Contribution of long-term series in the characterization, quantification and understanding of biodiversity changes

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Context. Characterizing and quantifying the changes taking place at different levels of organization (populations, communities) and identifying the factors involved in these changes is of particular interest in a context where biodiversity patterns are strongly impacted by various anthropogenic pressures, such as climate change. While the first two aspects (i.e. characterizing and quantifying) have been the subject of numerous studies that have notably allowed us to assess the risks of extinctions of numerous species and ecosystems (Stephens et al. 2016, Pecl et al. 2017), little is known about the factors involved in spatio-temporal changes in biodiversity. In particular, the relative contribution of the influence of biotic (e.g. predation, competition) and abiotic (e.g. climate variations, pollution, habitat loss) factors on population dynamics, spatial distribution of species and assemblage rules in communities remains poorly understood in many ecosystems. This is especially true for marine ecosystems. Although some tools theoretically address these issues (e.g. joint distribution models), inferences are currently limited by data that do not capture the complex changes that occur in time and space for several species simultaneously (i.e. most inferences are based on presence/absence data collected at a given time; Blanchet et al. 2020). Furthermore, most studies do not consider the interactions that exist between communities located at different trophic levels (e.g. between primary producers and primary consumers) which limits our understanding of overall ecosystem functioning. For example, in coastal ecosystems, while recent studies have demonstrated the importance of interactions between benthic and pelagic compartments on material and energy flows (Griffiths et al. 2017), these two compartments are mostly studied separately. The increasing availability of long-term databases - regarding both biodiversity and environmental factors - could provide a better understanding of which factors influence biodiversity patterns. In this respect, the historical data collected in the framework of the "Impact des Grands Aménagements" (IGA) monitoring represent a unique opportunity to characterize, quantify and identify the factors involved in biodiversity variations at different trophic levels. Improving our understanding of ecosystem functioning is essential to predict and anticipate the effects of anthropogenic pressures on species (their associations as well as their abundance), or the demography and composition of communities. Thus, this project aims to better understand the functioning of coastal ecosystems (intertidal and subtidal) by characterizing and quantifying changes at different levels of organization and then identify the factors responsible for the observed variations. It has three objectives:

Objective 1: Build a standardized long-term database

The data collected in the framework of the IGA monitoring on different NPPs (Nuclear Power Plants) represent a vast source of information with more than 40 years of data collected on 4 sites located in the Channel (Flamanville, Gravelines, Paluel, Penly). This temporal follow-up

is unique and of great ecological significance. However, the heterogeneity of the data and the changes in sampling protocols that have taken place over time require additional checking and standardizations in order to (*i*) homogeneize the information present in the different taxonomic compartments (e.g. temporal coverage, taxonomic resolution, number of spatial replicates), (*ii*) identify potential sampling biases (e.g. change of protocol or operators) and (*iii*) obtain a usable database to conduct relevant analyses to characterize the changes and identify the factors involved in the variations observed at different levels of organization (e.g. change of protocol or operators). (ii) identify potential sampling biases (e.g. change of protocol or operators) and (*iii*) conduct relevant analyses to characterize the changes and identify the factors involved in the variations observed at different levels of organization (e.g. multivariate analyses to document changes at the community level). Preliminary work has already been done on the Gravelines site database, with encouraging results.

Objective 2: Characterize and quantify changes in populations and communities

This objective will rely on temporal trend analyses conducted at different levels of organization (populations, communities, trophic guilds) and different trophic levels (phytoplankton, zooplankton, benthos) in order to assess whether consistent/dissimilar signals emerge between different sites. Such analyses have already been conducted in terrestrial environments (Lehikoinen et al. 2016, Stephens et al. 2016) but remain very limited in marine environments. The identification of a global signal could reflect the influence of a factor that acts on a large scale such as climate change.

Objective 3: Assess the relative contribution of biotic and abiotic factors

While many studies have highlighted the role of the environment and anthropogenic pressures on populations and communities (e.g. species displacement due to climate change), few have considered the role of biotic factors on the observed variations. Recent studies have demonstrated the contribution of long-term time series for the coupled analysis of population (or community) dynamics to understand the interactions that exist between species (Barraquand et al. 2018). The IGA database has unique temporal information for several key species at different trophic levels. In this objective, the idea will be to use modeling approaches (e.g. multivariate autoregressive model) to determine the nature and strength of the interactions that govern the structure of benthic and pelagic communities (phytoplankton and zooplankton) and to evaluate the response times (lags) in the temporal dynamics according to trophic compartments. Attention will be paid to the differences and similarities observed between the different communities (e.g. one can expect a stronger influence of biotic interactions in benthic communities compared to pelagic communities). Another aspect will be to study the temporal stability of biotic interactions in a dynamic environmental context (climate change).

Objective 4: Understand the dynamics of coastal ecosystem functioning

While biotic interactions are investigated separately in each community – or compartment (phytoplankton, zooplankton, macrobenthos) –in objective 3, the objective 4 will aim to understand the dynamic links that exist between the different trophic compartments. Using structural equation models, we will try to understand how environmental variations modify material and energy flows in food webs. For example, by modifying the quantity (abundance)

and quality (e.g. presence of taxa with high nutritive value) of resources in the environment (phytoplanktonic compartment), seasonal variations in temperature can have an indirect effect on zooplanktonic communities with consequences on benthic communities.

Overall, this project aims to (1) describe and quantify long-term changes at different levels (population - communities), (2) improve our understanding of the role of biotic interactions in the structuring of benthic and pelagic marine communities, (3) evaluate the links between these two compartments by studying the coupling of population and community dynamics, and (4) understand the dynamics of ecosystem functioning.

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Scientific collaborations

- IFREMER teams in « Laboratoires Environnement Ressources » (eg Boulogne and Port en Bessin) – M. Ropert, T. Hernandez, G. Wacquet
- University teams from the Réseau des Stations Marines
- Research group « EVOLECO »