Estuarine, Coastal and Shelf Science 81 (2009) 179–190

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Anthropogenic disturbance on nursery function of estuarine areas for marine species

A. Courrat [a,*], J. Lobry [b], D. Nicolas [c], P. Laffargue [d], R. Amara [d], M. Lepage [c], M. Girardin [c], O. Le Pape [a]

[a] Agrocampus Ouest, Laboratoire d'Ecologie Halieutique, UMR INRA ESE 985, 65 rue de St. Brieuc, CS 84215, 35042 Rennes, France
[b] IFREMER, EMH, rue d'Ile d'Yeu, B.P. 21105, 44311 Nantes Cedex, France
[c] Cemagref (French Institute of Agricultural and Environmental Engineering Research), U.R. ECOSEMA, 50 avenue de Verdun, Gazinet, 33612 Cestas Cedex, France
[d] Université du Littoral, UMR 8187 CNRS LOG, 32 avenue Foch, 62930 Wimereux, France

ARTICLE INFO

Article history:
Received 20 June 2008
Accepted 20 October 2008
Available online 5 November 2008

Keywords:
essential fish habitat
nursery grounds
estuaries
fish indicators
anthropogenic disturbances
contamination

ABSTRACT

Estuaries serve as nursery grounds for many marine fish species. However increasing human activities within estuaries and surrounding areas lead to significant habitat loss for the juveniles and decrease the quality of the remaining habitats. This study is based on the data of 470 beam trawls from surveys that were conducted in 13 French estuaries for the purpose of the European Water Framework Directive. It aimed at testing the effects of anthropogenic disturbances on the nursery function of estuaries. With a multispecific approach based on ecological guilds, two fish metrics, abundance and species richness of Marine Juvenile migrant fishes, were used as proxies for the estuarine nursery function. Indices of heavy metal and organic contaminations were used to estimate anthropogenic disturbances impacting these estuaries. Fish metrics were described with statistical models that took into account: (a) sampling protocol, (b) estuarine features and (c) contamination. The results of these models showed that the fish metrics highly depend on the sampling protocol, and especially type of gear, depth and salinity, which highlights the necessity of considering such metrics at the sampling (trawl haul) scale. Densities and species richness of Marine Juvenile fishes appeared to be strongly and negatively correlated to contamination indices. These results are consistent with the hypothesis that human disturbances impact the nursery function of estuaries. Finally, the densities of Marine Juvenile migrant species appeared as a potential robust and useful fish indicator for the assessment of the ecological status of estuaries within the Water Framework Directive.

1. Introduction

Estuaries are transitional zones of interaction between land and sea that present a very high level of productivity (Whittaker, 1975; Costanza et al., 1997). Because of some of their features, such as high salinity variations, low depths, muddy grounds, warm water, higher turbidity, the presence of various and rich habitats and high food availability, estuaries serve as nursery grounds for many marine fish species (Gibson, 1994; Elliott and Dewailly, 1995; Able et al., 1999; Riou et al., 2001; Jones et al., 2002; Meng et al., 2002; Le Pape et al., 2003b; Peterson, 2003; McLusky and Elliott, 2004; Elliott et al., 2007; Franco et al., 2008): juveniles aggregate in these areas where their fitness is enhanced through better feeding conditions, optimal growth, refuge opportunities and high connectivity with other habitats (Beck et al., 2001).

Nevertheless, estuarine zones are also characterized by a high level of human activity. More than 60% of the world's population lives within 60 km of the coast (Post and Lundin, 1996). The increasing urban and industrial development within estuarine areas leads to significant habitat losses (Coleman et al., 2008) for the juveniles. Furthermore, estuaries are the discharge point for all particles stemming from anthropogenic activities carried out within the drainage basin, including urban and industrial development as well as intensive agriculture. Therefore, in addition to increasing quantities of nutrients and organic materials, estuarine waters and sediments accumulate xenobiotics such as heavy metals and organic contaminants, which tends to degrade the quality of the remaining estuarine habitats for juvenile fishes. As a consequence, the essential nursery function of estuarine areas may be reduced by these anthropogenic disturbances (Gibson, 1994; Able et al., 1999; Costa and Cabral, 1999; Jones et al., 2002; Whitfield and Elliott, 2002; Gilliers et al., 2006; Coates et al., 2007; Le Pape et al., 2007). Recruitment level and population size of the concerned marine species may then be dramatically affected (Peterson et al., 2000).

* Corresponding author.
E-mail address: acourrat@hotmail.com (A. Courrat).

0272-7714/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2008.10.017

To monitor the quality of estuarine zones, the use of biological indicators that take into account their ecological function is becoming a widespread method (Basset and Abbiati, 2004; Coates et al., 2007). In particular, indicators based on fish communities are recognized as useful tools to assess anthropogenic impacts on estuaries (Costa and Elliott, 1991; Deegan et al., 1997; Hughes et al., 1998; Whitfield and Elliott, 2002; Borja et al., 2004; Harrison and Whitfield, 2004; Harrison and Whitfield, 2006; Breine et al., 2007). For example, to assess if transitional waters (estuaries and lagoons) within the European Union are in a good ecological status by 2015, the Water Framework Directive (WFD—Directive 2000/60/EC; Anonymous, 2000) has introduced, among others, the use of fish indicators and these tools are being developed all around Europe within this framework.

In that WFD purpose, a large data set was created in France from fish samplings carried out within 13 estuaries presenting various degrees of human activity (Gilliers et al., 2006; Amara et al., 2007). Based on this data set, our aim was to bring out and to measure the impact of anthropogenic disturbances on the nursery function of estuaries. Our approach was to make inter-estuaries comparisons of the nursery function, i.e. to compare the sampled estuaries on the basis of multispecific fish metrics that were used as proxies of the estuarine nursery function (Elliott and Dewailly, 1995). We modelled the impacts of anthropogenic disturbances, estimated thanks to contamination indices used as proxies for human pressure, on the estuarine nursery function after controlling for the variability stemming from the sampling design and some estuarine features.

2. Materials and methods

2.1. Beam trawl survey data

In 2005 and 2006, 13 estuaries were investigated throughout France (Fig. 1), in spring and autumn, with a standardized sampling procedure (Lepage and Girardin, 2005).

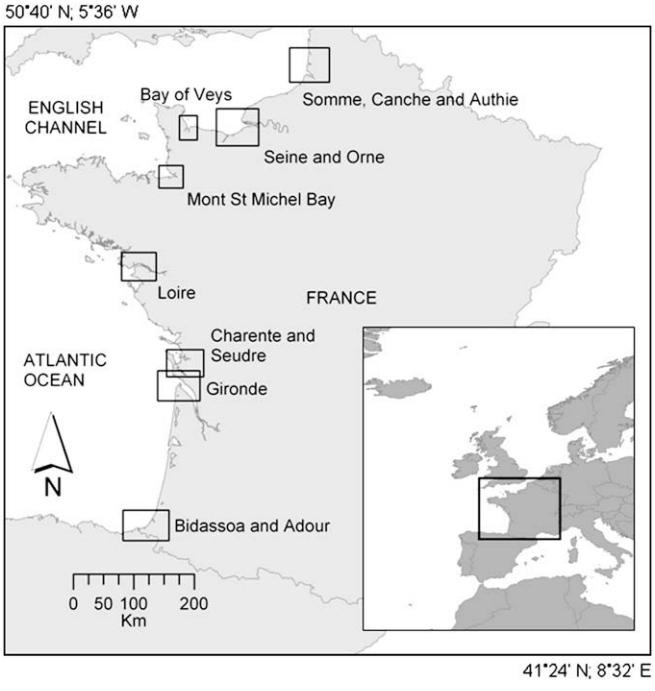

Fig. 1. Location of the 13 French estuarine areas studied in the present work. In lower right corner: general location of the study area.

Two types of beam trawl were used. One had an opening of 2.7 m wide and 0.6 m high and its net had 20-mm stretched mesh in the cod end. The other beam trawl had an opening of 1.5 m wide and 0.5 m high and a net with 10-mm stretched mesh in the cod end. The 2.7 m wide beam trawl was used only in big estuaries while the 1.5 m wide beam trawl was used everywhere. Hauls were performed only in daylight, for about 15 min and at a towing speed ranging from 1.5 to 3 knots. Between 12 and 65 beam trawls were performed per estuary and per season, with a mean of 23. In total, 470 beam trawls were carried out.

For each beam trawl haul, salinity (measured using the Practical Salinity Scale) and depth were recorded at the beginning of the haul. Investigated depths range from 0.5 m to 20.5 m. As investigated areas were sometimes located far upstream the estuaries (i.e. close to the freshwater environment), salinity measures could range from 0 to 36. In each estuary, sampling points were chosen in order to sample the greatest part of potential fish habitats and to cover all the estuarine areas, from the upstream limit of tide to the open sea. Hence a wide range of salinities and depths was sampled in each of the 13 estuaries.

All fishes collected were identified, measured and counted. 71 fish species were caught and more than 15,500 individuals were measured. When the number of fish from a species in a beam trawl was superior to 30, only a representative subsample of 30 individuals was measured if size were homogeneous.

2.2. General approach for the evaluation of the impacts of anthropogenic disturbances on the estuarine nursery function

Fig. 2 presents the general methodology adopted for this study. Specific fish metrics were used to assess the nursery function of the sampled estuaries. Similarly, indices of contamination were used to quantify the level of anthropogenic disturbances that impact the sampled estuaries. As estuaries present a high degree of intra-variability, it is difficult to standardize the sampling procedure for the acquisition of fish data (Mouillot et al., 2006). Therefore our approach was based on the idea that it was necessary to take first into account the effects of the sampling procedure on the fish metrics. Indeed, spatial gradients play a major role in estuaries, particularly the salinity gradient that depends on the relative influence of freshwater and marine water inflow (McLusky, 1981; McLusky and Elliott, 2004; Greenwood, 2007; Vinagre et al., 2008). For this purpose fish metrics were calculated at the beam trawl scale. Second, we tested for the impact of some estuarine features on the selected fish metrics. Only after these two main sources of variability were taken into account, the score of each estuary for the studied fish metrics was estimated. Last, the link between these scores and the level of anthropogenic disturbances was tested (Fig. 2).

2.3. Fish metrics for the nursery function

Fish metrics regarded as proxies for the estuarine nursery function, i.e. related to juvenile stage of marine fishes, were opted for.

2.3.1. Multispecific approach based on ecological guilds

A multispecific approach based on ecological guilds was used to describe the use of estuaries as nursery grounds by marine fish species. This study focused on juveniles of fish belonging to the ecological guild called "Marine Juvenile (MJ) migrant species". This guild regroups marine fish species that use estuaries primarily as nursery grounds but usually spawn and spend much of their adult life at sea, while often returning seasonally to estuaries when adult (Elliott and Dewailly, 1995). Whether a species belongs or not to this group was determined from Elliott and Dewailly (1995), Quéro