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Spring habitats of small pelagic fish communities in the Bay of Biscay

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ABSTRACT

Mapping habitats of species communities helps to inform on the ecological processes which drive their distribution. This information is critical to identify suitable areas for spatial management, aimed at preserving biodiversity, ecosystem functions or essential habitats. While demersal fish have been extensively studied at the community scale, small pelagic fish have mainly been characterised at the population scale. This paper presents a community-based approach on the biodiversity of small pelagic fish, with the aim to: (i) define small pelagic fish communities, (ii) characterise their spatial and interannual dynamics, and (iii) assess their habitats. We present a Multiple Factor Analysis (MFA)-based method that characterises the spatio-temporal variability in a series of multivariate maps. The main components of variability in these maps are identified to define "characteristic areas" displaying contrasting conditions in both MFA ordination and geographical spaces. Characteristic habitats of fish communities were defined by the correlation between the main components of variability from MFAs applied to maps containing fish information on one hand, and on hydrographic variables on the other hand. The analysis of the long term PELGAS survey series of fish biomass and hydrological indices maps resulted in the characterisation of mesoscale latitudinal gradients and coarse to mesoscale onshore-offshore gradients in both fish and hydrology datasets. A community with anchovy (*E. encrasicolus*) and chub mackerel (*S. colias*) as indicator species was consistently distributed in southeast Biscay. This area was associated with higher bottom temperatures, which likely affected the fish community through physiological processes. A second community with small clupeiforms as indicator species was found in coastal spawning habitats. These habitats were typically characterised by low salinity, a probable proxy for high productivity and good feeding grounds for those species. Mapping the habitats of small pelagic fish communities may inform marine spatial management, aimed at preserving biodiversity, ecosystem structure and function. In addition, it may help in achieving maximum sustainable yields of these commercially important species, and contribute to achieving and maintaining good environmental status of shelf seas ecosystems.

1. Introduction

Spatial heterogeneity and patterns arise from the interplay of processes occurring at multiple scales and are functional properties of ecosystems (Legendre, 1993; Levin, 2000). At the single species level, variability in spatial distribution results from variability in biotic and abiotic environmental conditions, and internal population behaviour (Petitgas et al., 2014). At the ecosystem level, biodiversity originates from the exploitation of heterogeneity in the environment, and through the evolutionary displacement of the way species utilize the environment (Levin, 2000).

Habitat can be defined as the environmental conditions that are favourable to an organism (e.g. for its presence, growth, Petitgas et al., 2014). In order to better understand the ecological processes driving the distribution of organisms, habitat maps have been extensively produced by modelling the spatial distribution of organisms as a function of environmental conditions using statistical regression techniques (Guisan and Zimmermann, 2000; Le Pape et al., 2014). These habitat suitability maps of individual species have been used to identify and select suitable areas in marine spatial planning initiatives, such as Marine Protected Areas (Le Pape et al., 2014).

However, the same area often contains multiple species and their different life stages. Few studies have explicitly investigated this biotic control on individual species distribution stemming from the interactions of multiple co-occurrent species (Georgescu et al., 2009). Moreover, with the advent of more holistic natural resources management approaches (e.g. Ecosystem Approach to Fisheries, Garcia et al., 2003; Ecosystem Integrated Assessment, Levin et al., 2009), the preservation of biodiversity, or of ecosystem processes such as productivity, as well as habitats used by multiple rare or economically important species, are

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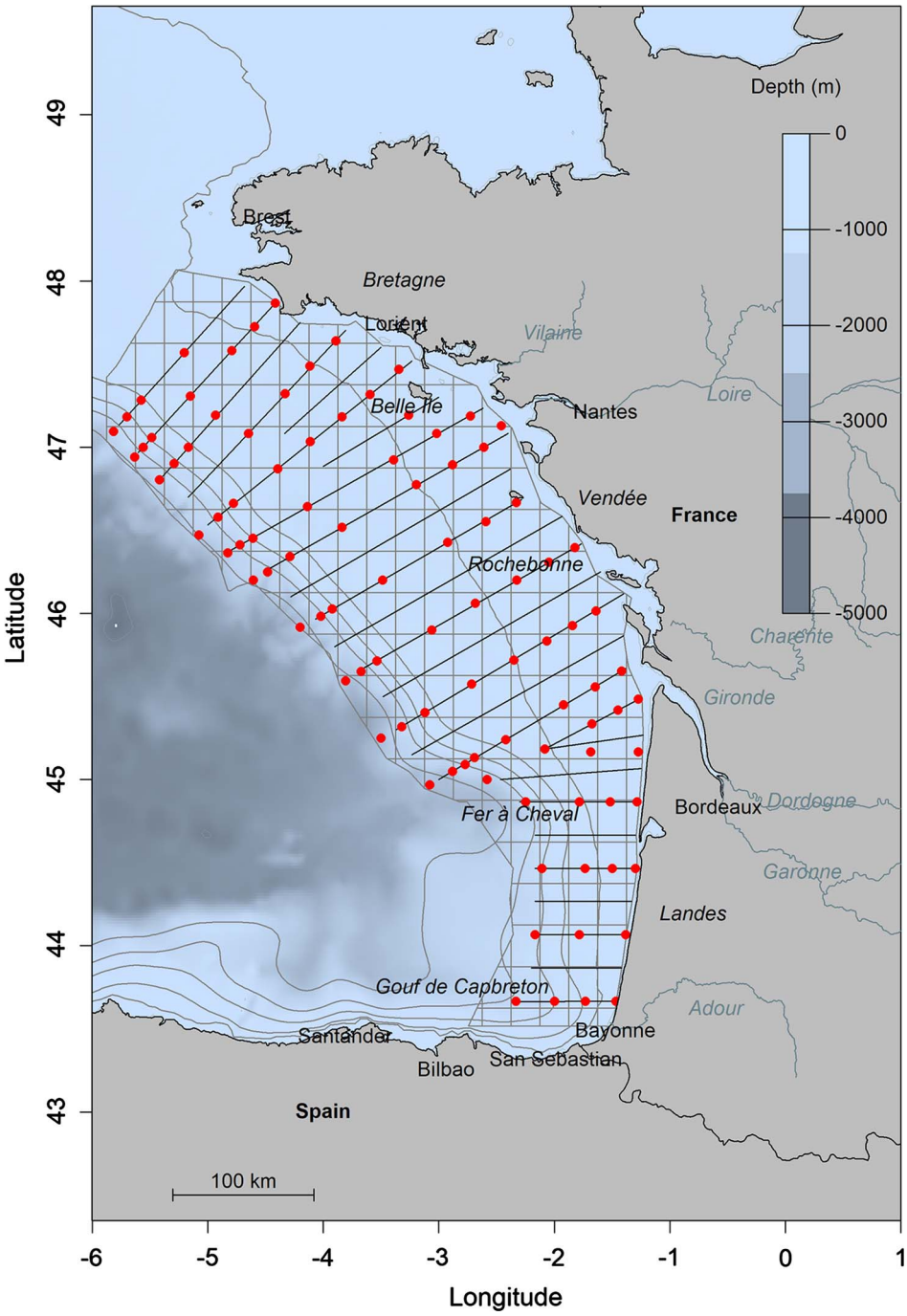

Fig. 1. PELGAS survey sampling scheme. Solid lines: systematic line transects, red dots: hydrobiology stations. Light grey grid: block averaging grid. Light grey lines: 100, 200, 300, 400, 500 m isobaths. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

now included in marine management objectives (Whaley et al., 2007). Community-based modelling approaches (reviewed in Legendre and Legendre, 2012) may in this case be preferred to modelling of many species separately (Whaley et al., 2007).

For decades, ecologists have used multivariate methods (Legendre and Legendre, 2012) to model the species abundances recorded at sampling sites as a function of environment parameters, and to get insights on eventual interactions between species consistently found at the same location (competition, predation, etc.) (Borcard et al., 1992; Legendre et al., 1997; Mueter and Norcross, 1999; Whaley et al., 2007; Georgescu et al., 2009). In marine ecology, long-term studies (> 10 y) have shown that demersal or benthic fish assemblages with consistent composition can be persistently observed in the same place over significant time periods (e.g. Gomes, 2001; Vaz et al., 2007). The analysis of the spatial and temporal dynamics of such demersal fish communities (sensu Fauth et al., 1996) has led to the definition of specific habitats, and provided important inputs for marine resource and human use spatial planning (Vaz et al., 2007).

Conversely, small pelagic fish spatial distributions have mainly been studied at the individual species level (e.g. Petitgas et al., 2014; Bertrand et al., 2016; Gastauer et al., 2016), or by comparing few dominant species, generally anchovy and sardine (e.g. Bertrand et al., 2004; Bonanno et al., 2014; Saraux et al., 2014). This is certainly due to the relatively lower number of small pelagic species in “wasp-waist” ecosystems (Cury et al., 2000), and to the classical dominance of a single species in upwelling areas (Fréon et al., 2005). Small pelagic fish are moreover more mobile and complete more frequent and larger migrations than demersal and benthic species, to cope with larger fluctuations of pelagic ecosystem hydrobiological conditions. The higher mobility rate of pelagic fish reduces the odds of observing