The reef effect induced by wind farms and their grid connection

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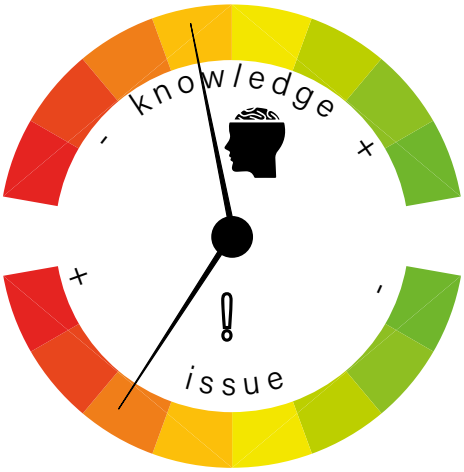
COME3T

COME3T, a committee of experts for environmental issues related to offshore renewable energies, brings together neutral, independent experts to provide scientific knowledge and recommendations in response to environmental issues associated with offshore renewable energy.



Question deemed
"a major issue for which knowledge is insufficient"
by the experts

Scientific experts

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Introduction

The installation and operation of offshore wind farms generate a range of effects on the marine environment. To describe these phenomena, we often come across the terms **relay effect**, **reef effect**, **reserve effect** and **FAD (Fish Aggregating Device) effect** which can be difficult to distinguish between.

In this bulletin, the experts worked together to define these different terms and to focus on the reef effect and its consequences on fish populations, and more widely on all mobile species. More information on the notion of relay effect and the propagation of non-indigenous species is available in COME3T Bulletin n°2.

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Definitions

Anthropogenic pressure

Manifestation of human activities in the environment that may take the form of a change in status, in space or time, of the physical, chemical or biological characteristics of the environment[1].

Effect

Objective consequences of the introduction of one or more pressures liable to generate impact on the marine living environment[1].

Impact

Transposition of an effect on the different compartments of the marine ecosystem taking into account its sensitivity, defined by its capacity to tolerate changes to the environment (resistance), and the time required for it to recover following these changes (resilience)[1]. For example, the introduction of a substrate on the seafloor (pressure) may lead to an increase in local abundance (effect) and have a varying degree of impact on the ecosystems according to their sensitivity.

Reef effect

Increase in the environment's capacity to host hard substrate or sedentary organisms (i.e. species present most of the time, on an annual or at least seasonal basis) as a result of the introduction of a hard substrate of anthropogenic origin (e.g. a wind turbine foundation). The reef effect applies at the scale of the artificial structure and its immediate surroundings. According to the experts, the reef effect induces other effects, including the temporary aggregation of mobile species, and has consequences for the marine ecosystem at different scales.

Mobile species temporary aggregation effect

Also referred to as the **attraction effect**. These terms refer to the temporary, local increase in the biomass of mobile fauna around an artificial structure (Fig. 1). This effect may be a consequence of the reef effect in areas where offshore renewable energy (ORE) systems are installed and relates to mobile species (mainly fish) present within an area exceeding the surface area of the ORE farm. The "fish aggregating device" (FAD) effect is an example of the temporary aggregation effect.


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[1] Definition taken from the work of the working group on cumulated effects under the French Ministry in charge of the environment and derived from the French order of 17 December 2012 relating to the definition of good ecological status.

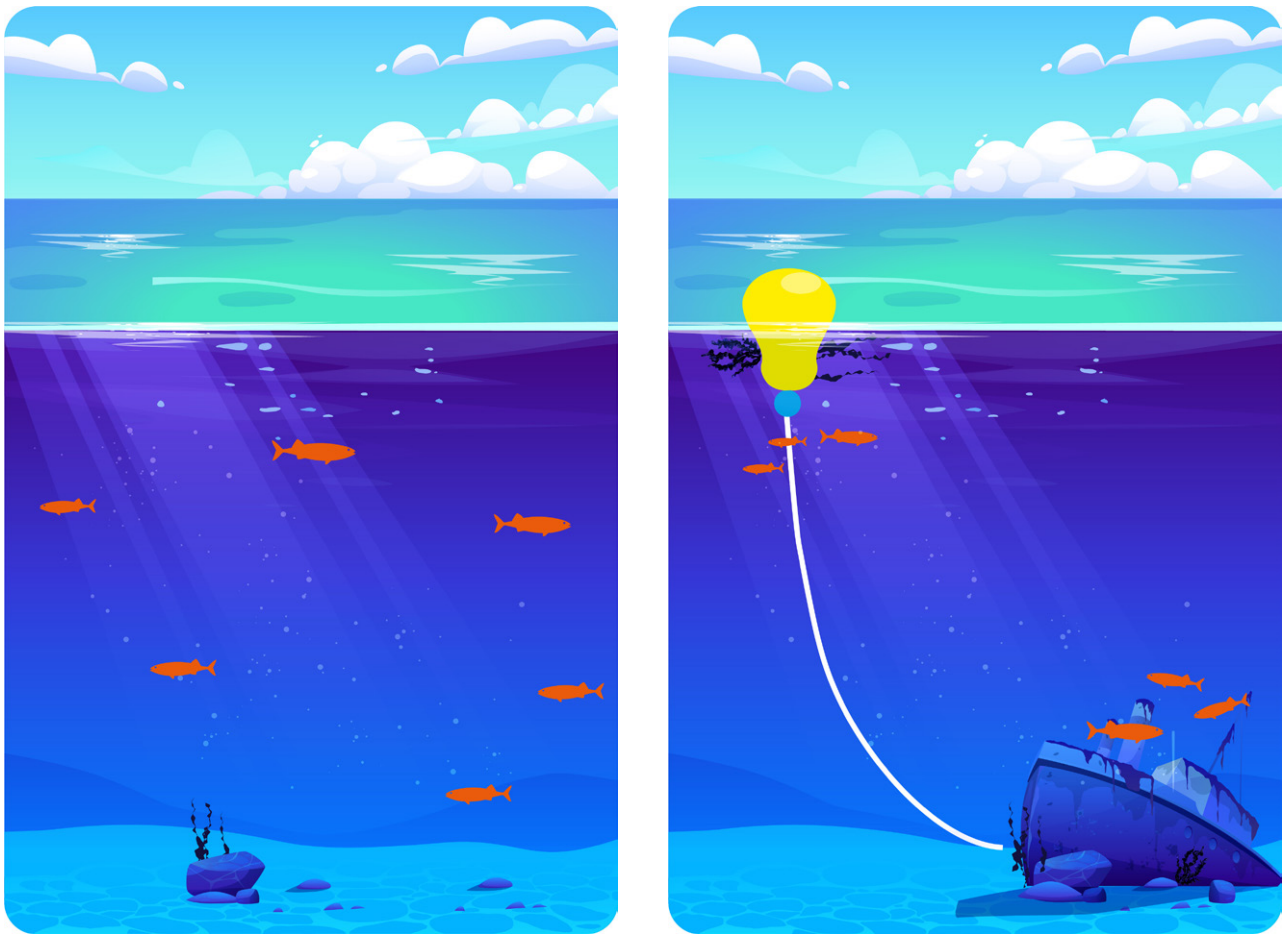

Fig. 1 *Illustration of the mobile species temporary aggregation effect with the introduction of anthropogenic structures. This effect does not necessarily increase the production of individuals but rather concentrates them within the same area.*

Reserve effect

Effect related to changes in uses (shipping traffic, pleasure boats, fisheries, etc.) in the farm area which initially affects the abundance, biomass and individual size spectra (and other demographic criteria) of exploited species, and which can potentially have consequences at fish population level (for instance, on functional diversity or structure), or even at ecosystem level.

Trophic relationships

Refers at all feeding relationships between living organisms in an ecosystem (the description of who eats who). Different trophic levels exist and can be divided into three categories: producers, consumers and decomposers.

Biofouling

Biofouling is a biological process which occurs whenever a medium is introduced into an aquatic environment, or a surface already present in the environment becomes bare. This natural or man-made structure forms a new available surface where attached living organisms can develop.[2].

[2] Definition taken from the Bibliographical Atlas of Biofouling (Quillien & al., 2018).

Characterisation of the reef effect

The installation of an offshore wind farm (representing the "driving force" - Fig. 2) triggers many changes in the status of the marine environment, including the introduction of an artificial hard substrate (pressure - Fig. 2). The introduction of this pressure will have different consequences on the ecosystem such as the modification of hydrodynamics, loss of natural substrate, the **reef effect**, etc.


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The reef effect involves the regular or permanent presence of sedentary or substrate-dependent species[3] and induces the temporary presence of very mobile species (temporary aggregation effect).

According to the experts, the reef effect generates a variety of responses (red box - Fig. 2) on the ecosystem's ecological functions (blue text - Fig. 2) which can be divided into four main categories:

- Variation in abundance and biomass
- Variation in diversity
- Changes in connectivity
- Changes in trophic relationships

For instance, the reef effect can trigger changes in **connectivity** by expanding the area of distribution of certain species that naturally live in the coastal environment towards waters further offshore. These four categories are illustrated in the figure below for the development of a wind farm (Fig. 2). As illustrated in the figure, the presence of offshore wind farms can also generate a **reserve effect** due to changes in uses. The extent of this reserve effect may be modulated by the **reef effect** and its capacity to create a habitat that may be more or less favourable (availabilty of food resources for instance) to certain species.

[3] Substrate-dependent species are particularly sensitive to the degradation of the environment on which they depend.

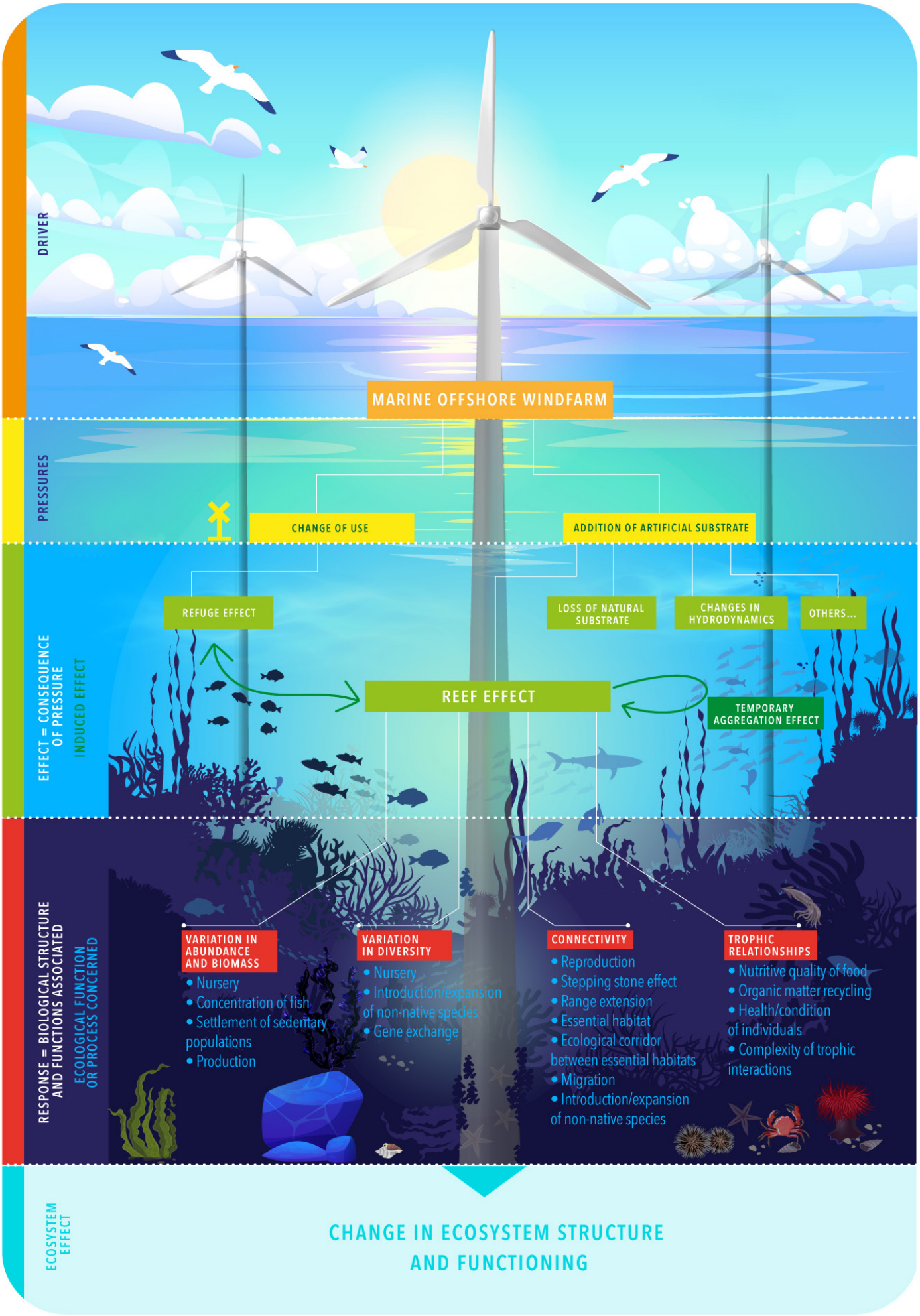


Fig. 2 *Illustration of the potential consequences of the reef effect on mobile species and more specifically on fish communities following the development of an offshore wind farm.*

Consequences of the reef effect at different scales

The consequences of the reef effect are reported at different scales, here illustrated at the scale of the structure, the farm and the region (Fig. 3). It is important to note that **the notions illustrated in this figure are not specific to the types of wind turbines shown**.

A few important notions relating to Figure 3:

- The consequences of the reef effect will be different according to the type of substrate and the original habitat.
- The volume and surface area available on the artificial substrate will modulate the extent of the consequences of the reef effect: for instance, the weight of biofouling on a floating structure is estimated to be six times greater than that of a monopile structure (Le Marchand, 2020).
- The exposure of artificial structures to tides can affect the extent of the consequences of the reef effect: for example, floating structures are not affected by variations in water level due to tides.
- The consequences on the ecological functions will be variable according to the depth of the artificial structures in the environment.

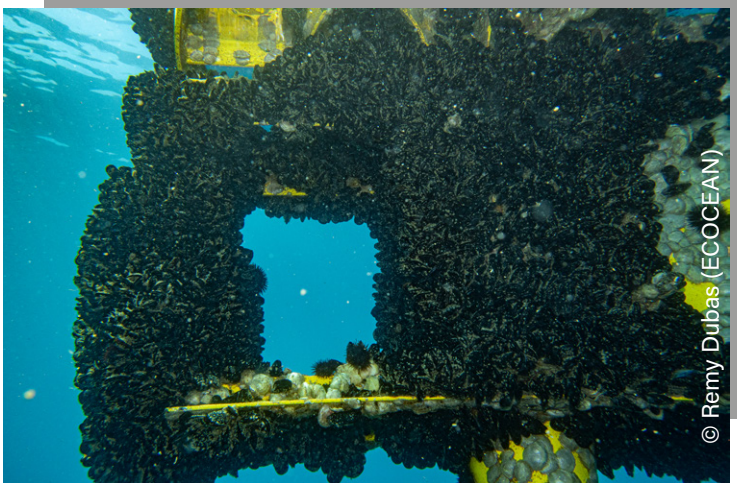
[1] Changes in connectivity

Here, changes in connectivity are illustrated at regional level:

- Mobile fish aggregate temporarily around structures and move between different areas/habitats.
- The sedentary fish that are regularly or permanently present around artificial structures are also liable to move between coastal habitats and those created by wind farms according to their life cycle (for breeding for example).

[2] Changes in abundance and/or biomass

Here, changes in abundance and/or biomass are illustrated with an increase in the number of individual fish aggregated around the structure, together with sedentary species and passing species.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[3] Changes in diversity and trophic relationships

The changes in trophic relationships are illustrated here by the presence of sedentary species, feeding on species that developed on or around the artificial structure and attracting passing predators. The change in diversity caused by the reef effect is illustrated here on two natural substrates.

[3.1] Natural rocky substrate

If an artificial substrate is laid on a natural rocky substrate, it will cause little change in species diversity.

[3.2] Natural sandy substrate

In a habitat with a natural soft substrate, the introduction of an artificial substrate is liable to attract a new community composed of species from rocky areas.

[4] Changes in diversity and abundance and/or biomass

Here, changes in diversity, abundance and/or biomass are illustrated by the presence of the export cable in an essential nursery habitat. Cable-laying can affect such nursery grounds (burial or cable protection with riprap or protective shells). When the farm is in operation, the introduction of a hard substrate (on a soft or rocky substrate) can provide an additional habitat for hard substrate species.

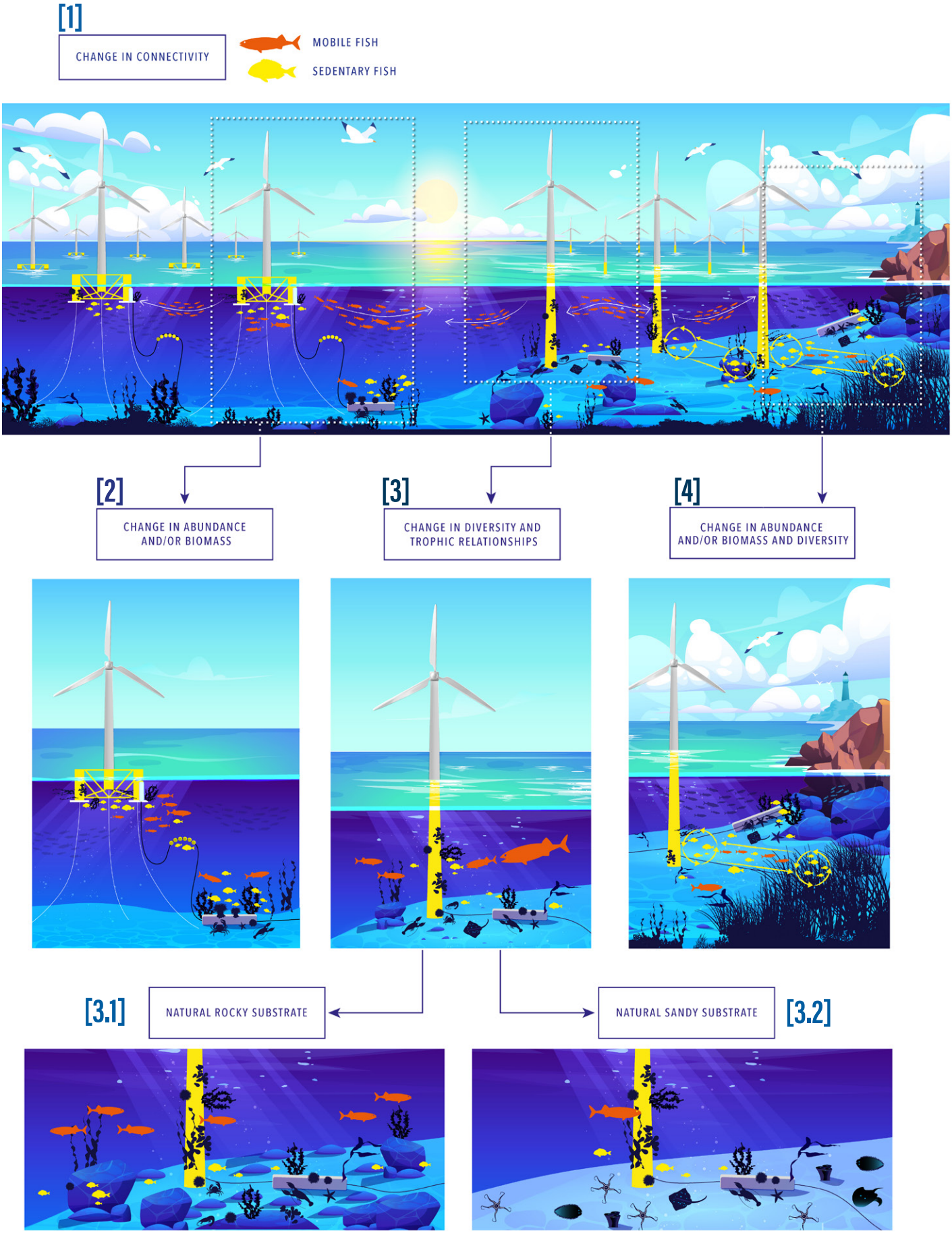

Fig. 3 *Conceptual illustration of the potential consequences of the reef effect at different scales.*

The reef effect of wind farms in an anthropogenic landscape

The extent of the consequences of the reef effect on the marine ecosystem is largely modulated by the combination of different anthropogenic activities (Fig. 4). The reef effect can be induced by different types of anthropogenic structures (wind farms, wrecks, artificial reefs, port structures) which can boost habitat connectivity and expand the distribution of hard substrate species (also known as the relay effect).

In order to reconcile the sustainable development of maritime activities and the preservation of marine ecosystems, marine spatial planning defines the zones suited to the maintenance and development of certain uses of the sea. Within the boundaries of offshore wind farms, changes in certain practices/activities could lead to a reserve effect during the operational phase. Combined with the introduction of new structures in the marine environment (foundations, floaters, cable protection systems, etc.), this reserve effect could be amplified by the reef effect, these two effects being intrinsically linked.

Fig. 4 *Diagram illustrating the reef effect at different scales in an anthropogenic landscape.*

Issues and knowledge

The experts consider knowledge of the reef effect to be insufficient. The quantification of the reef effect is an important parameter in ecosystem models, but the data currently available does not provide a robust understanding of ecosystem structure and functioning. Given the consequences that the reef effect can have on the ecosystem, the management of the reef effect is deemed to be a relatively important issue by the experts.


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France Energies Marines is the Institute for Energy Transition dedicated to offshore renewable energies. Its missions: to define, set up and apply the scientific and technical environment required to overcome the obstacles related to the development of ORE technologies while ensuring optimal environmental integration. Built on a public-private partnership, the Institute is at the interface between institutional (local authorities, regions, etc.), academic, scientific and industrial (project developers and leaders) stakeholders.

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