Science of the Total Environment 639 (2018) 465–475

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Beyond classic ecological assessment: The use of functional indices to indicate fish assemblages sensitivity to human disturbance in estuaries

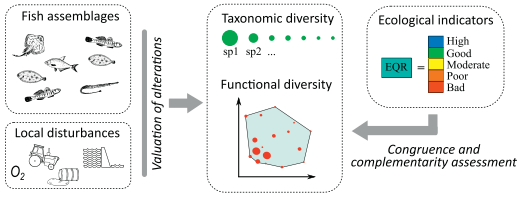
Nils Teichert *, Mario Lepage, Jérémy Lobry

Irstea, UR EABX, 50 avenue de Verdun, 33612 Cestas, France

HIGHLIGHTS

- Impact of human disturbances on fish assemblages was assessed in estuaries.
- Taxonomic and functional indices were compared to current ecological indicators.
- Local disturbances mostly affected dominant benthic species with redundant traits.
- Functional indices provide insights not reflected by taxonomic and fish indicators.
- Collapse of redundancy in impacted estuaries is a crucial concern for management.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 22 March 2018
Received in revised form 14 May 2018
Accepted 14 May 2018
Available online xxxx

Editor: D. Barcelo

Keywords:
Estuary
Fish assemblage
Local disturbance
Functional traits
Functional redundancy
Ecological status

ABSTRACT

Assessing ecological health of aquatic ecosystems is crucial in the current context of biodiversity loss to guide and prioritize management actions. Although several fish-based indices were developed to assess the ecological status of estuarine ecosystems, they do not provide guidance on the causal responses of communities to disturbances. The functional trait-based approach provides an understanding of how human disturbance affects the composition of biological and ecological traits in assemblages, as well as their consequences for ecosystem functioning. Here, we evaluate the responses of fish assemblages to human disturbance in 30 French estuaries using several taxonomic and functional indices (e.g. diversity, evenness or redundancy). We tested whether these indices can provide additional information on the human impacts and health of assemblages that are not reflected by the ecological indicator (fish-based index ELFI). Results indicated that high values of local human disturbances were associated to a decrease in fish abundance, decrease in species richness and reduced functional redundancy, whereas taxonomic and functional evenness increased. In contrast, the functional richness remained stable suggesting that the functional traits of species removed by stressors were maintained by more tolerant species. Indeed, we found that the local disturbances mainly resulted in a decrease in the proportions of small benthic species feeding on macro-invertebrates, which were dominant in the studied estuaries. Some functional alterations were detected by the fish-based index, but the decline of functional redundancy was not reflected, highlighting a serious concern for management. Indeed, the abrupt collapse of functional redundancy in response to local disturbances can decrease the ability of assemblages to maintain certain species traits in the face of future environmental disturbance, including climate change. From a management perspective, the application of such functional redundancy measure in monitoring programs can help stakeholders identify sensitive areas where conservation efforts need to be planned.

* Corresponding author.
E-mail address: nils.teichert@irstea.fr (N. Teichert).

https://doi.org/10.1016/j.scitotenv.2018.05.179
0048-9697/

1. Introduction

In estuarine and coastal environments, the structure and functioning of ecosystems has dramatically changed over the last century due to local human stressors, such as over-exploitation of resources, habitat fragmentation, chemical pollution or species invasions (Lotze et al., 2006). These local impacts are expected to be magnified by climate change through cumulative effects (Crain et al., 2008; Halpern et al., 2008) and specific threats (Baptista et al., 2015; Woodward et al., 2010). In this context, assessing the health and vulnerability of the ecosystem is a central concern for environmental managers who must ensure long term ecosystem functioning and avoid further degradation (Vasconcelos et al., 2017). To achieve this goal, ambitious surveillance programs have been implemented worldwide (e.g. Borja et al., 2012; Borja et al., 2008; Perez-Dominguez et al., 2012), particularly in Europe through the Water Framework Directive (WFD; 2000/60/EC). The latter requires the establishment of biotic indicators to quantify the ecological status of water bodies from several biological quality elements, from phytoplankton to fish (Hering et al., 2010; Reyjol et al., 2014). In this context, several assemblage descriptors related to species composition and ecological structure are developed to quantify the degree of biotic alteration caused by human disturbances compared to reference sites with little or no anthropogenic influence (Birk et al., 2012; Karr, 1981). The outcomes are then combined into a multimetric index to assess the health status of the assemblages (i.e. from bad to high status), which can be used as decision criteria to define conservation priorities and develop restoration measures.

In estuaries, fish and benthic invertebrate communities, as well as phytoplankton, have been increasingly monitored as valuable indicators of ecological quality because of their sensitivity to a wide range of environmental disturbances (Borja et al., 2012) and their roles in ecosystem functioning (Holmlund and Hammer, 1999) and ecosystem services (Grizzetti et al., 2016). Hence, several fish-based indices have been developed for estuaries in Europe by comparing the responses of several biological metrics to gradients of environmental degradation and combining them in multimetric indices (e.g. Lepage et al., 2016; Perez-Dominguez et al., 2012). Selected metrics generally describe the assemblage composition and abundance of specific functional guilds (e.g. ecological guild, trophic guild), so most of indices give at least partial insights into functional changes induced by human disturbances (Perez-Dominguez et al., 2012). However, direct information on the functional structure (e.g. functional diversity, evenness or redundancy) remains largely untapped in the implementation of ecological assessment (Colin et al., 2018). While multimetric indicators provide a general overview of human impact synthesized in a single score, functional approaches can provide a more integrated way of understanding the causal responses of communities to disturbances (Mouillot et al., 2013). Indeed, understanding how the composition of biological and ecological traits of species is affected by disturbance can guide conservation and management efforts (Dolbeth et al., 2016b). Moreover, by focusing on ecological traits or the role of species in ecosystem, the outcomes of functional approach may be more readily extended to the local context than taxonomic responses which are related to the biogeographical context (Colin et al., 2018).

Numerous studies emphasized the usefulness of functional approaches to detect the impact of disturbances on fish assemblages (e.g. Sagouis et al., 2016; Teresa and Casatti, 2017), including in the marine and estuarine environment (e.g. Baptista et al., 2015; Henriques et al., 2014; Selleslagh et al., 2012a; Villeger et al., 2010). For example, Dolbeth et al. (2016b) highlighted the complementarity of several indices to describe the structural and functional responses of fish assemblages to human disturbance in tropical estuaries. In such an approach to functional diversity, species traits are used to construct a multidimensional space from which several indices are calculated to convert the species distributions and abundance into functional insights (Villeger et al., 2008). These synthetic indices can thereafter be used to detect modifications in the functional structure of community in response to changes in the environmental condition or particular anthropogenic disturbances (Mouillot et al., 2013). For instance, human-induced disturbances can filter out species depending on their traits resulting in the elimination or decrease in abundance of species whose traits are sensitive to stressors. This is generally reflected in the convergence of species traits and the collapse of functional diversity (Buisson et al., 2013; Mouillot et al., 2013). This functional homogenization pattern occurs when species affected by stressors support singular functional role in the community. However, in highly redundant assemblage, the loss of sensitive species may be compensated if similar functional traits are shared by other species more tolerant to disturbances (Rosenfeld, 2002; Yachi and Loreau, 1999). In redundant coral reef fish assemblages, Brandl et al. (2016) have recently demonstrated that, while most of the functional indices do not respond, the functional originality increases when faced with an increase in habitat degradation suggesting a loss of redundancy that may increase the vulnerability of assemblage to future environmental disturbances. In such a case, the functional redundancy can play a crucial role in promoting resilience by buffering the functional alterations caused by species loss and stabilizing the functional richness (Mouillot et al., 2014).

Estuaries are transition ecosystems shaped by major environmental gradients, e.g. salinity, oxygen, depth, due to their position at the interface between marine and freshwater environments (Attrill, 2002). Therefore, fish assemblages include estuarine resident species, but they also include freshwater and marine species that typically use estuaries at a specific life stage, as well as migratory diadromous species (Potter et al., 2015). Although this variety of life history traits promotes functional diversity, the functional redundancy is generally high in estuaries compared to other continental aquatic ecosystems (Teichert et al., 2017a). The huge constraints imposed by natural environmental fluctuations, e.g. physico-chemical parameters, tidal range, limit the range of ecological strategies (Mouillot et al., 2007; Teichert et al., 2017b) and contribute to increased functional redundancy in fish communities (Dolbeth et al., 2016a; Villéger et al., 2012). Accordingly, estuarine assemblages are generally composed of few dominant species considered as stress-tolerant and well-adapted to cope with the high variability of environmental parameters. They are characterized by small and short-lived organism mainly associated with r-strategists rather than K-strategists (Gray and Elliott, 2009). In this context, the estuarine quality paradox emphasizes the difficulty of disentangling the effects of anthropogenic stress and natural constraints on biotic assemblages (Dauvin, 2007; Elliott and Quintino, 2007). Since functional properties are expected to be more stable than structural ones, functional approaches should be effective to detect the impact of human disturbance improving our understanding of how stressors affect fish assemblages (De Jonge et al., 2006). Nevertheless, taking environmental influence into account remains essential to accurately assess the effect of stressors when modeling the responses of biological indicators (Courrat et al., 2009; Sagouis et al., 2016). Indeed, van der Linden et al. (2016a) reported a predominant contribution of natural factors for to explain the functional changes in benthic assemblages of estuaries subjected to anthropogenic disturbance of the seafloor.

In this context, the present study aims to assess the impacts of human disturbances on estuarine fish assemblages based on a comparative analysis of taxonomic and functional indices. We then tested whether these indices can provide additional information on the effects of human impacts and on assemblage health that were not already integrated into current ecological quality indicators. Specifically, we used a database of 30 French estuaries (period 2006–2016) to describe and quantify the responses of fish assemblages to a local human disturbance gradient, taking into account the influence of environmental variables. We then assessed the capacity of the current fish-based index (Estuarine and Lagoon Fish Index, ELFI) used in the WFD to detect and reflect the functional alterations of fish assemblages (Delpech et al., 2010). We expected functional approaches to provide additional insights about