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A fish-based index of estuarine ecological quality incorporating information from both scientific fish survey and experts knowledge

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ABSTRACT

In the Water Framework Directive (European Union) context, a multimetric fish based index is required to assess the ecological status of French estuarine water bodies. A first indicator called ELFI was developed, however similarly to most indicators, the method to combine the core metrics was rather subjective and this indicator does not provide uncertainty assessment. Recently, a Bayesian method to build indicators was developed and appeared relevant to select metrics sensitive to global anthropogenic pressure, to combine them objectively in an index and to provide a measure of uncertainty around the diagnostic. Moreover, the Bayesian framework is especially well adapted to integrate knowledge and information not included in surveys data. In this context, the present study used this Bayesian method to build a multimetric fish based index of ecological quality accounting for experts knowledge. The first step consisted in elaborating a questionnaire to collect assessments from different experts then in building relevant priors to summarize those assessments for each water body. Then, these priors were combined with surveys data in the index to complement the diagnosis of quality. Finally, a comparison between diagnoses using only fish data and using both information sources underlined experts knowledge contribution. Regarding the results, 68% of the diagnosis matched demonstrating that including experts knowledge thanks to the Bayesian framework confirmed or slightly modified the diagnosis provided by survey data but influenced uncertainty around the diagnostic and appeared especially relevant in terms of risk management.

1. Introduction

Coastal and estuarine ecosystems are particularly vulnerable to evolution of human activities (Henocque and Denis, 2001; Hoegh-Guldberg and Bruno, 2010) and their degradation is widely observed, e.g. Elliott and Hemingway (2002). In that context, regulation tools such as the European Water Framework Directive (WFD) aims at stopping this degradation process and at restoring aquatic ecosystems to a good ecological status (WFD – Directive 2000/60/EC; European Council, 2000). To fulfil this objective, multimetric indices are widely used to assess the ecological quality of aquatic ecosystems (Hughes and Oberdorff, 1999). A metric is defined as a measurable variable having an ecological meaning, which can be associated to any structural or functional aspect of biological assemblages (Coates et al., 2007). Combining several metrics in a multimetric index assures that the resulting indices are holistic and sensitive (Deegan et al., 1997; Karr and Chu, 1999). A large variety of multimetric indices aims at detecting the ecological impact of stressors, e.g. Hering et al. (2006).

As fish integrate a large variety of anthropogenic pressures (Elliott et al., 1988; Karr, 1981), fish assemblages are generally considered as appropriate to develop indicators of ecosystem quality. Consequently, numerous fish-based multimetric indices have been developed in the context of the WFD (Pont et al., 2006), especially in transitional waters, e.g. Borja et al. (2004), Breine et al. (2007, 2010) and Delpech et al. (2010). However, most of those indices suffered from two main weaknesses. First, qualitative estimates of the respective weight of metrics, correlations among them and redundancy in information made combinations of metrics in those indices sensitive to the calculation method. Second, most of those indices did not quantify uncertainty around their assessment (Perez-Dominguez et al., 2012) though it is especially important

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for managers (Breine et al., 2007; McAllister and Kirkwood, 1998). Indeed, the probability for a water body to reach a score below good status is necessary in terms of risk management (WFD – Directive 2000/60/EC; European Council, 2000). Bootstrap methods were applied with success by Pont et al. (2006) to estimate these probabilities but they required a large amount of data, making them inappropriate in data poor situations, especially in estuarine systems where large standardized sets of surveys data are lacking (Nicolas et al., 2011).

Delpech et al. (2010) proposed an indicator called ELFI to assess the ecological status of French estuaries. This indicator was based on pressure-impact models, as proposed by Courrat et al. (2009), in order to select relevant metrics that are sensitive to anthropogenic pressures. However, this indicator suffered from the two weaknesses previously mentioned. Recently, an original method to build multimetric stressor specific indices was proposed and applied on the French lagoons (Drouineau et al., 2012). This approach based on the Bayesian theory took up both two challenges. First, based on the Bayesian theory, it allows an objective combination of the metrics by incorporating all the information in a probabilistic framework. Secondly, this method provides a measure of uncertainty in its assessment. Consequently, it is hoped that applying this framework to the indicator developed by Delpech et al. (2010) would significantly improve the indicator.

Drouineau et al. (2012) proposed to further incorporate experts knowledge within the French lagoons fish-based index in order to combine both experts knowledge and fish data in the ecological assessment. Integrating experts knowledge in such multimetric index could lead to valuable improvement (Martin et al., 2005; Murray et al., 2009). Experts knowledge may provide a qualitative but global image (Knapp et al., 2011) of the ecological status of an ecosystem not only based on a particular ecological feature (ecological communities or habitats). Furthermore, it does not require expensive scientific surveys. Indeed, most indices are based on surveys with a limited time and space scale, sampling a limited fraction of fish assemblages. Consequently, they are based on restricted image of the ecosystem.

In this context, the present approach developed a fish-based multimetric index for French estuaries, applying the Bayesian method proposed by Drouineau et al. (2012) and incorporating experts knowledge. This index proposed to fulfil weaknesses of the index developed by Delpech et al. (2010) while using its pressure-impact approach and the method developed by Courrat et al. (2009) to select core metrics. The combination of fish data and experts information into the Bayesian framework is described, the impact of the integration of the experts knowledge in the ecological assessment and its interest for monitoring estuarine ecological status are analysed.

2. Materials and methods

The proposed multimetric index illustrated in Fig. 1 was based on two types of data: fish data from scientific surveys and experts knowledge. Fish data were correlated to an anthropogenic pressure index using pressure-impact statistical models (Courrat et al., 2009; Delpech et al., 2010) (top box in Fig. 1). Then models were used to convert fish observations in probabilities of experiencing pressures (Drouineau et al., 2012) (left part of the second box). Experts assessments were aggregated to provide a global assessment per water body (right part of the second box) that was used as a prior in a Bayesian framework that combined both types of data (Drouineau et al., 2012) (third box). This allowed to put forward a pressure level applied on the fish communities of the studied water body. Pressure was decomposed in 5 equal pressure classes. Probability for a water body to be in each class was calculated (fourth box). Last, this level was associated to a quality level (last box).

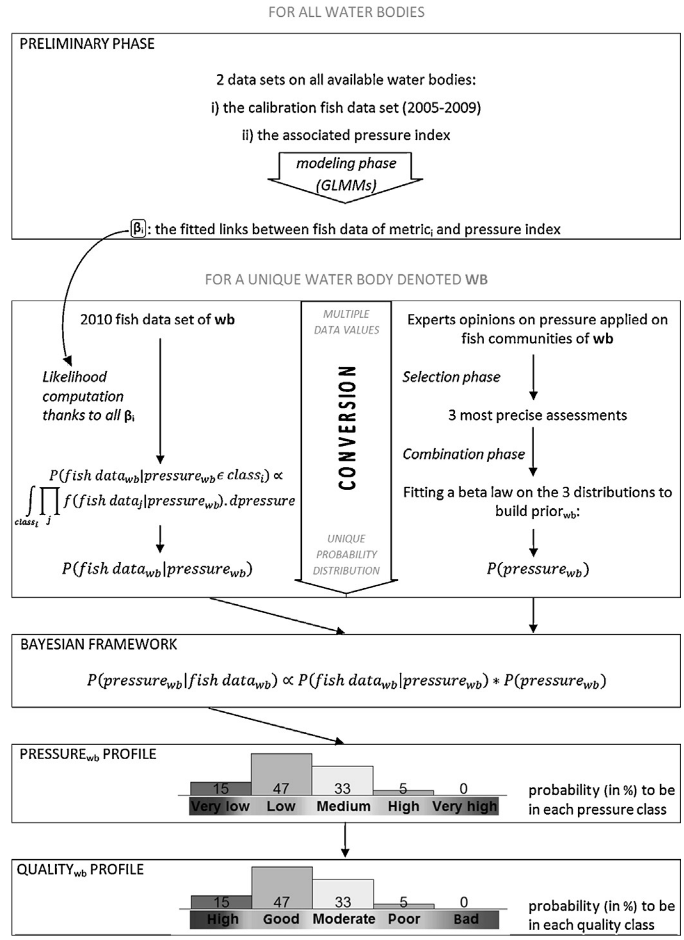

Fig. 1. General methodology to develop the index.

3. Data sets

3.1. Fish data and pressure-impact models

A panel of 36 water bodies located along the French coasts of the English Channel and the Bay of Biscay were sampled between 2005 and 2009. A subset of 22 water bodies was sampled in 2010 to complete the WFD schedule (Fig. 2). Indeed, each water body had to be sampled at least 3 years during the 6-year WFD programme. A detailed description of the sampling protocol was provided by Delpech et al. (2010) and Lepage and Girardin (2006). Each monitored water body was sampled in spring and autumn with a beam trawl. Hauls were distributed along the salinity gradient and 3 salinity classes were defined (Delpech et al., 2010): oligohaline class ([0–5] g L^{-1}), mesohaline class ([5–18] g L^{-1}) and polyhaline class (>18 g L^{-1}). In each season, at least 6 hauls were carried out in each salinity zone of each water body. A minimum of 12 hauls was carried out in the water bodies having only one salinity zone (e.g. Downstream Seine). In each trawl haul (sample), each fish was identified to the species level and each species was assigned to functional ecological guilds related to its diet and its use of the estuarine ecosystems along its life cycle (Elliott and Dewailly, 1995).

The lack of pristine estuaries to define reference conditions involved the use of statistical modelling (Delpech et al., 2010; Pont et al., 2006). A solution was to develop pressure-impact models (Borja et al., 2006). However, a proxy of anthropogenic pressure