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Fish assemblage changes along a trophic gradient induced by agricultural activities (Santa Lucía, Uruguay)

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ABSTRACT

The input of nutrients into rivers and other aquatic ecosystems is one of the most common causes of damage to the integrity of the ecosystem. The use of biological communities for water quality assessment is a common and effective practice. Among these biological indicators, the fish community is one of the most used in monitoring programs and ecosystems studies and so there is much knowledge about their response to the process of eutrophication. In this study we analyzed the fish composition, diversity and evenness in fourteen reaches, of low stream orders within a basin with differing land use intensity.

The structure of the fish community was related with physiochemical water composition by canonical correspondence analysis, which enabled us to group the fish species according to their specific tolerance to eutrophication. Oligotrophic habitats were characterized by a higher evenness, larger individuals, a fish composition of at least 40% of sensitive species (*Crenicichla scotti*, *Gymnogeophagus gymnogenis*, *Gymnogeophagus* sp., *Heptapterus mustelinus*, *Hoplias malabaricus* and *Rhineloricaria* sp.) and less than 20% of very tolerant ones (*Astyanax fasciatus*, *Cnesterodon decenmaculatus*, *Corydoras paleatus*, *Cyphocharax voga*, *Hisonotus* sp., *Pimelodella australis*). Eutrophic reaches showed the opposite community features and a fish composition with more than 40% of very tolerant species and less than 20% of sensitive ones. Among the fourteen study reaches, four were classified as oligotrophic, six as mesotrophic and four as eutrophic.

1. Introduction

Eutrophication is a severe and globally widespread problem that causes major environmental, economic and social damages. Land use changes (agriculture, forestry, urbanization, animal production, logging of native forests), result in major global changes that affect lotic systems (Allan and Castillo, 2007). More than a decade ago in 1998, the U.S. Environmental Protection Agency (EPA) reported that 40% of known water quality problems were caused by nutrient enrichment (Justus et al., 2010). Agriculture represents a diffuse source of nutrients and may be considered as the main cause of eutrophication of surface waters (Chambers et al., 2006; Freeman et al., 2007). Several studies have described how agricultural activities are strongly correlated with the increase of sediments and nutrients concentrations in streams (Ahearn et al., 2005; Allan et al., 1997; Chambers et al., 2006; Freeman et al., 2007; Karr and Schlosser, 1978; Strayer et al., 2003). In 2006, the U.S. Geological Survey estimated that rivers in agricultural watersheds transport a high percentage of the nitrogen and phosphorus annually applied to crops (more than 50% and 20% respectively) (Justus et al., 2010). The continuing degradation of river ecosystems highlights the need and importance of monitoring these areas.

The use of biological communities for water quality assessment is a common and effective practice (Justus et al., 2010), that has been increasingly used since the middle of the last century (Hawkes, 1979; Giller and Malmqvist, 1998; Oberdorff et al., 2001; Rosenberg and Resh, 1993; Stainbrook et al., 2006). The presence of a "balanced" community in an aquatic ecosystem is an excellent indicator of low anthropogenic impacts (Araujo, 1998). While the use of benthic macroinvertebrates has been most widely used and studied, other studies have shown that the fish assemblage is particularly sensitive to different types of anthropogenic impacts (Adam and Bailey, 2011; Araujo, 1998; Bistoni et al., 1999; Brown, 2000; Harris and Silveira, 1999; Wolter et al., 2000) and may be used as bioindicators.

The use of fish communities as indicators of ecological integrity was first proposed by Karr (1981) and has since been frequently used worldwide (Adam and Bailey, 2011). Among the advantages of using the fish community as bioindicators are their ease of identification, their generally known life history, and the volume of

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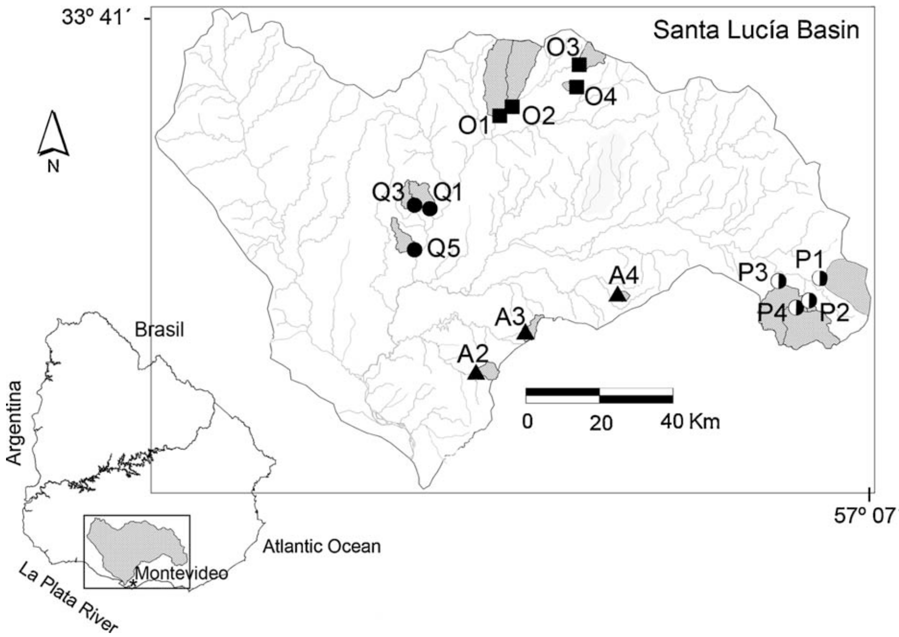

Fig. 1. Location of the Santa Lucía basin in Uruguay and detail of the study basins in each region indicated by letters.

accumulated knowledge about their trophic level and other ecological requirements (Araujo, 1998; Oberdorff et al., 2001). Moreover, since they may be located at the top of the food web, they allow us to have an integrated vision of the aquatic environment as a whole (Araujo, 1998; Oberdorff et al., 2001). This integration of information can also be considered in an ample spatial scale due to the high mobility of these organisms (Oberdorff et al., 2001).

Fish species differ in their tolerance to water quality changes which permits the creation of categories of species according to their ability to live in degraded environments (Araujo, 1998). In general, the first species to disappear are those with more specific diets, such as carnivores and insectivores (Harris and Silveira, 1999), and/or those without mechanisms to tolerate low oxygen levels. In highly degraded environments, omnivorous species are usually found along those with air-breathing mechanisms, such as Cyprinodontiformes, resulting in a more simple and hierarchical community (Bistoni et al., 1999).

Biological criteria are valuable for assessing human alterations to ecological integrity because they directly measure the conditions of the threatened resource, they detect the problems that other methods may miss or underestimate and provide a systematic process for measuring progress resulting from the implementation of water quality programs (Karr, 1991).

The aim of this study is to classify the most common fishes in the Santa Lucía basin according to their tolerance to water quality changes and to develop new biological indicators of environmental impairment (erosion, eutrophication). We also aimed to group the stream reaches according to their fish community and physiochemical composition and to add new biological criteria for the evaluation of the ecological integrity of aquatic ecosystems.

2. Materials and methods

2.1. Study area

This study was carried out in the Santa Lucía river basin, located in the south of Uruguay (33°41′–34°51′S; 54°59′–57°7′W, Fig. 1). It has an area of 13,310 km^2, a maximal altitude of 250 m above sea level and drains into the estuary of the Rio de la Plata. Although only 9% of Uruguay's population live in the basin (ca. 300,000 inhabitants), it provides drinking water for the two million inhabitants of the metropolitan area of Montevideo.

Previous studies defined three main geological and landscape regions; the meta-morphic eastern hills, the crystalline north plain and the sedimentary south Plate plain and four main uses within the basin (Achkar et al., 2004; Arocena et al., 2008). The dairy farming is the main land use and economic activity, occupying 64% of the basin area. It is followed by intensive and extensive breeding of cattle for meat (7 and 17% respectively) and horticulture (7%), restricted to the metropolitan area of Montevideo city (Arocena et al., 2008). Many water quality problems in the basin have been addressed in the past, including increased sediment loads and the eutrophication of streams and reservoirs (Arocena et al., 2008). Chalar et al. (2011) carried out a study with the aim to assess the impairment of the water resources in the Santa Lucía basin, caused by the process of eutrophication. The study was based on the assemblage of the benthic macroinvertebrates and consisted in the diagnosis of 28 stream reaches covering the main regions of the landscape and land uses. One of the main results of the study was the positive relationship between the intensity of land use (% cultured areas), estimated by satellite images and the trophic state of stream reaches.

Considering these antecedents and due to logistic limitations we selected a sub sample of previous study reaches for the present survey. Fourteen stream reaches were selected in four regions of the Santa Lucía basin covering a wide range of land use intensity and all landscape regions. Region A corresponded to the sedimentary south plain dominated by dairy cattle production, region O was characterized by the crystalline south plain with extensive cattle breeding, region P was dominated by metamorphic eastern hills and extensive cattle breeding and region Q, in the north, had prevailing crystalline rocks and dairy cattle production (Fig. 1, Table 1). It is important to note that dairy is usually combined with crop production to meet the nutritional needs of cattle.

The choice of the study reaches in each sub basin was based on the availability of permissions and accessibility to the water courses and the absence of direct impacts or physical modifications of the channel (dams, channel rectifications). Selected reaches corresponded to permanent and wadeable stream sections of order