LANICE CONCHILEGA, FISHERIES AND MARINE CONSERVATION: TOWARDS AN ECOSYSTEM APPROACH TO MARINE MANAGEMENT

Rabaut Marijn

Research Group Marine Biology, Biology Department, Ghent University, Krijgslaan 281, S8, 9000 Ghent, Belgium
E-mail: Marijn.rabaut@ugent.be

Oceans and coastal seas are being heavily exploited, leading to biodiversity losses and degradation of the integrity of ecosystems. Of all human activities at sea, fisheries is considered to be one of the most intensive. The vision on the marine environment has proved to be largely utilitarian until now, which has lead to a focus on the maintenance of the benefits from the exploitation of resources. In the end, this approach did not prove to be efficient and in response to continuous degradation, concepts as 'ecosystem approach' have now become the key concepts to manage the marine environment. In this respect, 'marine protected areas' (MPAs) have been installed in an attempt to halt the deterioration of the sea. The integration of marine conservation and fisheries management is therefore necessary and should be based on ecological knowledge. The North Sea is one of the most exploited marine areas in the world, with the Belgian part of the North Sea (BPNS) as a symbol for the intensivity of these activities. Therefore, the coastal marine areas that are situated in North-Western Europe and largely consist of sedimentary sand banks and swales are the focus of this thesis. Particularly in this system, macrobenthos (*i.e.* invertebrate fauna larger than 1mm) is recognized as fundamentally important in the functioning of marine ecosystems and this ecosystem component is the focal point of this thesis. High density aggregations of the ecosystem engineer *Lanice conchilega* (sandmason) are further studied in depth. *Lanice conchilega* is a tube dwelling bristle worm (Annelida, Polychaeta, Terribellidae). Experiments were designed to generate insights that can support conservation strategies and the relation with impacts of fisheries activities is investigated. As the management of important ecosystem engineers may protect numerous associated species and functions by expanding distributional limits for a lot of species, these organisms have been proposed as conservation targets in modern marine management. Therefore, proving the value of the ecosystem engineer *L. conchilega* within this framework is the basic aim of the thesis. Chapter 1 pictures the broader context of conservation and fisheries management as well as what is the state of the art on the knowledge of *L. conchilega*.

Chapter 2 evaluates the effect of this species on the macrobenthic community and on sediment characteristics of its habitat based on a long term data set in Belgian coastal waters. Both sediment composition and community structure of the associated macrofaunal matrix are affected by the presence of *L. conchilega*. There is a positive correlation between the steadily increasing macrobenthic densities and densities of *L. conchilega* ($R = 0.59$; $p < 0.001$). Species richness is increasing with *L. conchilega* densities, except for the highest *L. conchilega* density class. There from we can conclude that *L. conchilega* is able to restructure the macrobenthic community in a ''babushka" like organization, indicating that *L. conchilega* expands the niche breadth of several associated species. A species rank list is created according to each species' association with *L. conchilega*. This species rank list is extensively discussed based on all ecological knowledge available. Species are favoured by the habitat modifying ability of the polychaete tubes, which create and regulate refuge for species, alter the interactions between local species and change the physical factors of the environment. Addendum I is fully complementary to Chapter 2 as it evaluates the ecosystem engineering consequences on a North Sea scale. The presence of *L. conchilega* in different habitats in the North Sea and its effect on the abundance, species richness, diversity and community structure in these habitats are evaluated. In four different habitats (shallow muddy sands, shallow fine sands, deep fine sands and shallow medium sands), the density of the surrounding benthos increases with increasing density of *L. conchilega* and were most obviously pronounced in shallow fine sands. This addendum shows that *L. conchilega* patches are responsible for an increased habitat quality in an otherwise uniform habitat, resulting in a higher survival of the surrounding benthic species.

Chapter 3 characterizes the physical features of dense aggregations and discusses this together with the biological characteristics in order to determine whether these dense aggregations can classify as 'reefs'. To classify as reefs, ecosystem engineering activities need to significantly alter several habitat characteristics. Results showed that the elevation and sediment consolidation of the biogenic mounds was significantly higher compared to the surrounding unstructured sediment. Areas with *L. conchilega* aggregations tend to be extensive and patchiness is high (coverage 5-18%). Individual aggregations are found to persist for several years if yearly renewal of existing aggregations through juvenile settlement occurred. This renewal is enhanced by local hydrodynamic changes and availability of attaching structures (adult tubes). This chapter concludes that the application of the definition for reefs as found in the Habitats Directive provides evidence that all physical and biological characteristics are present to classify *L. conchilega* as a reef builder. As a range of aggregation development exists, 'reefiness' is not equal for all aggregations and a scoring table to quantify *L. conchilega* 'reefiness' is presented.

The reef structures formed by *L. conchilega* are targeted in Part II to generate detailed knowledge on the impact of mobile fishing disturbance. Chapter 4 describes a laboratory experiment in which four disturbance regimes to *L. conchilega* reefs were applied. Survival drops significantly after 10 days and after 18 days (with a disturbance frequency of every 12 and 24 hours, respectively). Besides the physical impact on *L. conchilega* itself, Chapter 5 tests the vulnerability of the species that live in close association with *L. conchilega*. A treatment zone was exposed to a one-off experimental trawling during an intertidal *in situ* experiment. Subsequently, the impact on and recovery of the associated fauna is investigated for a period of nine days post-impact. Community analysis shows a clear impact followed by a relatively quick recovery. This impact and subsequent recovery is largely explained by two species: *Eumida sanguinea* and *Urothoe poseidonis*. Species analysis confirms the beam-trawl passage significantly ($p = 0.001$) impacted *E. sanguinea* for the whole period of the experiment. The experiment confirmed that closely associated species of *L. conchilega* reefs are impacted by beam-trawl fisheries. Chapter 4 and 5 (*i.e.* Part II) provides insight in the resistance and therefore also in the resilience of the reef system and indicates that the reef structure itself can persist under intermediate beam trawl pressure but the integrity of the reef is hurt as the system as a whole degrades immediately after disturbance.

The relation between the ecological value of the observed increased benthic diversity and the abundance for flatfish seemed to be an important knowledge gap. Therefore, Chapters 6 and 7 (*i.e.* Part III) investigate the ecological interactions between the benthic habitat created by *L. conchilega* and flatfish. The biotic structuring factor on flatfish' habitat preference was addressed for the first time. Chapter 6 investigates in an *in situ* experimental sampling design, the structuring effect of biogenic reefs on the distribution of post-larval *Pleuronectes platessa* in an intertidal nursery area. The density distribution of this flatfish species was significantly ($p < 0.0001$), which can be explained by the presence of *L. conchilega* reefs.

As effects on habitat preferences of flatfish within nursery areas are thought to be related to food availability as well, Chapter 7 evaluates the importance of biogenic habitats as a feeding ground for juvenile flatfish species (*P. platessa* and *Limanda limanda*). Both the distribution and feeding behaviour of the two flatfish species *P. platessa* and *L. limanda* are studied in function of the presence of high densities of an ecosystem engineer. In this chapter, two different ecosystem engineered habitats are tested for (*L. conchilega* reefs and *Owenia fusiformis* aggregations) and sampling is done in two different coastal areas (the BPNS and the Dutch part of the Wadden Sea). General responses are identified by comparing relative differences between ecosystem engineered habitats and adjacent non-ecosystem engineered habitats. Results show that both flatfish species select for the ecosystem engineered habitat. This behaviour is further investigated using stomach content analyses. For *P. platessa* occurring in *L. conchilega* reefs, this selection is explained as a feeding behaviour. For the habitats created by *O. fusiformis*, no such a relation is found. Therefore, Chapter 7 suggests that the juveniles use ecosystem engineered habitat both as a shelter (antipredation behaviour) and/or as feeding ground. These small-scale aspects of larger nursery grounds can be considered as 'Essential Juvenile Habitat' (EJH) and merit attention in habitat suitability models as well as in marine conservation measures. Part III shows that *L. conchilega* reefs also have bottom up effects on juvenile flatfishes. Linking these results to Part II points out that further modification of these biogenic habitats may lead to a loss of one or more ecosystem functions which flatfish species depend on.

In the last part of this thesis (Part IV), the results on *L. conchilega*, fisheries and marine conservation are discussed in the framework of their potential value in an application of the ecosystem approach supporting marine management. Chapter 8 brings literature on marine conservation strategies in soft-bottom temperate areas together in one 'systems approach' that provided answers to the questions 'why?', 'how?' and 'what is the effectiveness?' of MPAs. This 'systems approach' was visualized in a flow chart and includes three phases: setting policy objectives, decision making and evaluating the eventual effects of the MPA. The analysis indicates that the relation between fisheries and MPA-management is the most challenging because of conflicting interests and institutional differences. Activities limited in space and not relying directly on ecosystem functions (e.g. offshore energy production and aggregate extraction) are generally easier to manage than fisheries. The systems approach is applied to the Belgian case and proved useful in providing insight into the complex interactions of various authorities with scattered jurisdictions.

Chapter 9 further discusses the (international) legislative framework of marine protection. As marine ecosystems are threatened, conservation strategies are set out in international policy to face the large scale of the marine ecosystems. However, not only the scale is important to manage marine ecosystems, also ecosystem dynamics should have a prominent place in the strategies. The chapter points out that too strict interpretation of international legislation is expected to fail in its aim of implementing a sustainable use of the sea. The Belgian case has been developed as an example, pointing out that international (EU) legislation is excessively strictly interpreted which decelerates the implementation rate. We therefore suggest applying a robust though flexible interpretation of environmental legislation in the marine environment. We acknowledge that there is a risk of undermining the final goal of environmental legislation if increasing flexibility is translated into looser protection.

Finally, Chapter 10 discusses the results of the present thesis. The restructuring capacity of *L. conchilega* through its effect on the niche of several associated species has been re-evaluated by revisiting the original and fundamental concepts of niche theory. Furthermore, the wider resilience of *L. conchilega* reefs was attributed to the ecosystem engineer itself as well as by the closely associated species (which define the biological features of the reefs). This resilience is discussed with preliminary results of a one-off experimental beam-trawl study that has been performed on subtidal reefs. Chapter 10 continues by evaluating the conservation value of *L. conchilega* aggregations. From a general nature conservation perspective this particular tube builder is considered an important ecosystem engineer, and provides the template for other ecosystem processes, making *L. conchilega* useful within a conservation context. Therefore, the 'label' under which the aggregations may potentially be preserved has been discussed. Potential conservation under the 'reef label' is compared with the conservation value of other reef forming tube worms. These tube reefs all change the benthic community significantly without hosting unique species, they build elevated bioconstructions, generate a biogenic concretion through an increased consolidation, change the sedimentary environment and they can appear and disappear very fast but they all have similar mechanisms that enhance stability and longevity. However, prioritization between different habitats is possible and needed. The mapping of biogenic habitats within conservation strategies will be important and the use of remote sensing techniques (Addendum II and III) as well as species distribution models are discussed. Finally, the potential use of marine protected areas and the relation to fisheries management are discussed. This part provides an onset of how an ecosystem approach can be applied based on ecological insights and on focused research on anthropogenic impact. As ecosystem engineers merit increased scientific and conservation emphasis, the thesis results are to be interpreted as a first step towards the application of the ecosystem approach to marine management.

The thesis concludes that *L. conchilega* is not only a model organism for studying the sediment-animal-interactions contributing to the strength of a benthic engineer in modifying its habitat and thereby affecting other species, but it is also a useful ecosystem engineer within a conservation context. As such, the knowledge built up in this thesis can potentially contribute to the transition to a more resilient relationship between society and ecosystems.