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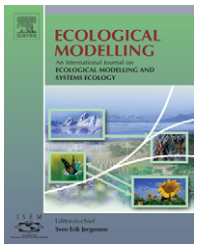

Predicting suitable habitat for the European lobster (*Homarus gammarus*), on the Basque continental shelf (Bay of Biscay), using Ecological-Niche Factor Analysis

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ABSTRACT

Predicting species distribution and habitat suitability (HS) modelling, across broad spatial scales, is now a major challenge in marine ecology. The resulting knowledge is of considerable use in supporting the implementation of environmental legislation, integrated coastal zone management and ecosystem-based fisheries management. This contribution considers the identification of seafloor morphological characteristics, together with wave energy conditions, that determine the presence of European lobster (*Homarus gammarus*); and it predicts suitable habitats over the Basque continental shelf (Bay of Biscay), in summer. The results obtained, by applying Ecological-Niche Factor Analysis (ENFA), indicate that lobster habitat differs considerably from the mean environmental condition over the study area; likewise, that it is restrictive in terms of the range of conditions in which they dwell. The best of the environmental predictors found to be: distance to the rock substrate; Benthic Position Index; wave flux over the seafloor; and the underlying bathymetry. A habitat suitability map was produced, with a high model quality (Boyce index: 0.98 ± 0.06). The most suitable habitat for European lobster are locations at the boundary between sedimentary- and rocky-bottoms, coincident with seafloor depressions with a steep slope, with medium to high wave energy conditions, and located within a range of water depths of 35–40 m. This approach demonstrates the applicability of the method in case studies where only presence data are available, together with the inclusion of environmental variables obtained from different sources.

1. Introduction

Natural resource management requirements (e.g., ecosystem-based approaches, marine protected areas, fishing, habitat identification), have led to the increasing use of species habitat modelling. Different statistical and mathematical techniques have been applied to develop predictive habitat distribution models (Guisan and Zimmermann, 2000). Amongst these, envelope-based approaches, such as Ecological-Niche Factor Analysis (ENFA), are considered particularly advantageous; this is because, with respect to more standard techniques, it does not require absence data. In ENFA, presence data is used instead, to compare with environmental conditions (Hirzel et al., 2002; Braunisch et al., 2008). ENFA has been applied more frequently to terrestrial habitat modelling (Estrada-Pena and Venzal, 2007; Vina et al., 2008), however, recently, it has been used also in the marine environment (Oviedo, 2007; Praca and Gannier, 2008; Skov et al., 2008).

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Habitat distribution models statistically link field observations, to a set of environmental variables or spatial predictors, reflecting some key characteristics of the niche (Guisan and Zimmermann, 2000; Hirzel and Guisan, 2002). Specifically, habitat suitability (HS) modelling has been used successfully in understanding species niche requirements and predicting potential species distribution, e.g., it has been applied to the spiny lobster (*Panulirus argus*), using satellite data in shallow water (Bello et al., 2005), to gorgonian corals in deep-water (Bryan and Metaxas, 2007), to squat lobster distribution in deep-water (Wilson et al., 2007), mapping macrobenthic communities (Degraer et al., 2008), and predictive mapping of fish species richness (Pittman et al., 2007). The application of such methods to marine species, linked closely to the benthic environment, requires reliable information on seabed characteristics. Multibeam echosounders (MBES) are becoming a standard tool for seafloor mapping, due to their ability to provide high-resolution data sets and extensive coverage; they are especially valuable for benthic habitat mapping and shellfish resource studies (Edwards et al., 2003; Kostylev et al., 2003; Orpin and Kostylev, 2006; Ryan et al., 2007).

In the particular case of shellfish, the American lobster (*Homarus americanus*) fishery is well known, on the basis of several studies (Incze et al., 2000; Rowe, 2002; Smith and Tremblay, 2003; Wahle, 2003). Conversely, for the European lobster (*Homarus gammarus*), most of the present knowledge has been derived from aquaculture studies (Van der Meeren, 2005). Fishery studies have been undertaken only in northern countries, such as the United Kingdom (Bannister and Howard, 1991; Smith et al., 2001; Lizarraga-Cubedo et al., 2003), Ireland (Browne et al., 2001; Tully et al., 2001) or Norway (Tveite, 1979; Agnalt et al., 2007).

In the Basque Country, a marine habitat mapping programme started in 2004 (Galparsoro et al., 2008), where one of the objectives was to determine habitat suitability for some key species, including the economically important *H. gammarus*. Although along the Basque coast this fishery is limited, in terms of number of fishing vessels or catches, its socio-economic importance in some ports is very high (Arregi et al., 2004). However, there is a lack of information on the *H. gammarus* fishery and on the official registration of catches (Borja, 1987), leading to an underestimate of the population size (Puente, 2002). This lack of information makes it difficult to understand the stock and its management to maintain a sustainable fishery.

The objectives of the present contribution are (i) to define the main seafloor features and wave energy conditions that determine the presence of *H. gammarus* and (ii) to predict habitat suitability for the lobster, using ENFA.

2. Materials and methods

2.1. Study area and lobster sampling

The study area is located in the inner continental shelf of the Basque Country, in the southeastern part of the Bay of Biscay (Fig. 1). The main lobster fishing ports within the area are those of San Sebastian and Pasaia.

H. gammarus is distributed along the eastern Atlantic, from Lofoten Islands (Norway) in the North Atlantic, to Morocco and the Black Sea in the Mediterranean (Holthuis, 1991). The lobster is territorial, with nocturnal activity (Smith et al., 1998); it feeds on a range of benthic invertebrates (Smith et al., 2001), mainly crustaceans and bivalve molluscs. The lobster appears usually in the infralittoral and the circalittoral (20–60 m water depth), over seabeds incorporating rock blocks and sandy galleries (Templado et al., 2004). Cooper and Uzmann (1980) have described how lobsters tend to excavate holes or tunnels with one or more exits below rocks, with there being a relationship between hole size and the size of the individual. Moreover, Howard (1980) has established a significant relationship between the size of individuals and substrate type.

Lobster sampling surveys were undertaken between 7 June and 10 August 2007, with a professional lobster fishing boat. The survey was carried out during the permitted period for fishing, in summer. A total of 17 lobster pot lines were laid, near the ports of San Sebastian and Pasaia (Fig. 1). Each line was 650 m long, including 60 pots. The initial, middle (or bearing change) and final positions of the lines were recorded, using GPS. In all cases, the pots were located at the limit between a rock bed and the presence of sand patches, based upon the experience of the fishermen. Pots were deployed in the afternoon and recovered in the morning, taking advantage of the night activity of the lobsters. For each line, the number of lobsters, their sex and morphometric measurements (carapace length and width) were recorded (Bald et al., 2008).

2.2. Multibeam echosounder data

Ship-borne MBES data were acquired, as part of the continental shelf characterisation and habitat mapping programme survey, between 2005 and 2006. Bathymetric and seafloor backscatter information were acquired, using high-resolution SeaBat 7125 and SeaBat 8125 MBES. Both sets of equipment had similar characteristics (RESON, 2002, 2006).

Most of the work was carried out using the SeaBat 7125 model; its operational frequency is 400 kHz, producing 256 beams in a 128° angle swath and using up to 50 swaths per second. The beam width is 0.5° along-track and 1° across-track, producing very small footprints; these, in turn, result in high horizontal resolution digital elevation models (DEM). The MBES was coupled with an Agp132 (TRIMBLE) global position system, receiving differential corrections. An OCTANS III (IXSEA) gyrocompass and motion sensor was utilised, to compensate for the movement of the vessel. Furthermore, a portable SVP 15 (RESON) was used, to measure sound velocity profiles throughout the entire water column (Ernstsen et al., 2006). The software package PDS2000 was used to integrate the MBES data, with the information from all the auxiliary sensors during the surveys—data acquisition and synchronization. This software was used in real-time, as well as in the post-processing of the integrated data. Tidal correction was applied using the nearest tide gauge and 1 m resolution seafloor DEM was produced in projected coordinate UTM, Zone 30 N (WGS84). The DEM was generalised into a 5 m grid, in order to increase the speed of computational processing; finally, it was exported into ESRI grid format and integrated into a Geographic Information System (ArcGIS; ESRI). The