Biological Conservation 161 (2013) 67–70

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Cold-water coral reef habitats benefit recreationally valuable sharks

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ARTICLE INFO

Article history:
Received 16 October 2012
Received in revised form 22 February 2013
Accepted 1 March 2013

Keywords:
Cold-water corals
Coral reefs
Sharks
Ecosystem function
Spawning
Sea angling

ABSTRACT

We provide a case study to demonstrate how a key ecosystem function of coral reefs (habitat provision) co-benefits both sharks and humans. Spawning grounds of the blackmouth catshark *Galeus melastomus* were discovered using seabed and video surveys on the Mingulay Reef Complex, a seascape of cold-water coral reefs off western Scotland. Spawning habitats were environmentally similar across years. Shark abundance of *G. melastomus*, a species valued by the recreational sea angling industry, was significantly higher nearer reef habitats. Our case study demonstrates how a local coral vulnerable marine ecosystem (VME) helps maintain key life stages of shark populations and provides socioeconomic benefits. Evidence for co-benefits between corals, sharks and humans provides a compelling case for identifying and protecting coral VMEs.

1. Introduction

Cold-water corals inhabit deep aphotic waters and host biologically rich animal communities (Roberts et al., 2009b). Sharks are known to use cold-water coral habitats for feeding, nursery grounds and social refuges (Morato et al., 2010). However the lack of knowledge about habitat use by sharks across their life cycles inhibits the development of effective management and conservation measures, particularly for deepwater species (Kinney and Simpfendorfer, 2009). We therefore have an ambiguous understanding of what functions cold-water corals perform in relation to deepwater sharks.

Some cold-water corals form vulnerable marine ecosystems (VMEs) whose structure and function are impacted by human activities such as bottom fishing. In 2006, regional fisheries management organisations (RFMOs) were called upon to adopt United Nations General Assembly resolution 61/105 to support sustainable deepwater fisheries with minimal environmental impact. But the identification of VMEs by RFMOs is inhibited by the lack of life history criteria such as the occurrence of fish spawning grounds (Weaver et al., 2011). Thus associations between sharks and corals are intriguing because they present novel opportunities for VME science and conservation. We propose that habitat use by sharks in coral VMEs represent "synergies" sensu Bennett et al. (2009) whereby one ecosystem function is enhanced by another. Identifying synergies facilitates science-based selection of candidate marine protected areas (MPAs) that could be based on indicators of habitat use by marine species (Thaxter et al., 2012). Garnering public support is also crucial for coral VME conservation: our value of ecosystems depends on charismatic fauna because public affinities for such species drive our willingness to pay for biodiversity conservation (Martín-López et al., 2007). Highlighting relationships between familiar fauna such as sharks and more enigmatic animals like cold-water corals therefore enhances public support while providing a scientific basis for RFMOs to assess VME occurrences.

We investigated synergies between sharks and corals at the Mingulay Reef Complex (Fig. 1a), a seascape of coral reefs 120–190 m deep off western Scotland (Roberts et al., 2005, 2009a) constructed by the hard coral *Lophelia pertusa*. Coral habitats greatly enhance biodiversity at the complex (Henry et al., 2010), a function that underpinned its designation as a proposed marine protected area (MPA) in 2010 covering an area of 115 km^2.

2. Material and methods

2.1. Spawning grounds

We have examined 102 benthic grab samples from the reef complex since 2003 that span all seasons. Despite having a limited

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0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.03.002

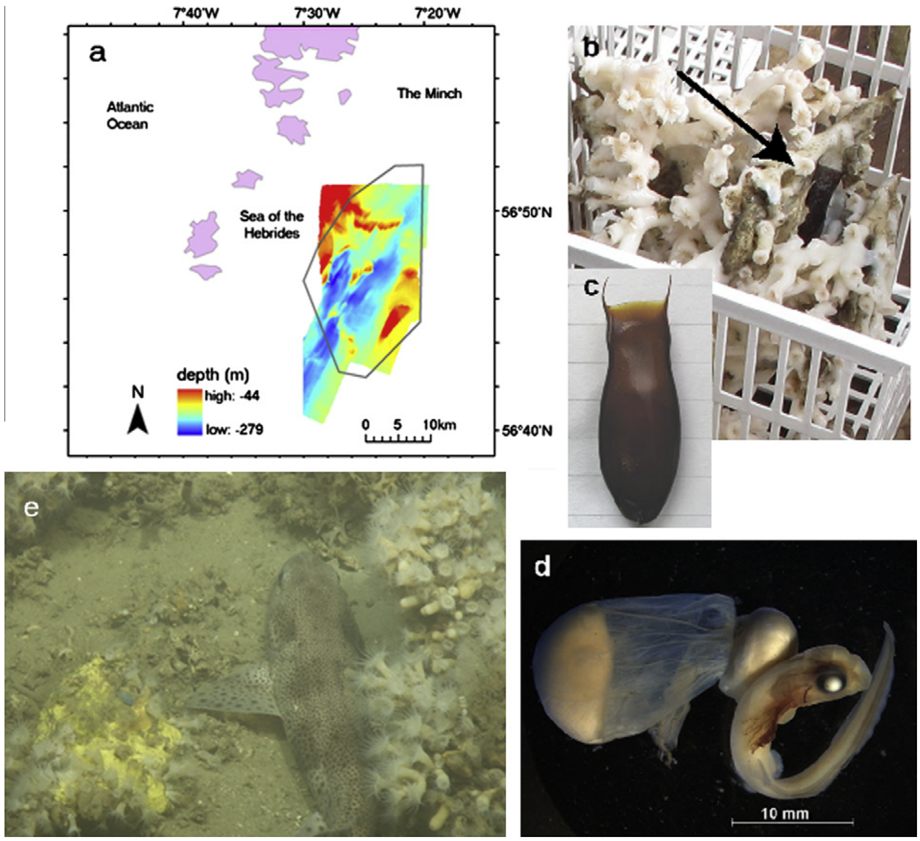

Fig. 1. Shark habitats on the Mingulay Reef Complex (inset a, showing the proposed MPA boundary). Egg nested in coral, 20 cm diameter (inset b). Egg mean length = 60 mm, width = 20 mm (inset c). *Galeus melastomus* embryo (inset d). The lesser spotted dogfish *Scyliorhinus canicula* resting among corals (inset e, credit to JC073 Changing Oceans Expedition, Heriot-Watt University).

spatial coverage of approximately 0.1 m^2, a video-assisted Van Veen benthic grab collected egg cases at two sites in July 2009 and 2011 on two reef stations, Mingulay Reef 1 and Banana Reef (Fig. 1b, Table 1). Egg cases were again observed on living corals during three video transects conducted by remotely operated vehicle (ROV) in May 2012 (Table 1). Notably, eggs have never been observed on adjacent sediments without corals. Egg morphology (Fig. 1c) was compared to other northeast Atlantic oviparous sharks. This confirmed their identity as the blackmouth catshark *Galeus melastomus*, a demersal shark found in deep shelf and slope waters of the northeast Atlantic and Mediterranean. Embryo size suggested that development was incomplete (length at Mingulay 25 mm, see Fig. 1d, versus near-term length 75 mm after Capapé et al., 2007).

Seabed terrain variables for each spawning station (Table 1) were derived from multibeam data collected during surveys in 2003 and 2006 (Roberts et al., 2009a) using ArcGIS 9.2 with ESRI Spatial Analysis and Benthic Terrain Modeler extensions (Wright et al., 2005). Variables included depth, slope (degrees of inclination), aspect (orientation measured in radians), rugosity (a non-metric measure of topographic unevenness) and the Bathymetric Position Index (BPI; a non-metric measure of whether the area is on a topographic high or low relative to the surrounding area; Wilson et al., 2007). The mean of each variable in a 10 m diameter buffer around each station was estimated as rate change between cells in a 3 $\times$ 3 neighbourhood.

2.2. Shark abundance

We examined potential effects of reef habitat on the abundance of *G. melastomus*, a catshark species valued by the recreational sea angling community (Donnelley, 2009) using a published

Table 1
Spawning habitat characteristics on the reef complex.

Variable	Site 1	Site 2	Site 3	Site 4	Site 5
Reef station	Banana Reef	Mingulay area 1	Mingulay area 1	Mingulay area 1	Mingulay area 1
Date	July 2009	July 2011	May 2012	May 2012	May 2012
Depth	165 m	169 m	172 m	172 m	172 m
Method	Van Veen	Van Veen	ROV	ROV	ROV
Latitude	56. 801500	56.826200	56.8261205	56.826119	52.826114
Longitude	−7.4533000	−7.3913000	−7.3902790	−7.3902785	−7.3902797
BPI	−18	−18	−18	−18	−18
Aspect	260°	332°	9°	9°	9°
Rugosity	1.011367	1.004460	1.010032	1.010032	1.010032
Slope	7.19°	3.16°	6.37°	6.37°	6.37°
# Eggs	2	3	1	4	1