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Distribution and habitat association of benthic fish on the Condor seamount (NE Atlantic, Azores) from *in situ* observations

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ABSTRACT

Distribution of fish assemblages and habitat associations of demersal fishes on the Condor seamount were investigated by analyzing *in situ* video imagery acquired by the Remotely-Operated Vehicles *ROV SP 300* and *Luso 6000*. A total of 51 fish *taxa* from 32 families were inventoried. Zooplanktivores (10 species) were the most abundant group followed by carnivores (23 species) and benthivores (18 species). Non-metric multidimensional scaling (MDS) analyses were performed on dive segments to visualize the spatial relationships between species and habitat type, substrate type or depth, with depth being the most significant parameter influencing fish distribution. Four major fish groups were identified from their vertical distribution alone: summit species (generally to <300 m depth); broad ranging species (ca. from 200 to 800 m); intermediate ranging slope species (ca. from 400 m to 800–850 m); and deeper species (800–850–1100 m). The fish fauna observed at the summit is more abundant (15.2 fish/100 m^2) and habitat-specialized than the fish observed along the seamount slope. Down the seamount slope, the summit fish assemblage is gradually replaced as depth increases, with an overall reduction in abundance. On the summit, three species (*Callanthias ruber*, *Anthias anthias* and *Lappanella fasciata*) had higher affinity to coral habitats compared to non-coral habitats. A coherent specialized fish assemblage associated to coral habitats could not be identified, because most species were observed also in non-coral areas. On the seamount's slope (300–1100 m), no relationship between fish and coral habitats could be identified, although these might occur at larger scales. This study shows that *in situ* video imagery complements traditional fishing surveys, by providing information on unknown or rarely seen species, being fundamental for the development of more comprehensive ecosystem-based management towards a sustainable use of the marine environment.

1. Introduction

Benthic habitats are physically distinct areas of seabed associated with the occurrence of particular species (see Harris and Baker, 2012). Understanding how fish associate with habitats is a central issue for an ecosystem-based approach to marine spatial planning (Agardy, 1997; Botsford et al., 1997; Schmiing et al., 2013).

The habitats formed by sessile emergent fauna are more structured and ecologically complex, harboring higher biological diversity and abundance, when compared to uniform and monotonous sedimentary environments (*e.g.* Buhl-Mortensen et al., 2010; Freiwald et al., 2004). Cold-water corals (CWCs) and sponges are "habitat engineering" sessile organisms occurring on continental and insular shelves and slopes, ridges and seamounts across most oceanic regions of the world (Roberts et al., 2006). In areas where environmental conditions are favorable, they aggregate densely and form three-dimensional habitats known as deep-sea coral reefs (Freiwald et al., 2004) and gardens (Bullimore et al., 2013; OSPAR, 2010) and sponge aggregations (Cook et al., 2008). These habitats may function as nursery, recruitment, feeding and/or shelter grounds for invertebrates and fishes, but actual evidence remains weak (*e.g.* Baillon et al., 2012; Buhl-Mortensen et al., 2010; Costello et al., 2005; Richer de Forges et al., 2000; Fosså et al., 2002). In oceanic regions, seamounts offer favorable conditions for corals and sponges and for an assortment of fishes (Rogers et al., 2007). Fishes typically considered to be associated with seamounts are schooling benthopelagic predators, like orange roughy and alfonsinos (Koslow, 1996; Morato et al., 2006), but seamounts also

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harbor many other bottom fish species not included in that ecological guild (*e.g.* Koslow et al., 2000; Fock et al., 2002a; Parin et al., 1997; Uiblein et al., 1999).

Bottom or near-bottom living-fish on seamounts are mainly known from surveys using fishing gears such as longlines and bottom trawls (*e.g.* Christiansen et al., 2009; Koslow et al., 2000; Kukuev, 2004; Menezes et al., 2012; Parin et al., 1997; Uiblein et al., 1999), which provide limited insights on small-scale fish behavior and habitat associations (Costello et al., 2005; Ross and Quattrini, 2007). Clearly, with each fishing method catching a particular type of fish species, the selectivity can be better tackled by using *in situ* imagery (*e.g.* Felley and Vecchione, 1995; Lundsten et al., 2009; Uiblein et al., 2003).

Over the last decade, image-based studies on deep-sea ecosystems have increasingly addressed fish-habitat associations, mainly in areas dominated by CWCs. The importance of gorgonians, black corals and other megafauna aggregations as fish habitats were investigated in the Northeast Pacific, from the Bering Sea to California (Krieger and Wing, 2002; Miller et al., 2012; Stone, 2006; Tissot et al., 2006), Hawaii (Parrish, 2006) and Northwest Atlantic (Auster, 2005; Baker et al., 2012). Most of the observations ranged from 27 m in Aleutian Islands to 533 m in the Bering Sea, but in the Newfoundland canyons and the New England seamounts investigations extended down to lower bathyal bottoms (*i.e.* 351–2245 m and 1100–2500 m, respectively). The importance of *Lophelia pertusa* reefs as habitat for fishes was investigated in the boreal Northeast Atlantic (Biber et al., 2013; Costello et al., 2005; Husebø et al., 2002; Mortensen et al., 1995; Söffker et al., 2011), Mediterranean Sea (D'Onghia et al., 2010, 2011) and subtropical Northwest Atlantic (Quattrini et al., 2012; Reed et al., 2006; Ross and Quattrini, 2007, 2009). In the Gulf of Mexico, Sulak et al. (2007) investigated both habitats.

The results obtained by these studies are somewhat inconsistent since only Ross and Quattrini (2007, 2009) and Quattrini et al. (2012) described a specialized fish community associated to CWC reefs. The remaining studies generally found that fish abundance and diversity were higher in coral habitats, but not different from other 3-D bottom structures. Moreover, these studies could hard-substrate and Lophelia not identify any specific fish species or assemblage strictly associated to coral habitats. As a result, it is still debatable whether CWCs are obligatory (or essential) fish habitats since the nature and the ecological meaning of these associations for the population is yet poorly understood (*e.g.*, Auster et al., 2005; Auster, 2007).

The Azores region comprises more than 460 seamounts that typify the complex geomorphology of the area (Morato et al., 2013). Most are small and deep but some are large and may rise from abyssal and bathyal depths into the epipelagic layer. Due to their geomorphologic and hydrographic settings they represent optimal habitat for filter/suspension feeders such as corals and sponges (Rogers et al., 2007). Indeed, more than 20 distinct coral biotopes and 8 sponge aggregations have so far been recognized across the Azorean seamounts and island slopes (Tempera et al., 2012a) and the region harbors a considerable high diversity of CWCs (Braga-Henriques et al., 2013) and sponges (Van Soest et al., 2012). Therefore, it is expected that coral gardens and sponge aggregations habitats are widespread over seamount and islands slopes.

Since the oceanographic expeditions in the late 19th century, the Azorean fish fauna has been regularly studied (see Santos et al., 1995, 1997). Its predatory demersal component living in the seamounts is the best known, mainly because those species are targeted by the bottom longline commercial fishery operated from the islands (Menezes et al., 2006, 2012; Menezes and Giacomello, 2013; Silva and Pinho, 2007). Bottom trawling has never been introduced as a commercial fishing technique in the region and since 2005 a formal ban has been established by a European Regulation with the aim to protect vulnerable bottom habitats, namely corals gardens and reefs (Probert et al., 2007). However, in 2000 an exploratory trawl survey directed at orange-roughy (*Hoplostethus atlanticus*) showed the limitations and bias of our knowledge on seamount-associated fishes. Apart from the unsuspected large reproductive aggregations of orange-roughy at the top of some deep seamounts (> 800 m), fifteen fish species were recorded that were previously unknown from the region (Menezes et al., 2009, 2012; Melo and Menezes, 2002).

Despite the existing knowledge on Azorean fish fauna, small-scale interactions between deep-sea fish and their benthic habitat have been virtually ignored, due to the scarcity of *in situ* visual studies. The Azores were visited by several international expeditions using underwater imagery since the advent of scientific submersibles (Tempera et al., 2012a). During the last decades, most of those have been concentrated on the Azores hydrothermal fields (*e.g.* Cuvelier et al., 2009; Desbruyères et al., 2001), supporting some *in situ* studies of the occurrence and behavior of fishes associated with those ecosystems (*i.e.* Biscoito et al., 2002; Saldanha, 1994). Only recently have the island and seamount slopes started to be more thoroughly explored using optical platforms but published literature concentrated on describing benthic invertebrate communities (*e.g.* Braga-Henriques et al., 2012; Wisshak et al., 2009), the presence of anthropogenic litter (Pham et al., 2013) or habitat mapping (Tempera et al., 2012a,b).

The present work provides the first detailed description of the composition, vertical distribution and habitat associations of the demersal fish communities found on a mid-Atlantic seamount between 200 and 1100 m depth, as observed by Remotely-Operated Vehicles (ROVs). It aims to contribute to an integrated understanding of the ecology and dynamics of Condor seamount, which was selected as a case study area for multidisciplinary scientific programs and projects (Giacomello et al., 2013).

2. Materials and methods

2.1. Study area

The Condor is a shallow seamount located 17 km southwest of Faial Island, in the Azores archipelago. This ridge volcano is 39 km long and 23 km wide, with sloping flanks extending to over 1800 m depth from a narrow flattened summit developing between 180 m and 250 m (Fig. 1; Tempera et al., 2012b; Tempera et al., 2013). From the 1980s until 2010, when the seamount was closed to fisheries (Giacomello et al., 2013), commercial longline fishing exploited these grounds for demersal fish (Menezes and Giacomello 2013). The benthos is characterized by dense patches of coral gardens on the summit and predominantly sediment covered slopes with discontinuous patches of coral and sponge dominated habitats (Tempera et al., 2012b).

2.2. Survey design

ROVs were used to visually assess fish occurrence, distribution and habitat association patterns on the seamount. A total of 19 dives were executed, covering 23,800 m^2 of seafloor and providing over 22 h of bottom imagery (Figs. 1 and 2; Table 1). The northern slope of Condor seamount was surveyed by the working class ROV *Luso* (Bathysaurus XL), operated from R/V *Almirante Gago Coutinho* in 2010. Four dives were performed, totaling 5802 m length of bottom transects surveyed corresponding to 20 h 10 min of imagery, between 210 and 1097 m depth. The seamount summit was surveyed in 2010 and 2011 by 15 short dives with the 300 m rated ROV *SP* operated from the R/V *Águas Vivas*, totaling 2 h 52 min of bottom imagery over a distance of 3613 m, between 210 and 259 m depth.