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# Difference in responses of two coastal species to fluctuating salinities and temperatures: Potential modification of specific distribution areas in the context of global change

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ABSTRACT

In the past several years, all numerical models have forecasted an increase in extreme climatic events linked to global change. Estuarine waters at the interface of marine and freshwater bodies are among the most volatile ecosystems, particularly for aquatic species, and will be strongly influenced by the temperature with extreme flooding events. This study aimed to quantify the acclimation capacity of coastal fish species to estuarine plume modifications. The thicklip mullet (*Chelon labrosus*) and European seabass (*Dicentrarchus labrax*) were selected as representative species of estuarine ecological guilds. These fish were subjected to an experiment mimicking a brief freshwater intrusion (35–5). These experiments were conducted at two different temperatures that these two species would encounter during their incursion from the sea through estuarine waters to freshwater habitats. The experimental results confirmed the high capacity for acclimation of both species to changes in salinity and temperature. Interspecific differences were observed. For example, the salinity has a greater effect on the metabolism of the seabass than on that of the mullets. Meanwhile, the temperature has a greater effect on the mullets. These differences in metabolic responses to fluctuating salinities and temperatures may modify the use of estuarine waters by these species and should be considered when predicting future specific distribution areas in the context of global change.



## 1. Introduction

Most studies on the impact of climate change on aquatic ecosystems have usually focused on the most visible aspect of global warming: the increase in mean water temperature and drought frequencies. However, according to the scenarios developed by the Intergovernmental Panel on Climate Change (IPCC, 2014), an increase in the magnitude and frequency of flood events is also expected. Risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding, are already accentuated with an additional warming of 1 °C (IPCC, 2014) and will undoubtedly get worse in the coming years. In a large continental integrated analysis, Lehner et al. (2006) showed that the areas most prone to a rise in flood frequencies are northern and northeastern Europe.

Freshwater plumes have a considerable physical impact on marine areas. The influence of plumes from an average river system (e.g. Adour in France, which has a mean flow of 350 $m^3$ $s^{-1}$) can reach 20 m in depth and over 15–20 km in horizontal distance (Ferrer et al., 2009). However, the influence can be much greater. For example, the source of the low-salinity surface waters in the western English Channel is the plumes from the Loire and Gironde Rivers, which are located several hundred kilometres away along the French Atlantic coast (Kelly-Gerreyn et al., 2006). There is also considerable biological interest in freshwater plumes. For numerous marine species along the east Atlantic coast, nurseries are located in coastal, tidal, or estuarine areas and are likely to be influenced by plumes (Jenkins et al., 1997; Le Pape et al., 2003;

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Rochette et al., 2010). Because of their higher productivity, nurseries can be considered to be more favourable for the development and growth of young fish stages (Able, 1999; Gibson, 1994; Grover et al., 2002; Holbrook et al., 2000; Peterson, 2003). For instance, in the Couesnon estuary (France), periodic sampling at different seasons has shown high fish diversity (28 different species), with a majority of the species represented by post-larvae and juveniles stages (Laffaille et al., 2001b). The higher biological favourability of these nurseries can be explained by several factors, such as the prey diversity (Miller et al., 1984), higher temperature (Macpherson and Duarte, 1991), and lesser predation pressure (Ruiz et al., 1993).

Global changes would increase the unpredictability of plumes and strongly modify numerous coastal abiotic factors that depend on freshwater inputs, such as the temperature, salinity, concentration of suspended matter, oxygen concentration (linked with temperature and salinity), and concentration of pollutants. These modifications may favour the use of estuarine habitats by very plastic species with great adaptability to changes in salinity, such as the euryhaline wanderer and catadromous species (McDowall, 1987, 1988).

Although there are about 200 European estuarine fish species (Elliott and Dewailly, 1995), the assemblages are often reduced and limited to the same main species (Nicolas et al., 2010; Maitland and Lyle, 1991). These species are divided into different ecological guilds (Elliott and Dewailly, 1995), including marine seasonal migrants and marine juvenile migrants likely to be able to cope with tidal salinity changes. Such migratory behaviour would be an advantage for them to reach highly productive habitats with lower interspecific competition. The question is how such species can adapt to the increasing unpredictability of plumes. In this context, the aim of this study was to experimentally compare the physiological abilities of species from these two guilds to cope with the large range of salinity observed in estuaries, from euhalin (more of 30) to oligohalin (0–5) waters, at two different temperatures.

The European seabass *Dicentrarchus labrax* is one of the most numerous of species in estuaries (Nicolas et al., 2010) and is described as a marine juvenile migrant (Elliott and Dewailly, 1995). This species is very common and widespread along European and North African coastal areas. The top piscivorous predator (Kottelat, 2008), it exploits both coastal and shallow waters (Pickett and Pawson, 1996; Sanchez Vazquez and Munoz-Cueto, 2014) and for this reason is usually described as euryhaline fish species. Each year, young seabass colonise supratidal and intertidal marsh creeks and subtidal and intertidal flats to feed (Laffaille et al., 2001a). Grey mullets, although less abundant in estuaries (Nicolas et al., 2010), also have a key role and are described as marine seasonal migrants.

There is no clear consensus on the catadromous character of mullets. According to McDowall (1997), the main differences between a catadromous and euryhaline wanderer species is the frequency of freshwater incursion. Euryhaline wanderers perform occasional incursions in freshwater to feed, while catadromous species make regular migrations and complete their adult growth in freshwater. Thinlip mullets (*Liza ramada*) have classically been the only species of mullets designated as catadromous (Kottelat, 2008). Others species of grey mullets, like *Mugil cephalus*, *Chelon labrosus*, *Liza aurata*, and *Liza saliens*, are also sometimes considered to be marine migrants (Franzoi et al., 2010) with cyclical migrations between marine coastal areas and transitional waters. Grey mullets are the only fish species able to exploit the great productivity of the biofilm in intertidal areas and probably play an important ecological role in C transfer from inter-to sub-tidal areas (Carpentier et al., 2014).

These two fish species are undoubtedly strongly linked to estuarine and/or coastal low salinity waters. In particular, adults and juveniles European seabass perform daily tidal migrations from marine to estuarine waters for feeding (Laffaille et al., 2001a; Kelley et al., 1987; Pawson et al., 1987). A lack of study and knowledge about thicklip mullets *C. labrosus* has led to no clear evidence for them having similar behaviour, but their presence during flood tides and at low salinity in several estuaries and marshes supports this hypothesis (Gautier and Hussenot, 2005; Lasserre and Gallis, 1975; Nicolas et al., 2010; Feunteun et al., 1999). According to the literature, these two species have similar osmoregulation capacity (Gautier and Hussenot, 2005; Sanchez Vazquez and Munoz-Cueto, 2014) despite belonging to different ecological guilds; thus, their specific responses to salinity and temperature and by extension to climate change can be contrasted.

Previous studies have already analysed the impact of salinity and temperature variations on fish metabolism by mimicking the characteristics of coastal waters influenced by plume. A large range of patterns has been observed. Long-term experiments were performed on European seabass juveniles in swim tunnels to monitor the effect of changes in the salinity on the critical speed, cardiac performance, and oxygen consumption during exercise. These are considered a proxy of the global metabolism and are thus called $MO_2$. No significant effects were observed after 18 h of exposure to freshwater (Chatelier et al., 2005), which confirmed the high plasticity of this species. In contrast, the number of feeding events and swimming activity of the golden grey mullet (*L. aurata*) were found to increase with the water temperature (Como et al., 2014). Although described as euryhaline, thicklip mullets (*C. labrosus*) cannot live for long periods of time in entirely freshwater habitats (Lasserre and Gallis, 1975). The inability of thicklip mullets to develop long-term hypo-osmoregulation in freshwater probably limits the upstream penetration of this species (Lasserre and Gallis, 1975). In brackish water (15), the growth of thicklip mullets is not affected (Cardona et al., 2008), which suggests that this species also has high plasticity.

In the present study, an experiment was performed to mimic an incursion into a freshwater plume over one tide (i.e. about 6 h), which is a common pattern for thicklip mullet (*C. labrosus*) and European seabass (*D. labrax*) individuals in northwestern European coastal catchments (Laffaille et al., 2001a). The variability in responses of both fish species' metabolism to short-term salinity variations at different temperatures was compared. The current mean water temperature in the estuaries of the Bay of Biscay during the main feeding period of these species (April–May) was selected as a reference temperature (17 °C), and a second temperature corresponding to the observed warm peak in the above region over the same period (21 °C) was also selected. Based on the known plasticity of the two species to salinity and temperature, contrasting results in terms of the metabolism responses were hypothesised. The expectation was to obtain some keys to better anticipating how these species and thus the guilds they represent will react to the increasing unpredictability of coastal fluvial plumes, which is expected in the next decades as a consequence of global warming.

## 2. Material and methods

### 2.1. Fish collection, acclimation, and stress removal

Twelve adult or sub-adult thicklip grey mullets (*C. labrosus*) were caught with a fishing rod at the mouth of the Rance estuary near Saint-Malo (northwestern France) in November 2014. Twelve adult or sub-adult European seabass (*D. labrax*) were bought from a fish farm at the mouth of the Auray estuary near Vannes (northwestern France) in November 2014. The two collection sites were located in euhaline waters. After sampling, the fish were anaesthetised with 40 mg $l^{-1}$ of a benzocaine (ethyl 4-aminobenzoate)