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# Predicting fish community properties within estuaries: Influence of habitat type and other environmental features

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ABSTRACT

Statistical models predicting species distributions are essential not only to increase knowledge on species but for their application in conservation and ecologically-based management. The variation of fish species richness and abundance in the most representative habitats (saltmarsh, mudflat and subtidal) in five estuaries along the Portuguese coast was analysed through seasonal sampling surveys in 2009. Generalized additive models (GAM) were developed to describe the variation of species richness and abundances with a set of geomorphologic, hydrologic and environmental characteristics from the sampled estuaries and habitats. GAM were chosen as the complex interactions dominating these ecosystems and species distribution are non-linear. Final models built for each estuary and for all estuaries together performed well during the calibration phase and also during the validation phase, where an unused data sub-set from each estuary was used. There was not a similar combination of variables retained by the models for the studied estuaries but factors such as the area of the habitat, the distance to estuary mouth, percentage of mud in the sediment and depth were commonly retained. The partial effect of these predictor variables on the variation of species richness and abundance in the estuaries varied markedly and the importance of preserving the heterogeneity of habitats within estuaries was highlighted. Models for each individual estuary performed better than models for estuaries combined. Predictive models could be useful as a preliminary tool to prepare long-term conservation plans at different scales.



## 1. Introduction

Estuaries are one of the most productive ecosystems on Earth (Costanza et al., 1997), and have been the subject of considerable ichthyological research, some of which specifically focussing on the key environmental factors affecting the structure of estuarine fish communities (Selleslagh et al., 2009). These systems are exposed to great environmental variability, with the life cycle of most of organisms showing clear seasonal patterns in growth, reproduction and abundance (Coma et al., 2000; Maes et al., 2004). Understanding the relationships between environmental factors and fish species distribution in estuaries is of fundamental importance, and attaining quantitative predictions of the patterns of occurrence and abundance of fish species in estuaries represents an essential goal for its application in reserve planning (Corsi et al., 1999; Austin, 2002; Elith et al., 2006) or biodiversity conservation (Gray et al., 2006; Lira-Noriega et al., 2007; Ko et al., 2008).

The quantification of such species environment relationships represents the core of predictive geographic modelling in ecology (Guisan and Zimmermann, 2000). Many predictive models based on correlating presence and abundance data of species with environmental predictors have been widely used (Manel et al., 1999; Ko et al., 2008) through a variety of statistical methods, often in conjunction with Geographic Information Systems (GIS) and remote-sensing (Austin, 2002).

Within coastal and marine ecosystems recent attempts have been made to statistically model the responses of fish species to environmental variables on a large scale and to use these models to predict their distribution and occurrence (Nicolas et al., 2010; França et al., 2011). Nevertheless, there are increasing demands in order to obtain reliable and quantitative predictive tools, as they are required to interpret species preferences and tolerances to current environmental conditions, as well as species response to anticipated changes in environmental conditions (Ysebaert et al., 2002).

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Research on predictive techniques applicable to species distribution is still far from producing a reliable modelling system (Guisan and Zimmermann, 2000; Hirzel and Guisan, 2002).

Traditionally, models used in ecology to predict potential species distributions were multivariate in nature and based on linear functions, however, they led to some statistical and theoretical concerns, and methods able to model non-linear relationships are now available (Ko et al., 2008). These models are better tools towards accurately predicting species distribution (Stockwell, 2007). As the number and complexity of these models evolve, difficulty over which one to choose represents an increasing challenge (Ko et al., 2008). Recently, several reviews, methodological comparisons and interpretations on the value, use and application of the different methods have been made (Austin, 2007). These pointed out that uncertainty still exists as to which model is the best to select under different spatial scales and/or species characteristics (Zaniewski et al., 2002).

Recent loss of estuarine habitat due to constant demands from a wide range of human activities in coastal areas has resulted in an increased attention by managers and researchers towards the importance of fish habitats. Concerns about severe habitat loss and degradation in estuaries have prompted managers to identify, prioritize and protect essential habitats for estuarine organisms (Bacheler et al., 2009; França et al., 2012). Habitat distribution models are among the available tools that allow the linking of species distribution to environmental conditions (Zuchetta et al., 2010). Such models use quantitative methods to infer species environmental requirements from conditions at known occurrences (Guisan and Zimmermann, 2000). Some authors have also developed habitat distribution models aimed at identifying fish nursery habitats; for example for flatfish, both in coastal waters and in estuaries or lagoons (Stoner et al., 2001; Manderson et al., 2002; Eastwood et al., 2003; Le Pape et al., 2003, 2007; Nicolas et al., 2007). As starting point, a basic understanding of habitat use by the species of interest is required for all of these techniques (Bacheler et al., 2009).

Estuaries along the Portuguese coast have been intensively studied in recent years, and different dimensions of their nursery role and habitat use for juveniles of several commercially important fish species evaluated (e.g. Cabral et al., 2007; Leitão et al., 2007; Pombo et al., 2007; Vasconcelos et al., 2010). Furthermore, the spatial patterns of habitat use by fish assemblages in these estuaries have shown that in addition to saltmarsh habitats, that generally supported elevated densities of fish, particular species were found to be associated with specific habitat types, highlighting the important role different habitats play in the functioning of these estuarine ecosystems (França et al., 2009).

The aim of the present study was to develop statistical models (generalized additive models) to predict variation in fish species richness as well as abundance in different estuarine habitats based on environmental features. The variation of these environmental variables within each system, and at different scales, as well as the robustness and reliability of the models were also evaluated.

## 2. Material and methods

### 2.1. Study area

Five estuarine systems along the Portuguese coast were considered in this study: Ria Aveiro, Tejo, Sado, Mira and Guadiana (Fig. 1). These systems differ considerably in terms of their geomorphologic and hydrologic characteristics (Table 1): Tejo and Sado present the largest areas with 320 $km^2$ and 180 $km^2$ respectively, and Mira is the smallest with 5 $km^2$. The Tejo estuary has considerably higher mean river flow values (300 $m^3\ s^{-1}$) as well as larger estuary mouth width (5.3 km) than the other estuaries. In addition, anthropogenic pressure index according to Vasconcelos et al. (2007) also varies, ranging from 0.14 to Mira estuary to 0.76 for the Tejo estuary, the most pressured system. Moreover, habitat complexity (score based on the structure and patchiness of the habitats present in the estuary and their areas, with higher scores attributed to estuaries with more complex habitat structures and larger areas of the different habitats) can be considered high in Ria de Aveiro (score 3), medium in Tejo and Sado (2) and low in Mira and Guadiana (score 1). Shallow areas predominate in all the estuarine systems as mean depths vary between 1 and 6 m (Table 1).

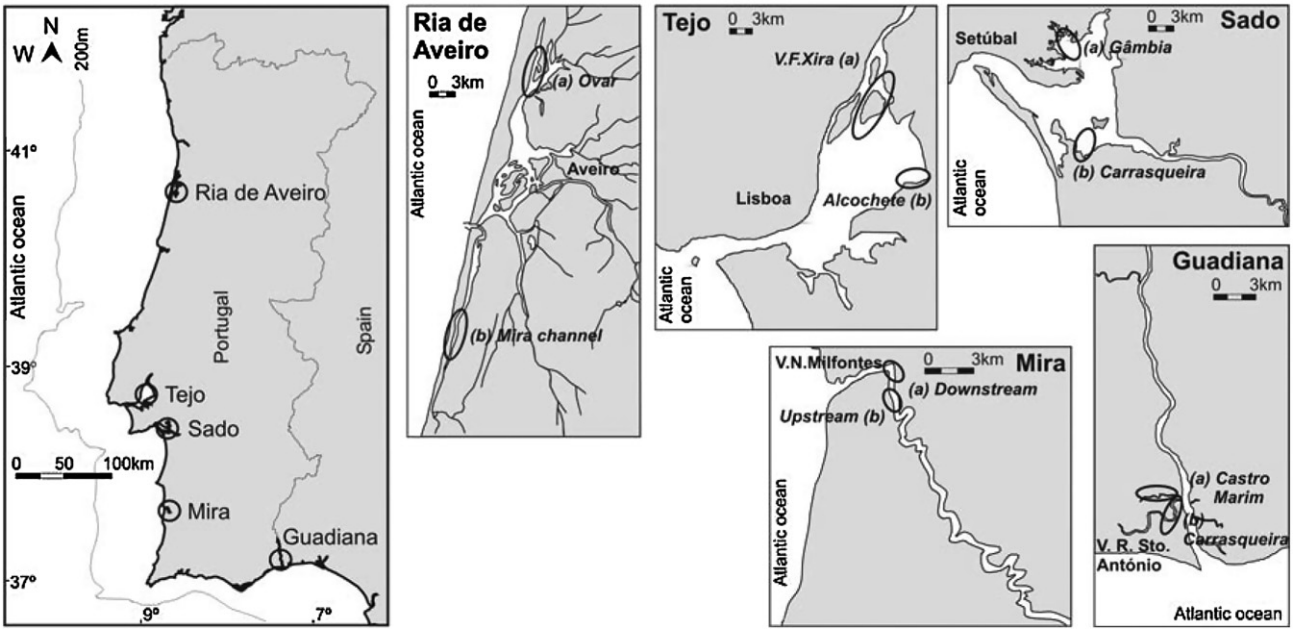


**Fig. 1.** Estuarine systems sampled in the Portuguese coast. Also shown is the location of sites within each estuary where the three habitats (saltmarsh, mudflat and subtidal) were sampled.