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Using artificial devices for identifying spawning preferences of the European squid: Usefulness and limitations

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ABSTRACT

Sustainable management of exploited stocks demands, among others issues, to identify the spawning spatio-temporal patterns and eventually to protect the spawning grounds of the target species. Squid seems to aggregate at this crucial period of the life-history, which implies increasing vulnerability to fishing. Unlike those of other loliginid species, the spawning preferences of the European squid are largely unknown because finding egg clutches of this species in the wild is challenging. Validated records from research programs are virtually inexistent but unsystematic records from, for example fisherman, suggest that squid spawns regularly on artificial structures. Here, we report for first time a description of the spatio-temporal pattern of squid spawning on artificial devices (ADs). Thirty ADs were deployed over one year at a marine reserve (Cabrera National Park). ADs were distributed covering the three main types of benthic habitat, and ranging from 5 to 50 m depth. ADs were sampled monthly. Three main patters have been evidenced: (i) squid would prefer sandy bottoms for spawning, (ii) spawning would peak in spring, and (iii) squid would expand their spawning areas to shallower waters during the coldest months. It is debatable to extrapolate these patterns to those actually takes place in natural conditions. However, given the heavy fishing effort exerted on squid and data scarcity, the precautionary approach supports to take data from ADs as a starting point for advising sustainable management. Assuming that spawning at ADs and at the wild are correlated, the first pattern may be related to the faster marine currents that prevail on sandy bottoms or the smaller abundance of potential predators in these habitats. The second pattern may be related with the typical phytoplankton–zooplankton cascade that, in the Western Mediterranean, takes place just preceding spring. While the third pattern is in accordance with the hypothesis that squid may undergo a spawning migration.

1. Introduction

Habitat degradation and overfishing may cause severe decline in some exploited living marine resources (Worm et al., 2006). Cephalopods are important target species for fisheries worldwide (Boyle and Rodhouse, 2005), thus stocks are potentially susceptible to overfishing (Pierce and Guerra, 1994). As in the cases of other short-lived species, squid abundance experiences important between-year variability and depends on environmental variability (e.g., temperature; Pierce et al., 2008), which complicates management.

In an effort to promote sustainable fisheries, different management strategies have been implemented to reduce fishing mortality, mainly through fishing limitations. Conventional regulations consist in limiting days-at-sea, closing areas, closing seasons and implementing gear restrictions (Morales-Nin et al., 2010). However, in some cases, this conventional approach has been ineffective (Hutchings, 2000). Therefore, integrating species-specific fishing limitations with a broader management strategy has been proposed (Roberts et al., 2005). This new paradigm implies, for example, that the biology and ecology of the species to be protected should be considered to achieve a successful regulatory implementation. For example, the movement characteristics of a species should be known to determine the optimal extension of a marine protected area (Walters, 2000; Taylor and Mills, 2013). To address such integrated management strategy, previous research

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has indicated the importance of identifying and eventually protecting essential fish habitats (EFHs; Rosenberg et al., 2000). An EFH is the habitat identified as essential to the requirements of a species at any critical stage of the life history. EFHs would require special protection for improving stock status and ensuring long-term sustainability (Valavanis and Smith, 2007). Therefore, the protection of EFHs is a challenge and should be considered when managing fisheries (Benaka, 1999).

Population dynamics of most short-lived species are characterized by important spatio-temporal variability, which, in the specific case of cephalopod fisheries, complicates the implementation of any management option (Pierce and Guerra, 1994; Boyle and Rodhouse, 2005). Nevertheless, sustainable development of the South African squid fishery was achieved after identifying and protecting some preferential spawning areas of the chokka squid, *Loligo reynaudii* (Augustyn and Roel, 1998), which supports the potential usefulness of characterizing EFHs of cephalopods.

The European squid, *Loligo vulgaris* Lamarck (1798), experiences considerable fishing pressure. This valued resource is one of the most exploited cephalopods in European waters (Pierce et al., 2010). In the Mediterranean Sea, the European squid is targeted by the trawl fishery (González and Sánchez, 2002), the artisanal fishery (hand-line-jigging with attraction lights and seine fishing; Guerra et al., 1994; Lefkadltou et al., 1998; Cabanellas-Reboredo et al., 2011; Ulaş and Aydin, 2011) and the recreational fishery (Cabanellas-Reboredo et al., 2014). A large recreational jigging effort concentrates at specific grounds (inshore waters at 20–35 m depth; Cabanellas-Reboredo et al., 2014) during the reproductive season of this species (winter–spring; Šifner and Vrgoč, 2004). Previous reports have suggested that the pattern depicted by the recreational fleet may be related to inshore–offshore spawning migrations of this species (Cabanellas-Reboredo et al., 2012a, 2014). Squid may undergo these spawning migrations in an attempt to maximize spawning success (Villanueva et al., 2003; Cabanellas-Reboredo et al., 2012a) by optimizing embryonic development (e.g., seeking an optimal temperature range; Şen, 2005). Inshore spawning aggregations are highly vulnerable to fishing (Boyle and Rodhouse, 2005). Therefore, fishing mortality is expected to intensify during a critical period in the squid life-history (Pierce and Guerra, 1994; Boyle and Rodhouse, 2005). The identification of spawning areas could play an important role in ensuring the stock sustainability as is the case of the above-mentioned *L. reynaudii* (Augustyn and Roel, 1998; Cochrane et al., 2014). Unfortunately, unlike other exploited loliginid species (e.g., *L. reynaudii* or *Loligo opalescens*) whose spawning grounds have been well identified, delimited and characterized (Sauer et al., 1993; Foote et al., 2006), data on explicit observations of the spawning spatio-temporal spawning patterns of *L. vulgaris* are not available.

L. vulgaris females have been reported to lay eggs in clusters attached to different hard substrates or branched sessile organisms (Jereb and Roper, 2010). However, to find squid eggs at the wild seems to be very challenging. The study area considered here is a National Park, thus a large number of systematic scientific sampling programs (scuba diving visual censuses) have been completed but reports of egg clutches are merely anecdotic (Vázquez-Luis et al., Submitted). Conversely, non validated or unsystematic reports of egg clutches attached to fishing gears and other artificial structures (e.g., ropes of acoustic tracking structures; Cabanellas-Reboredo et al., 2012b) are relatively frequent. When detecting natural egg clutches is difficult or impossible, the use of artificial substrates has been suggested as an alternative sampling methodology (e.g., in the case of *Perca fluviatilis*; Gillet et al., 2013) and they has been already used in the case of *L. vulgaris* (Villa et al., 1997).

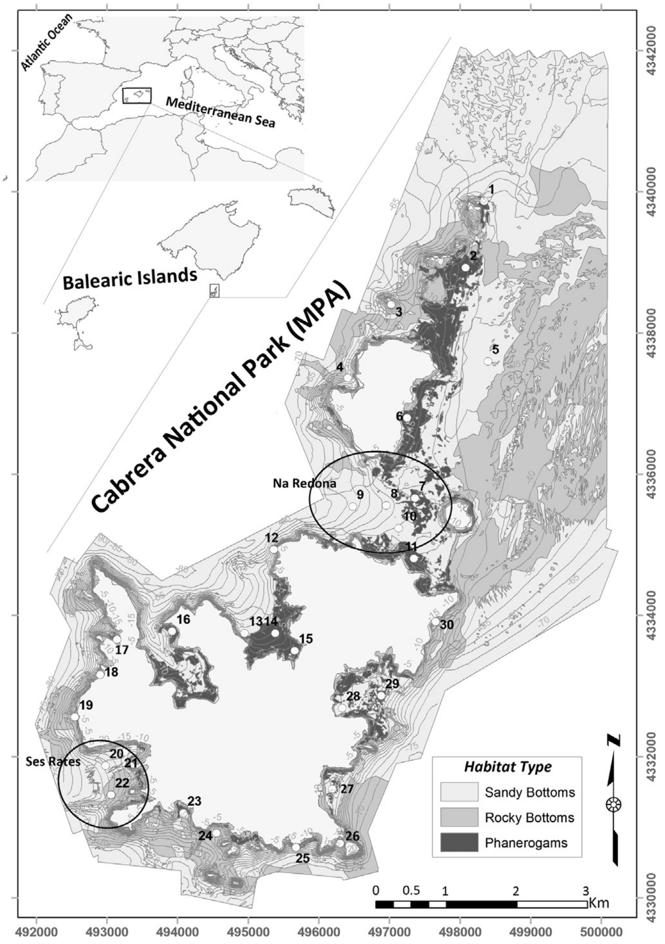

Fig. 1. Location of the study area and distribution of artificial devices (ADs) on the three main benthic habitats around Cabrera National Park. Na Redona and Ses Rates locations are highlighted by circles. Isobaths are designated at 5 m intervals.

Here we reported for first time a description of the spatio-temporal pattern of squid spawning on artificial devices (ADs). Three main patters have been evidenced: (i) squid would prefer sandy bottoms for spawning, (ii) spawning peak takes place in spring, and (iii) squid would expand their spawning areas to shallower waters during the coldest months. The interpretation of the data obtained with ADs is not straightforward because the patterns observed may be biased in relation to the natural patterns. However, in the case of no data and applying a precautionary approach to a heavily exploited resource, the use of ADs may be a valuable starting point for implementing effective management measures.

2. Materials and methods

2.1. Study area

This study was conducted at Cabrera Archipelago National Park (CNP) (Balearic Islands, NW Mediterranean; Fig. 1). The CNP is a combination of nineteen small islands that form one of the largest marine reserves in the Mediterranean, with a coastline of 54 km and 87 km^2 of marine protected area.

Fishing started very early at Cabrera, with archaeological evidence of fish salting during Roman times (Frontera et al., 1993). Fishing activity, especially recreational fishing, was important from the 1960s (Massutí, 1991). After the enforcement of the marine reserve in 1991, a total of 80 small-scale boats were registered to fish in CNP waters (Coll et al., 1999). However, the current fishing effort is unknown (although most likely smaller) because these boats also operate outside the CNP. The main activity of these