Allocations de Recherche Doctoral 2019

Titre du sujet de thèse	Estimation des diversités fonctionnelle et phylogénétique en fonction de l'état de santé des écosystèmes structurés par les espèces ingénieurs : cas des herbiers à *Zostera marina* et *Z. noltii* et des récifs à *Sabellaria alveolata*
PhD Title	**Fun**ctional and phylogenetic **Dive**rsity as related to ecological state in bio-engineered communities supported by eelgrass *Zostera marina* and *Z. noltii* and the marine polychaete *Sabellaria alveolata*
ACRONYM	**FunDive**
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Laboratoire/unité d'accueil, localisation	Laboratoire d'Ecologie Benthique Côtière (LEBCO) Ifremer Centre Bretagne
Employeur envisagé	Ifremer
Ecole doctorale de rattachement	EDSM

Summary – *1200 caractères*

Biodiversity tends to be greater when ecosystems are in good ecological state. However, ecosystem processes are not directly influenced by species diversity, but rather by the ecological contributions of interacting species to the ecosystem. Conservation management and policies are typically based on a single measure of biodiversity: species richness, but this measure assumes every species plays the same role and has therefore limitations in representing the full range of ecosystem functions. Furthermore, much of the current knowledge on biodiversity effects on functioning has resulted from work conducted on communities representing a single trophic level, typically terrestrial plants. Recent research has shown that different trophic levels may respond differently to perturbations in the environment, and that patterns in biodiversity may differ between primary producers and consumers in response to disturbance.

The goal of this thesis project is to better understand the relationship between biodiversity (*sensu* species richness), functional diversity and ecological state in two habitats supported by bioengineering species representing two trophic levels: eelgrass beds (genus *Zostera*) and *S. alveolata* polychaete reefs. Biodiversity will be estimated using traditional taxonomic methods, as well as with two different proxies for functional diversity: one based on the functional traits of species and another based on the phylogenetic relatedness of species. We will assess how environmental perturbations may affect loss of function in these communities by examining changes in functional diversity and their ecosystem consequences along gradients of environmental or human impact.

Key-words : Biodiversity, Benthic Community Ecology, Functional Diversity, Phylogenetic Diversity, Engineering Species, Foundation Species, Reef

Expected profile – *400 caractères*

The candidate will have a Masters in ecology, evolution or biology. Experience in molecular biology and demonstrated skills in biostatistics (via previous internships) are required. Experience in taxonomic identification of benthic marine invertebrates is highly desired.

Résumé – *1200 caractères*

La biodiversité a tendance à être plus importante lorsque les écosystèmes sont en bon état écologique. Cependant, les processus écosystémiques ne sont pas directement influencés par la diversité des espèces en soi, mais plutôt par les contributions écologiques d'espèces en interaction dans l'écosystème. La gestion des écosystèmes naturels est généralement basée sur une seule mesure de la biodiversité: la richesse spécifique, mais cette mesure fait l'hypothèse implicite que toute les espèces sont fonctionnellement importantes et présente *de facto* des limites dans sa représentation de l'ensemble des fonctions des écosystèmes. En outre, une grande partie des connaissances actuelles sur les effets de la biodiversité sur le fonctionnement résultent de travaux menés sur des communautés représentant un seul niveau trophique, généralement des plantes terrestres. Des recherches récentes ont montré que différents niveaux trophiques peuvent réagir différemment aux perturbations de l'environnement et que les patrons de biodiversité peuvent différer entre producteurs primaires et consommateurs en réponse aux perturbations.

L'objectif de ce projet de thèse est de mieux comprendre la relation entre nombre d'espèces (richesse spécifique), diversité fonctionnelle et état écologique dans deux habitats soutenus par des espèces ingénieures représentant deux niveaux trophiques: les herbiers de zostères (genre *Zostera*) et les récifs construits par le polychète *S. alveolata*. La biodiversité sera estimée à l'aide de méthodes taxonomiques traditionnelles, ainsi que de deux méthodes différentes pour quantifier la diversité fonctionnelle: l'une basée sur les traits fonctionnels des espèces et l'autre basée sur la parenté phylogénétique des espèces. Nous évaluerons comment les perturbations environnementales peuvent affecter la perte de groupes fonctionnels dans ces communautés en examinant les changements dans la diversité fonctionnelle et leurs conséquences sur les écosystèmes le long des gradients d'impact environnemental ou humain.

Mots-clés : Biodiversité, Ecologie des Communautés Benthiques, Diversité Fonctionnelle, Diversité Phylogénétique, Espèces Ingénieurs, Espèces Fondatrices, Récifs

Profil de candidature souhaité – *400 caractères*

Le(a) candidat(e) aura un Master en écologie, évolution ou biologie. Expérience en biologie moléculaire et connaissance de méthodes en biostatistiques (par des stages précédents) est requise. Une expérience en identification taxonomique des organismes marins est fortement désirée.

Research Project Description

1– Scientific Context

Marine ecosystems provide numerous resources that are beneficial to society (Duraiappah et al., 2005). However, human activity is drastically affecting marine habitats and eroding the biodiversity they harbor. A direct consequence of this ongoing process is the degradation of ecosystem functions and by extension, the loss of ecosystem services (Palumbi et al., 2009; Pimm et al., 2014). Biodiversity tends to be positively correlated with Ecosystem Function (BEF) (Cardinale et al., 2006, 2007) but this relationship remains poorly understood, as ecosystem processes are not directly influenced by species diversity only, but rather by the ecological contributions of interacting species to the ecosystem. Conservation management and policies are typically based on a single measure of biodiversity: species richness and species composition, but these measures have limitations in representing the full range of ecosystem functions, as they assume that every single species plays a similar ecological role. Furthermore, much of the current literature on biodiversity research is focused on biodiversity within a single trophic level, typically terrestrial plants (Cardinale et al., 2011). Recent research has shown that different trophic levels may respond differently to perturbations in the environment, and that patterns in biodiversity may differ between primary producers and consumers in response to disturbances (Duffy, 2002; O'Connor et al., 2017).

In the marine environment, high biodiversity is often associated with ecosystem engineers (Goldberg, 2013). While coral reefs are emblematic biodiversity hotspots in the tropical oceans, ecosystems engineered by marine plants or animals are the temperate oases of diversity. Among marine plants, eelgrass beds of the genus *Zostera* constitute important habitat for fish and invertebrates in shallow subtidal environments. Temperate reefs constructed by marine polychaete *Sabellaria alveolata* are estimated to be the largest and one of the most common biogenic reefs in Europe and are hotspots for biodiversity (Dubois et al., 2002). *S. alveolata* reefs constitute an interesting example to further explore the relationships between biodiversity and ecosystem functioning, given that in *S. alveolata* reefs, higher species richness is generally associated with a degraded reef state (Jones et al., 2018) as opposed to patterns observed in many terrestrial communities that show a decrease in species richness with disturbance (Flynn et al., 2011).

The overarching goal of this thesis project is to characterize the relationship between biodiversity and ecological state in two temperate habitats supported by bioengineering species that represent two trophic levels: eelgrass beds of the genus *Zostera* and *S. alveolata* polychaete reefs. Biodiversity will be estimated using traditional taxonomic methods, as well as with two different proxies for functional diversity, one based on the functional traits of species (Lavorel & Garnier, 2002) and another based on the phylogenetic relatedness of species (Cadotte et al., 2008, 2013). We will explore to what extent trait- and phylogenetic-based methods can characterize functional diversity in eelgrass beds and *S. alveolata* reefs and how metrics based on different types of information perform. We will assess how environmental perturbations may affect loss of function in these communities by examining changes in functional diversity and their ecosystem consequences along gradients of environmental or human impact. Furthermore, we will evaluate the best diversity metric(s) to assess the ecological state of engineered habitats and ecosystems.

2- Goals

1. Examine how environmental and human stressors affect biodiversity in communities having good and impacted ecological states.
2. Compare how environmental impacts affect biodiversity in communities supported by primary producers (eelgrass) and primary consumers (polychaetes).
3. Evaluate how changes in species diversity affect functional diversity (quantified as both phylogenetic diversity and functional trait diversity) and ecosystem functioning.

In this thesis project we will test the following null hypotheses:

a. Traditional measures of biodiversity (ie species richness) show the same trends as functional diversity (based on biological traits and/or phylogenetic distances) in good vs impacted habitats.
b. Functional diversity estimated with biological traits show the same trends as estimates based on evolutionary history (phylogenetic distances).
c. The relationship between functional diversity and ecosystem functioning is the same in communities supported by primary producers (*Zostera marina*) compared to secondary producers (*Sabellaria alveolata*).

3- Methodology

a. Sampling :

For eelgrass communities, 5 sites identified for the Life MarHa project will be sampled for suprabenthic communities inhabiting the eelgrass in good and impacted ecological states. These include sites spanning a variety of environmental conditions within France: Chausey, Golfe du Morbihan, Bassin d'Arcachon, Bidassoa and Etang de Thau. For *S. alveolata* polychaete reefs, 10 sites identified for the REEHAB project will be sampled for microbenthic communities inhabiting the reefs in good and impacted ecological states. These include sites spanning a broad latitudinal gradient in Europe, including 4 sites in the United Kingdom, 4 sites in France and 2 sites in Portugal.

b. Biodiversity estimates :

Samples will be sorted and identified to the lowest taxonomic level (species, when possible) using traditional taxonomic methods. Abundance and biomass will be estimated for each species. Traditional biodiversity metrics will be calculated, such as Species Richness, Simpson's and Shannon's diversity indices. A matrix of functional traits will then be compiled for all species identified, including morphological (size, mode of reproduction, fecundity, etc.) and ecological (trophic level, habitat position, etc.) traits. Functional traits will be obtained from existing databases (for example, compiled from previous studies conducted in our group) or obtained from the literature. Functional groups will be generated by clustering species with similar traits. Phylogenetic diversity will be estimated by sequencing the mitochondrial cytochrome oxidase 1 gene (*cox-1*) from all species present in each community. *Cox-1* is a commonly used gene for DNA barcoding studies, known for being variable across the large number of taxonomic groups likely to be encountered in our study. Two global phylogenies will be generated for all species present in eelgrass and polychaete reef communities, and phylogenetic diversity will be estimated as the total branch length for each the community sampled in each study site and according to ecological state. These various metrics of biodiversity will then be compared across environmental and ecological states in order to evaluate how stressors impact biodiversity and how different types of metrics perform for a given stressor.

c. Ecological State Assessment:

The main proxy we intend to use to evaluate good ecological state is secondary production, as measured by estimated biomass (ie dry weight of each species x abundance). Secondary production/ biomass is used in many studies as a proxy for good functioning, in part because it is relatively straight-forward to measure (Cardinale et al., 2007; Jetz et al., 2014; Duffy et al., 2016).

This PhD project will also benefit from data collected in the MarHa project, which will evaluate the ecological state of *Zostera marina* in various sites in France. In MarHa, we also plan to estimate primary production and carbon storage as ecosystem functions – but these measurements will be conducted by partners in the project, and not by the PhD student himself. Nevertheless, these will be important ecosystem functions that will be used test the relationship between biodiversity/functional diversity and ecosystem functioning.

4- Ressources Available

This project will rely on three existing projects: MarHa (T. Bajjouk, LEBCO), INDIGENE (T. Bajjouk, LEBCO) and REEHAB (S. Dubois, LEBCO). Sampling in eelgrass will rely on efforts already in place for the MarHa project – field sampling and sample processing will be conducted concurrently with sampling for MarHa and will benefit from logistics and resources already in place for this project. Likewise, sampling in *S. alveolata* reefs will rely on existing resources from Ifremer and from REEHAB partners. Molecular analyses will be conducted in LEBCO, supported by funds from INDIGENE (*Zostera* spp.). Complementing funds for molecular analyses for *S. alveolata* will be requested in 2019 (target: EC2CO). Data analysis will be supervised by the thesis advisors, using methods already employed in our lab.

5- Originality

The current paradigm for biodiversity research is that higher diversity is indicative of good ecological state and good ecosystem functioning. However, recent research shows that there is much variability in the relationship between biodiversity and ecosystem functioning, and that considering biodiversity without knowledge of the functional role of species can be misleading. This thesis project proposes to examine biodiversity from a functional perspective, utilizing species functional traits and phylogenetic relationships as proxies of functional diversity. The effects of environmental change on biodiversity and ecosystem functioning, and how to best describe changes in functional diversity, are central topics of debate in community ecology in recent years, and have important repercussions for conservation and management. We hope to contribute new data that will allow patterns in biodiversity to be characterized in two different and widespread types of marine habitats, engineered by primary producers (eelgrass) and consumers (polychaetes), that may provide further insight into how functional diversity varies with ecological state and disturbance.

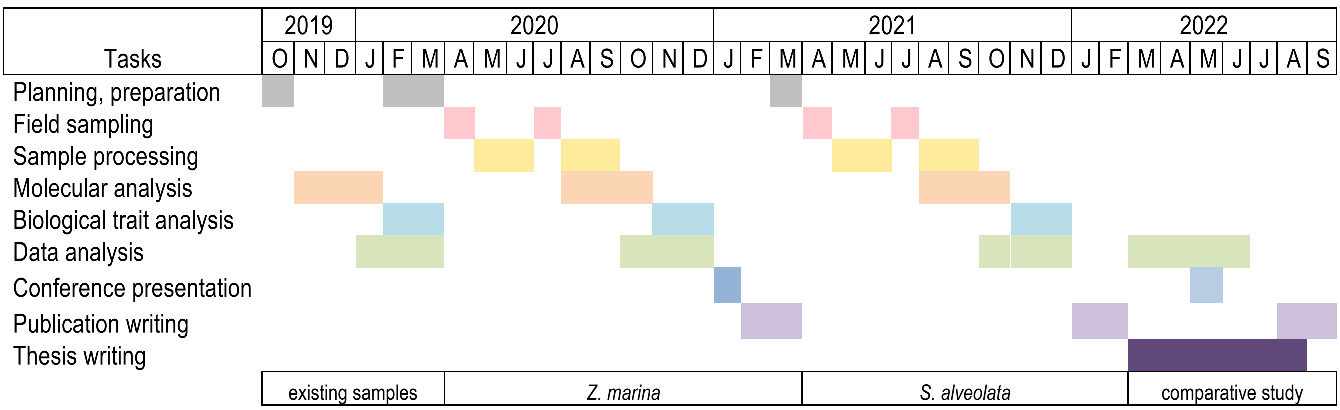
While various examples exist to demonstrate the utility of using functional and phylogenetic diversity in terrestrial ecology (Cadotte et al., 2008, 2012; Devictor et al., 2010; Flynn et al., 2011; Spasojevic & Suding, 2012), the marine literature to date is limited to fish and corals (Mouillot et al., 2011, 2016; D'Agata et al., 2014), and many of these studies are targeted on a particular taxonomic group. The originality of our work will be to provide new examples in temperate benthic marine communities spanning a diversity of phyla that will allow us to further evaluate the generality of these trends. From previous work in our group, we see that at least in *Sabellaria alveolata* reefs, species richness is not necessarily correlated with good ecological state. This PhD project will hopefully allow us to better understand why.

6- Collaborations

Within Ifremer, this project will involve a number of researchers participating in the MarHa and INDIGENE projects, including researchers and technicians in LEBCO and 3 of the Littoral Units (Bretagne Nord, Arcachon and Languedoc-Roussillon).

This project will also benefit from a number of international collaborators, involved in the REEHAB project led by Stanislas Dubois: Prof. Louise Firth (University of Plymouth, UK), Prof. Andrew Davies (Bangor University, UK) and Prof. Fernando Lima (University of Porto, Portugal).

7- Timeline



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