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Geomorphological, trophic and human influences on the bamboo coral *Isidella elongata* assemblages in the deep Mediterranean: To what extent does Isidella form habitat for fish and invertebrates?

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ABSTRACT

We analyzed what are the best ecological conditions for megafauna associated with the bamboo coral *Isidella elongata* based on the geomorphological, physical and trophic information taken in 3 stations (St1, St2, St3) off the southern Catalonian coasts at 620 m depth in June 2011. Results were compared with assemblage compositions recorded in past cruises (May 1992, 1994) at the same 3 stations. St1 was in a fishing ground exploited since the 1940s over a relatively wide slope at ca. 22 km from the nearest canyon head; St2 and St3 were on a narrower slope closer to canyon heads and to the Ebro river mouth than St1. *I. elongata* had formed (to May 1994, at least) a dense coral *forest* at St2–St3 (to ca. 255 colonies/ha at St3), and some isolated colonies (to ca. 0.9 colonies/ha) were still collected in 2011. Fish and invertebrate communities significantly differed between St1 and St2/St3, with two macrourid fishes (*Trachrhynchus trachyrhynchus* and *Nezumia aequalis*) and two decapods (*Plesionika martia* and *Plesionika acanthonotus*) more abundant at St2/St3. The following ecological indicators imply better food conditions for megafauna at St2–St3 and for *I. elongata* itself: (i) greater density of zooplankton (copepods, euphausiids, and others) as potential prey for planktivores (including *I. elongata*); (ii) greater biomass and mean weight of epifaunal and infaunal deposit feeders; (iii) higher feeding intensity, *F*, at St3 for benthos feeders (*Phycis blennoides*, *N. aequalis* and *Aristeus antennatus*). Also, at St2–St3 we found higher near-bottom turbidity (indicating particle resuspension: food for suspension feeders) and finer and more reduced (E_h) sediments. The results let us suggest that corals and accompanying fauna preferently found optimal ecological conditions in the same habitat, while habitat-forming capacity by *I. elongata* seemed weak to generate these conditions. Coral *forests* may enhance detritus accumulations around them, improving habitat conditions for benthos feeders (e.g. macrourid fish). At St3 our *side-scan sonar* recorded three types of tracks produced by trawler doors, which match with three identified vessels occasionally operating in the area. After this low fishing activity off the Ebro Delta since the mid-1990s, almost all colonies of *I. elongata* has been removed. However, this impact has hardly altered fish and invertebrate composition without any significant loss of diversity, pointing also toward a rather low capacity of *I. elongata* facies in forming habitat for megafauna on muddy bottoms of the Mediterranean slope.

1. Introduction

One of the most important factors generating heterogeneity in the seafloor landscape over muddy bottoms of continental margins is the occurrence of fields (or meadows) of sessile colonial organisms such as cnidarians, Hexactinellid sponges and deep-water gorgonian corals. Within a relatively homogeneous environment such as the deep sea, gorgonian fields are important because they may increase habitat complexity, enhance marine community diversity at meso-spatial scales and increase ecological niche dimensions (Gage and Tyler, 1991).

Bamboo corals (Fam. Isididae) are gorgoniaceans distributed worldwide in deep waters (mainly between 200 and 1500 m depth, but also to abyssal depths, Etnoyer and Morgan, 2005; Maynou and Cartes, 2012) with 138 known species. Most species form single-species fields on soft-bottom sediments. As colonial corals have a ramified tree form, the association of colonies more or less spaced over the seafloor is known under different names deriving from terrestrial landscapes (*meadows*, *fields*, even *forests*: e.g. Krieger and Wing, 2002, Etnoyer and Morgan, 2005).

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Some species have colonies reaching to 3 m height (Krieger and Wind, 2002) that are long lived (Andrews et al., 2002). Ages based on^{14}C data suggest longevities for isidids from the Gulf of Alaska of 75–126 years (Roark et al., 2005) and radial growth rates of ~110 μm/yr for *Isidella* sp. off Tasmania. Ages and growth rates vary widely among genera, even those inhabiting the same depth and area (Sherwood et al., 2009). In comparison to deep-water corals in the subclasses Hexacorallia, gorgoniaceans are poorly known, especially in their ability to form essential habitat for other organisms (Fosså et al., 2002; Krieger and Wind, 2002; Etnoyer and Morgan, 2005; Metaxas and Davis, 2005), their influence on trophic relationships and their role as refuge areas for large fauna (fish, decapod crustaceans: Krieger and Wing, 2002). Indications of higher abundance and larger size of some commercial fish in *Lophelia pertusa* reefs compared with surrounding areas may be related with higher food availability in the reefs (Husebø et al., 2002), and this possible role for *Isidella elongata* in the western Mediterranean has been discussed recently (Maynou and Cartes, 2012; Cartes et al., 2009a).

Little has been published about communities associated with *I. elongata* facies since the basic distribution, depth and slope preferences of this soft coral were established (Dieuzeide, 1960; Pérès, 1985). One of the few exceptions is the recent compilation by Maynou and Cartes (2012) of all information originated by trawl surveys in the Balearic Basin in the last three decades. *Isidella elongata* (with colonies to 70 cm height) is almost exclusively restricted to the Mediterranean Sea, but extending by transport of larvae in the westward outflow to the adjacent Gulf of Cadiz and North Morocco (Grasshoff, 1988; 1989). It inhabits compact slope muds between 500 and 1200 m depth on slopes not exceeding a 5% gradient (Pérès, 1967; Bellan-Santini, 1985; Oceana, 2011). Other and special adaptations are known for bamboo corals; for example, they can reach high densities in oxygen minimum zones throughout the deep Northeast Pacific (Baco, 2007). Some fish and decapod crustaceans reach maximum densities in bottoms inhabited by *I. elongata*, which is the case of the deep-water shrimps *A. antennatus* and *P. martia*, both of high commercial interest (Maynou and Cartes, 2012). However, as depth is the main factor affecting the distribution and density of marine species (Gage and Tyler, 1991; Cartes et al., 2009a), it is unknown whether these species are really associated with the habitat that *Isidella* may generate or they share a preference for a common bathymetric range with concrete physical and trophic characteristics. Analyses of assemblages associated with *I. elongata* incorporating simultaneous environmental data have never been performed.

In addition to natural variability, human impacts altered not only shelf (Watling, 2005) but also deep-sea ecosystems, e.g. in the NE Atlantic in the last 20 yrs (Hall-Spencer et al., 2007). The most evident human effect on *Isidella* fields has been from trawling activity (Maynou and Cartes, 2012), though likely that was not the only impact. Some authors (Pérès, 1985) have suggested indirect effects on soft-bottom communities from the historic deforestation done in Mediterranean countries with consequent increases in sediment runoff by rivers. This may in turn increase turbidity close to the bottom in *Isidella* habitats, enhancing clogging in polyps and altering their function as active filter feeders (Rogers, 1999). This is feasible in the case of *I. elongata*, considering that isidid polyps are non-retractile. In any case, trawling activity removes colonies of this rigid gorgonian, cutting the calcareous bases of the colony near the sea floor. The stumps can remain in the mud for a long time (Maynou and Cartes, 2012). In addition, the effects that bottom-trawling (e.g. tracks of doors trawlers) has on soft-bottoms, the biological diversity and production, are well known, although information is almost restricted to highly impacted areas of the continental shelf (Jennings et al., 2001; Gray et al., 2006). The occurrence and persistence of tracks and their biological effects on deep-sea ecosystems is almost unknown (but see for hard-cold *L. pertusa* reefs: Fosså et al., 2002; Mortensen et al., 2008).

In addition to an initial study by Maynou and Cartes (2012), we report here a mesoscale study on three slope stations, analyzing possible geomorphological, physical and trophic differences among them in order to define the optimal habitat characteristics of *I. elongata* and slope communities associated with this gorgonian. In 1994, we found pristine *forests* of *I. elongata* off Catalonian coasts near the Ebro River (north-western Mediterranean), where trawling activity began 2 years later. This gave us the opportunity to compare the current state of *I. elongata* communities through the design of the experimental survey ANTROMARE0611. The objectives of this study are: (i) to characterize and compare fish and invertebrate assemblages co-existing with different *I. elongata* fields; (ii) to analyse the effect of bottom-trawling on the diversity and composition of these communities; and (iii) to investigate physical environmental factors (geomorphological, geophysical and climatic) that may explain mesoscale spatial variability of *I. elongata* communities.

2. Methods

2.1. Study area

The study area corresponds to the upper slope (300–1000 m depth) of the continental margin, off the Ebro delta (Fig. 1). The area alternates between smooth open slope regions, 2°–4° gradient, and steep areas associated with steep tributary canyons 1 km wide on average, converging to the Valencia Channel (Figs. 1 and 2). Three stations, from N to S, St1 (40°54N–1°35 E), St2 (40°41N–01°26 E) and St3 (40°34N–01°26E) were sampled over the slope of S Catalonian coasts between the Cape of Salou and the Ebro River Delta (Fig. 1) at depths between 615 and 648 m. Samples were collected on board the R/V *Sarmiento de Gamboa* during the cruise ANTR0611 (18–25 June 2011, project ANTROMARE, CTM2009-12214-C02-01). St2 and St3 were located at depths inhabited by the *facies* of the gorgoniacean *I. elongata* (as recorded in the cruise GeoDelta1 in May 1994) while St1 was in front of the port of Tarragona, an area historically (since the 1940s) submitted to substantial trawling in search of the red shrimp *A. antennatus*.

2.2. Geomorphological data

Geomorphological information was recorded using the deep-sea multibeam echosounder Atlas Hydrosweep DS, emitting 184 beams at a frequency of 14.5–16 kHz, the deep-towed large-scale Sidescan Sonar system Edge-Tech 2400-DSS/DT-1, emitting a frequency of 120 kHz and covering 1 km^2 areas, and dotted with 400 kHz sub-bottom profiles (only at S3). Post-processing of multibeam data was performed with the CARIS-HIPS software system. After correcting the soundings for water column sound velocity variations and cleaning them with a ping graphical editor, gridding of the filtered data was carried out to obtain the final digital terrain model. Footprint resolution was 20 m for the insonified areas. Side Scan Sonar (SSS) records were visualized and compiled into a high-resolution mosaic image (1 m) using SonarWiz software from Cheasepeake Technology. Side Scan Sonar (SSS) hauls (on St3) were performed previously to trawling in that area.

2.3. Fauna data

The biomass and structure of megafauna (fish, decapod crustaceans, and epibenthic invertebrates) assemblages and of infauna/zooplankton were analysed among stations. Megafauna was