentation*

The increase in water turbidity is one of the main impacts detected, and it happens both during the execution phase, where it is of greater importance, and during the operation phase. The effects that sediment resuspension can cause indirectly in the transport and deposition of suspended sediment were also analyzed.

The installation of anchors, chains, and cables on sedimentary substrate, and the consequent sediment resuspension, are likely to cause direct effects on water quality (turbidity, alteration of the trophic and chemical states), and in turn indirect effects on the biota that may be affected by the turbidity plume, particularly hard-bottom filtering and suspension-feeding species. It should be noted that no such seabed has been detected in the project area, the seabed affected being composed entirely of fine sands and muds.

In general, regarding the alteration in water turbidity, the main effects on marine fauna are a decrease in visibility (affecting the behavior of certain species in their ability, among other aspects, to capture prey or detect predators) or, if prolonged over time, affecting the feeding and breathing capacity of suspension-feeding and filter-feeding animals, including fish, whose gills may suffer physical damage due to the presence of abrasive particles in the water.

Reduced light penetration also affects the depth of the photic zone (the layer where sufficient light reaches for photosynthesis) and thus the primary production capacity of algae and phanerogams.

The subsequent deposition of suspended sediment on the seabed would have its greatest impact on sessile species, particularly on those species most sensitive to sedimentation.

Considering these effects, the area with the greatest sensitivity and potential impact due to turbidity is considered to be the *Cymodocea nodosa* meadow in the shallower area, at depths below 20 m, close to the exit of the route through the HDD. In the remaining area affected by the evacuation route and the area where the wind turbines will be installed, no significant presence of structuring sessile species was detected.

The increase in turbidity may also have an associated impact on water quality, when possible pollutants present in the sediment are mobilized. This potential impact is dismissed, given that the analysis of sediment samples taken in the area affected by the project shows no evidence of significant contamination.

In the Tramuntana project, during construction, the foreseeable increase in turbidity is mainly associated with the activities of drilling execution (HDD) in the maritime-terrestrial zone and export submarine cable burial by jetting for its protection. Both actions are temporary (with a permanence of the impact in the order of hours) and their effects on turbidity are reversible. In this phase, anchoring activities of anchor and mooring lines are short-time events, and have a lower capacity to generate turbidity, as well as the laying of inter-array cables, a part of whom can rest directly on the seabed, without the need for burial.

During operation of the wind farm, since most of the submarine cables are buried and immobile, the only contribution to increased turbidity on the seabed is that associated with the wind turbine anchoring systems, due to the resuspension of sediments from the seabed that may be produced by the movements of the mooring lines under the effect of waves and wind.

#### 5.1.1. Impact of HDD on Turbidity and Sedimentation (Construction Phase)

The HDD is a small diameter borehole that is drilled between the entrance pit, located on land behind the beach dunes, and the exit point in the sea 1770 m away from the previous one, at a depth of about 16 m. This is the technical solution proposed to allow the landing of the submarine cables without affecting the seabed surface and the biological communities present on it, some *Cymodocea nodosa* meadows of high ecological value.

These boreholes are drilled using drill heads operated from land and assisted by a jack-up structure (platform with legs) near the exit point (Figure 3).

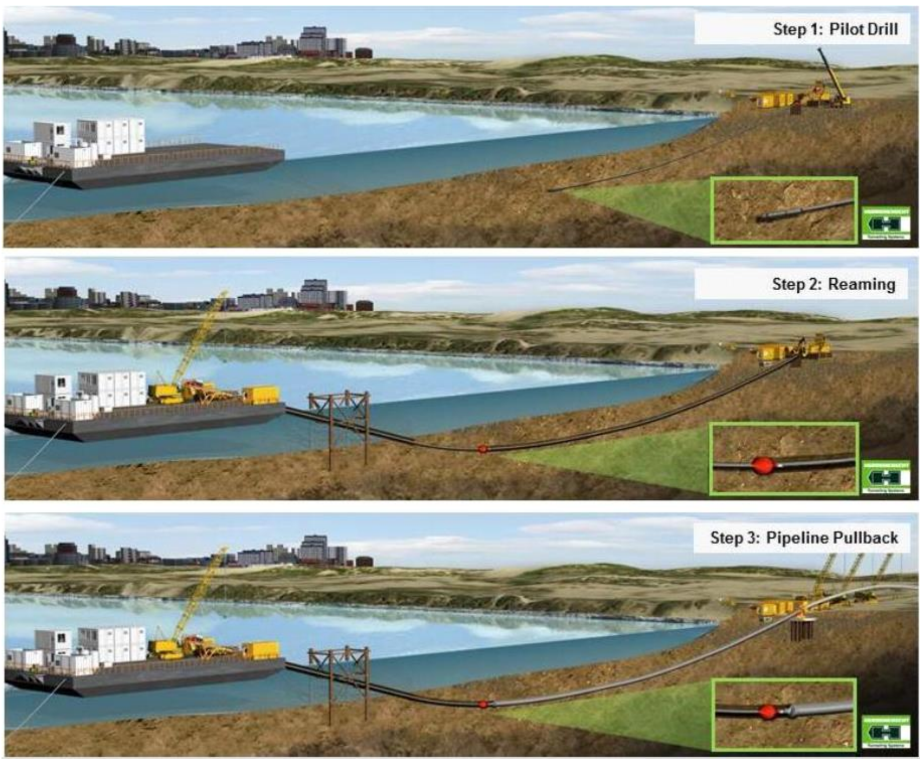



**Figure 3.** HDD drilling scheme for land–sea transition. Source: Herrenknecht.

The drilling system requires the use of bentonite fluid (composed of water, bentonite, which is a natural clay, and a small proportion of polymeric additives, wetting and dispersing agents), to facilitate drilling and to extract the excavated material, which is constantly recirculated and recycled to an onshore separation plant. Only at the exit of the drilling head at the end of drilling path is the loss of a limited volume of this fluid foreseeable. This fluid would temporarily increase turbidity around the exit point.

To reduce the dispersion and sedimentation of these bentonite clays around the exit point, containment measures are planned to be implemented by temporarily casing the exit point, to allow collection and recycling of the clays.

Based on the dispersion studies of the most unfavorable bentonite fluid emission scenarios, carried out by means of the MOHID numerical model, the predicted impact, characterized by the exceeding of the reference turbidity level (defined in accordance with Additional Provision IX of Law 22/1988 of 28 July 1988 on Coasts as 1.5 times the normal average of suspended solids measured in pre-operational state, i.e., 6.75 mg/L), is temporary (lasting less than 2 h), of low intensity (with maximum values not exceeding 40 mg/L), and limited to the immediate surroundings (distances of approximately 30 m).

#### 5.1.2. Impact of Jetting Operations on Turbidity (Construction Phase)

The jetting technique consists of opening a trench in the seabed by applying pressurized water jets that causes the soil beneath and around the cable to fluidize, allowing the cable to sink through the suspended sediments to the bottom of the trench, to the required burial depth (Figure 4).

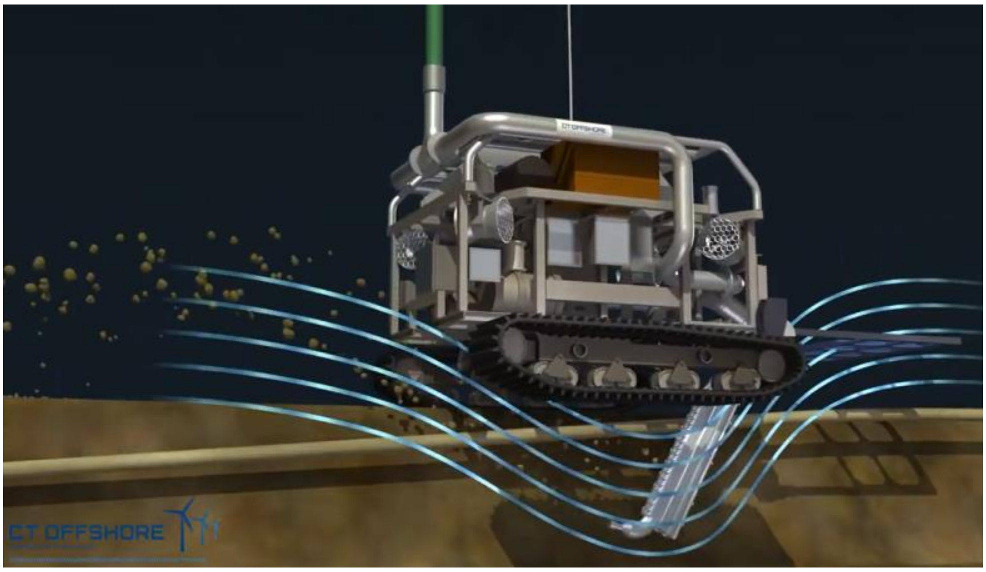



**Figure 4.** Example of subsea cable burial by jetting. Source: CT Offshore.

This technique minimizes the impact footprint and sediment resuspension, being the cable installation and burial method that generates less spatial impact (reduced trench width) and less temporal impact (reduced execution time) of those analyzed in the project.

This burial technique would be applied from the drilling exit point (HDD) to the wind farm site, about 24 km away.

To assess the effect of this operation, the sediment dispersion generated per m of advance was simulated again by the MOHID numerical model, considering a conservative hypothetical situation, in which it is assumed that all the sediment in a 2 m $\times$ 1 m trench is resuspended. The results of suspended solids concentration in the water column under this assumption show that the time duration of significant concentrations (above 6.75 mg/L) near the bottom is, in all cases, low: 3 h in the shallowest areas and those closest to the phanerogam meadows (<20 m) and up to 5 h in the deepest ones (120 m).

The impacts are therefore temporary (no more than 3–5 h above the reference threshold of 6.75 mg/L), of low intensity (maximum values below 40 mg/L), and limited again to the immediate surroundings (distances of less than 30 m), and mostly in areas of soft, non-vegetated substrate, so that the effects of the temporary increase in turbidity in the benthic zone on the physical environment and biota are considered compatible, temporary, and of low magnitude. By way of comparison, it should be noted that these levels of suspended solids and their persistence are equivalent to those usually produced during sea storms around the meadows.

Sedimentation in the shallow zone is limited to the area near the trench, and at a distance of more than 30 m does not exceed 2 cm. In the 30 m closest to the trench, 3 cm of thickness can occasionally be reached, between 30 and 60 m distance, 2 cm are not exceeded, and at more than 60 m, 1 cm is not exceeded.

It should be emphasized that the numerical modeling carried out is very conservative, since it considers the suspension of all the material present in the trench. In real observations made in other projects for laying and burying submarine power cables [13,14], the volume of resuspended material has been less than 30% of the trench volume, and the mobilized material accumulates mostly in a short radius around the trench (at a distance of less than 10 m).

#### 5.1.3. Turbidity Impact of the Movement of Turbine Mooring Lines (Operation Phase)

The anchoring systems for floating turbines are composed of three to four mooring lines, consisting of chains connecting the floating platforms with anchors buried more than 10 m below the seabed (Figure 5). Part of these catenaries rest on the seabed to counteract the movement of the turbines under the effect of wind and waves with its weight.

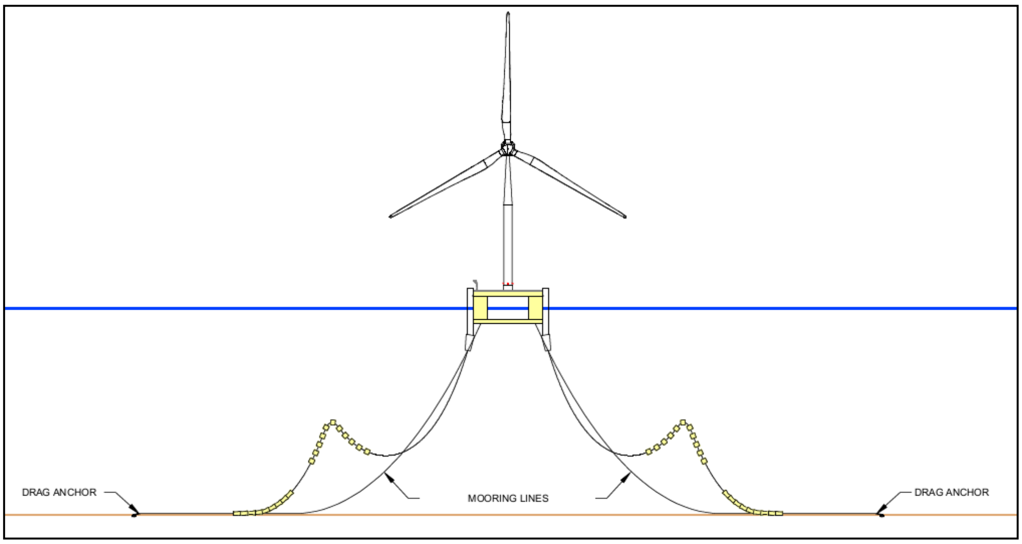



**Figure 5.** Schematic of the subsea mooring and cabling system of a floating turbine. Source: SENER.

A part of this resting section, approximately 330 m long, will be subject to certain movements that may cause the sediment to resuspend along its contact with the bottom, which may have indirect effects on the biota present in the area, in this case mostly benthic macrofauna that colonize the soft bottoms, as well as demersal species (e.g., hake).

It is estimated that the area affected by this effect is of the order of 1650 $m^2$ for each catenary (along the resting section and with a maximum arc of movement of 4°), or up to 6600 $m^2$ for each turbine (considering 4 mooring lines). Considering the area affected by the 35 planned turbines (0.23 $km^2$) compared to the total area where the wind farm would be installed (about 95 $km^2$), the area affected by this impact is about 0.24%. By contrast, the area currently subject to resuspension and turbidity on the seabed due to trawling activities in the Gulf of Roses (assuming a fleet of 21 vessels with an average operation of 180 days per year, with 5 h of fishing periods) is estimated at 950 $km^2$ (95,000 Ha). In addition, this activity generates turbidity values much higher than those associated with the mobility of the mooring lines of a wind farm [11].

Based on the studies carried out, analyzing the possible movements in the catenaries, low speed movements are expected and the effects are not likely to reach a distance greater than 5 m at both sides of the chain, but will be limited to the furrow of maximum amplitude of the footprint considered for the catenary. The level of turbidity generated would therefore be close to that observed due to natural variability, and lower than that usually produced during episodes of strong currents or anthropogenic activity (e.g., if compared to the effect on turbidity produced by trawling, which turbidity plumes can exceed 100 m of thickness and reach suspended solids concentration of 200 mg $L^{-1}$ close to the sea bottom [15]).

The temporal effects of turbidity, although significant, will therefore be of low magnitude and low periodicity occurrence, considering the slowed movement of the chains. These effects on the physical environment are considered compatible, considering the adaptive capacity of the species that colonize the affected sedimentary bottoms.

#### 5.1.4. Overall Assessment of the Impact on Turbidity and Sedimentation

During the construction phase, the impact on the increase in turbidity and sedimentation is considered significant in the shallow area, considering that it happens in waters of protected natural areas (RN2000) and the presence of the marine phanerogam *Cymodocea nodosa* meadow in the landing area, despite the fact that the effect is temporary (hours) and the rate and spatial extent of sedimentation is limited.

By assessing the different descriptors of each impact (turbidity and sedimentation), according to the described methodology, a Moderate impact rating is obtained for both during the construction phase, as shown in Table 2:

**Table 2.** Overall assessment of the impact on turbidity and sedimentation during the construction phase.

| Attribute | Turbidity | | Sedimentation | |
|---|---|---|---|---|
| | **Characterization** | **Rating** | **Characterization** | **Rating** |
| Sign | Negative | (−) | Negative | (−) |
| Extension | Partial | 2 | Partial | 2 |
| Persistence | Temporary | 2 | Permanent | 4 |
| Synergy | Synergistic | 2 | Synergistic | 2 |
| Effect | Direct | 4 | Direct | 4 |
| Recoverability | Immediate | 1 | Immediate | 1 |
| Intensity | Medium | 2 | Low | 1 |
| Moment | Immediate | 4 | Immediate | 4 |
| Reversibility | Short period | 1 | Medium period | 2 |
| Accumulation | Simple | 1 | Cumulative | 4 |
| Periodicity | Continuous | 4 | Continuous | 4 |
| TOTAL RATING | MODERATE | −29 | MODERATE | −32 |

In terms of the impact on this vector during the operation phase, the expected impacts on turbidity are very limited, restricted to less than 1% of the project area, which in relation to the current impact of trawling in the area occupied by the park where this activity would cease (about 600 ha, equivalent to 6% of the park's surface), represents, both in terms of the extent and magnitude of the impact, a relative improvement in terms of turbidity conditions and recoverability of the seabed from sediment resuspension. From the modeling carried out, it is concluded that the levels of suspended solids in the water column derived from the movement of the chains are scarcely significant (less than 2 mg/L at distances of less than 25 m) at all times, being considered of low intensity and persistence (levels of less than 1 mg/L in less than 2 h).

The assessment of these impacts in the operation phase is summarized in Table 3:

**Table 3.** Overall assessment of the impact on turbidity and sedimentation during the operation phase.

| Attribute | Turbidity | | Sedimentation | |
|---|---|---|---|---|
| | **Characterization** | **Rating** | **Characterization** | **Rating** |
| Sign | Negative | (−) | Negative | (−) |
| Extension | Partial | 2 | Partial | 2 |
| Persistence | Permanent | 4 | Permanent | 4 |
| Synergy | Synergistic | 2 | Synergistic | 2 |
| Effect | Direct | 4 | Direct | 4 |
| Recoverability | Immediate | 1 | Immediate | 1 |
| Intensity | Low | 1 | Low | 1 |
| Moment | Immediate | 4 | Immediate | 4 |
| Reversibility | Short period | 1 | Medium period | 2 |
| Accumulation | Simple | 1 | Cumulative | 4 |
| Periodicity | Continuous | 4 | Continuous | 4 |
| TOTAL RATING | MODERATE | −28 | MODERATE | −32 |

### *5.2. Analysis of the Project's Impact on Underwater Noise*

The project has the potential to alter the acoustic environment of the area, both during the construction and operation phases.

In the study area, background underwater noise (reference situation), which is related to natural sources (e.g., wind) and artificial sources (e.g., maritime traffic, professional fishing), was measured by means of PAM (Passive Acoustic Monitoring) equipment. The recorded noise values reach peaks (SPL) of 156–159 dB re 1 µPa and cumulative averages (SEL) of 134–139 dB re 1 µPa at the wind farm proposed location. The greatest contribution is from maritime traffic, highlighting the important fishing activity linked to the port of Roses.

Underwater noise has the potential to alter the acoustic environment of the area and affect several species, especially marine mammals, with special attention to cetaceans present in the study area (mainly bottlenose dolphins), and chelonians such as loggerhead turtles (with less presence in the area).

The acoustic impact will depend on the distance to the source of the receptor. Considering the distribution of cetaceans in the study area, observed during the monitoring campaigns carried out during the last year, the main type of detected cetaceans are dolphins (bottlenose and striped dolphins), associated with a medium frequency hearing range (150–160 kHz), and to a lesser extent species with a low frequency hearing range (7–35 kHz), such as the fin whale.

In relation to the potential effect on turtles (loggerhead turtle), a reference level RMS of 166–175 dB re 1 µP [16] is considered to be the range for behavioral change effects, based on experimental measurements with species in captivity.

According to *MAGRAMA* [17], the reference levels for the definition of exclusion zones are 160 and 180 dB rms, corresponding to thresholds for which behavioral changes and physiological damage are detected in cetaceans, respectively.

#### 5.2.1. Noise Impact during the Construction Phase

During the construction phase, the main source of noise is associated with the vessels that will install the wind turbines and their anchoring systems and lay the cable. The underwater noise emission is proportional to the speed of the vessels, which, due to the nature of the work to be carried out, will generally be low (between 3 and 5 knots).

Other sources of noise identified in this phase are the use of acoustic devices for positioning during cable laying or anchor installation (echo sounders, sonars, acoustic positioning systems), the use of pumping equipment and the pressurized water jetting system (jetting), displacement along the bottom, sliding (dragging), and finally machinery on board for lifting and lowering equipment.

One of the main differences between the projected wind farm (with floating foundations) and most wind farms in the world (which have fixed foundations) is that in this case no pile driving activities are carried out for the execution of foundations. Pile hammering is the main source of underwater noise impact identified by the scientific community in association with offshore wind farms, having been analyzed in a large number of studies that show its impact on certain marine species, particularly cetaceans. Consequently, this important impact does not happen in a project such as Parc Tramuntana, as no impulsive, high-energy noise will be generated during construction.

Thus, the noise that may be generated during the construction phase does not differ much from noise associated with other types of maritime works, associated with low frequencies (e.g., navigation), and is of a temporary nature.

According to the consulted literature, the noise generated by cable-laying ships in shallow waters is of the order of 164–188 dB re 1 µPa, at 1 m from the source, acting at frequencies between 0.7 and 50 kHz: surface ship 180 dB (CEDA, 2011) [18], 164–170 dB (Nexans Skagerrak). In relation to underwater activities, a reference of burial works at 1 m from the source is available, with emissions up to 188.5 dB (at 11 kHz) [19] or 174 dB [20]. It should also be noted that modern newly built vessels reduce acoustic emissions and vibrations from engine operation very significantly.

The effects of the construction phase on this variable are considered significant, although the existing risk of direct effects is limited to the presence of wildlife in the vicinity of the noise source, noting that the negative effects would be temporary and that noise generation would be progressive, with a chasing effect that avoids further damage to the animals. The assessment of this impact in the installation phase is therefore moderate (Table 4):

**Table 4.** Assessment of the impact on submarine noise during the construction phase.

| Attribute | Characterization | Rating |
|---|---|---|
| Sign | Negative | (−) |
| Extension | Extensive | 4 |
| Persistence | Temporary | 2 |
| Synergy | Synergistic | 2 |
| Effect | Direct | 4 |
| Recoverability | Immediate | 1 |
| Intensity | Medium | 2 |
| Moment | Immediate | 4 |
| Reversibility | Short period | 1 |
| Accumulation | Simple | 1 |
| Periodicity | Continuous | 4 |
| TOTAL RATING | MODERATE | −28 |

As the main corrective measure, the use of modern workboats with low noise emission certifications (e.g., Silent-E) is proposed [21].

#### 5.2.2. Noise Impact during the Operation Phase

During the operation phase of the wind farm, the main source of underwater noise generation will be the wind turbines themselves, which will produce continuous noise due to the movement of the blades, transmitted mainly through vibrations along the floating platform and the bottom-anchoring chains, and to a much lesser extent directly through the water surface, since the change in medium (air/water) produces a significant attenuation of atmospheric sound.

There will also be transient noise related to the movement of the anchor chains on the bottom due to the movement of the floating turbines.

In addition to the noise from the wind turbines, there will be noise from the vessels responsible for maintenance/repair tasks, similar in nature to that expected during the construction phase. The impact of these vessels will have a limited frequency (20 days/year), similar to those currently caused by marine and fishing traffic.

In order to characterize the impact of underwater noise produced by the turbines, the existing literature on the subject was analyzed, coming from the scarce experiences in other floating offshore wind farms, specifically the studies and measurements of underwater noise in the Hywind Tampen wind farm [22], the first floating technology wind farm installed off the coast of Norway, in the North Sea.

In this wind farm, the noise recorded during operation was characterized as continuous and low frequency (25, 50, and 125 Hz). The results did not exceed in any case an SPL of 160 dB re 1µPa (reference level adopted as a threshold to determine the limit of the cetacean disturbance zone, according to *MAGRAMA* recommendations [17]), and the isophone range of 120 dB re 1 µPa, assimilable to the background noise recorded at the Hywind Tampen wind farm site), occurs, according to the developed acoustic modeling on the basis of measurements, at circa 2 km from the wind turbines, with a maximum noise footprint of approximately 40 km$^2$.

Similar experiences in the environmental monitoring phase of a fixed foundation (jackets) wind farm operating at a depth of 25 m off New York Bay, the Block Island Wind Farm [23], show maximum noise values generated during operation of up to 120 dB re 1 µPa at a distance of 50 m from the turbines, at a site with a background noise of 110 dB re 1 µPa.

These levels are considered an approximation to the underwater acoustic footprint that may be produced by Parc Tramuntana, whose increase in the acoustic scenario around the wind turbines will be cumulative depending on the number of wind turbines and the environmental conditions of the surroundings. It is estimated that this acoustic increase will be attenuated to the background noise levels existing at a distance of approximately 2 km or less (since in the case of Tramuntana the background noise is more intense than that existing in the other reference wind farms analyzed).

The expected RMS levels from this distance (around 120 dB re 1 uPa) are significantly lower than the background noise and the thresholds that would cause annoyance to the most sensitive species identified (dolphins and sea turtles), which are not highly abundant in the wind farm site area.

After this analysis, the effects of the operation phase on this variable are considered significant, of partial extension (affecting the area near the wind farm's footprint), and of medium magnitude due to the acoustic levels generated. The risk of direct effects is limited to the presence of fauna in the vicinity of the noise source, which is irregular and periodically distributed. The assessment of this impact during the operation phase is shown in Table 5:

**Table 5.** Assessment of the impact on submarine noise during the operation phase.

| Attribute | Characterization | Rating |
|---|---|---|
| Sign | Negative | (−) |
| Extension | Extensive | 4 |
| Persistence | Permanent | 4 |
| Synergy | Synergistic | 2 |
| Effect | Direct | 4 |
| Recoverability | Immediate | 1 |
| Intensity | Medium | 2 |
| Moment | Immediate | 4 |
| Reversibility | Short period | 1 |
| Accumulation | Cumulative | 4 |
| Periodicity | Continuous | 4 |
| TOTAL RATING | MODERATE | −38 |

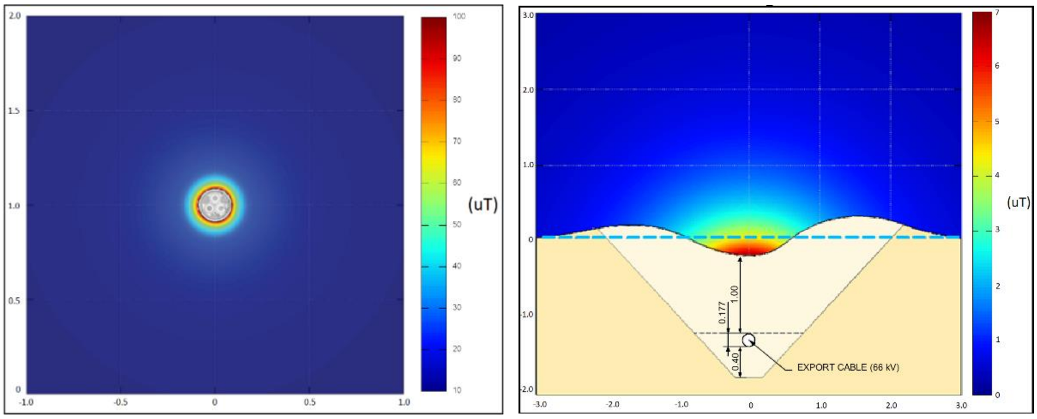
The applicable measures are the monitoring of acoustic levels and the recording of cetacean activity in the area, through visual censuses and the installation of hydrophones, to verify the levels and activity of potentially affected fauna.

### *5.3. Analysis of the Project's Impact on Electromagnetic Fields (EMF)*

This potential impact is only likely to occur during the operation phase, as it is associated with the transmission of electricity generated by the wind farm through the submarine cables.

The interconnection cables (inter-array) installed in the offshore wind farm and the export cables will operate in alternating current at 66 kV–50 Hz. An analysis of the EMF generated by these cables was carried out using numerical modeling based on the *Biot–Savart* analytical calculation for the different cable segments (both the dynamic inter-array cables, which connect the turbines to each other, and the buried export cables, which connect the wind farm to shore). This model adopted a conservative calculation, considering the most unfavorable possible scenario (cable operation at full load), and without considering the shielding effects due to the cable protection armor.

This simulation of EMF levels (see Figure 6) obtains magnetic field levels (B) for the maximum inter-array cables at the surface of the conductors of 90 µT and, for the evacuation cable, a maximum level of 5 µT on the seabed.




(**a**) (**b**)

**Figure 6.** EMC modeling for the inter-array (**a**) and export (**b**) cables.

The electric field (E) induced by the 66 kV conductors will be zero on the outside of the cables, since it is blocked by the metallic screen of the cable itself.

The potential effects of EMF on aquatic fauna include the possible disorientation of migratory species that use the terrestrial magnetic field for orientation during navigation, behavioral alteration with attraction or repulsion effects (barrier effect), as well as potential physiological damage at the cellular level.

As a reference, it should be noted that normal values of the earth's geomagnetic field can range from 20 to 75 µT, depending on the geographical location.

In order to assess which of these effects could be relevant to the project, a large amount of literature was consulted to analyze the effects of EMF on different species (Table 6):

**Table 6.** Documented effects of EMF on marine species.

| Species | Threshold Value | Effect | Source |
|---|---|---|---|
| Eel (*Anguilla anguilla*) | 5 $\mu$T (direct current) | Course deviation during migration | Westerberg and Begout-Anras (2000) [24] |
| Turtle (*Caretta caretta*) | 4.9 $\mu T\_$ | Disorientation of juveniles during migrations periods | Fuxjager et al. (2011) [25] |
| Mussel (*Mytilus galloprovincialis*) | 300–1000 $\mu T\_$ | Alteration of cellular processes for adults in the laboratory | Ottaviani et al. (2002) [26]<br>Malagoli et al. (2004) [27] |
| Shrimp (*Crangon crangon*) | 10–100 $\mu T\_$<br>800 $\mu T\_$ | Behavioral disturbance in adults<br>Attraction effect on adults | Hutchinson et al. (2018) [28] |
| Fish and macroinvertebrates | 1–3.2 $mT\_$ | No significant long-term behavioral effects detected | Woodruff et al. (2012) [29]<br>Bochert and Zettler (2004) [30] |
| Elasmobranchs | 91 $\mu$V/m | Alteration of behavior by attraction or repulsion | CMACS (2003) [31]<br>Gill and Taylor (2001) [32] |
| | 60,000 $\mu$V/m | Narcosis | Smith (1974) [33] |
| Elasmobranchs and rajoids | 1/8 to 8 Hz | Electrosensitivity within the frequency range | Kalmijin (2000) [34]<br>Walker et al. (2003) [35] |

In relation to species sensitive to electric fields, elasmobranchs would be the most potentially affected group, whose ability to detect these fields is very sensitive, detecting levels of less than 0.5 V/m (5 nV/cm).

Among the species considered in the bibliography, the most important because of their potential presence and migratory habits are the loggerhead turtle (*Caretta caretta*), the bottlenose dolphin (*Tursiops truncatus*), devil fish (*Mobula mobular*), and the main protected species of elasmobranchs with a potential presence in the study area due to their conservation status: common thresher (*Alopias vulpinus*), basking shark (*Cetorhinus maximus*), tope shark (*Galeorhinus galeus*), bluntnose sixgill shark (*Hexanchus griseus*), shortfin mako shark (*Isurus oxyrinchus*), smooth-hound (*Mustelus* spp.), blue shark (*Prionace glauca*), and spiny dogfish (*Squalus acanthias*).

The maximum magnetic fields generated by the project are within the range of values detectable by marine fauna.

The field generated by the inter-array cables in the wind farm area (up to 90 $\mu$T) will be detectable by potentially present species of interest. Considering that the cables analyzed do not alter the electric field, significant effects on elasmobranchs are dismissed, although their behavior will be analyzed during the operation phase. This effect is localized in the closeness of the cables, as the magnetic field levels attenuate rapidly a few meters away.

The potential effects on fauna are considered locally limited; it should be noted that the cable's footprint in the sea bottom is approximately 10,000 $m^2$, less than 1% of the wind farm's area, and barely perceptible (<5 $\mu$T) at short distances (<1 m). Due to the extent of these fields and the magnitude of EMF and derived effects, they are not considered to have a significant barrier effect on migratory species.

In the case of the fields associated with the export cables (<5 $\mu$T), these are of limited magnitude, close to the levels of natural electromagnetic disturbances that regularly happen (*Nyqvist* et al., 2020) [36], and are therefore expected to be barely perceptible by potentially affected fauna, as the cable is buried deep enough for the field to attenuate to levels that are practically imperceptible at the seabed surface.

It should be noted that in EMF monitoring surveys of buried electrical interconnections, levels of the order of nT are usually detected. Considering its continuous route to the coast, the species of interest potentially affected would be the loggerhead turtle, in the event of passing through to nest on nearby beaches, and the bottlenose dolphin, due to its local presence. However, due to the magnitude of the impact, as described above, the effect on these species is considered insignificant. These values can also be extrapolated to the subway cable line through the HDD.

On the other hand, it should be noted that it is foreseeable that in the operating phase the EMF generated will be lower than that modeled, considering the maximum regular operating loads contemplated and the additional shielding provided by the cable protection armor; according to the literature consulted, these levels would not be capable of causing physiological damage or significant changes in the behavior of the fauna present in the project area.

Anyway, the increase in EMF during the wind farm's operation phase was considered a significant effect, mainly in the wind farm's footprint area (where the inter-array cables are located). This impact is considered moderate, according to the following attribute classification (Table 7).

**Table 7.** Assessment of the impact of EMF on marine fauna.

| Attribute | Characterization | Rating |
|---|---|---|
| Sign | Negative | (−) |
| Extension | Partial | 2 |
| Persistence | Permanent | 4 |
| Synergy | Simple | 1 |
| Effect | Direct | 4 |
| Recoverability | Immediate | 1 |
| Intensity | Medium | 2 |
| Moment | Immediate | 4 |
| Reversibility | Short period | 1 |
| Accumulation | Simple | 1 |
| Periodicity | Continuous | 4 |
| TOTAL RATING | MODERATE | −30 |

Among the main mitigation measures, in addition to the design of the cables to reduce EMF through shielding and burial in the evacuation route, it is proposed to monitor EMF levels in the inter-array cables and in the evacuation route, as well as the monitoring of cetaceans, turtles, pelagic communities (including elasmobranchs), and benthic macrofauna.

### *5.4. Analysis of the Project's Impact on Marine Circulation and Nutrient Distribution*

Once the offshore wind farm is in operation, the operation of the wind turbines could generate changes in the atmospheric and oceanic dynamics due to the capture and modification of wind energy. On the other hand, the floating platforms, with a draft of −15 m, could generate a certain wave reduction effect or local alteration of the currents.

The main expected effect could be the reduction in wind energy in the area of the wind farm, associated to the wake effect, which consists of the reduction of wind speed and kinetic energy downwind of the wind farm.

It is considered that the capacity of the underwater structures to alter the hydrodynamic regime of the Gulf of Roses is very low, considering the depth at which the wind farm is located (>100 m) and that the installed structures (floating platform, chains, anchors, and inter-array cables) are not large enough to produce a significant reduction in current flows, stratification, or vertical transport phenomena in the water column.

Although these effects may happen, they will be very localized in the immediate surroundings of the structures and of little entity at the level of the Gulf of Roses (where they will probably be imperceptible), which does not confer the ability to become cumulative or synergistic downstream. The effect of this potential reduction in the wind and hydrodynamic regime on the development of species and habitats is assumed to be low, due to the expected low incidence of the reduction in physical effects on the column and seabed of the installed wind turbines, as well as the capacity of biological adaptation of the species potentially affected to small changes in the circulation.

This impact has first been assessed on the basis of a critical analysis of the existing literature, and a rigorous study by IHCantabria about the impact of the project on wind fields and marine currents has also been undertaken, by means of numerical modeling. This study, whose methodology has been presented to the Spanish National Research Council (CSIC) experts for their approval, and no objections have been received from them, will provide quantitative information on the foreseeable variation in current speeds in the area of the Gulf of Roses.

As a result of the bibliographic analysis, some scientific publications that analyze and document wind field alteration effects were identified, mainly based on wind farms located in the North Sea [37]. In some cases, it is suggested that these alterations could lead to increases in precipitation, although the predicted changes are so small in magnitude that it is difficult to distinguish them from natural variability. According to Platis et al. (2018) [38], the wake effect is greater under stable atmospheric conditions than under turbulent conditions. When conditions are turbulent, such as those associated with the Tramuntana winds that will feed the wind farm, the wake effect is restricted to the local area inside the wind farm and the immediate surroundings.

It should also be noted that in general, regarding wind disturbance, the numerical models give overestimated values with respect to the field measurements. This divergence between modeled and measured values indicates deficiencies in the knowledge of the effects. Measurements made in the "Horn Rev" and "Nysted" fields in the Baltic Sea show reductions of 8–9% immediately after the field, and 2% at distances between 5 and 20 km [39]. As for the regional effect, it is estimated to be small, the energy loss in the first kilometer of the atmosphere being 0.007%. The conclusion is that floating wind farms may have a minor to moderate impact on atmospheric and oceanic dynamics (depending on the location and size of the wind farm), although there is insufficient specific knowledge of the cascading effects of large-scale atmospheric and oceanic processes to reduce the current uncertainty.

In relation to the possible effect of the alteration of currents on the distribution of nutrients, Van Berkel et al. (2020) [40] point to the potential upwelling effect associated with the wake, causing the upwelling of deep-water mass to the surface. However, this effect depends on the relative direction between the wind and the coast, being a frequent phenomenon on the Atlantic coast but not so in the western Mediterranean.

It should be noted that the bibliographic references in which appreciable variations in the current regime have been observed as an indirect consequence of the presence of a wind farm correspond to cases in shallow areas, with fixed foundation wind farms, and with a high concentration of turbines, being scenarios not very comparable with the project scenario.

The results of the hydrodynamical study by means of numerical modeling developed by IHCantabria show that the effect of the wind farm over the surface currents and those averaged over the water column in the coastal area is very small, with an averaged difference in the currents magnitude below 1 cm/s and maximum values of 1 cm/s during 98% of the time.

In the proximities of the wind farm in the open sea, the differences obtained, in both surface and averaged water column, remain below 1 cm/s at the north, east, and west from the farm, while at the south this difference is up to 2 cm/s, which represents an averaged variation inferior to 3.5% of the average speed registered in the study area by the buoy of *Puertos del Estado*.

In any case, to confirm the potential impact, the mitigation measures and Environmental Monitoring Plan propose monitoring the wind and current regime of the involved area, as well as monitoring the thermohaline structure of the main indicators of the water masses (temperature, salinity, turbidity), nutrients in the water column, and monitoring the evolution of the main pelagic and benthic communities in the affected area, whose evolution will be analyzed with a Before-After Control-Impact (BACI) study approach.

The impact is considered significant, permanent (during the life of the wind farm), and synergistic. Due to the uncertainty of the effect and the fact that mitigation measures cannot be developed, a medium magnitude is assigned to it. The resulting classification is shown at Table 8:

**Table 8.** Assessment of the impact on marine hydrodynamics.

| Attribute | Characterization | Rating |
|---|---|---|
| Sign | Negative | (−) |
| Extension | Extensive | 4 |
| Persistence | Permanent | 4 |
| Synergy | Synergic | 2 |
| Effect | Direct | 4 |
| Recoverability | Immediate | 1 |
| Intensity | Medium | 2 |
| Moment | Immediate | 4 |
| Reversibility | Short period | 1 |
| Accumulation | Cumulative | 4 |
| Periodicity | Continuous | 4 |
| TOTAL RATING | MODERATE | −38 |

### *5.5. Analysis of the Impact of the Project on the Proliferation of Invasive Alien Species*

Another aspect that has been identified by scientists as a possible threat to marine biodiversity, in association with offshore wind farms, is their potential to promote the proliferation of invasive alien species.

According to the available knowledge by the scientific community on the proliferation of allochthonous species in the Mediterranean, either introduced intentionally or by chance by different ways, it is currently considered that this phenomenon could be one of the main causes of biodiversity loss in the Mediterranean. The number of invasive alien species inventoried in this sea in 2012 reached almost a thousand (more than 5% of the species present in this sea), with more than 300 identified in the western basin [41].

There is a wide variety of species with the potential to become invasive, although organisms with the ability to attach to hard surfaces (biofouling), including mollusks, are generally the most notorious. The known introduction ways are numerous, one of the most relevant being the opening of the Suez Canal in 1869, which involved communication between the Red Sea and the Mediterranean Sea, favoring the migration of numerous species from the Red Sea to the Eastern Mediterranean, some of which have come to spread throughout the Mediterranean basin [42].

Other known ways of anthropogenic introductions are the transport of sessile species attached to the hull of merchant ships or other structures moving from one place to another, the discharge of ballast water, which carries planktonic and nektonic organisms (some of which are larval stages of invasive species), the introduction of species of interest for mariculture and fish farming (which often carry parasitic organisms), the intentional or accidental release of specimens by aquariums, or even the recent proliferation of microplastics in the seas [43].

Regarding this threat, it is also worth noting the effect that climate change is likely to have on this phenomenon, since it is expected to affect, by modifying water temperature, the structure of marine communities, providing more opportunities for exotic species to disperse and compete with and displace native species [42].

Based on current knowledge, and in relation to the structures and actions foreseen in the project, the following possible routes of entry of allochthonous species into the project area are contemplated:

- Through adherence to the structures of the foundation floaters, during their towing from the manufacturing or assembly port:
  The structures are expected to be manufactured either in western Mediterranean ports, with a low probability of introduction of new species, or from the Atlantic ports of the Iberian Peninsula. The rest of the elements that will remain on the seabed (submarine cables, anchors, and chains) are not expected to be exposed to marine colonization outside the park, since they will be transported aboard ships.

In both cases, the main means of transport will be semi-submersible vessels between the manufacturing port and the wind turbine assembly port (e.g., in Tarragona), so possible adhesions will only occur during transport between the port of Tarragona and the wind farm site. The probability of introduction of allochthonous species is therefore very low, and comparatively lower than that which may be due to the transit of merchant ships coming from the Strait of Gibraltar or the Suez Canal to ports in the western Mediterranean.

- By attachment to working vessels during construction (cable-layers, tugboats, etc.):
  These vessels are highly specialized and generally work in all the world's oceans, so there is a possibility that they may carry allochthonous species attached to their hulls, with potential for invasion and displacement of native species.
  However, this is not a significant threat, in relation to the number of vessels with which it is associated, compared to the intense maritime traffic of merchant ships, pleasure craft, fishing boats, or cruise ships that sail the waters of the western Mediterranean from other seas.
- By releasing ballast water from the foundation platforms:
  The floating turbine foundation platforms have ballast systems that involve filling or emptying tanks integrated into their structure to contribute to the stability of the whole. The partial filling of these tanks will be carried out at the assembly port (Tarragona), ending at the location of the wind farm.
  It is therefore not foreseeable, as has been argued above in the case of the adhesion entry route, that these ballast waters will constitute a significant entry route for invasive non-native species.

Finally, the potential effect of the floating structures themselves, as well as the anchoring system and the inter-array cables, which will be the only elements exposed to marine colonization, should be evaluated as possible elements of attraction and settlement of invasive alien marine species. This effect, far from introducing new species, could only contribute to a greater growth of the species present in the area. Its effect would be equivalent to that provided by any structure capable of providing a substrate for the settlement of sessile organisms, especially if it is located within the photic zone, where photosynthesis occurs and with it the greatest growth of biomass. That is, it would be equivalent to that associated with boat hulls, buoys, fishing gear, artificial reefs, or shallow rocky bottoms.

It should also be noted, in the case of platforms, that these structures are protected against corrosion and biofouling by means of cathodic protection systems and/or impressed current, which significantly minimizes biological adhesion. Therefore, only the surface of the chains and inter-array cables would be exposed to colonization at a relevant level.

It is possible that the presence of the floating structures may generate slight changes in the behavior of pelagic species, which may be attracted or repelled in their immediate environment depending on their feeding, predatory, shelter, or reproduction habits. However, these effects are not considered to be relevant in terms of compromising the conservation of these species, especially when compared to other pressures on these species in the project area, such as trawling or maritime traffic.

For all of the above reasons, the effect of the project on the proliferation of invasive alien species was considered not significant for the purposes of impact assessment.

## 6. Conclusions

The social controversy related to the introduction of offshore wind power in Catalonia has scaled to a scientific debate about its environmental compatibility, and specifically in relation to the Parc Tramuntana project. Recent publications have contributed to sustaining this debate, without being adequately based on rigorous analysis of both the characteristics of the project and its specific location within the Gulf of Roses, so it has been considered appropriate to provide an exhaustive analysis of the main impacts identified by the scientific community in relation to offshore wind farms.

The aim of this report was therefore to dispel some of the uncertainty that motivates this opposition, based on detailed information and quantitative data, in order to place these impacts in a realistic context and determine their true magnitude.

This is possible because a series of diverse and detailed studies have been developed over the last two years to assess the environmental impact of the project, which are relatively advanced and ready to provide some well-founded conclusions. In the meantime, the study continues to be prepared and, once the relevant studies are completed, it will be submitted as part of the documentation required by current legislation for the environmental processing of the project. Although this procedure contemplates a 30-day public information phase, it is desired to maintain a less limited channel of dialogue and prior communication, for which reason the promoter commits to advance as far as possible the conclusions that emerge from the environmental studies and to make them available to any interested person through the project's web page.

It should be noted that both the project and the corresponding environmental impact study are being developed in accordance with current environmental processing regulations and based on the Scope Document submitted by the General Directorate for Environmental Quality and Assessment of the Ministry of the Environment. Likewise, the design of the wind farm's infrastructure is in accordance with the conditions established by urban and sectorial regulations.

Based on the studies carried out, which are based on a standardized methodology, the impact of the project is objectively classified as MODERATE on vectors such as turbidity and sedimentation, underwater noise, hydrodynamic circulation, or the alteration of electromagnetic fields, and NOT SIGNIFICANT on aspects such as the proliferation of invasive exotic species (Table 9).

**Table 9.** Summary of analyzed environmental impact ratings and characterization.

| Impact Assessment | Phase | Rating (-) | Characterization |
|---|---|---|---|
| Turbidity | Construction<br>Operation | 29<br>28 | MODERATE<br>MODERATE |
| Sedimentation | Construction<br>Operation | 32<br>32 | MODERATE<br>MODERATE |
| Submarine noise | Construction<br>Operation | 28<br>38 | MODERATE<br>MODERATE |
| EMF on marine fauna | Construction<br>Operation | N/A<br>30 | N/A<br>MODERATE |
| Marine hydrodynamics | Construction<br>Operation | N/A<br>38 | N/A<br>MODERATE |
| Proliferation of invasive exotic species | Construction<br>Operation | N/A<br>N/A | N/A<br>N/A |

Impacts on turbidity and sedimentation are expected along the evacuation cables track during construction stage and only in the close vicinity of turbine moorings during the operational stage.

Submarine noise is expected also during both stages, mainly associated to construction equipment and ships during construction and to both maintenance ships and turbine structure vibrations during operation, although emission levels are not expected to be higher than current background noise in the area or to cause severe damage to sensitive species present in the area.

EMF are only expected in operational stage, being significant mainly in the close vicinity of the floating inter-array cables. Generated fields are expected to be detectable by sensitive species, but not strong enough to cause severe alterations in their behavior.

The impact on marine hydrodynamics, based on numerical modeling, is expected to be low, limited to changes in currents magnitude of 1–2 cm/s in the vicinity of the wind farm during operational stage.

Finally, the effect of the project on the potential proliferation of invasive species was considered not significant, as there are small chances for the introduction of alien species associated to project structures, being irrelevant when compared with other identified introduction vectors in the area.

In general, the studies carried out allow to anticipate a low impact of the floating offshore wind farm project on marine biodiversity in the area of implementation, which makes it compatible with the conservation of such biodiversity.

In addition, most of the significant impacts identified allow the application of measures to mitigate their effects, as well as their follow-up during the environmental monitoring derived from the environmental processing, which will make it possible to know the evolution of the wind farm's effects on the environment, as well as the adoption of additional measures if necessary.

These initial conclusions address only certain environmental aspects of the project that have been identified as being of greatest concern to some members of the scientific community. As the environmental impact study progresses, it is expected that conclusions regarding other potential environmental or socioeconomic impacts will also be published.

It is clear that any project, of whatever nature, introduces certain changes in the environment and therefore has an associated impact. However, it is equally true that it is imperative to slow down climate change by all available means, among which the transformation of the energy generation model to a renewable model is a priority.

It should be remembered that the effects of climate change predicted by the IPCC for the coming decades (many of which are already occurring today, including in the Mediterranean) include an increase in the temperature of the planet and its oceans, the extinction and anomalous migration of species, colonization by invasive species, the modification of marine currents and acidification of the seas, droughts, and catastrophic climatic phenomena.

Therefore, the suitability or otherwise of offshore wind power in Catalonia should not be evaluated solely from the perspective of its effect on biodiversity, especially considering that climate change itself will certainly introduce much more drastic changes in Mediterranean ecosystems than those that can be attributed to any individual project, resulting in more severe, lasting, and irreversible impacts on marine biodiversity.

Thus, from an equanimous and global vision, the assessment of a project such as Parc Tramuntana should be carried out with scientific rigor and without falling into the tunnel vision that only focuses on the local negative impacts, without placing them in context. Because, according to environmentalists [44], even if it is accepted that, like any other renewable energy project or any other type of project, it may have a certain level of impact on local biodiversity, the relationship between this impact and the protection of biodiversity throughout the Mediterranean is largely in favor of the latter.

Finally, in response to the arguments calling for a halt to marine renewables under a precautionary principle that only greater scientific knowledge can overcome, it is necessary to indicate that unfortunately the time available for the study is limited, since the climate emergency is already a reality and requires an urgent response. It is therefore a priority to join efforts to ensure the optimal response to the climate challenge, as is being done in neighboring countries.

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## References


1. Acord de Govern de la Generalitat de Catalunya, de 14 de Maig de 2019, de Aprovació de la Declaració de Emergència Climàtica a Catalunya. Available online: https://govern.cat/govern/docs/2019/05/14/15/12/9ff53be9-20cc-4ce1-9c7c-cdd5dc762187.pdf (accessed on 26 April 2022).
2. Acuerdo del Consejo de Ministros el 21 de Enero de 2020 Por el que se Aprueba la Declaración del Gobierno Ante la Emergencia Climática y Ambiental. Available online: https://www.miteco.gob.es/es/prensa/declaracionemergenciaclimatica_tcm30-506551.pdf (accessed on 26 April 2022).
3. European Parliament Resolution of 28 November 2019 on the Climate and Environment Emergency (2019/2930(RSP)). Available online: https://www.europarl.europa.eu/doceo/document/TA-9-2019-0078_EN.pdf (accessed on 26 April 2022).
4. Institut Català de l'Energia. Llei de Transició Energètica de Catalunya i Transformació de l'Institut Català d'Energia at l'Agència d'Energia de Catalunya. Available online: http://icaen.gencat.cat/ca/participacio/llei-de-transicio-energetica-de-catalunya-i-transformacio-de-linstitut-catala-denergia-en-lagencia-denergia-de-catalunya/ (accessed on 26 April 2022).
5. Institut Català de l'Energia. Prospectiva Energètica de Catalunya 2050 (PROENCAT 2050). Documento Resumen Presentado el 4 de Febrero de 2022. Available online: http://icaen.gencat.cat/es/l_icaen/prospectiva_planificacio/ (accessed on 26 April 2022).
6. Ministerio para la Transición Ecológica y el Reto Demográfico. Proyecto de Real Decreto/2021 por el que se Aprueban los Planes de Ordenación del Espacio Marítimo de las Cinco Demarcaciones Marinas Españolas. 2021. Available online: https://www.miteco.gob.es/es/costas/temas/proteccion-medio-marino/ordenacion-del-espacio-maritimo/default.aspx (accessed on 26 April 2022).
7. Salvador, S.; Gimeno, L.; Sanz Larruga, F.J. The influence of regulatory framework on environmental impact assessment in the development of offshore wind farms in Spain: Issues, challenges and solutions. *Ocean. Coast. Manag.* **2018**, *161*, 165–176. [CrossRef]
8. Verma, S.; Akshoy, R.P.; Nawshad, H. Selected Environmental Impact Indicators Assessment of Wind Energy in India Using a Life Cycle Assessment. *Energies* **2022**, *15*, 3944. [CrossRef]
9. Kouloumpis, V.; Azapagic, A. A model for estimating life cycle environmental impacts of offshore wind electricity considering specific characteristics of wind farms. *Sustain. Prod. Consum.* **2022**, *29*, 495–506. [CrossRef]
10. Chowdhury, N.E.; Shakib, M.A.; Xu, F.; Sayedus, S.; Islam, M.R.; Bhuiyan, A.A. Adverse environmental impacts of wind farm installations and alternative research pathways to their mitigation. *Clean. Eng. Technol.* **2022**, *7*, 100415. [CrossRef]
11. Lloret, J.; Turiel, A.; Solé, J.; Berdalet, E.; Sabatés, A.; Olivares, A.; Gili, J.M.; Vila-Subirós, J.; Sardá, R. Unravelling the ecological impacts of large-scale offshore wind farms in the Mediterranean Sea. *Sci. Total Environ.* **2022**, *824*, 153803. [CrossRef]
12. Conesa, V. *Guía Metodológica para la Evaluación del Impacto Ambiental*, 4th ed.; Mundi-Prensa: Madrid, Spain, 2010.
13. Seacon. *Sediment Spillage during Array Cable Installation at Nysted Offshore Wind Farm*; Report 0402-1-1-L001 rev.1; GS SEACON APS: Ringsted, Denmark, 2005.
14. Elliott, J.; Smith, K.; Gallien, D.R.; Khan, A.A. Observing Cable Laying and Particle Settlement During the Construction of the Block Island Wind Farm. In *Final Report to the U.S. Department of the Interior*; Bureau of Ocean Energy Management, Office of Renewable Energy Programs: Washington, DC, USA, 2017; p. 225.
15. Martín, J.; Puig, P.; Palanques, A.; Ribó, M. Trawling-induced daily sediment resuspension in the flank of a Mediterranean submarine canyon. *Deep. Sea Res. Part II Top. Stud. Oceanogr.* **2014**, *104*, 174–183. [CrossRef]
16. McCauley, R.D.; Duncan, A.J.; Penrose, J.D.; McCabe, K.A. Marine Seismic Surveys: A Study of Environmental Implications. *APPEA J.* **2000**, *40*, 692–708. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.624.3763&rep=rep1&type=pdf (accessed on 26 April 2022). [CrossRef]

17. Ministerio de Agricultura, Alimentación y Medio Ambiente. Documento Técnico Sobre Impactos y Mitigación de la Contaminación Acústica Marina. Madrid. 2012, p. 146. Available online: https://www.miteco.gob.es/es/costas/temas/proteccion-medio-marino/doc-tecnico-impactos-mitigacion-contaminacion-acustica-marina_tcm30-157028.pdf (accessed on 26 April 2022).
18. CEDA. Ceda Position Paper: Underwater Sound in Relation to Dredging. *Terra Aqua* **2011**, *125*, 23–28.
19. Taormina, B.; Bald, J.; Want, A.; Thouzeau, G.; Lejart, M.; Desroy, N.; Carlier, A. A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. *Renew. Sustain. Energy Rev.* **2018**, *96*, 380–391. [CrossRef]
20. Nedwell, J.R.; Workman, R.; Parvin, S.J. *The Assessment of Likely Levels of Piling Noise at Greater Gabbard and Its Comparison with Background Noise, Including Piling Noise Measurements Made at Kentish Flats*; Report No. 633R0115; Subacoustech Environmental Limited: Southampton, UK, 2005.
21. DNVGL. Rules for Classification, Ships. Part 6 Additional Class Notations, Chapter 7 Environmental Protection and Pollution Control. Edition January 2017. Available online: https://rules.dnv.com/docs/pdf/DNV/ru-ship/2017-01/DNVGL-RU-SHIP-Pt6Ch7.pdf (accessed on 26 April 2022).
22. Martin, B.; MacDonnell, J.; Vallarta, J.; Lumsden, E.; Burns, R. HYWIND Acoustic Measurement Report: Ambient Levels and HYWIND Signature. Technical Report for Statoil by JASCO Applied Sciences. 2011. Available online: https://www.equinor.com/content/dam/statoil/documents/impact-assessment/hywind-tampen/Equinor-Hywind-Acoustic-Measurement-Report-JASCO-00229-December-2011.pdf (accessed on 26 April 2022).
23. HDR. Field Observations during Wind Turbine Operations at the Block Island Wind Farm, Rhode Island. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2019-028. 2019; p. 281. Available online: https://espis.boem.gov/final%20reports/BOEM_2019-028.pdf (accessed on 26 April 2022).
24. Westerberg, H.; Bégout, M.L. Orientation of silver eel (*Anguilla anguilla*) in a disturbed geomagnetic field. Advances in Fish Telemetry. In Proceedings of the 3rd Conference on Fish Telemetry, Norwich, UK, 1 January 2000; pp. 149–158.
25. Fuxjager, M.; Eastwood, B.; Lohmann, K. Orientation of Hatchling Loggerhead Sea Turtles to Regional Magnetic Fields along a Transoceanic Migratory Pathway. *J. Exp. Biol.* **2011**, *214*, 2504–2508. Available online: https://www.researchgate.net/publication/51489400_Orientation_of_hatchling_loggerhead_sea_turtles_to_regional_magnetic_fields_along_a_transoceanic_migratory_pathway (accessed on 26 April 2022). [CrossRef]
26. Ottaviani, E.; Malagoli, D.; Ferrari, A.; Tagliazucchi, D.; Conte, A.; Gobba, F. 50 Hz Magnetic fields of varying flux intensity affect cell shape changes in invertebrate immunocytes: The Role of potassium ion channels. *Bioelectromagnetics* **2002**, *23*, 292–297. [CrossRef] [PubMed]
27. Malagoli, D.; Gobba, F.; Ottaviani, E. 50 Hz magnetic fields activate mussel immunocyte p38 MAP kinase and induce HSP70 and 90. *Comp. Biochem. Physiol. C Toxicol. Pharmacol.* **2004**, *137*, 75–79. [CrossRef] [PubMed]
28. Hutchison, Z.; Sigray, P.; He, H.; Gill, A.; King, J.; Gibson, C. *Electromagnetic Field (EMF) Impacts on Elasmobranch (Shark, Rays, and Skates) and American Lobster Movement and Migration from Direct Current Cables (No. BOEM 2018-003)*; Bureau of Ocean Energy Management (BOEM): Narragansett, RI, USA, 2018. Available online: https://espis.boem.gov/final%20reports/5659.pdf (accessed on 26 April 2022).
29. Woodruff, D.L.; Ward, J.A.; Schultz, I.R.; Cullinan, V.I.; Marshall, K.E. Effects of Electromagnetic Fields on Fish and Invertebrates. In *Task 2.1.3: Effects on Aquatic Organisms Fiscal Year 2011 Progress Report-Environmental Effects of Marine and Hydrokinetic Energy (No. PNNL-20813 Final)*; Pacific Northwest National Laboratory (PNNL): Richland, WA, USA, 2012. Available online: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20813Final.pdf (accessed on 26 April 2022).
30. Bochert, R.; Zettler, M.L. Long-Term Exposure of Several Marine Benthic Animals to Static Magnetic Fields. *Bioelectromagnetics* **2004**, *25*, 498–502. Available online: https://www.researchgate.net/publication/8338761_Long-term_exposure_of_several_marine_benthic_animals_to_static_magnetic_fields (accessed on 26 April 2022). [CrossRef] [PubMed]
31. CMACS. A Baseline Assessment of Electromagnetic Fields Generated by Offshore Windfarm Cables. COWRIE Report EMF-01-2002-66. 2003. Available online: https://tethys.pnnl.gov/sites/default/files/publications/COWRIE_EMF_Offshore_Cables.pdf (accessed on 26 April 2022).
32. Gill, A.B.; Taylor, H. The Potential Effects of Electromagnetic Fields Generated by Cabling between Offshore Wind Turbines upon Elasmobranch Fishes. Countryside Council for Wales 2001. CCW Contract Science Report No 488. Available online: https://tethys.pnnl.gov/sites/default/files/publications/Gill%20and%20Taylor%202001.PDF (accessed on 26 April 2022).
33. Smith, E. Electro-physiology of the electrical shark-repellant. *Trans. Korean Inst. Electr. Eng.* **1974**, *65*, 1–20.
34. Kalmijn, A.J. Detection and Processing of Electromagnetic and Near-field Acoustic Signals in Elasmobranch Fishes. *Philos. Trans. R. Soc. Lond. Board Biol. Sci.* **2000**, *355*, 1135–1141. [CrossRef]
35. Walker, M.M.; Diebel, C.E.; Kirschvink, J.L. Detection and use of the Earth's Magnetic Field by Aquatic Vertebrates. In *Sensory Processing in Aquatic Environments*; Collins, S.P., Marshall, N.J., Eds.; Springer: New York, NY, USA, 2003; pp. 53–74.
36. Nyqvist, D.; Durif, C.; Johnsen, M.G.; de Jong, K.; Forland, T.N.; Sivle, L.D. Electric and Magnetic Senses in Marine Animals, and Potential Behavioral Effects of Electromagnetic Surveys. *Mar. Environ. Res.* **2020**, *155*, 104888. [CrossRef]
37. Farr, H.; Ruttenberg, B.; Walter, R.; Wang, Y.-H.; White, C. Potential environmental effects of deepwater floating offshore wind energy facilities. *Ocean. Coast. Manag.* **2021**, *207*, 16. [CrossRef]
38. Platis, A.; Siedersleben, S.; Bange, J.; Lampert, A.; Bärfuss, K.; Hankers, R.; Canadillas, B.; Foreman, R.; Schulz-Stellenfleth, J.; Djath, B.; et al. First in situ evidence of wakes in the far field behind offshore wind farms. *Sci. Rep.* **2018**, *8*, 2163. [CrossRef]

39. Christiansen, M.B.; Hasager, C.B. Wake effects of large offshore wind farms identified from satellite SAR. *Remote Sens. Environ.* **2005**, *98*, 251–268. [CrossRef]
40. Van Berkel, J.; Burchard, H.; Christensen, A.; Mortensen, L.O.; Svenstrup Petersen, O.; Thomsen, F. The Effects of Offshore Wind Farms on Hydrodynamics and Implications for Fishes. *Oceanography* **2020**, *33*, 108–117. [CrossRef]
41. Zenetos, A.; Gofas, S.; Morri, C.; Rosso, A.; Violanti, D.; García Raso, E.; Cinar, M.E.; Almogi-Labin, A.; Ates, A.S.; Azzurro, E.; et al. Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterr. Mar.* **2012**, *13*, 328–352. [CrossRef]
42. Otero, M.; Cebrian, E.; Francour, P.; Galil, B.; Savini, D. Monitoreo de Especies Marinas Invasoras at áreas Marinas Protegidas (AMP) del Mediterráneo: Estrategia y Guía Práctica Para Gestores. UICN 2013. p. 136. Available online: https://portals.iucn.org/library/efiles/documents/2013-008-Es.pdf (accessed on 26 April 2022).
43. Subías-Baratau, A.; Sànchez-Vidal, A.; Di Martino, E.; Figuerola, B. Marine biofouling organisms on beached, buoyant and benthic plastic debris in the Catalan Sea. *Mar. Pollut. Bull.* **2022**, *175*, 113405. [CrossRef] [PubMed]
44. Pastor, X. L'eòlica Marina, Una Aliada de la Biodiversitat. Published at el Diari de Girona, on 6 March 2022. Available online: https://www.diaridegirona.cat/opinio/2022/03/06/l-eolica-marina-aliada-biodiversitat-63484707.html (accessed on 26 April 2022).