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Composition and structure of the larval fish community related to environmental parameters in a tropical estuary impacted by climate change

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A B S T R A C T

Mangrove ecosystems have long been considered essential habitats and are commonly viewed and referred to as “nursery areas”. They are highly sensitive to climate change, and environmental transformations in these ecosystems are expected. The Sine Saloum estuary is a case of a system affected by global climate change where reduced precipitation and temperature increase have resulted in an inversion of the salinity gradient. Within the estuary, the composition and structure of the larval fish community related to environmental parameters were investigated using neuston and ring trawl nets. Larval fishes were sampled at 16 stations distributed along a salinity and distance-to-the-sea gradient during four field campaigns (November 2013, February, June, and August 2014) covering an annual cycle. This is the first study documenting the spatial and temporal assemblages of fish larvae in an inverse estuary. The total of 41 taxa representing 24 families and 34 genus identified in this study was lower than that of other tropical estuaries. Clupeidae spp. was the dominant taxon, accounting for 28.9% of the total number of fish larvae caught, followed by Gerreidae spp. (21.1%), *Hyporamphus picarti* (18.8%), *Diplodus bellottii* (8.9%), *Hypleurochilus langi* (4.8%), Mugilidae spp. (4.4%), and Gobiidae sp.1 (3.5%). A total of 20 taxa were recorded within the upper estuary region, whereas 29 and 37 taxa were observed in the middle and lower reaches, respectively. While larval fish were captured at all sites and during all seasons, abundances and richness decreased with increasing salinity. Larval fish assemblages also showed a clear vertical structure corresponding to three distinct water strata. Salinity, water temperature, and dissolved oxygen were the variables that best explained the spatial and temporal differences in larval fish assemblages. It is difficult to forecast the future situation for this system but so far, compared to other mangrove estuarine systems, we have observed the loss of freshwater species in favour of species of marine origin. The information provided in the present study is a contribution to the knowledge of tropical biodiversity and modifications of the ichthyoplankton communities in the context of climate change and future green fund action.

1. Introduction

Estuarine and coastal ecosystems such as nearshore coral reefs, seagrass beds, salt marshes, lagoons, and mangrove forests are known to support numerous important functions (Beck et al., 2001). Providing a great deal of key ecosystem services, like coastal protection, water purification, carbon sequestration, fisheries, raw materials, and more recently tourism related activities; they influence human welfare both directly, through direct usage, and indirectly, via impacts on supporting and regulating services in other environments (Barbier et al., 2011; Brehmer et al., 2013; Costanza et al., 1997).

Amid these ecosystems, mangroves are among the most productive and biogeochemically active environments (Barbier et al., 2011). They have high primary and secondary productivity (Bouillon et al., 2008; Jennerjahn and Ittekkot, 2002) supporting a

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great abundance and diversity of ecologically and commercially important fishes and invertebrates (Primavera, 1998; Robertson and Duke, 1987). Many studies have shown that mangrove habitats can supply abundant and diverse food, and provide shelter for young fishes, where they occur at higher densities, avoid predation more successfully, and grow faster than in a different habitat (Laegdsgaard and Johnson, 2001; Verweij et al., 2006; Nagelkerken et al., 2008). Moreover, there is evidence that the hydrodynamic processes in mangrove areas enhance the entrapment of planktonic larvae (Chong et al., 1996). For these reasons, mangrove estuarine ecosystems have long been considered essential habitats and are commonly viewed and referred to as "nursery areas" (Manson et al., 2015; Faunce and Serafy, 2006; Field et al., 1998; Chong et al., 1990; Bell et al., 1984; Weinstein and Brooks, 1983). There is also an assumption that there is a positive correlation between the area of mangrove habitat in an estuary and fisheries landings (Carrasquilla-henao and Juanes, 2016; Manson et al., 2015; Aburto Oropeza et al., 2008; Meynecke et al., 2007; Lee, 2004). This paradigm predicts that changes in mangrove attributes, for instance mangrove loss or local disturbance, would then lead to a reduction in, or a massive loss of fisheries production in coastal waters. Strengthening this view, several authors have emphasized the importance of estuaries for marine fisheries by demonstrating that a large part of the landings around the world is made up of species that spend part of their lives in estuarine waters (Barletta et al., 2005, 1998; Brehmer et al., 2006; Pauly, 1988). Moreover, groups of commercially important species classified as estuarine-dependent are often the base for economic valuation of mangroves (Nagelkerken et al., 2008).

These reasons are often invoked as grounds for the protection and conservation of mangrove estuarine ecosystems, and yet, these areas continue to decline, and in some cases worryingly fast (Polidoro et al., 2010; FAO, 2007; Alongi, 2002; Valiela et al., 2001). Throughout history, estuaries have played a critical role in human development. However, anthropogenic threats have made the estuaries one of the most degraded ecosystems on earth (Edgar et al., 2000). The impacts come from a long list that includes coastal development, dredging, filing and draining of wetlands, hardening of shorelines with riprap or concrete, upstream dams and diversions that alter freshwater inflow, land-based pollution, and overfishing (Lotze et al., 2006). More recently, the effects of climate change such as sea-level rise, an increase in the number, duration, and intensity of tropical storms, and longer periods of drought in some regions are now recognized as important stressors threatening estuarine ecosystem functioning (Scavia et al., 2002). Accordingly, local and national conservation plans stress the need to get more information on such ecosystem.

Located in Senegal, West Africa, the Sine-Saloum estuary has been affected by climate change and direct human disturbances, and consequently has undergone significant environmental transformations (Mbow et al., 2008; Xenopoulos et al., 2005). This estuarine system became permanently inverted in the late sixties due to the increasing lack of freshwater inflow (Barusseau et al., 1985; Pagès and Citeau, 1990), a direct consequence of the prolonged drought (known as the Sahelian drought) that has affected the entire Sahel region (Nicholson, 2005; Nicholson et al., 2000). Accordingly, salinity increases upstream and values throughout the system are usually greater than that of seawater. During the dry season (November to June), the difference between upstream and downstream could reach up to 90 (Diouf, 1996). What are currently unknown are the changes and impacts of this important environmental modification (inversion of the salinity gradient) in the Sine Saloum on its function as an essential habitat and important nursery area; both characteristics generally attributed to classic estuaries. Coupling this with indications that many arid regions are becoming drier as a result of climate change (IPCC, 2008, 2014), there is a need for managers and decision makers to understand and ultimately anticipate the gross effects of such natural and anthropogenic disturbances to these systems as they may further exacerbate the existing stresses on the food security and economy of these affected regions.

In the Sine Saloum estuary, several studies on adult fish assemblages have been undertaken during the last decades (Ecoutin et al., 2010; Simier et al., 2004; Vidy, 2000; Diouf, 1996). Although many species could settle temporarily or permanently, few are dominant in terms of abundance and the ichthyofauna is dominated by a few species belonging to three main families: Clupeidae, Mugilidae, and Cichlidae (Simier et al., 2004; Diouf, 1996). The environmental conditions favour the establishment of a fish fauna mainly composed of species of marine origin and most of them are juvenile forms of species from the continental shelf (Simier et al., 2004). However, to have a comprehensive picture of the Sine Saloum estuary situation, early life stages of fish must be included and to our knowledge no study has been conducted and published on larval fish assemblages. This paper presents results of the first multispecies ichthyoplankton investigation in an inverse estuary, the Sine Saloum system. The aims were (1) to describe the composition and structure of the larval fish community, and (2) to analyse the influence that abiotic factors, in particular salinity, have on the distribution of fish larvae in this ecosystem. The present study is a contribution to a better knowledge of the organization and dynamics of larval fish assemblages in high salinity environments, particularly in inverse estuaries.

2. Materials and methods

2.1. Study area: the Sine Saloum estuary

The Sine Saloum estuary (13°30′ 14°30′ N, 16°00′-16°80′ W) is located in Senegal (West Africa) and covers an area of approximately 800 km^2 of open water (Fig. 1). It comprises three main branches/rivers (Saloum, Diomboss, and Bandiala) that are connected to each other by a vast network of small mangrove creeks locally named "bolong". The Saloum channel is 7–15 m deep; with maximum depth of 25 m, while the Diomboss and Bandiala have maximum water depth of 10 m (Saos and Pagès, 1985). Mangrove forests cover almost the entire southern portion of the system and

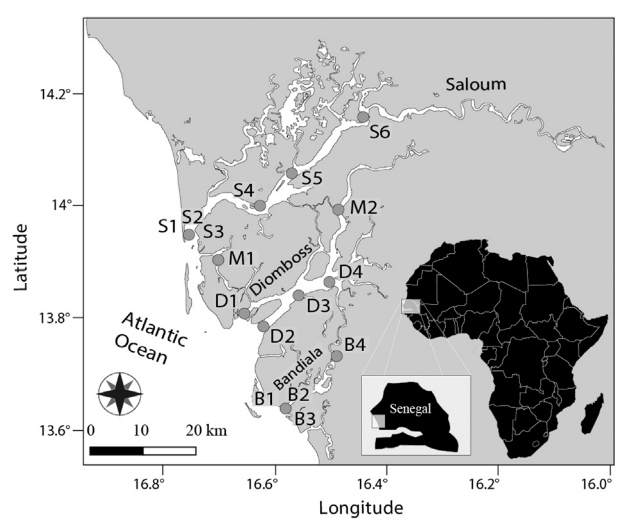

Fig. 1. Map of the Sine Saloum estuary and location of the 16 sampling sites. (S: Saloum, D: Diomboss, B: Bandiala, M: Mangrove/Bolong).