

# A 25-year marine reserve as proxy for the unfished condition of an exploited species



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## ARTICLE INFO

### Article history:

Received 20 April 2016

Received in revised form 1 September 2016

Accepted 6 September 2016

Available online xxxx

### Keywords:

No-take marine reserves

Long-term protection

Unfished conditions

Fisheries depletion

Artisanal fisheries

Spiny lobster

## ABSTRACT

In the absence of a historical baseline, long-term no-take marine reserves can provide a reference to the unfished condition in exploited species of limited mobility. This study documents the recovery of the lobster *Palinurus elephas* within a large Mediterranean no-take marine reserve (MR) and uses it as a baseline to assess stock status in exploited grounds in the region. Lobster indices of density and biomass within the MR continued to increase after 25 years of protection, a period close to the species' lifespan. Catch per unit effort (CPUE) in weight more than doubled from years 21<sup>st</sup> to 25<sup>th</sup> without fishing in the reserve while the increase of CPUE in numbers was only 20%. This faster increase in biomass reflected individual growth and spillover of predominantly smaller lobsters to adjacent grounds. A highly depleted status of exploited populations was inferred from the demographic structure and CPUEs, with fishery:MR ratios and reproductive potential indices below 0.05. In the MR the size-class of maximum egg production increased over time, in contrast to stable sizes classes in fished areas. The contribution of small lobster (<90 mm CL) to overall egg production was only 1.5% in the MR and 30% in the fished areas. Mortality estimated from recent size compositions was three to four times higher in fished areas than inside the MR, resulting in a reduction in predicted spawning potential per recruit close to 20% of the unfished level. This experiment emphasizes the value of long-term no-take areas as reference laboratories for investigating fishing effects.

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## 1. Introduction

Compared to large-scale fisheries, small-scale fisheries are data-limited, available studies tend to be short-term, and the status of populations they exploit is rarely assessed (Costello et al., 2012). The small-scale, multispecific, diverse and idiosyncratic nature of artisanal fisheries are not the only features that deter data collection. The close interaction of observers involved in field work with artisanal fishers means that monitoring studies will depend as much on the human component as on the technical and monetary resources available. Another difficulty is that these fisheries often have a long history, lacking a reference to the pristine or early exploitation status. This is the shifting baseline problem – where the concept of what the natural system was changes continually over time (Pauly, 1995). Well-enforced marine reserves can alleviate the problem in the case of species of limited mobility (relative to the size of the reserve), by providing a reference point that may approach the unexploited population structure (Hilborn et al., 2004).

Spiny lobsters are particularly suitable for spatial management because of their restricted adult mobility and hence propensity for depensation if populations are reduced below critical levels (Jennings,

2001). They are the subject of a number of long-term studies of marine reserves, which with limited exceptions document swift responses of abundance and body size after protection (Hoskin et al., 2011; Kelly and MacDiarmid, 2003; MacDiarmid and Breen, 1993; Pande et al., 2008; Shears et al., 2006), but see Freeman et al. (2012) and Mayfield et al. (2005).

Among the edible spiny lobsters in the Mediterranean (Holthuis, 1991), *Palinurus elephas* (Fabricius, 1787) has been historically considered an excellent food, as portrayed in a 3rd century Roman mosaic from the “House of 516 Dionysus and Ulysses” (Spanier et al., 2015). Its yields started to decrease during Roman times and deterioration of the stocks worsened in the 20th century with the intensification of effort and introduction of modern technologies (Spanier et al., 2015). Fishing techniques changed from the use of pots or diving to the use of trammel nets, which are significantly more efficient and resulted in further population declines, particularly in Atlantic populations (Goñi and Latrouite, 2005). At present, the Mediterranean population of *P. elephas* is considered overfished but it is still targeted by artisanal boats in many areas, especially in archipelagos and islands (Groeneveld et al., 2013). Published declines of catch per unit effort in Atlantic fisheries and widespread concern for the lack of proper assessment of its status led to the classification of *P. elephas* by the IUCN as Threatened Vulnerable (Goñi, 2014).

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*Palinurus elephas* is a long-lived, slow-growing species that matures at 3–4 years approximately 80 mm carapace length (CL) in the Mediterranean and reproduces once a year (Goñi et al., 2003a). Tagging studies indicate that adult movement is restricted with most individuals moving <5 km (Goñi and Latrouite, 2005). European fisheries are managed by a minimum landing size (90 mm CL in the Mediterranean and 95 mm CL in the Atlantic) and the prohibition of landing berried females (Goñi and Latrouite, 2005). Some fisheries (e.g., Balearic Islands NW Mediterranean) have a 7-month closed season covering the egg bearing period.

The Columbretes Islands Marine Reserve (hereafter “the MR”), located in the north-western Mediterranean (Spain), was established in 1990 as a no-take area (Fig. 1). The MR covers 55 km<sup>2</sup> and previously harboured traditional fishing grounds of *P. elephas*. Its empowering legislation prohibits all commercial fisheries and all lobster fishing, and regulations are well enforced. At present, the most traditional and profitable commercial *P. elephas* fisheries in the Mediterranean occur around archipelagos and islands, such as the Balearic Islands and around the Columbretes MR (Fig. 1). These fisheries have been used as controls in a long-term study that monitored the recovery of *P. elephas* within the MR since 2000. Although information on lobster abundance before MR implementation is not available, local fishermen corroborate that prior to MR creation catch rates were at a minimum. Density of *P. elephas* within the MR at the end of the 20th century was estimated to be 6–20 times greater than in comparable fished areas depending on the season (Goñi et al., 2001) and spillover supplied lobster to the

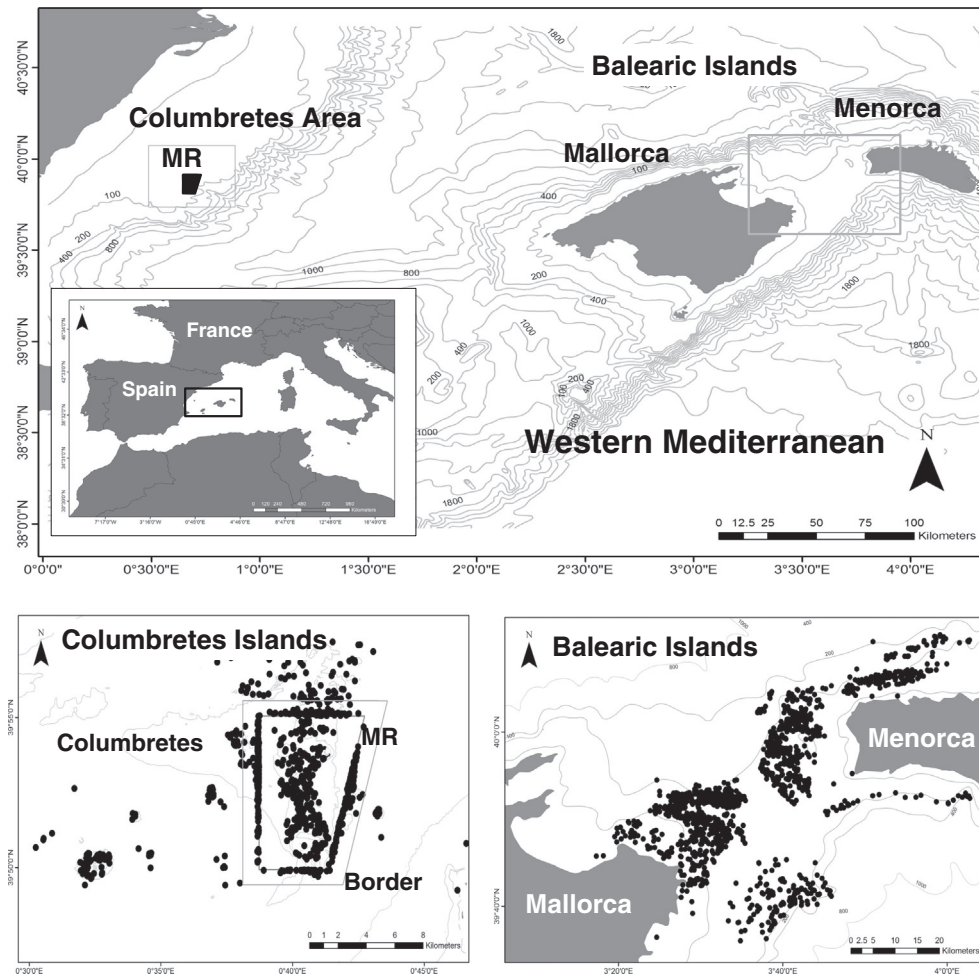
adjacent fishery (Goñi et al., 2006), providing a net annual benefit to the local fishery of 12% of the catch in weight (Goñi et al., 2010).

The prohibition of fishing in the MR for 25 years offers a unique opportunity to contrast the abundance and population structure in fished and unfished conditions. In this study we: 1) assess the trajectory of lobster density and biomass in the no-take MR during the period extending from years 11 to 25 since fishing ceased, and 2) evaluate the status of Western Mediterranean *P. elephas* fisheries using as reference the contemporary status of lobster in the MR. We do that in terms of density and biomass, demography, reproductive potential and mortality.

## 2. Material and methods

### 2.1. Study areas and fisheries

The study was conducted in two regions of the Spanish Mediterranean: the Columbretes Islands, where the MR is located, and the Balearic Islands (Fig. 1). Lobster fishing effort in the Columbretes Islands region is distributed in “Border” grounds surrounding the MR (<1 km from the boundary) and in contiguous and patchily distributed grounds of “Columbretes” (1–30 km from the boundary) (Goñi et al., 2010). The traditional fishing grounds of the Balearic Islands region occur around the Mallorca and Menorca Islands, 150 km away. The MR harbours volcanic rock and coralligenous habitats (maërl beds), with patches of gravel, sand, and mud extending down to 80 m depth. Fishing grounds



**Fig. 1.** Upper box: Study region in the Western Mediterranean showing the location of the study areas of Columbretes and Balearic Islands. Lower box: Experimental fishing sets in the Columbretes Islands marine reserve (MR) and commercial fishing sets in the Border (<1 km from MR boundary), Columbretes (1–30 km from MR boundary), Mallorca and Menorca fishing grounds. Fishing sets are represented by black dots.

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