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Spawning habitat selection by *Octopus vulgaris*: a new tool for sustainable management of this resource in NE Atlantic

Ángel Guerra (1), Jorge Hernández-Urcera (1), Manuel E. Garci (1), Marta Sestelo (2), Marcos Regueira (1), Ángel F. González (1), Miguel Cabanellas-Reboredo (3), Matías Calvo-Manazza (3), and Beatriz Morales-Nin (3)
(1) Instituto de Investigaciones Marinas (CSIC), Eduardo Cabello 6, 36208 Vigo, Spain; (2) Department of Mathematics, Autonomous University of Barcelona, Bellaterra (Cerdanyola del Vallès), Spain; (3) Instituto Mediterráneo de Estudios Avanzados (ICSIC-UIB), Esporles, Islas Baleares, Spain. Present contact details: angelguerra@iim.csic.es, Phone +34 986 231930.

Summary

The spawning habitat selection of a population of *Octopus vulgaris* subject to fishery pressure was studied in the Cíes Islands within the National Park of the Atlantic Islands of Galicia (NW Spain) located in the Ría de Vigo's mouth. The technique used was visual censuses by scuba diving. We conducted 93 visual censuses from April 2012 to April 2014. The total swept area was 109.4 ha (4.15 % of the total marine area of the Cíes Islands). The spawning habitat of preference for *O. vulgaris* includes the categorical variables zone (south, central and north), type of substrata and depth. The estimated occurrence of egg clusters and spawning dens was focused in a specific area within a zone of 158 ha (5.98% of the total marine area of the Cíes Islands) located between 5 and 30 m depth, covered by hard bottom substrate. The opportunity to implant a management strategy based on the protection of the spawning habitats of the species is discussed.

Introduction

The most important cephalopod species in Galicia is the common octopus (*Octopus vulgaris* Cuvier, 1797), which yields an average annual catch ranging from 2,500 to 4,000 tonnes. The species is caught by a huge (around 1,600 boats) in bottoms ranging from 5-7 m to a maximum depth of 150 m (Otero *et al.* 2005; Regional Autonomous Government of Galicia, 2013), which even include the National Park of the Atlantic Islands of Galicia (NAPAIG). Despite the existent management measures, there are some signs that this resource is currently overexploited, as occurring with other ones in the Ría de Vigo (Guerra et al., 2008). To ensure long-term sustainability of the *O. vulgaris* artisanal fishery an Integrate Management (IM) approach would be appropriate. One of the difficulties in adopting this type of governance is to define and characterize habitats and ecosystems to be managed. We consider that this approach would be feasibly applied in those areas for brooding *O. vulgaris* females, considering that the spawns of this species are commonly set in easily protected rocky crevices. Information on the spawning habitat selection for any octopus species is practically non-existent. This paper set out to identify and characterize preferential spawning habitats for *O. vulgaris*. We consider this paper a first step to elaborate a contingency plan to protect and preserve the spawning areas of the species.

Material and Methods

Observations were made in the NAPAIG, which has a total maritime surface of 7,285 ha. Within NAPAIG, our work comprised samplings around the Cíes Islands (Fig. 1), whose maritime area covers 2,637.77 ha. Four visual censuses randomly distributed were performed monthly, from April 2012 to April 2014. The location of each visual census was performed by GPS. Two or three scuba divers carried out each census simultaneously between 5 and 30 m depth. An original method estimating swept area in each census was developed. Any substantive information was recorded with a SONY video camera HDR-CX700. Bottom temperature was recorded with a diving computer, and other oceanographic variables with CTD. Once in the laboratory, the recorded images were examined to verify the type of bottom substrate, presence of octopus, and number of egg clusters and spawning dens. The type of bottom substrate was defined by the dominant underlying matrix and classified as soft (sand, "maërl", sand with some rock outcrops and gravel) and hard (cobble, bedrock and outcrop). Data were stored in three bases: i) images, ii) substrate, oceanographic and other variables and, iii) observations and incidents. ArcGIS

software was chosen to represent the maps of environmental preferences. Habitat features (such as season, depth, zone, bottom temperature, swept area and bottom substrate type) were evaluated as predictors of presence/absence of spawning nests using Generalized Additive Models. All the statistical analysis was performed on the free R software using the *mgcv* package (Wood, 2006) for fitting the model and the *FWD select* package (Sestelo *et al.*, 2013) to select the used model.

Results and Discussion

A total of 93 visual censuses (104.2 diving hours) were undertaken. The total swept area was 109.4 ha (4.15 % of the total marine area of the Cíes Islands). A total of 21 females taking care of their egg masses and 54 spawning dens were found at depths ranging from 9 to 30 m. Temperature ranged from 13 to 17ºC.

The results indicated that the best statistical model to identify and characterize spawning habitat of preference for *O. vulgaris* includes the categorical variables zone and bottom substrate and the continuous variable depth (as a smooth effect). The highest probability is obtained in the north of the park on depth ranging from 8 to 20 meters. The probability of presence of spawning nests on hard substrate is approximately 45% higher than on soft one. All these results seems to conclude that the species *O. vulgaris* has a remarkable preference for spawning in areas with hard bottom substrate and moderate depths and that these characteristic are found at the north zone of the park. The area where the occurrence of egg clusters and spawning nets was highest occupied an extension of 158 ha.

Ensuring a fully protected area within the NAPAIG would conserve and enhance a preferential habitat for the species. Furthermore, in order to minimize social conflicts between all users, the implementation of this management measure should be gradual, through an adaptation plan.

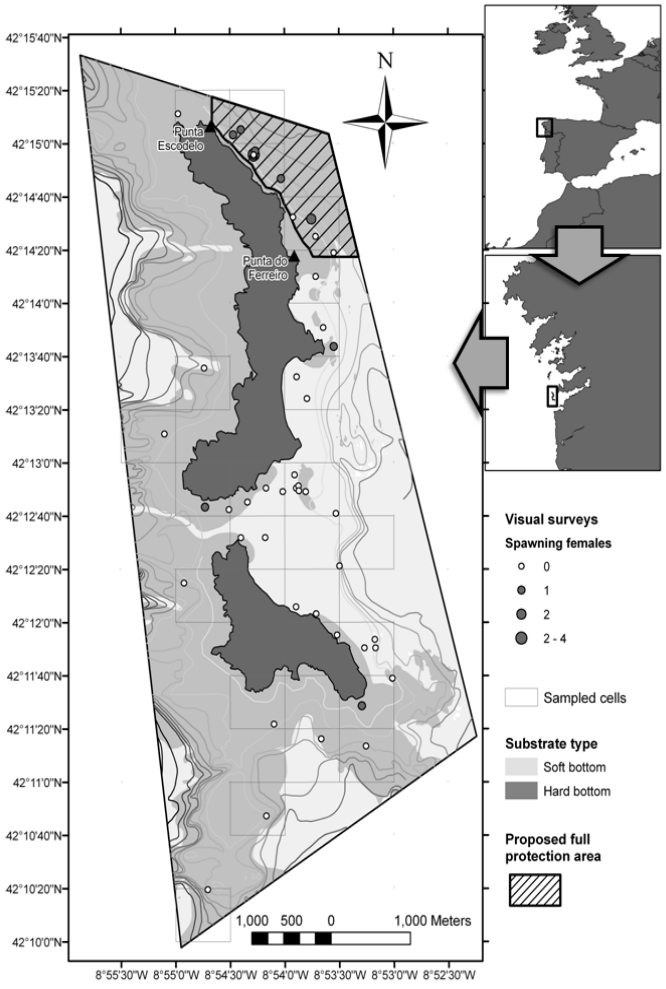

Figure 1. Spawning habitat of preference for *Octopus vulgaris* in the Cies islands (NAPAIG).

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