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Changes over a decade in fish assemblages exposed to both environmental and fishing constraints in the Sine Saloum estuary (Senegal)

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ABSTRACT

To investigate the changes in the fish assemblage of the Sine Saloum estuary (Senegal) over a 10-year period, it was surveyed during a complete hydrological cycle (three principal hydro-climatic seasons) first in 1992 and then in 2002–2003. The sampling protocol for the two surveys was identical, using the same sampling technique, the same collection periods, and the same sampling stations.

The Sine Saloum is an inverse estuary in terms of its salinity gradient. It is affected by the intense drought that has occurred in this biogeographic region for more than 50 years. The estuary is also subjected to high fishing pressure. The second data-collection period followed a few years of higher recorded rainfall (approximately 35% higher than in 1992) and was characterized by increased fishing pressure (over 50% higher than in 1992).

For the two study periods, the same set of indicators were calculated, including fishing indicators (catches, density, yields), size-based indicators (size structures, mean length, maximum observed length, size spectra), ecological indicators (richness, species diversity, K-dominance models, ABC curves, ecological categories) and trophic indicators (mean trophic level, trophic composition of catches).

Overall, the main changes in the estuary's fish assemblage between 1992 and 2002 were (1) a loss in total biomass (40% less) for an equivalent species richness (approximately 55 species); (2) a decrease in the maximum observed lengths for many species (mean decrease of 17%); and (3) a decrease in the mean trophic level (more than 0.11 units). Analysis by bio-ecological and trophic category showed that the main species concerned were benthophagous species and, to a lesser degree, generalist predator species from marine origin that inhabit the estuary more or less permanently.

1. Introduction

Estuaries are of great importance for many fish species of both freshwater and marine origin. They play an essential role in providing nurseries and reproduction zones for numerous species, mainly of marine origin; they offer a favorable habitat for resident estuarine species; and they constitute migratory routes for catadromous and anadromous species (Vidy, 2000; Elliott and McLusky, 2002; Martinho et al., 2007, 2008). However, due to anthropogenic effects, these transition systems are subjected to intense environmental pressures linked to eutrophication, overfishing, building construction, and general environmental degradation (Martinho et al., 2008).

Sets of indicators have been established by several authors to monitor environmental changes in the quality of estuaries. However, a number of these indicators are difficult to interpret or do not take into account the complexity of the ecosystem (Dauvin and Ruellet, 2009). For these reasons, many authors believe that, considering the functional and ecological role of fish, ichthyic communities, as indicators of environmental changes, could constitute a useful tool in providing a global definition of the health of an ecosystem (Soto-Galera et al., 1998; Whitfield and Elliott, 2002; Harrison and Whitfield, 2004; Noble et al., 2007).

Generally, most indicators that are used to define an ecosystem's health status refer to assemblages and populations of fish living in an unstressed environment (Deegan et al., 1997; Harrison et al., 2000; Degnbol and Jarre, 2004). However, due to the widespread anthropization of aquatic ecosystems, it has become difficult to define such a reference assemblage. This has led some authors to use long-term time series to determine the trends for assemblages subjected to stress and abandon the idea of a reference ecosystem (Jennings et al., 1999; Laurans et al., 2004; Rochet et al., 2005). Others have justified their studies by comparing several similar

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ecosystems (Laë et al., 2004), particularly estuaries of the same biogeographic region (Elliott and Dewailly, 1995; Elliott et al., 2007; Franco et al., 2008; Harrison and Whitfield, 2008; Selleslagh et al., 2009).

In developing countries, and particularly in West Africa, few time series of indicators exist that enable the monitoring of the health status of inland or estuarine aquatic ecosystems. Similarly, reference sites as defined by Deegan et al. (1997) have virtually disappeared because of intense anthropization around these transition ecosystems. The collection of information is often sporadic (collected in response to varied requests), making data comparison difficult. In the Ebrié Lagoon (Côte d'Ivoire), a comparison of the fish assemblage over a 20-year interval was conducted using data from several sources (Albaret and Ecoutin, 1990). Smith et al. (2008) compared Caribbean estuarine fish communities sampled 27 years apart, justifying their approach of the temporal variability by the use of a comparable sampling methodology.

The aim of the study presented in this paper was to investigate the changes over a 10-year period in the fish assemblage of an estuary in Senegal: the Sine Saloum Delta. In a study conducted in 1992 (Simier et al., 2004), the spatial organization of the fish assemblage of the Sine Saloum estuary was influenced by three major criteria: inclusion in one of the three branches of the Sine Saloum, the distance to the sea, and finally, a channel-bank gradient. In 2002, a new sampling, conducted using similar methods as the previous study, was carried out (unpublished data), which enables a comparison of the assemblages on a 10-year scale.

The Sine Saloum estuary is an inverse estuary, as defined by Pritchard (1967), due to very low freshwater inputs. Since the estuary has no tributaries, these inputs are essentially limited to rainfall (Diouf, 1996). Consequently, the salinity increases upstream whatever the season, reaching high values in the upper estuary (>100 at Kaolack, Fig. 1). One major explanation for this is that the region has endured an intense drought for several decades (Pagès and Citeau, 1990). Between 1992 and 2002, rainfall increased in this estuarine region (Sène and Ozer, 2002; Mbow et al., 2008), a change that *a priori* would favor the equilibrium of the assemblage. However, due to intense anthropization in this region of Senegal – not far from the country's capital, Dakar – fishing pressure has greatly intensified.

This study allows us to understand better the effects on the estuary's fish assemblage of changing environmental conditions on the one hand, and overfishing on the other, over a decade. For each of the study periods, a set of indicators was used, including: fishing indicators (catches, density, and yields), size-based indicators (size structures, mean length, maximum observed length, size spectra), ecological indicators (richness, species diversity, K-dominance models, ABC curves, ecological categories) and trophic indicators (mean trophic level, trophic composition of catches).

2. Materials and methods

2.1. Geographic location

The Sine Saloum Delta is located 100 km south of Dakar, between 13°35' and 14°10' North and 16°03' and 16°50' West. This

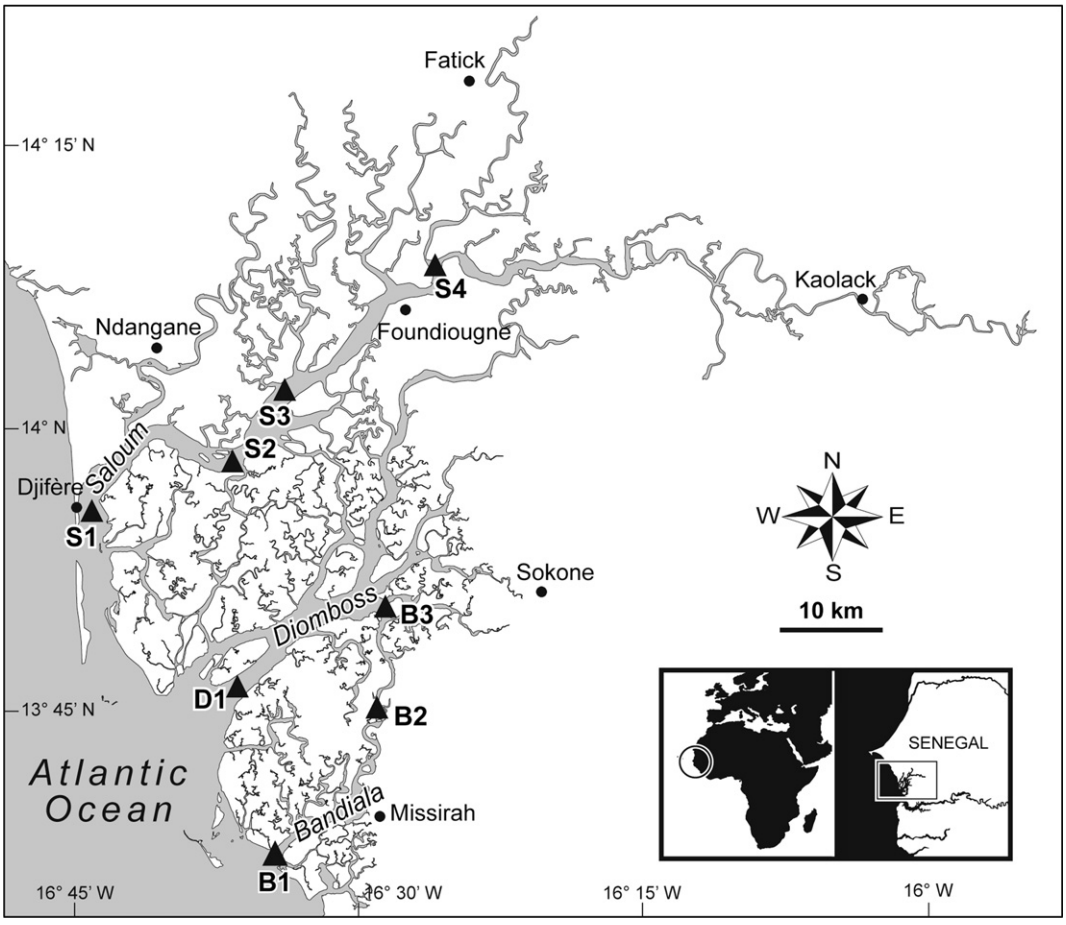

Fig. 1. Sine Saloum estuary and location of sampling sites.