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## First description of a new worm bait fishery in the NW Mediterranean Sea

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### Abstract

Most commercial clam stocks in the NW Mediterranean Sea have collapsed over the last few decades and, as a result, most clam dredge fishermen have been forced to leave the fishing sector. Recently, in order to sustain their economic activity, some fishermen have modified dredges to target sea worms to sell as bait for recreational fisheries. This study provides the first information about this new worm bait fishery on the Catalan Maresme coast (NE Spain). The local administration has regulated only a few aspects of the fishery: users (2 boats), geographical limits (40 km; between 0-7 m depth), fishing time (6:00-14:00) and dredge design (the same as those used for smooth clams but with interior structures to retain worms and an open back). Fishing activity takes place throughout the year. Fishermen target three worm bait species: *Sigalion squamosus*, *Ophelia neglecta* and *Halla parthenopeia*. A mean of 233.37 individuals of *S. squamosus*, 167.93 of *O. neglecta* and 2.17 of *H. parthenopeia* are gathered per boat and day. Worm baits are sold directly to local recreational fishing shops as a quality product at the highest prices on the market. This fishery has a high social and economic value for the Maresme coast, helping to maintain small-scale fishermen jobs with an economic benefit similar to clam fishing.

**Keywords:** Invertebrate fishery management; polychaete; bait collection; new fisheries; dredges.

### Introduction

Recreational fishing is a widespread and worldwide leisure activity, playing an important socio-economic role in coastal areas (Westera *et al.*, 2003). This activity is particularly important on the Mediterranean coast of Spain. Franquesa (2004) estimated that recreational fishing generates around 550-650 million Euros per year, more than professional fisheries. There are 118,354 fishermen with official licenses in Catalonia alone (NE Spanish coast) (Catalan Government; official data), with angling being the most common fishing technique used among recreational fishermen. Baeta & Cardona (2005) estimated that angling represents 63% of the recreational fishing on the Catalan coast. As a result of this intense activity, there is a high demand for baits. Many invertebrates are used as baits (*e.g.* crabs, limpets, clams, sipunculid worms, fish, etc.), yet sea worms are among the most popular baits in Catalonia. The majority of anglers buy sea worm baits in specialized shops and only a few of them collect sea worm baits at the beach and do so exclusively for their own use.

Historically, there has never been a professional trade in fishing or gathering that markets sea worm baits on

the Catalan coast, as occurs in other European areas such as southern England, Portugal and the Atlantic coast of Spain (*e.g.* Bay of Cadiz) where fishermen collect sea worm baits for their own use or to sell on the intertidal fringe (Fidalgo e Costa *et al.*, 2006; Watson *et al.*, 2017). Although there are no official statistics on the Spanish baits market, most of the market consists of imported wild live polychaetes from Asia (mainly China and Vietnam) and North America (USA) and they are also imported by air or ground from European aquaculture facilities (*i.e.* France, United Kingdom, Netherlands etc.) (Fidalgo e Costa *et al.*, 2006; Sá *et al.*, 2017). The most frequently imported polychaetes sold in specialized shops are: *Alitta virens*, *Glycera dibranchiata*, *Perinereis aibuhitensis*, *Perinereis lineata*, *Marphysa sanguinea* and *Hediste diversicolor*. However, these species, which are traded, sold and used alive, represent a tremendous risk for accidental introduction (Haska *et al.*, 2012).

The Maresme coast (Catalonia, northeastern Spain) was among the main clam fishing areas along the Mediterranean coast of Spain. There was an important level of clam fishing activity with a small-scale fleet of 17 boats that targeted clams using traditional clam dredges. The main target species was the smooth clam *Callista chione*,

although occasionally other clams (*Glycymeris glycymeris*, *Donax variegatus*, *Dosinia lupinus*, *Dosinia exoleta*, *Macra glauca*, etc.) and fish (*Trachinus* sp., *Solea* sp. and *Bothus podas*) were caught as by-catch. However, as a result of the combination of different anthropic activities (i.e. sand-dredging for beach nourishment and inadequate management of the small-scale clam fisheries), the smooth clam landings have declined progressively since 1997 and as a result, the fishing area was officially closed in December 2015 (Baeta *et al.*, 2014; Baeta *et al.*, 2018). Most of the fishermen (approx. 30 people) were forced to abandon fishing activity due to the scarcity of resources (Baeta *et al.*, 2018). Some of these fishermen recently decided to swap their target species for others in order to continue with their fishing activity. These fishermen modified their clam dredges converting them to “sea worm bait dredges” to focus exclusively on sea worms and sell them on the local market as a quality product in the form of live angling fishing baits. The main objective of this short communication is to provide the first description of this new and unique small-scale fishery using modified clam dredges and exclusively targeting sea worms for bait.

## Material and Methods

The Maresme coast stretches northeast for approx. 51 km. It is located in the northeast of the metropolitan area of Barcelona and is one of the more heavily populated and industrialized areas in Spain. Its coastline is located between the Tordera River Delta (northeast) and the Tiana seasonal stream (southwest), which displays a NE-SW trend (Fig. 1). Along this coast, there is a narrow infralittoral plain, 0-30 m, which runs parallel to the coastline and is dominated by reflective beaches of coarse granitic sand.

Worm baits are collected at sea, on board the standard clam fishing boat (10 m in length; 100 HP). Each boat typically tows three or four modified clam dredges (frame mouth width 70 cm; height 53 cm; depth 120 cm) along the bottom of the sea, lasting for 30 min at a

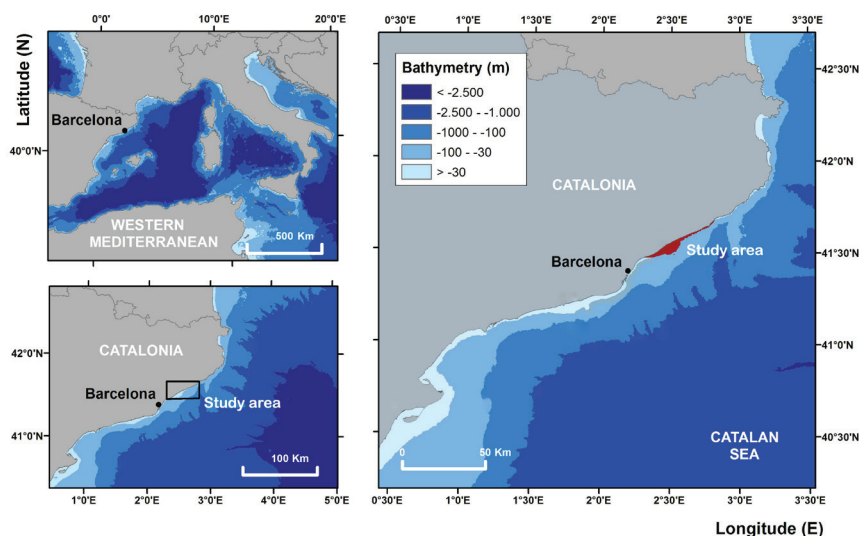
towing speed of 3 to 5 kn (Table.1). The towing speed to target smooth clams is slightly faster, between 5 to 6 kn. The mean number of tows per boat and day is 15 in the summer and 10 in the winter. For smooth clams, these numbers are 20 in summer and 15 in winter. Dredges are rigged with metallic teeth along the lower leading edge. They include several structures to retain worms, but are open at the back (Fig. 2). Fishermen are continuously working on innovative developments for dredge design in order to maximize their catch. As a result, they use different types of dredges simultaneously (with a few modifications on structures to retain worms inside the dredge) (Fig. 2). The mesh size of the dredges on the top, bottom and both sides is a constant 29 x 29 mm, the same mesh size used to target smooth clams.

The analysis of the fishery was carried out using official information from landings (from January 2016 to December 2017), legal documents from the Catalan Government and informal interviews with fishermen. A non-parametric Kruskal-Wallis test was used to determine seasonal differences in resource appropriation (worm species per boat and day).

## Results

### Management

The local Administration (DG Pesca; Catalan Government) has defined a worm bait management plan (ARP/362/2015) that regulates this fishing activity. The plan includes regulations regarding: (1) *User and resource boundaries*: Legitimate users should have a special fishing license for gathering worm baits and should belong to a Fishing Guild (“Confraria de Pescadors”). The number of legitimate users allowed is only 2 (2 fishing boats and 2 fishing licenses), but the number of fishermen allowed per boat is 2. The fishing area extends 40 km along the Maresme coastline between 0-7 meters depth (the functional area runs from 1.5 to 7 meters depth). The smooth clam fishing area occupies the same zone but from 5 to



**Fig. 1:** Map of the study area, the Maresme coast (northwestern Mediterranean Sea).

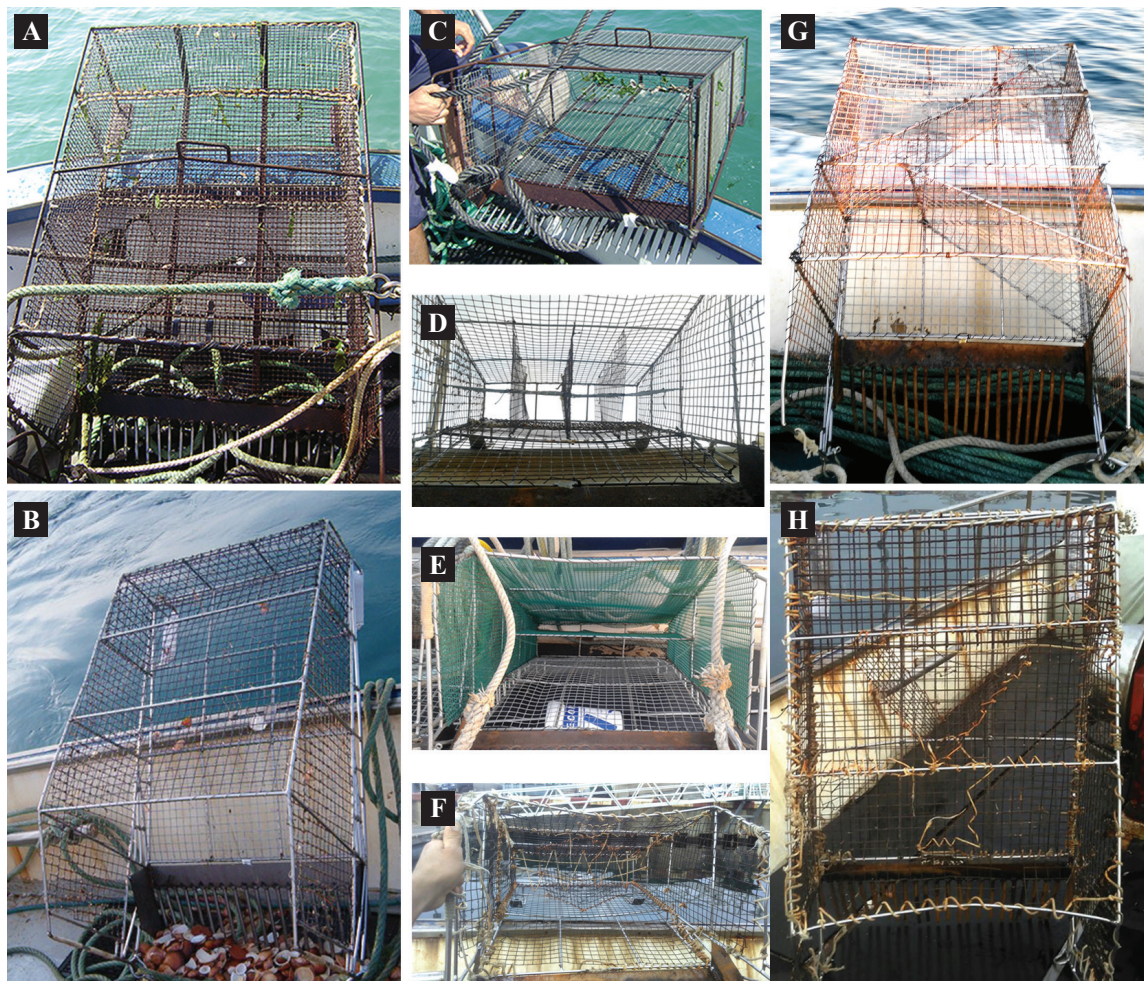
30 meters depth. Today, the smooth clam fishing area is closed to fishing activity. (2) *Regulations on appropriation and provision rules*: fishing is limited to the period between 6.00 am and 14:00 pm and a vague description of fishing gear design is provided (*i.e.* worm bait dredges should be similar to clam dredges but with the back lacking mesh.). (Fig. 2) No information on local conditions of worm baits (*i.e.* the size, the status of stocks) or on the impact of worm bait dredges on benthic communities (including smooth clams) are included.

### Target species and landings

Fishermen target three different worm bait species: *Sigalion squamosus* (Delle Chiaje, 1830) (“cuc blanc”), *Ophelia neglecta* (Schneider, 1892) (“cuc bomba”) and *Halla parthenopeia* (Delle chiaje, 1828) (“cuc llobar-rer”) (Fig.3). The main species collected is *S. squamosus*; fishermen collect an average of 233.37 (SE ± 8.94) individuals per boat and day; *O. neglecta* is the second most collected species with an average of 167.93 (SE ± 9.33) individuals per boat and day; and *H. parthenopeia* is collected with an average of 2.17 (SE ± 0.33) individuals

per boat and day. No seasonal variations were detected in *S. squamosus* landings (individuals per boat and day), since no significant differences were observed between months during the study period. However, landings of *O. neglecta* and *H. parthenopeia* showed seasonal oscillations. The Kruskal-Wallis one-way analysis of variance showed significant differences between months, among the collected individuals per boat and day for *O. neglecta* (H = 89.18; df = 16; P < 0.001) and *H. parthenopeia* (H = 36.85; df = 16; P < 0.005). Landings per boat and day of *O. neglecta* dropped after spring and rose after summer, but no clear tendency was observed for *H. parthenopeia*. Regarding the seasonality of the total landings by species, *S. squamosus* showed higher total landings in summer and lower in winter; *O. neglecta* showed higher total landings in spring and no clear tendency was observed for *H. parthenopeia* (Fig. 3).

Epibenthic and infaunal species appear frequently as a by-catch in the worm bait fishery; *i.e.* mainly bivalves (*Callista chione*, *Macra corallina* and *Donax variegatus*), crustaceans (*Thia scutellata*, *Portunus hastatus* and *Lambrus angulifrons*) and echinoderms (*Echinocardium* sp. and *Astropecten* sp.). All the by-catch fauna is returned alive to the sea after each trawl.



**Fig. 2:** (A-C) Clam dredges used on the Mediterranean coast of Spain (including the Maresme coast) (frame mouth width 70 cm; height 53 cm; depth 120 cm). Back part of the clam dredges is meshed. Mesh to target wedge clam and striped venus clam is 13 × 13 mm, whereas dredges to target smooth clam is 29 × 29 mm (D-H). Different types of worm bait dredges used by fishermen on Maresme coast. The worm bait commercial mesh size is 29 × 29 mm, but the back part of the dredge is open.

**Table 1.** Smooth clam and worm bait dredge design and fishing operation specifications.

Technical specifications	Target species	
	smooth clam	worm baits
Dredge dimensions	mouth width 70 cm; height 53 cm; depth 120 cm	mouth width 70 cm; height 53 cm; depth 120 cm
Dredge mesh size	29 x 29 mm	29 x 29 mm
Dredge back	With mesh	With no mesh
Tow speed	5-6 knots	3-5 knots
N° tows per day	15-20	10-15
Tow duration	30 minutes	20 minutes
Depth	5-30 meters	1.5-7 meters

### Sales, distribution and marketing

Fishermen obtain similar economic benefits from the worm bait fishery compared to clam fishing. However, fishermen do not sell worm baits at the traditional fish auction; worm baits are sold directly to local recreational fishing stores, inside the Metropolitan area of Barcelona, and exceptionally to other coastal towns of Catalonia (approx. a radius of 50 km around the port of landing). Often, the fishermen themselves, once they have landed the product, have to distribute worm baits to the different shops by car. *S. squamosus* is sold at a price of 0.65 € per individual, *O. neglecta* is quoted at 0.50 € per individual and *H. parthenopeia* is quoted up to 5-8 € per individual (depending on the size). Polychaetes are sold to all shops at the same price throughout the year. The retail prices of polychaetes (sold to recreational fishermen) are as follows: *S. squamosus* is sold at the shops for about 1-1.20 € per individual, *O. neglecta* is sold for 0.95 to 1 € per individual and *H. parthenopeia* is sold for 9 to 12 € per individual (depending on the worm size).

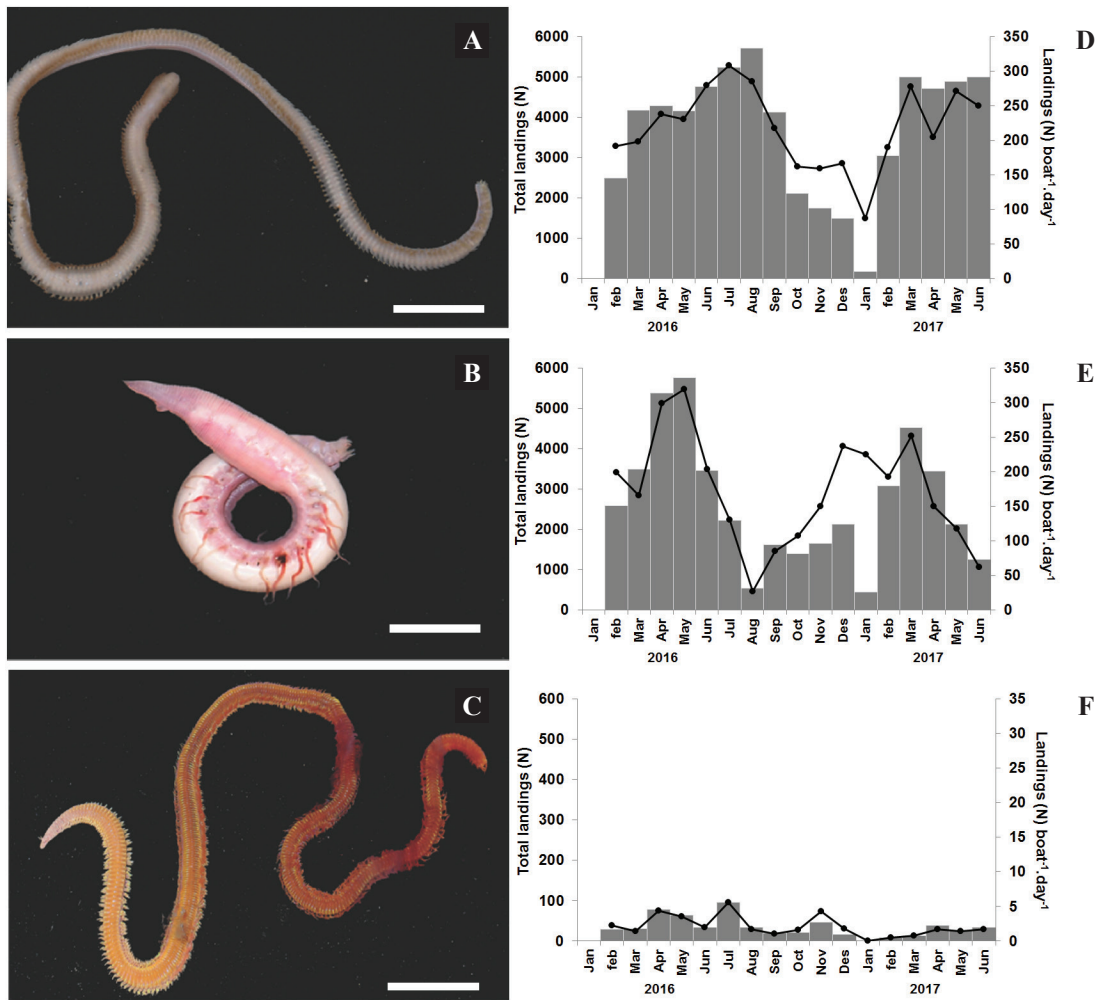
### Discussion

Harvesting of sea worms for recreational fishing bait is a lucrative activity carried out in many coastal areas worldwide. Watson *et al.* (2017) estimated that at least 121,000 TM are globally collected per year, valued at € 6.91 billion. The current rise in the small-scale fishery of local and native sea worm baits could be an excellent opportunity to revitalize the small-scale fishing sector in the NW Mediterranean Sea. The small-scale fisheries strongly impact the European Mediterranean coastal areas, both ecologically and economically. However, small-scale fisheries have traditionally been poorly managed, monitored and regulated given their low economic impact and their low volume of catches (Guyader *et al.*, 2013). These types of fisheries are declining in many parts of the Mediterranean Sea. On the Catalan coast, for example, the number of boats has decreased by 40.35%, from 949 boats in 2000 to 383 boats in 2016 (Catalan Government; official data). The decrease in the number of vessels has been particularly severe in the clam dredge

fleet; more than 95% of the vessels have left this fishery over the last 50 years (Baeta *et al.*, 2018). This dramatic decline in the clam dredge fisheries is not exclusive to the Catalan coast, but has been seen throughout the north-western Mediterranean Sea, where most of the fisheries have collapsed in recent decades (*e.g.* wedge clam *Donax trunculus*, striped venus clam *C. gallina* and smooth clam *C. chione*) (Baeta, 2015; Baeta *et al.*, 2018). The worm bait fishery may partially restore the small-scale fishing sector, in particular the clam dredge fleet, and this action in turn could serve as an example for similar areas along the northwestern Mediterranean coast.

Regarding the target species harvested along the Masresme coast, *S. squamosus* (Delle Chiaje, 1830) and *O. neglecta* (Schneider, 1892) are commercially fished exclusively in Catalonia. However, the third species, *H. parthenopeia* (Delle Chiaje, 1828), is also gathered as a target species in Bitter Lake and Lake Timsah (Suez Channel, Egypt), where worms are collected by hand during snorkeling at depths ranging between 1 and 5 m (Osman *et al.*, 2010). Moreover, *H. parthenopeia* is occasionally gathered as a by-catch by the bottom trawlers throughout the Mediterranean Sea and sold to local retailers. The three worm bait species are highly appreciated and considered a quality product by the local recreational fishermen because they appear to have more success in catching fish, in particular the most valuable species (*e.g.* sea bass *Dicentrarchus labrax*, the gilthead seabream *Sparus aurata*, and the sand steenbras *Lithognathus mormyrus*). Local worm baits are currently sold in the local market (in the metropolitan area of Barcelona, and exceptionally to other coastal towns of Catalonia); however, they have great economic potential and could be exported to other coastal areas in the Mediterranean.

Unfortunately, there is little information about the biology and ecology of local worm baits. *S. squamosus* (family Sigalionidae) is a large, white polychaete (length: 300 mm; width: 10 mm) with a carnivorous diet. It is distributed in a wide range of sediments (from mud to coarse sands) between 3 to 1800 meters depth, including sea-mounts and knolls; it is found from the Shetlands (north-eastern Atlantic), to the Mediterranean Sea including the Azores Islands and the Canary Islands, and to northwest Africa and South Africa (southeastern Atlantic) (Muir,



**Fig. 3:** Target worm bait species: (A) *Sigalion squamosus*; (B) *Ophelia neglecta* and (C) *Halla parthenogenia*. White line indicates 1cm. Monthly total landings (Number of individuals) and fishing effort (Number of individuals. boat<sup>-1</sup>. day<sup>-1</sup>) by species and month (from January 2016 to June 2017): (D) *Sigalion squamosus*; (E) *Ophelia neglecta*; and (F) *Halla parthenogenia*.

1989; Mackie & Chambers, 1990; Gillet & Dauvin, 2003; Horton *et al.*, 2019). *O. neglecta* (family Opheliidae) is a light pink, medium-sized polychaete (length: 80 mm; width: 15 mm) and is a surface deposit-feeder. It is distributed in sandy sediments (from fine to coarse sand) between 0 to 103 meters depth from the Brittany (north-eastern Atlantic) to the Mediterranean Sea (Mazé *et al.*, 1990; Rouse, 2001; Horton *et al.*, 2019). *H. parthenopeia* (family Oeonidae) is a very large polychaete (length: 800 mm; width 20mm) with a dark red coloration. It has a carnivorous diet based on the consumption of bivalves. This polychaete feeds by wounding their prey and secreting abundant mucus with paralytic activity forcing the prey to open its valves. It then ingests the bivalve suctioning off soft tissues (Lori *et al.*, 2014). In the eastern Mediterranean, *H. parthenopeia* has two reproductive periods -one in May and the second from November to January. It inhabits soft sediments, from mud to coarse sands, in intertidal and sublittoral waters (Osman *et al.*, 2010). This polychaete is distributed between 0 to 80 m on soft bottoms from mud to coarse sand sediments from the Bay of Biscay (north Atlantic) to the Mediterranean Sea including the Suez Channel (Osman *et al.*, 2010; Horton *et al.*, 2019).

The local Administration has a well-defined geographical limit on the worm bait fishery. However, it has prohibited fishing inside the smooth clam fishing area (between 5 to 30 meters depth) although there are no scientific studies that have determined that the fishing of worms baits have a negative impact on the possible recovery of the smooth clam bed. Furthermore, there are no studies that have examined the impact of smooth clam dredges on the benthic communities in the Mediterranean Sea. Moreover, most studies have focused on the impact of discarded individuals that enter the dredges and remain retained. For example, Baeta *et al.* (2019) showed that the by-catch constitutes an important proportion of the catch of clam fisheries on the Catalan coast, representing 86.52% of the biomass for striped venus clams and 56.52% of the biomass for wedge clams. These authors observed that 25.73% of these discards had severe damage or were killed, while 11.11% presented minor or partial damage. Typically, the species most impacted by the clam dredge fishing activity are fragile, infaunal species, with a soft-body/shell (Gaspar *et al.*, 2003; Gallardo-Roldán *et al.*, 2015; Urra *et al.*, 2017). The mortality of uncaught damaged and dead individuals dislodged and left in the dredge path has rarely been analyzed. Gas-

par *et al.* (2003) noted that an important proportion of these individuals were damaged (*i.e.* between 16.88% and 29.17% of severely damaged/dead individuals). A specific study is needed to examine the impact of worm bait dredges on benthic communities since all of these dredges have a closed mesh back and leave practically no discards. Expanding the fishing zone to 30 meters depth would undoubtedly improve fishery catches and economic benefits for fishermen. It would also allow an increase in the number of boats dedicated to this activity, and consequently the number of jobs.

The consumption of native worm bait species to meet the local recreational fisheries demand would decrease imports of non-indigenous polychaetes and, in doing so, would decrease the potential risk of introduction of invasive species. The use of non-indigenous live baits by anglers would contribute to the dispersal of these species along the coast. Imported live worm baits have been shown to be potentially invasive (Osman *et al.*, 2010). The release of unused live baits into coastal habitats is a common practice among the anglers, where they may consequently become established. As an example, the current presence of one of the most common species, the Korean ragworm (*Perineris linea*), has been described as invasive on the Mar Menor, southeastern Spain (also in the Western Mediterranean Sea). Moreover, imported live baits are typically traded in cardboard boxes, where the presence of non-bait organisms (*e.g.* isopods, amphipods, gastropods etc.) and pathogens has also been noted (Mackie & Chambers, 1990; Gillet & Dauvin, 2003; Fidalgo e Costa *et al.*, 2006). Although Sá *et al.* (2017) stated that there is a low risk of introduction and dissemination of associated hitchhiker species, some risk still remains.

In conclusion, we strongly recommend an ambitious scientific study before giving the green light to small-scale worm bait fishery activity, given that it could negatively impact benthic ecosystem health. If this future study shows low impact on the ecosystem, the worm bait fishery could be an excellent opportunity to revitalize the small-scale clam fishing sector on the Maresme coast and throughout the NW Mediterranean Sea. Moreover, it could reduce imports of non-indigenous polychaetes for recreational fisheries, which would be particularly beneficial given that these exotic species have been proven to be invasive.

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