

Short communication

Assessing the ecological stress in a Garonne River stretch, southwest France

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ABSTRACT

In order to assess the level of ecological stress caused by the pollution from local disturbances in a stretch of the Garonne River, France, we applied the Abundance-Biomass Comparison (ABC) index, using fish assemblages. Data were collected in a 10-year span (1992–2002) in a reference site and in two pollution-exposed sites. The ABC index mean value in the reference site (S1) was 0.03 ± 0.002 (95% Confidence Interval – CI); for the polluted sites (S2 and S3), the values were -0.09 ± 0.002 (95% CI) and -0.12 ± 0.002 (95% CI), respectively. The ABC index showed that, besides flow variations, both downstream sites are statistically different ($p < 0.05$) from the reference site, but all three seem to be under moderate stress. Furthermore, we related our ABC scores to water quality and flow regime variables in the reference site and one of the polluted sites by means of a cluster analysis. The results showed that, in the reference site, the ABC scores are closely related to the flow regime, while in the polluted site, downstream a urban area, ABC is related to water quality variables such as phosphates and total phosphorous. We argue that ecological indicators can help decisions on environmental damage liability.

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1. Introduction

Lotic ecosystems provide valuable environmental services, including water for agricultural production, tourism, leisure, fisheries and navigation (Acuña et al., 2013; Gilvear et al., 2013). These ecosystems are, nevertheless, under the pressure of industrial and urban effluents, erosion, runoff from agricultural activities, and changes in river morphology (Ibarra, 2005). Such disturbances generate ecological stress.

Ecological stress, due to either natural or anthropogenic activities, provokes diverse physiological responses on an individual level and, in chronic cases, affects biological community structure (Rambouts et al., 2013). Warwick (1986) introduced a simple method for determining ecological stress by means of the Abundance-Biomass Comparison (ABC) index. Under free-stress conditions, the fish community is assumed to be approaching equilibrium and the biomass is dominated by few large species, each represented by few individuals. But as stress becomes more severe, fish communities become increasingly dominated numerically by

small species. The scores of the index are negative in heavily stressed conditions, near zero in moderately stressed situations, and positive for no stress. The ABC index has proved useful for assessing communities of benthic invertebrates (Warwick, 1986; Beukema, 1988; Meire and Dereu, 1990; Warwick and Clarke, 1994; Rakocinski et al., 2000), as well as riverine (Coeck et al., 1993; Penczak and Kruk, 1999; Pinto et al., 2006), estuarine (Villanueva, 2004; Cerfolli et al., 2013) and marine fishes (Yemane et al., 2005).

The pressures of industrial activities and recreational demands imposed on aquatic ecosystems have resulted in biological stress at different levels of organization, especially on fish populations (Crook et al., 2015). In fact, fish are reckoned as good indicators of an ecosystem's ecological state (Lasne et al., 2007; Pont et al., 2007; Rambouts et al., 2013). As in many other basins, the Garonne River is an interesting example for analyzing the interaction between economic activities and ecological indicators (Baque, 2006).

Our interest in studying this area is because the Garonne basin is one of the most important basins in the world (Revenga et al., 1998) as it contains a river network with a diversity of habitats comprising several ecoregions which range from the mountains to the Gironde estuary. Furthermore, since a number of human activities are related to rivers in this basin (Baque, 2006), we try to understand how these activities can be conciliated with new concepts of water quality and ecosystem health (Carr and Neary, 2008). The European Water Framework Directive (EWFd) requires a chemical and ecological assessment of European waters by 2015 and needs

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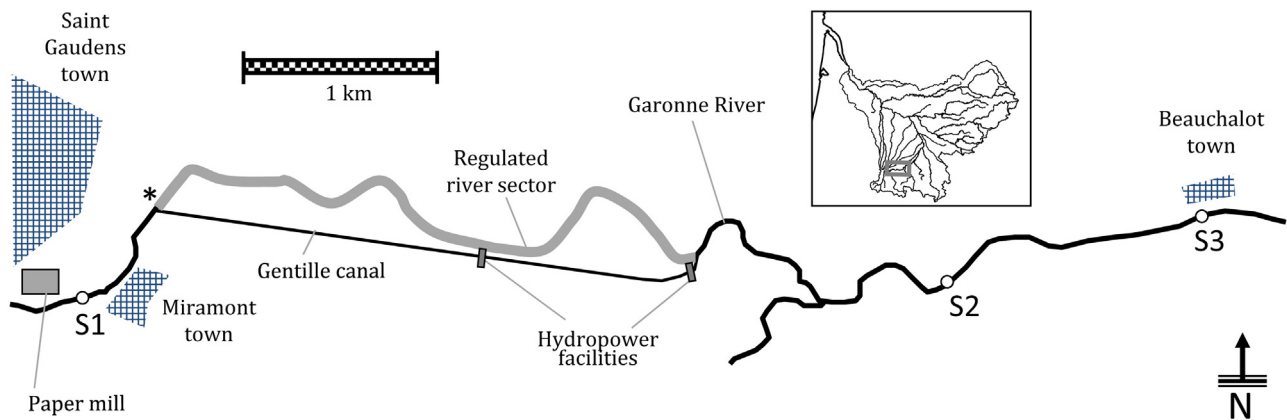


Fig. 1. Study area in the stretch on the Garonne river. A reference site (S1) and two downstream (S2 and S3) sites were sampled. The star shows the effluent discharge coming from St. Gaudens town and the paper mill.

Source: Ibarra (2004).

an integrated, risk-based management approach to achieve this goal (Brack et al., 2009). Aside from using chemical status concepts to reduce excessive water contaminations, another of its leading principles is the reflection of ecological state based on ecological quality ratios. In fact, it acknowledges that studying and regenerating biotic communities is essential for sustainable development (Reyjol et al., 2014).

Thus, this paper aims to present a case study for assessing the level of ecological stress of a fish community in a stretch of the Garonne River, southwest France, by means of the ABC index. Another major purpose of the study is to present a jackknifing methodology for a multi-year application for this index, and its quantitative relationship with water quality and flow regime variables. This paper further develops the preliminary results reported by Ibarra (2004).

2. Methods

2.1. Area of study

The area under study is situated near the town of Saint Gaudens in the Department of Haute-Garonne, in the piedmont of the Pyrénées range, southwest France, and has a special interest for environmental policy for several reasons. On the one hand, important economic activities provide social benefits such as commerce, tourism, sportfishing, hiking, hydropower generation and most notably, paper pulp production by the CDRA-TEMBEC paper mill. The paper mill has a relevant role in the local economy but also has an environmental cost as it uptakes water in order to produce white pulp and then discharges the used water into the Garonne River. Indeed, paper mill effluents affect physicochemical and ecological dynamics of both riverine and marine living resources (Ihejirika et al., 2011; Kanu and Achi, 2011; Dey and Das, 2013; Negi and Rajput, 2013) and can also induce pathologies on human populations (Lee et al., 2002). In 1995, a waste treatment plant was set up as a secondary treatment for biodegradable substances coming from the paper mill and from the city of Saint Gaudens. Once the plant was working, the paper mill increased in 68% its annual production from 1996 onwards and was required to monitor effluent impacts on both water quality and fish populations in the river (Lim, 2000).

On the other hand, rivers are environmental assets that need to be conserved and protected because they provide ecosystem services such as biodiversity maintenance, microclimate regulation, flood control and amenities values (Postel and Thompson, 2005). The river in this sector has an average width of 50 m, with a substrate dominated by pebbles and gravel (80%) and

about 20% of blocks and flagstones, and a rather rapid flow. This stretch of the Garonne River is defined by Reyjol et al. (2001) as a transition between a Salmoniform-dominated assemblage and a Cypriniform-dominated assemblage. Ibarra et al. (2005b) demonstrated that fish assemblages form, in fact, nested patterns in an aggregated hierarchy in the whole Garonne river system.

2.2. Field collections

Electrofishing of fish populations was carried out in the stretch between Saint Gaudens and Beauchalot towns during late summer (i.e. early and mid-September) in 1992 and 1994–2002 using a fixed Heron-type group (tension: 600–900 V and intensity: 1–2 A) in three sampling sites: one upstream (site 1) of the paper mill effluent serving as the reference site, and two about eight km (site 2) and nine km (site 3) downstream (Fig. 1). This scale of analysis allows a more accurate interpretation of the ABC index performance.

All three sampling sites were chosen in non-regulated flowing sectors. It should be noted that sampling site 3 was located several km upstream from the present location due to changes after hydrological events in 1995. However, this new sampling site was chosen as having the most similar conditions to the former site (Lim, 2000). Each sampling site was fished twice with successive passages at a constant fishing effort according to the DeLury method, following the recommendations of Laurent and Lamarque (1974). Total weight and total length of fish were recorded before putting them back to the river. Fish biomass and fish abundance were thus calculated by the De Lury method using Winfish© software (Segura, 1998). Appendix A shows fish species composition for the three sampling sites during the study period.

The resulting data set (available as supplementary material) was used to evaluate the ABC method.

2.3. Index computation

Warwick (1986) had introduced a simple method for determining the presence of stress in a given area based on abundance distribution. Later, Clarke (1990) suggested the calculation of W (termed after Warwick) as:

$$W = \frac{\sum_{i=1}^S (B_i - A_i)}{50(S - 1)} = \text{ABC index} \quad (1)$$

where B_i is the biomass value and A_i is the abundance (or individual) rank value of each species rank (i) and A_i and B_i do not necessarily refer to the same species. S is the number of species in the sample.

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