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Effects of salinity on fish assemblage structure: An evaluation based on taxonomic and functional approaches in the Casamance estuary (Senegal, West Africa)

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The utility of taxonomic and functional approaches in assessing the structure of fish communities is tested in the hypersaline estuary of the Casamance river using data from surveys of commercial fisheries conducted between April and July of 2005. Both taxonomic and functional diversity decrease from downstream to upstream regions of the estuary. In terms of species composition, marine-estuarine species (33.3–46.3%, depending on the site) and estuarine species of marine origin (29.3–41.7%) dominate the exploited population in the Casamance estuary. In contrast, the proportion of strictly estuarine species observed upstream is twice that observed downstream.

Quantitative analysis based on biomass landed distinguishes two groups in the population: (1) a group of species that is dominant downstream, containing primarily terminal predators and secondary consumers categorised as marine species that are occasional or accessory in estuaries, estuarine marine species, and estuarine species of marine origin; and (2) a group of species characteristic of the upstream region, dominated by a few species (*Sarotherodon melanotheron*, *Tilapia guineensis*, and *Mugil cephalus*) mainly of strictly estuarine and/or herbivorous categories and *Elops lacerta*, a carnivore fish. The outcomes of the two approaches are similar, and both indicate that the fish community in this estuary is under the influence of strong environmental disturbance. However, the scales at which the specific and functional approaches most reliably reflect environmental conditions are different. The taxonomic approach, i.e., the use of specific biomass is more appropriate at the ecosystem scale and therefore more accessible to local human communities, whereas the functional approach is better suited to regional and sub-regional studies because of the change in species composition from one environment to another.

1. Introduction

The importance of estuarine ecosystems is widely acknowledged throughout the world. Estuaries are transitional ecosystems between the sea and the mainland, are highly variable and support a rich biodiversity, of which fish (larvae, juveniles, and adults) are one of the most important components (Yáñez-Arancibia et al., 1993; Whitfield, 1994, 1999). Estuaries play an important role in the bioecology of fish species, serving as nursery areas that are crucial for the renewing of stocks (Cowley et al., 2001; Mumby et al., 2004; Barletta et al., 2005). They also support a major fishing industry and contribute to meeting the animal protein needs of human populations (Houde and Rutherford, 1993; Blaber, 1997).

As estuarine ecosystems are located in coastal areas, they are subjected to increasing pressures from industrial and/or domestic pollution, resource exploitation, dam construction, and climate change (Vitousek et al., 1997; Scheren et al., 2002; Mumby et al., 2004; Lotze et al., 2006). The importance of estuarine environments and the threats to which they are exposed have resulted in increased scientific interest in these environments, as shown by the growing number of studies in these areas since the 1980s (Faunce and Serafy, 2006).

Many studies of estuarine ecosystems have been based on the taxonomic approach, i.e., the use of specific biomass or abundance to describe the patterns of biotic communities and elucidate their structuring variables (Elliott et al., 2007). Alongside this approach, a new functional approach has been developed in recent years. This

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approach involves separating species into functional groups based on life history traits such as reproductive mode, diet, and degree of dependence on the estuary (Nordlie, 2003; Elliott et al., 2007; Mouillot et al., 2007; Franco et al., 2008; Lobry et al., 2008). The use of functional groups facilitates both the simplification of the complex biotic communities and ecosystems studied (Potter et al., 1986; Albaret et al., 2004; Elliott et al., 2007) and the comparative analysis of communities across ecosystems whose species compositions vary widely (Harrison and Whitfield, 2006, 2008; Barletta and Blaber, 2007; Franco et al., 2008). The use of functional groups to diagnose the impact of a disturbance in an ecosystem implies that more or less homogeneous (functionally similar) units respond similarly to environmental conditions and respond differently from other functionally distinct groups (Growns, 2004; Franco et al., 2008; Olden et al., 2010).

The taxonomic and functional approaches are not incompatible, and they have been used in combination in some studies to understand the dynamics of estuarine ecosystems at different spatial and/or temporal scales (Harrison and Whitfield, 2004; Simier et al., 2004; Vega-Cendejas and de Santillana, 2004; Hoeinghaus et al., 2007; Ecoutin et al., 2010). However, questions remain about the complementarity of the two approaches, the benefits of using one over the other, and the applicability of each approach (Devictor et al., 2010).

This study addresses these questions by combining the taxonomic and functional approaches to assess the effects of prolonged drought on the health of fish communities in the Casamance estuary in Senegal, West Africa (Fig. 1), using data from scientific monitoring of the landings of artisanal fisheries. The transformation of this ecosystem into an inverse hypersaline estuary is thought to have begun in 1973 (Mikhailov and Isupova, 2008) and to have become complete during the drought period from 1977 to 1981 (Savenije and Pagès, 1992). Since the environmental disruption of this ecosystem and its transformation into an 'inverse' estuary (Pitchard, 1967), the Casamance River has been the subject of many studies. These have focused on both abiotic and biotic components including geomorphology (Saos et al., 1987), hydrology (Savenije and Pagès, 1992; Pagès et al., 1995; Thiam and Singh, 2002), phytoplankton (Pagès et al., 1987, 1995; Pagès, 1994), foraminifera and zooplankton (Debenay and Pagès, 1987), shrimps (Le Reste, 1987, 1992) and the fish population (Albaret, 1987). study aims to assess the extent to which taxonomic and functional approaches reveal the changes caused by hypersalinisation, using both historical and recent data on the fish population of the Casamance estuary. This estuary, in which extreme salinities are sometimes observed in the upstream region (172 in June 1986 at about 220 km from the sea; Pagès, 1986) and in which an inverse salinity gradient has existed for over 30 years, is well suited for this type of investigation. The hypothesis underlying this work is that different fish species and functional groups react differently to salinity, leading to differences in fish community structure determined mainly by environmental differences between the upstream and downstream regions of the estuary.

2. Study area

Located in southwestern Senegal, the Casamance River is formed by the confluence of several small rivers that dry up during the dry season (Thiam and Singh, 2002). It is 350 km long (with 260 km of permanent river) and drains a watershed of 14 000 km^2 (Saos et al., 1987). In the southern part of Senegal, the climate is sudano-guinean, characterised by the alternation of two seasons (Thiam and Singh, 2002): a wet season from mid-May to mid-September and a dry season during the rest of year.

The relief of the Casamance River basin is flat, with the highest point (75 m) located 400 km from the sea. The slope is generally very weak in the upper region (0.5 m km^{-1}) and almost zero on the last 200 km of river (Marius, 1985; Pagès, 1986; Pagès et al., 1987).

The river flow is remarkably low, with an average annual discharge of 3 $m^3 s^{-1}$ (Pagès, 1986). The freshwater inputs into the river are seasonal and occur mainly between the onset of the rainy season and November (Thiam and Singh, 2002). In the years 1960–1980, the annual water balance in the river was negative, with shortfalls of freshwater estimated to be between 300 and 800 mm (Pagès, 1986, 1994).

The salinity of the Casamance shows an increasing longitudinal profile from downstream to upstream. Salinity increases throughout the river during the dry season, with maxima that vary across years.

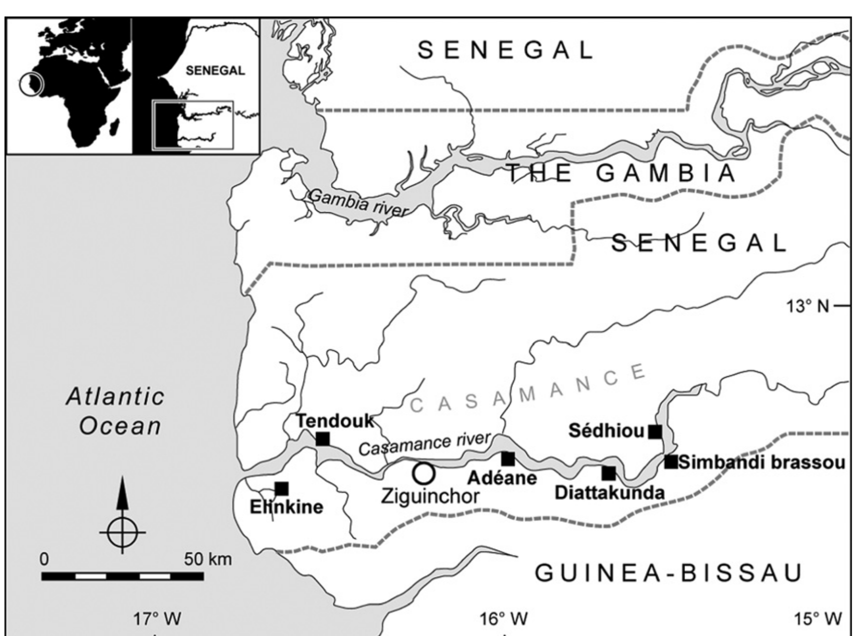

Fig. 1. Geographic location of the Casamance River and the sampled villages (open circle = regional capital and meteorological station; black points = sampled villages).