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Small-scale patterns of deep-sea fish distributions and assemblages of the Grand Banks, Newfoundland continental slope

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ABSTRACT

Deep-sea fishes are the target of directed fisheries and are considered a conservation concern. Yet, we still know little about the factors that affect deep-sea fish distributions and assemblage patterns on relatively small spatial scales. We used results from remotely operated vehicle surveys that observed 105 km (~346 960 m^2) of seafloor over a depth range of 351–2245 m in three canyons off Newfoundland to examine the occurrence, behavior, habitat specificity, and regional assemblage patterns of deep-sea fishes in this region. We found distinct assemblages based on both depth and habitat classifications. The most obvious unique assemblage was that associated with outcrops, which served as habitat for relatively rare species such as *Neocyttus helgae*, *Hoplostethus atlanticus*, and *Lepidion eques*. Several coral habitats hosted distinct assemblages when compared to other habitats with low or medium structural complexity. Our results illustrate that any program targeted at protecting deep-sea ecosystems must protect a wide-range of habitats and depths to conserve a variety of fish species and assemblages.

1. Introduction

In general, we know little about the biology of deep-sea fishes (Bailey et al., 2009; Baker et al., 2009), and even less about their community dynamics, the factors that influence small-scale distributions, and the functional role of deep-sea fish habitats. Ecologists widely accept the importance of shallow-water corals as habitat for fishes, but debate parallel functions for deep-water corals. The role and importance of deep-water corals as habitat for fishes remain unclear (Buhl-Mortensen et al., 2010; Roberts et al., 2009). Some studies suggest that deep-water corals provide refuge (Costello et al., 2005; Krieger and Wing, 2002), enhance prey capture (Costello et al., 2005; Husebo et al., 2002), and serve as nursery or spawning grounds (Costello et al., 2005; Koenig et al., 2005) for deep-sea fishes. In the latter case, supporting evidence includes records of swollen, gravid *Sebastes* spp. on *Lophelia* reefs (Costello et al., 2005; Fossa et al., 2002; Husebo et al., 2002) and ray egg cases on reefs (Costello et al., 2005). In general, corals are thought to create structure in an environment where structurally complex habitats are often scarce (Buhl-Mortensen et al., 2010).

Higher abundances of several fishes have been recorded in areas with coldwater corals compared to areas without corals. Costello et al. (2005) found greater fish species richness and abundance in *Lophelia*-associated habitats than in surrounding areas and argued that reefs may play an important functional role as fish habitat in deep-water ecosystems. Higher catches and larger individuals of redfish (*Sebastes marinus*), ling (*Molva molva*), and cusk (*Brosme brosme*) inside *Lophelia* reefs off Norway compared to those outside (Husebo et al., 2002) further support this hypothesis. Off Alaska, 85% of the economically important fish were associated with corals or other emergent fauna (Stone, 2006) and off Ireland, *Guttigadus latifrons* was only observed in areas with live corals (Soffker et al., 2011).

Some research suggests that fish only use deep-coral and sponge habitats opportunistically (Auster, 2005; Tissot et al., 2006). Auster (2005) argued that high local densities of fishes do not mean that corals enhance fish populations. Dense corals and epifauna hosted equivalent fish communities in the Gulf of Maine compared to less complex habitats. These results indicate that coral habitats may not be functionally unique and provide similar levels of shelter and prey compared to other complex habitats (such as boulder fields) (Auster, 2005). Another study

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further hypothesized that the physical structure of reefs attracted redfish, and not the coral itself (Husebo et al., 2002). This perspective was defended using observations of redfish associated with shipwrecks, or found hiding in the vicinity of large boulders or sponges (Husebo et al., 2002). Tissot et al. (2006) found six species of fishes more abundant adjacent to coral colonies than predicted, but concluded that corals and fishes simply co-occurred in the same habitats.

One of the only quantitative studies that showed convincing evidence of obligate relationships examined fish assemblages in deep-reef habitats off the southern United States (Ross and Quattrini, 2007). These researchers found distinct fish assemblages in prime reef and transition reef habitats compared to off-reef habitats (Ross and Quattrini, 2007), suggesting that deep reefs host unique fish communities.

Until recently, trawl survey data were the only means to study fish-coral relationships off Newfoundland. Edinger et al. (2007) found highest species richness of fishes in fishing sets that contained small gorgonian corals, but found no strong relationships between corals and abundances of the 10 groundfish species examined. Nonetheless, trawls are not ideal for studying such patterns at small scales because they sample large areas of the seafloor in a region with relatively small, patchy coral distributions (KD Baker, unpublished data).

The vulnerability of deep-sea fishes to overexploitation has been demonstrated by the boom-and-bust of many deep-sea fisheries (Koslow et al., 2000), dramatic population declines of fishes over relatively short time scales (Devine et al., 2006), the indiscriminate impact of fisheries on non-target species (Bailey et al., 2009), and the potential for lengthy recovery times (Baker et al., 2009). The idea that corals may influence fish distributions underscores the urgency of understanding these relationships. As destruction and threats to deep-sea corals continue to mount (Fossa et al., 2002; Hall-Spencer et al., 2002; Turley et al., 2007), availability of aggregating sites, survival probability, and population resilience of deep-sea fishes could be in precipitous decline.

We present the results from an *in situ* camera-based survey of deep-sea fishes conducted through a variety of coral and non-coral habitats on the Newfoundland continental slope. Specifically, we examine patterns in fish assemblages in relation to both depth and habitat classifications, and discuss the conservation implications of these findings. We also describe fish occurrence, behavior, and reaction to the ROV, and examine habitat specificity in relation to the complexity of habitats.

2. Materials and methods

2.1. Survey design

We used the remotely operated vehicle (ROV) ROPOS (Remotely Operated Platform for Ocean Science) (CSSF, 2010) to examine the fauna of three submarine canyons on the slope of the Grand Banks south of Newfoundland: Halibut Channel, Haddock Channel, and Desbarres Canyon (Fig. 1). A small bank separates Halibut Channel and Haddock Channel, which are situated approximately 110 km and 175 km east of Laurentian Channel, respectively, and approximately 150 km and 200 km northwest of Desbarres Canyon, respectively. The temperature regimes in the three canyons were similar, averaging $\sim$5.0 °C during relatively shallow dives ($<$1100 m) and $\sim$4.4 °C during relatively deep dives ($>$1100 m). ROPOS performed video surveys from *CCGS Hudson* in July 2007, and was equipped with lasers placed 10 cm apart to indicate scale. Depth, temperature (during most dives), date, time, altitude, and position were logged at 1-second intervals.

We planned 1-km transects along depth contours every 200 m between 2200 and 600 m and along contours every 100 m in waters shallower than 500 m. We standardized transects by keeping the ROV as close to the bottom as possible ($<$1 m), maintaining a constant slow speed (approx. 0.2–0.5 m s^{-1}) while tilting the color camera down slightly on a wide-angle view in order to image the seafloor and water column directly above. Whenever possible, the camera was angled so the 'horizon' was in the center of view and the farthest field of view was approximately 5 m and 6 m wide (estimated using lasers). The camera

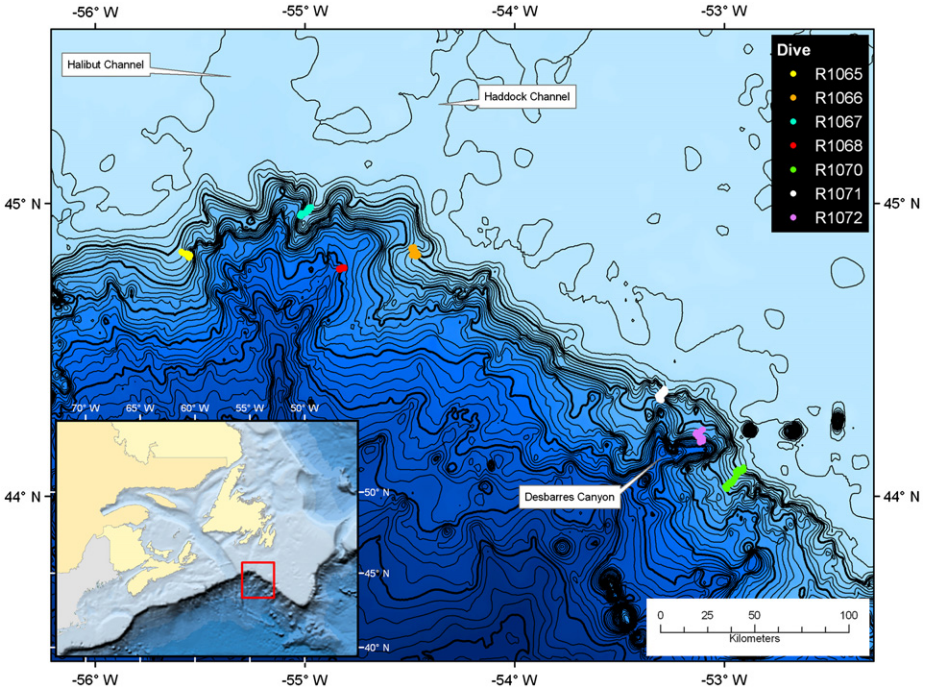

Fig. 1. Map indicating location of ROV dive sites during a 2007 cruise off the Grand Banks, Newfoundland, Canada.