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Otolith microchemistry interrogation of comparative contamination by Cd, Cu and PCBs of eel and flounder, in a large SW France catchment

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ABSTRACT

Individual European flounder and European eel levels of contamination by cadmium, copper and 7PCBs were related to their retrospective pattern of habitat use, using a combined toxicology and otolith microchemistry approach. The results showed that both species used the freshwater, the upper and lower estuarine habitats. There was a strong difference in the level of contamination of eel compared to flounder, with higher levels of PCBs, copper (Cu) and cadmium (Cd) in eel. The differences of contamination between muscle and liver were also specific to the considered species. The choice of the river habitat at an early age seemed to increase the risk of exposure to PCBs. The results suggested that the use of the upper estuary was related to a higher level of copper for both species and of PCBs for the flounder. The higher level of liver cadmium was measured for fish spending the longer time in the lower estuary.

1. Introduction

Because of their wide distribution range and their ubiquitous habitat use during their growth phase, Eel *Anguilla anguilla* and flounder *Platichthys flesus* have been chosen as key species to investigate risk exposure to contaminants. Both species have very similar life history traits. Eel and flounder, share a catadromous life strategy, which consists of spawning at sea and in growing in inland water habitats, either in estuaries, in rivers or in coastal waters (McDowall, 1997). *P. flesus* and *A. anguilla*, also have a similar dietary ecology, characterized as benthic/epibentic, with very high trophic positions (Pasquaud et al., 2008), which expose them to the risk of contamination by metallic and organic contaminants and to the risk of trophic web bioaccumulation. Both species use estuarine habitats, during their growth phase, for long periods of time, up to 5 years for flounder and up to 15 years for eels (Tesch, 2003) although eel and flounder have different reproductive strategies and, as a consequence, a different lipid metabolism. Eel undertake a long journey of migration to the spawning ground in the Sargasso sea (circa 6000 km) (Tesch, 2003), while the flounder reproduces in coastal areas in the 20–50 m depth zone (Masson, 1987). In addition, eel reproduces once in its lifetime and dies shortly after reproduction (semelparity) while flounder is a repeat spawner (iteroparity). Consequently, the lipids accumulated for migration and reproduction are stored in large quantity throughout the growth stage period and invested only once for eel, whereas the lipids are accumulated in relatively lower quantity just before reproduction and renewed completely after each spawning event for flounder. In the Gironde estuary, SW France, Eel and flounder, together with thin lipped mullet *Liza Ramada*, carried the highest load of Cd, Cu, Zn and Hg, out of the eight fish species investigated (Durrieu et al., 2005). Another study focussing on Cd contamination load of eel further confirmed that eels were exposed to high levels of Cd, with liver Cd concentrations varying in line with the habitat of collection (Pierron et al., 2008). Significant levels of organic contaminants and metals were also detected for eels and flounder in the Gironde system (Marchand et al., 2003; Tapie et al., 2006; Evrard et al., 2010). Tapie et al. (2006) showed that the level of contaminants in the eel organs varied between the salinity zones and the different habitats of collection in the Gironde system; Cd and PCB concentrations seemed to be more elevated in the liver of fish collected in the upstream saline estuarine zone. Despite this, a large inter individual variability was observed and no clear relation between habitat of collection and the related level of contamination could be established. Furthermore, despite the fact that Cd and PCB are commonly bio-accumulated in fish tissues, a clear link between fish age and load of contaminants could not be detected, suggesting that other individual traits, such as the migration pattern or habitat use pattern, might explain the between individual difference. Otolith chemistry is increasingly being used in fish ecology to track fish migration (Campana, 1999; Elsdon et al., 2008). Otoliths are part of the teleost sensory system dealing with hearing,

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pressure and motion (Popper and Lu, 2000). They are composed of calcium carbonate deposited on a protein matrix. Successive layers of otolith material are deposited throughout the life of the fish and incorporate a wide range of trace elements into the structure during the otolith growth. Trace elements such as strontium Sr and barium Ba are particularly suited for tracing movements of fish across water masses of different salinity as Sr and Ba often display a gradient of concentration across estuaries and Sr and Ba are incorporated in otoliths proportionally to their concentration in the water (reviewed by Elsdon et al., 2008). Sequential measures of the Sr and Ba otolith composition along an otolith growth axis from the core to the edge (so called "life history transect") are used to infer fish movements throughout life (Elsdon et al., 2008). Based on otolith growth patterns and chemical composition, detailed individual eel chronologies of habitat use were described in the Gironde river basin (Daverat et al., 2005, 2006; Daverat and Tomas, 2006). The previous studies underlined that habitat use patterns differed between individuals, displaying either the residence in one habitat (estuary, river) or a residence in freshwater habitat (up to four years) followed by a switch to the estuarine, or coastal habitat. The ability for flounder juveniles to colonize rivers at some distance from the sea and above the tide level has often been recorded (Beaumont and Mann, 1984; Kerstan, 1991). Flounder and eels in the Gironde system have similar habitat use tactics (Daverat et al., 2011), with fish resident in their collection habitat and fish that have switched habitat during their growth phase. For the present study, eels and flounder were sub-sampled from two ecology studies on habitat use patterns (Daverat and Tomas, 2006; Daverat et al., 2011) in order to investigate the link between habitat use and contamination.

The objectives of this study are (i) to examine comparatively the levels [Cd], [Cu], and [7PCBs] for eel and flounder from the Gironde estuary, (ii) to investigate the relationship of these concentrations to several life traits: residency time of eel and flounder in the different habitats of the estuary, the nature of habitat used recently (i. e. during the year prior to capture) and age. To meet these objectives, an approach based on toxicology, otolith microchemistry and otolith structure was conducted.

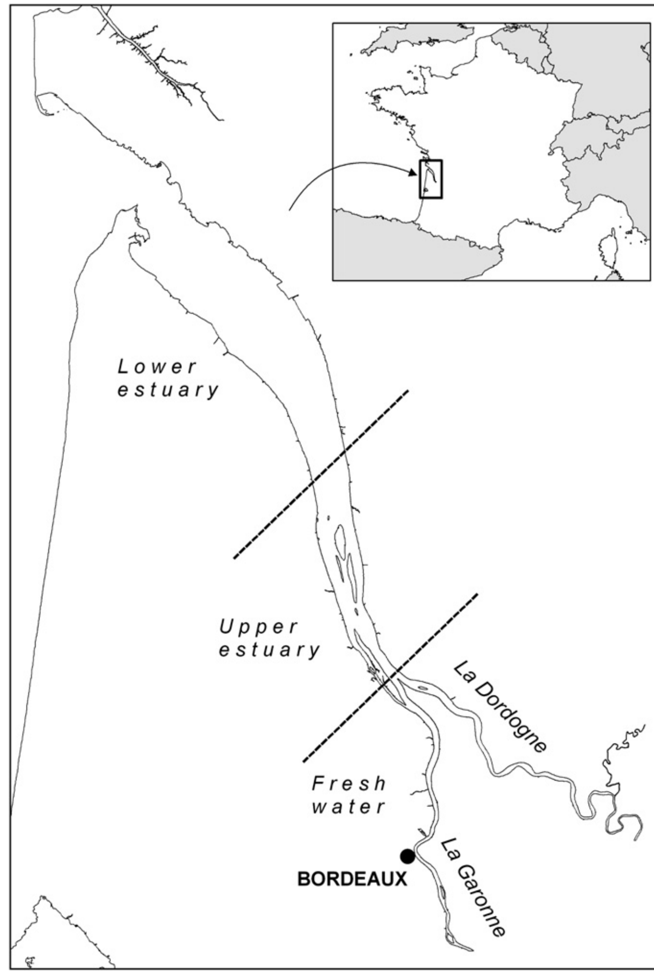

Fig. 1. Map of the Gironde estuary, showing the estuary zones, the upper estuary and the lower estuary zones as well as the connected freshwater areas.

2. Material and methods

2.1. The Gironde estuary

The brackish part of the Gironde tidal estuary is 76 km long (Fig. 1) with a high turbidity level in the water column. Its surface area is approximately 625 km^2 at high tide and the salinity gradient varies upstream between 33 and 0 and changes with tide and season (Castaing, 1981; Sottolichio, 1999). The limit of the brackish estuary is defined at the 0 psu salinity front. The freshwater tidal Gironde estuary encompasses the lower part of the Garonne and the Dordogne rivers. In the present study, the freshwater part of the system was noted as R (for "river"), the brackish zone connected to the freshwater tidal zone was noted as E (for "upper estuary") and the lower estuary, connected to the coastal zone was noted as M (for "marine waters") (Fig. 1). A spatial gradient of Cu and Cd accumulation may be observed in the estuary, as dissolved Cd and Cu concentrations increase with salinity (Kraepiel et al., 1997). Low PCB contamination levels of abiotic part were measured in the Gironde estuary (dissolved phase around 7 ng l^{-1} and sediment around 40 ng g^{-1} dw for the 7PCB); however, disparities of PCB accumulation were observed in eels collected in the different zones of the Gironde estuary (Tapie, 2006).

2.2. Fish

Fish were sub-sampled from two ecology studies on eels (Daverat and Tomas, 2006) and flounder (Daverat et al., 2011) habitat use patterns. The selection was representative of the diversity of habitat use patterns observed in the larger samples. The number of samples was in accordance with similar studies involving both toxicology and otolith microchemistry (Ohji et al., 2007; Lochet et al., 2008; Le et al., 2010). 15 eels were collected in May (9 eels) and September (6 eels) 2001 as described by Durrieu et al. (2005) in the upper estuary zone (E) and in the lower estuary zone (M). The 32 flounder were collected in January 2003 (20 individuals) and June 2003 (12 individuals) as described by Marchand et al. (2003), in the upper estuary zone (E). Individual weight and length of fish were recorded. The age of each individual fish was estimated using otolith increments. Sex was determined by a macroscopic examination of the gonads.

2.3. Individual chronologies of habitat use

Individual chronologies of habitat use of eels were detected using Sr:Ca composition of otolith transect measured by Wavelength Dispersive Spectrometry, following the method described in Daverat and Tomas (2006) and Fablet et al. (2007). The chronologies of habitat use of the flounder were obtained after measurement of Sr:Ca and Ba:Ca along life transect of otoliths (Daverat et al., 2011). The concentrations of elements (Sr, Ba, Ca) in the otolith sample were determined using a Inductively Coupled Plasma Mass Spectrometry – Elan DRC II (Perkin Elmer) coupled with a high repetition rate Infra Red femtosecond laser ALFAMET (Alfamet, Novalase SA – Amplitude Systemes, France). Only the part of the