Chemosphere 91 (2013) 498–505

Contents lists available at SciVerse ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

A combined measurement of metal bioaccumulation and condition indices in juvenile European flounder, *Platichthys flesus*, from European estuaries

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HIGHLIGHTS

- ▶ Juveniles flounders (5–10 cm) were collected in three anthropogenic estuaries.
- ▶ Correlations were found between metal contents in sediment and in flounder liver.
- ▶ Condition index was lower in fish from anthropogenic estuaries than from reference.
- ▶ A significant decrease in lipid index was observed in fish from contaminated estuaries.
- ▶ Usefulness of metal bioaccumulation and juvenile fish condition combined measures.

ARTICLE INFO

Article history:
Received 23 July 2012
Received in revised form 4 December 2012
Accepted 9 December 2012
Available online 18 January 2013

Keywords:
Flounder
Metal
Fish condition
Lipid index
Biomonitoring

ABSTRACT

Condition indices and metal bioaccumulation of early life stages of juvenile flounder (5–10 cm) were determined in three anthropogenic estuaries (the Scheldt, Seine and Loire) and compared to a reference site (the Canche). Significant correlations were found between metal concentrations in sediment and (i) fish liver for Cd, Cu, Ni, Pb, V and Zn and (ii) fish gills for Cd and Mn. Metal accumulation in juvenile flounder from the three anthropogenic estuaries coincided with significantly lower Fulton's K indices (from 0.99 ± 0.03 to 1.06 ± 0.01 mg mm^{-3}) compared to those from the Canche estuary (from 1.02 ± 0.01 to 1.13 ± 0.01 mg mm^{-3}). This discrepancy in fish condition index increased with fish size and therefore, strongly depends on the time juvenile spend in estuary. Muscle lipid contents and Triacylglycerol to Sterol ratios were significantly lower in fish collected in the Scheldt (lipid content: 21.3 ± 3.6%), Seine (17.9 ± 19.8%) and Loire (19.5 ± 2.4%) estuaries compared to those originating from the Canche (38.3 ± 4.6%). This study highlights that combined measures of both fish metal contents and condition indices gives a relevant assessment of juvenile fish health growing in anthropogenic estuaries.

1. Introduction

In recent years, the scientific community has become increasingly aware of the impacts of chemical contaminants on marine environmental quality. In order to screen for potential toxicity of complex mixtures of chemicals present in environmentally many indicator organisms have been used in aquatic environment. Fish have been widely documented as useful indicators of environmental water quality, chiefly due to their wide dispersion and long lifespan. In particular, flatfish appear to be good model species to examine the effects of contaminated sediment. European flounder (*Platichthys flesus*), an abundant flatfish in European coasts, have been used in several biomonitoring programs since the 1970s (Jensen and Cheng, 1987; Cossa et al., 1992). It is an estuarine species that resides during its juvenile stage in estuaries, being also tightly linked to estuaries in the adult stages (Kirby et al., 2000). Moreover, the flounder is a benthic fish living in contact with the sediment, the major compartment for contaminant storage in the aquatic environment, and is thus particularly exposed to chemical stress (Minier et al., 2000; Koehler, 2004). In general, studies using flounder as a bio-indicator were performed with large organisms, above 20 cm, since small fish do not provide such large amounts of tissue for chemical and biological analyses. However, juveniles are most abundant along estuarine or coastal areas which serve as a nursery ground and represent a critical life stage for fish population renewal (Gibson, 2005; Selleslagh et al., 2009). Indeed, mortality is high during the first several months of fish life and

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0045-6535/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.chemosphere.2012.12.010

only the few individuals surviving can contribute to the recruitment success (Beck et al., 2001). Recent experimental studies showed that juvenile fish are very sensitive to environmental contamination (Kerambrun et al., 2012a,b). In field, Amara et al. (2009) have denoted a decrease of juvenile flounder growth in a French anthropogenic estuary, the Seine, compared to less impacted estuaries. To our knowledge, until now, no field investigation has been devoted to the metal bioaccumulation and also their biological effects in such juvenile fish, although these stages can be more sensitive than the adult stages.

Bioaccumulation patterns of metal in fish tissues can be used as effective indicators for both monitoring metal contamination of the environment and evaluating their bio-availability (Larsson et al., 1985). Fish health indicators, as condition and lipid storage indices, inform on metabolic cost induced by chemical contaminants and indirectly on the energetic status and growth of the exposed individual (Adams et al., 1990). Thus, they can reflect fish probability to survive. These biological indices present the advantage to be relatively easy to measure and offer relevant information on fish health. Fulton's K index and lipid index, based on Triacylglyerol on Sterol ratio, were successfully used to assess effects on chemical contaminants on juvenile fish (Kerambrun et al., 2012a,b).

The aim of the present study was to evaluate, in a field situation, the effects of chemical contaminants on 0-group flounder from three estuaries impacted by human activities (the Scheldt, Seine and Loire estuaries) by comparison with a reference site (the Canche estuary). Metal, PAH and PCB concentrations were determined in estuarine sediments and metal concentration in fish liver and gills, two target organs of contaminant accumulation. These levels of chemical compounds were then put in relation with juvenile flounder health using the Fulton's K index and a lipid index.

2. Material and methods

2.1. Flounder sampling

Juvenile flounder were collected in October 2010 in three French estuaries along the Atlantic coast (The Canche, Seine and Loire) and in a Belgium estuary (The Western Scheldt) (Fig. 1). Whereas the Canche is a small estuary with low domestic, agricultural and industrial effluents, the Scheldt, Seine and Loire estuaries are subjected to strong anthopogenic influences and are chronically polluted by mixture of chemicals. Sampling was performed using a 1.5 m beam trawl, with one tickler chain and 5 mm mesh size in the cod end, towed by a zodiac against the current at two knots for 15 min. Immediately after sampling, 0-group flounder (879 individuals between 50.9 and 99.7 mm total length, TL) were sorted alive on board, kept in ice and transferred to −20 °C in laboratory.

Each fish was measured for total length (near to 0.1 mm) and weight (near to 0.01 g) to calculate Fulton's K condition index. Flounder used for chemical and biological analysis were chosen in order to avoid any difference in fish size between estuaries. Thirty flounder per estuary (TL: 79.8 ± 4.5 mm; W: 5.36 ± 0.96 g) were dissected for analysis of metal in livers and gills which were stored at −20 °C. Ten other fish per estuary were used for lipid analysis (TL: 70.1 ± 4.1 mm; W: 3.63 ± 0.65 g). Muscles were sampled and preserved at −20 °C for lipid analysis.

2.2. Environmental parameters and sediment chemical contamination

At each sampling station, physicochemical parameters (Temperature, salinity, oxygen, pH, turbidity) were recorded and presented in Table 1. Sediment was collected at low tide near each sampling station, kept in ice box and preserved at −20 °C in laboratory.

Sediment grain size distribution was analysed using a laser Beckman–Coulter LS 230. A classification was established using the proportion of mud (<50 μm), fine sand (50–200 μm) then medium and coarse sand (>200 μm).

In order to determine selected metals (Al, Cd, Cr, Cu, Mn, Ni, Pb, V and Zn) in the total and bioavailable fractions, sediments were dried at 40 °C to constant weight and were ground to a powder. For the determination of total metals, about 0.250 g of ground sediments were digested with HF (Suprapur, Merck) at 110 °C for 48 h, followed by a mixture of concentrated acids $HCl{:}HNO_3$ (3:1, v:v, Suprapur Merck) at 120 °C for 24 h. Metals associated with the

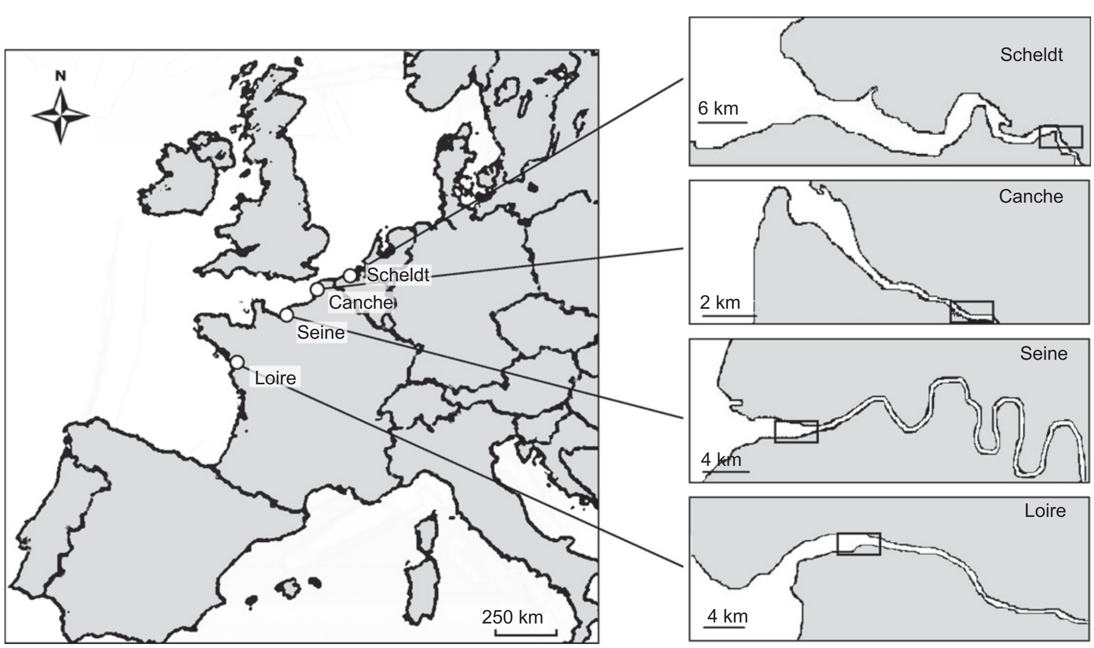

Fig. 1. Locations of the four estuaries (Scheldt, Canche, Seine and Loire). The rectangular area represented the fish sampled area.