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Assessing fish quality status in transitional waters, within the European Water Framework Directive: Setting boundary classes and responding to anthropogenic pressures

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ABSTRACT

Validation of the AZTI's Fish Index (AFI), proposed for the Basque Country (northern Spain), in assessing fish quality within the Water Framework Directive (WFD), is undertaken. The response to anthropogenic pressure is investigated, in setting the boundaries between the different quality status classes. Hence, 12 estuaries were sampled, at different frequencies, between 1989 and 2007, by means of a beam trawl. Significant ($p < 0.0001$) correlations were found between the AFI and oxygen saturation and ammonia. Oxygen quality standards are used to set boundaries between quality classes. Then, the AFIs obtained are compared with different anthropogenic pressures, including urban and industrial discharges, engineering works and dredging. The effects of the removal of some of these pressures are also studied. The total number of pressures within an estuary shows significant ($p < 0.009$) negative correlation with AFI, explaining between 51 and 62% of the variability in fish quality. The impact of pressures upon fish and demersal assemblages is detected as required by the WFD. Nonetheless, further investigation and intercalibration of the methods used, are necessary.

1. Introduction

The European Water Framework Directive (WFD; Directive 2000/60/EC) states the need to achieve 'a good ecological status', by 2015, for all European water bodies, including transitional (estuaries) and coastal waters (for details, see Borja et al., 2004; Borja, 2005). Biological elements are especially important, in assessing such a status, e.g. phytoplankton, macroalgae, angiosperms, benthos and fish. A similar approach has been adopted by the new European Marine Strategy Directive (MSD; Directive 2008/56/EC), in assessing the environmental status within offshore waters (Borja, 2006), together with other legislation world-wide (Borja et al., 2008).

In the particular case of fish, the WFD specifies that they must be assessed in freshwaters and transitional waters (and not in coastal waters), taking into account species composition, abundance and the proportion of disturbance-sensitive species. In fact, the trends in one or more of the community attributes (such as composition, trophic structure, diversity, abundance or biomass) can be used to monitor the ecological functioning, and health, of an estuarine ecosystem (Moore et al., 1995; Whitfield and Elliott, 2002).

As stated by Coates et al. (2007), most of the methods used to assess the ecological status, based upon fish, are derived from the metric-scoring system used in assessing the 'biotic integrity' of North American fish communities (Karr, 1981), i.e. the 'index of biotic integrity' (IBI). Derivations from this method have been used as a classification tool for fish quality assessment, world-wide (Deegan et al., 1997; Harrison et al., 2000; Gibson et al., 2000; Hughes et al., 2002; Whitfield and Elliott, 2002; Harrison and Whitfield, 2004, 2006); in recent times, it has served as basis for several methodologies applied under the WFD (Borja et al., 2004, 2009a; Breine et al., 2004, 2007; Coates et al., 2007), being some of them compared in Martinho et al. (2008). Recently, some of these methods have been applied to coastal waters under the MSD (Henriques et al., 2008).

According to the WFD, biological element methodologies used to assess ecological status should respond to anthropogenic pressures, rather than to natural variability (Solimini et al., 2006). However, very few studies have focused upon the response of these fish assessment methods to human pressures (Harrison et al., 2000; Cabral et al., 2001; Breine et al., 2007; Vasconcelos et al., 2007). Hence, there is a need to validate the proposed fish methodologies, against transitional water pressures, as has been undertaken for benthos (Borja et al., 2009b).

The WFD states that any sign of distortion, from type-specific conditions in the species composition and abundance of fish,

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together with the abundance of the disturbance-sensitive species, must be attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements. This distortion is calculated by means of the Ecological Quality Ratio (EQR), which represents the differences between monitored data and reference conditions (see Borja et al., 2004). The EQR, which ranges between 0 and 1, is divided into five quality classes (i.e. bad, near to 0; poor; moderate; good; and high, near to 1, status), according to the normative definitions within the WFD. The validation of the methodologies used in the assessment requires also the determination of boundaries between such quality classes.

Hence, the aim of this contribution is to validate the methodology proposed by Borja et al. (2004), in assessing fish quality within the WFD (named AZTI's Fish Index (AFI)), by studying the response to anthropogenic pressures; likewise, setting boundaries between the different quality status classes.

2. Methods

2.1. Sampling

A network of monitoring trawl lines along the 12 main Basque estuaries, from the inner, middle and outer reaches (three to five trawl lines, per estuary), was established by the Basque Government; this network provides water, sediment and biological quality information from a total of 39 sampling locations (Fig. 1). The demersal assemblage sampling was carried out every September–October, at high tide, between 2002 and 2007, once every 3 years at each of the estuaries. Moreover, some parts of the estuaries were sampled on the basis of long-term annual time-series: Barbadún (three trawl lines) and Nervión (five trawl lines), since 1989–1990; and Butroe (three trawl lines), since 1997; whilst others were sampled, discontinuously, since 1995 (Table 1). Locations were determined by the suitability of the sea-bed for trawling, as well as by the requirement to incorporate the whole of the salinity range within each of the estuaries.

At each of these trawl lines, three hauls (replicates) were collected, using a 1.5 m wide beam trawl with a tickler chain; the first part of the net has 10 mm mesh size and 8 mm mesh size cod end; and towed for 10 min at ~1.5 knots (sometimes the trawl period might differ, when rocks or other obstacles made the trawling difficult). Finally, fish and crustacean density were calculated taking into account then fishing effort calculated from the beam width, the time of trawling and the boat speed. Similar methodologies have been used by other authors, such as Elliott and Hemingway (2002), Johnson et al. (2008) and Selleslagh and Amara (2008). Samples were identified and counted on-board immediately. Species which could not be identified were fixed in a solution of 4% formalin, then examined in the laboratory.

The Basque estuaries can be divided into 14 water bodies (although, for this contribution, only 13 were considered; this was because the Oka estuary was considered as a single water body, instead of two bodies). These water bodies are distributed among three transitional types (see 'delimitation criteria', in Borja et al., 2004): (1) Type I – small river-dominated estuaries; (2) Type II – estuaries with extensive intertidal flats; and (3) Type III – estuaries with extensive subtidal areas (Table 1).

2.2. Pressures and environmental data

The estuaries and coasts of the Basque Country were investigated, to identify relevant and significant human pressures (Borja et al., 2006b). This information, together with the new information obtained after that study, is summarised in Tables 2 and 3. An overall pressure index was calculated for each estuary (see Table 2), using data from significant pressures listed within Table 8 in Borja et al. (2006b). Hence, a relative rating (3, 2, 1, and 0, respectively) has been allocated to each of the pressure levels described there (high, moderate, low, and without pressure, respectively). Subsequently, a 'mean overall pressure index' was calculated, for each of the estuaries. The lowest pressure indices were those of the Lea and Barbadún estuaries; the highest were those of the Nervión and Oiartzun (Table 2).

The main significant pressures identified for the Basque Country include urban and industrial discharges (affecting organic matter increase and oxygen consumption), and hydromorphological pressures (dykes and port construction, dredging, and land reclamation). Conversely, positive actions include the removal of discharges and water treatment programmes (at catchment and estuary levels, including wastewater treatment plants) (Table 3).

Hypoxia and ammonia are considered as being harmful for estuarine fishes (Eby et al., 2005; Eddy, 2005). Hence, oxygen saturation and ammonia have been used as environmental variables, to determine their effects on fish quality assessment. Data used in this investigation are those obtained from the Nervión estuary, which has an extensive dataset since 1989; this includes low tide bottom oxygen saturation and ammonia (on the basis of eight to 12 annual surveys). Oxygen was measured using membrane polarographic probes, whilst ammonia concentrations were determined by segmented-flow analysis, with Technicon AAIII systems, following Hansen and Grashoff, 1983. Mean oxygen and ammonia values have been derived on the basis of a 12 month sampling period (up to 12 data, from October of 1 year, to September of the next year); these were used to establish the

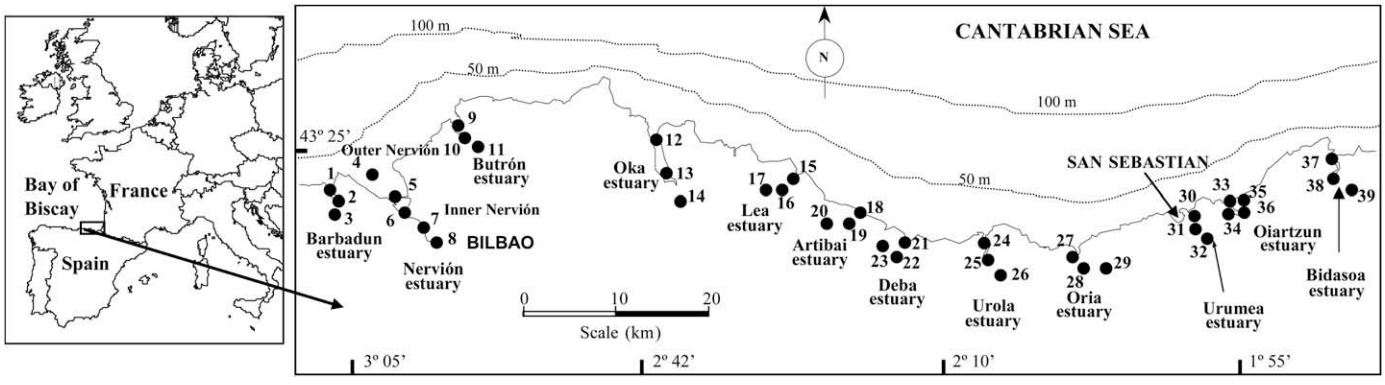

Fig. 1. Sampling locations (trawl lines) and water bodies within the estuaries of the Basque Country.