DOI: 10.1111/fme.12255

ORIGINAL ARTICLE

WILEY Fisheries Management and Ecology

Combining fishers' knowledge and cost-effective monitoring tools in the management of marine recreational fisheries: A case study of the squid and cuttlefish fishery of the Ría of Vigo (NW Spain)

S. Palas[1] | S. Villasante[2] | P. Pita[2]

[1]Rúa Salgado, Vigo, Spain

[2]Department of Applied Economics, Faculty of Economics and Business Administration, University of Santiago de Compostela, Santiago de Compostela, Spain

Correspondence
S. Palas, Rúa Salgado, Vigo, Spain.
Email: santi.palasotero@gmail.com

Funding information
Xunta de Galicia, Grant/Award Number: RECREGES Project; ED481B2014/034-0

Abstract

A new methodology based in the use of fishers' knowledge and cost-effective tools to obtain information about marine recreational fisheries (MRF) is presented. The squid and cuttlefish fishery of the Ría of Vigo (NW Spain) was selected because it is managed in a data-poor environment. In-depth interviews (57) were conducted with fishers, collecting ecological and socio-economic information. A cartography of fishing grounds based on their knowledge was obtained, while the intensity of effort and catches was mapped by the monitoring of two vessels with low-cost GPS data loggers. The 102 shore anglers and 248 recreational boats catch 8 t/year of European squid *Loligo vulgaris* and 11 t/year of common cuttlefish *Sepia officinalis* (11% of total catches on these species in the area). Shore anglers fish from 11 ports, while boat fishers use 14 fishing grounds (covering 30 km^2). Most of the catches (86%) are landed by boats, and their CPUE is higher in the outer part of the Ría of Vigo. The use of fishers' knowledge and cost-effective monitoring is encouraged to obtain information for the management of MRF. Given the economic contribution of MRF (260,000 €/year in direct expenses), this activity should be considered in the regulations.

KEYWORDS
cephalopods, fisheries assessment, fishers' knowledge, GIS, GPS data loggers, marine recreational fisheries

1 | INTRODUCTION

Recreational fishing has a significant effect on marine ecosystems, especially on coastal ecosystems, where, in many cases, it competes for space and resources with commercial fisheries (Cooke & Cowx, 2006; Lewin, Arlinghaus & Mehner, 2006). Although poorly studied, the high socio-economic relevance of recreational fisheries justifies it is taken into consideration by the managers of public resources (Arlinghaus, 2006; Cooke & Cowx, 2006). Marine recreational fishing is practiced by 9 million European citizens (2% of the population) and annually generates €6 billion in direct expenditures (K. Hyder, personal communication.).

Overall, despite its ecological, social and economic relevance, marine recreational fisheries (MRF) have been little studied in Europe (Pawson, Glenn & Padda, 2008), probably because academics and policy makers have been historically more interested in industrial fisheries (Cycon, 1986; Platteau, 1989; Weeratunge et al., 2014).

Recently, the current European Common Fisheries Policy (European Parliament and Council of the European Union, 2013) has promoted the integrated management of marine ecosystems and fishery resources (European Parliament and Council of the European Union, 2008). Therefore, EU member States must manage MRF in a sustainable manner, providing information on its impacts on marine ecosystems (Council of the European Union, 2008, 2009). Unfortunately,

European funds covering the collection of information necessary for the sustainable management of MRF (Council of the European Union, 2006) only affect those species under the regulation of total allowable catches (Council of the European Union, 2016). Therefore, most of the species captured by MRFs are de facto excluded from these European funding programmes. This lack of funding affects research and, consequently, informed management initiatives at all administrative levels.

In this context, fishers' knowledge is an alternative source of information (Hind, 2014; Stephenson et al., 2016), especially valid for the management of data-poor fisheries (Neis et al., 1999). In particular, mapping based on fishers' knowledge can provide valuable information complementary to traditional scientific knowledge (e.g., Anuchiracheeva, Demaine, Shivakoti & Ruddle, 2003; Aswani & Lauer, 2006; Close & Hall, 2006; Pita, Fernández-Vidal, García-Galdo & Muíño, 2016). However, to date, the use of fishers' knowledge has been poorly integrated in modern fisheries management (Huntington, 2000; Silvano & Valbo-Jørgensen, 2008; Stephenson et al., 2016), while its use in the management of MRF is anecdotal (Hind, 2014). This paper presents the use of fishers' knowledge as method to obtain key information for the sustainable management of MRF under data-poor environments, as is the case of many European countries.

Although Galicia (NW Spain) has a strong tradition and economic dependence on fisheries (Villasante et al., 2016), and the management of coastal fisheries, both commercial and recreational, is carried out in a typical data-poor environment (Arnáiz, 2001; Macho, Naya, Freire, Villasante & Molares, 2013; Molares & Freire, 2003). The Galician coastal fleet consists of 4,300 commercial vessels (Xunta de Galicia, 2016a), which use a relatively narrow continental shelf, that is rich in fisheries resources (Freire & García-Allut, 2000). Commercial fishers in Galicia usually share space and their currently impoverished fisheries resources (Pita & Freire, 2014) with a well-established MRF of about 60,000 fishers (Pita & Freire, 2016). One particular recreational fishery targeting squid *Loligo* spp. and cuttlefish *Sepia* spp., a very important fishery in other Spanish regions (Cabanellas-Reboredo, Alós, Palmer & Morales-Nin, 2012; Cabanellas-Reboredo, Palmer, Alós & Morales-Nin, 2017; Zarauz et al., 2013), has not yet been studied in Galicia. This paper examines this recreational fishery as a case study to investigate the use of fishers' knowledge as a cost-effective monitoring tool (Pita et al., 2016) to obtain critical information currently lacking about MRF to be used in integrated management of coastal ecosystems.

2 | MATERIALS AND METHODS

2.1 | Study area

Fishing for squid and cuttlefish is carried out in the Galician rías (Guerra & Castro, 1988; Simón, Rocha & Guerra, 1996) when these cephalopods arrive to reproduce (Cabanellas-Reboredo, Alos, Palmer, March & O'Dor, 2012; Cabanellas-Reboredo et al., 2014; Castro & Guerra, 1990). The Ría of Vigo (Figure 1) was selected as a study area because the biology of both squid and cuttlefish has been well studied (Castro & Guerra, 1990; Guerra & Castro, 1988; Otero et al., 2015). In addition, this area traditionally supports an intense MRF (Pita & Freire, 2014) that coexists with commercial fisheries for squid (Simón et al., 1996) and cuttlefish (Guerra & Castro, 1988), which will allow comparisons between both types of fisheries.

The Ría of Vigo has a length of 35 km and a width that varies between 12 km in its outer edge and less than 1 km in the Strait of Rande (Méndez & Vilas, 2005; Otero, 1926). The maximum depth of the central channel is 60 m in the outer part, while the average depth in its internal part, the San Simón Cove, is only 7 m (Méndez & Vilas, 2005).

2.2 | Collecting and using recreational fishers' knowledge

In-depth semi-structured interviews were conducted between September and November 2014, with key local informants selected among the recreational fishers operating in the study area to collect

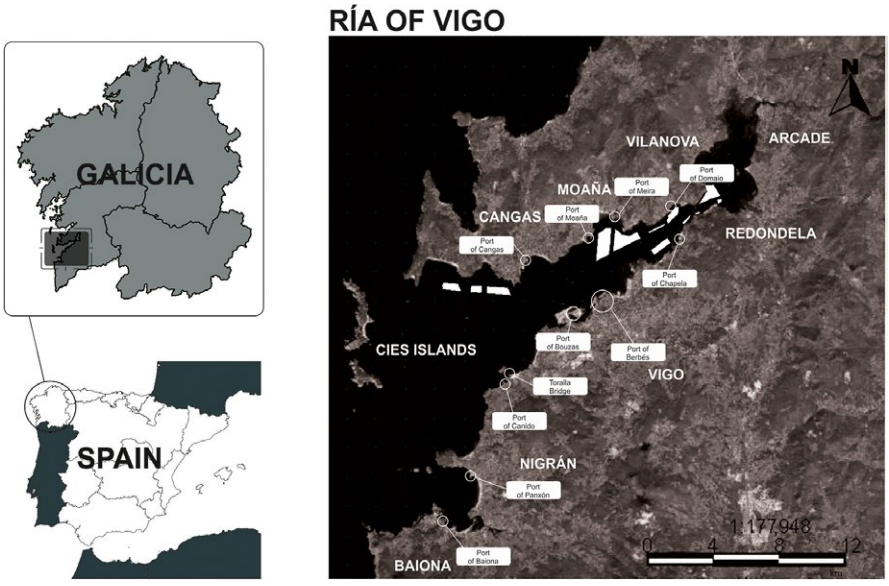

FIGURE 1 Study area of the Ría of Vigo. Main port facilities and human populations of the area are showed. Location of mussel farms is indicated by white polygons. [Colour figure can be viewed at wileyonlinelibrary.com]

ecological, social and economic information from the MRF for squid and cuttlefish. The informants were chosen following a snowball model (Goodman, 1961), starting with a small group of initial informants and expanding their numbers through their contacts and social networks. In this way, the different ports and access points of the fishers in the study area were also identified. During the interviews, the fishers reported the mean number of fishers and boats operating at each of the access points, their personal circumstances, their seasonal fishing cycle, annual catches and expenditures, and on the factors that influence their activity.

In addition, the fishers sketched their fishing grounds for each species on a nautical chart of the study area (following Pita & Muiño, 2014). The spatial information provided by the fishers was digitised and introduced into independent layers in GIS using ArcGIS 10.2.2 software (ESRI, 2015). The layers obtained from each of the fishers were added into a single layer for each species, but the zones in which two or more fishers agreed on the distribution of their fishing areas were also represented in the final cartography of the fishing grounds by species in the study area (Pita et al., 2016).

2.3 | Monitoring the squid and cuttlefish recreational boat fishery

A voluntary monitoring of the recreational boat fishery for squid and cuttlefish was carried out in the study area during the mentioned period of time. To achieve this, key experts with the highest degree of experience (years of fishing) in the fishery were identified among the fishers previously interviewed to collect their knowledge.

The fishers that agreed to participate in the monitoring programme provided key information currently lacking about their catch by species (in kg) in each of the fishing locations. The information was delivered in daily hand-written fishing logbooks that included the time spent in each location and the number of fishing lines. Thereafter, the information was digitised into a database integrated by the CPUE (kg/line-hr) of each of the fishing locations.

In addition, small (46.0 × 41.5 × 14.0 mm), simple, low-cost and portable (37 g) i-gotU GT-600 GPS data loggers were used to record the position of the boats every minute, throughout each fishing journey. After each fishing journey, data were downloaded and integrated into the database. The GPS tracks were mapped using ArcGIS 10.2.2 (ESRI, 2015) software. Transmission errors, records on land and at the ports of the area were excluded from the database.

Fishing and non-fishing activities were differentiated through the analysis of the speed of the boats following the methodology of Pita et al. (2016). The speed was calculated as the lineal distance separating consecutive GPS records, divided by the elapsed time between them. Thus, a cut-off level of 3 km/hr was estimated for the fishing activities by analysing the overall speed frequency distribution with the density tool in the R statistical software version 3.1.0 (R Core Team, 2015). Once the fishing locations of each journey were mapped, the CPUE reported by the fishers for each location was distributed equally among all of the GPS positions of the location. Subsequently, the distribution of the intensity of effort of the boats was obtained by counting the number of GPS positions of the fishing locations in 500 × 500 m grid cells using ArcGIS 10.2.2 (ESRI, 2015). Likewise, the distribution of CPUE by species was obtained by adding the CPUE associated to the GPS positions included in the 500 × 500 m grid cells.

3 | RESULTS

3.1 | Demographic, economic and ecologic features of the recreational squid and cuttlefish fishery in the Ría of Vigo

Most of the recreational shore anglers (≈80%) and half of the boat fishers (≈50%) who were asked to participate in this study agreed to answer the questions raised by the researchers. Thus, 42 interviews were carried out with shore anglers at 11 access points (port facilities) and 15 interviews were carried out with boat fishers based on six ports in the study area (Figure 1). The interviews lasted from 30 to 60 min, mainly depending on the differences in the expert knowledge of the working zones shown by each of the interviewed fishers.

The recreational fishers interviewed were mostly men (93% of the shore anglers and all boat fishers) with a medium level of education (they reported a mean of 2.07 ± 0.91 *SD*, where 1 = primary education and 5 = University PhD). Due to their relatively high mean age, 52.29 ± 14.11 years for shore fishers and 57.47 ± 8.11 years for boat fishers, many were already retired (14% and 53%, respectively). Their mean fishing experience was also high, 21.10 ± 17.05 and 37.0 ± 16.08 years, respectively.

Mean annual expenditure on fishing materials, travel and fishing permits declared by shore anglers fishing for squid (249 ± 426 €) was similar to that declared by shore anglers targeting cuttlefish (285 ± 163 €; Table 2). By contrast, due to the maintenance costs of their boats, mean annual expenditure of boat fishers targeting squid and cuttlefish was much higher (918 ± 659 € and 976 ± 648 €, respectively; Table 2). In addition, the mean acquisition cost of the recreational boats, generally of small size (4.96 ± 1.11 m in length) and low power (34.6 ± 36.9 CV), was 6,171 ± 4,549 €. Taking into account the mean number of shore anglers and boats (Table 1), and their mean expenses (Table 2), it was estimated that direct annual economic inputs from the recreational fishers of the Ría of Vigo reach 262,134 €. Most (90%) of this economic value comes from boat fishers (Table 2).

Recreational fishers reported that they mainly catch European squid *Loligo vulgaris* Lamarck and common cuttlefish *Sepia officinalis* L. in the Ría of Vigo, and very rarely other species of cephalopods, such as long-finned squid *Loligo forbesii* Steenstrup, elegant cuttlefish *Sepia elegans* Blainville, African squid *Alloteuthis media* (L.) and midsize squid *A. subulata* (Lamarck). The informants also reported that they operate in the same area as some recreational boat fishers and spear fishers who target common octopus *Octopus vulgaris* Cuvier.

Shore anglers indicated that they fish throughout the year (Figure 2), as they mainly operate in areas that are easily accessible with anchoring facilities protected from the waves (Figure 1). They fish at these facilities arriving at dusk or night (usually between 21.00 and 22.00 p.m.), preferably in areas with artificial lighting, and leave

TABLE 1 Mean number of shore anglers and boats (and *SD*) by species and fishing ground estimated for the Ría of Vigo

	Shore anglers (*N* ± *SD*)		Boats (*N* ± *SD*)	
Fishing ground	**Squid**	**Cuttlefish**	**Squid**	**Cuttlefish**
San Simón Cove				50.00 ± 0.00
Rande				7.00 ± 0.00
Chapela	8.20 ± 0.87			
Domaio	10.00 ± 0.00			10.00 ± 0.00
Meira	7.00 ± 0.00			
Berbés	10.00 ± 1.36			
Moaña (port)	8.13 ± 0.75			
Moaña (Con do Pego)				30.00 ± 0.00
Bouzas	7.00 ± 0.86			
Cangas (port)	5.83 ± 0.51			
Cangas (Salgueirón)				8.00 ± 0.76
Cangas (Borneira)				16.00 ± 1.51
Cangas (Liméns)				8.67 ± 0.87
Cangas (Nerga)				12.50 ± 0.94
Bao			10.47 ± 3.58	8.67 ± 2.08
Toralla bridge	23.50 ± 5.53	2.50 ± 0.11		
Canido	2.00 ± 0.00		6.25 ± 0.58	5.50 ± 0.19
Panxón	7.40 ± 0.57		16.50 ± 3.24	
Monteferro			23.33 ± 2.18	
Baiona	10.60 ± 1.78		25.00 ± 3.27	
Cíes Islands			10.00 ± 0.00	

The fishing grounds have been ordered according to their geographical situation in the Ría de Vigo; from internal to external.

TABLE 2 Recreational fishing effort and annual catches (and *SD*) by species and recreational fishing modality estimated for the Ría of Vigo

		Fishing effort		Annual catch		Annual expenses (€)	
Modality	**Species**	**Days per year**	**Hours per day**	**Per fisher/ boat (kg)**	**Total (t)**	**Per fisher/boat**	**Total**
Shore angling	Squid	139.52 ± 86.52	4.40 ± 1.36	25.36 ± 33.81	2.53 ± 3.74	249.05 ± 426.36	24,820 ± 46,745
	Cuttlefish	102.00 ± 34.93	4.00 ± 0.71	12.50 ± 12.01	0.03 ± 0.03	285.00 ± 163.10	713 ± 457
Boat fishing	Squid	69.27 ± 40.38	5.60 ± 0.83	41.43 ± 25.83	5.06 ± 1.21	917.50 ± 658.98	83,997 ± 72,090
	Cuttlefish	53.22 ± 14.61	–	54.17 ± 36.93	11.29 ± 3.29	976.15 ± 647.89	152,605 ± 107,420

between 02.00 and 03.00 a.m. Up to 90% of shore anglers targeting squid operate through the summer and autumn, while 73% operate in winter and 69% in spring (Figure 2).

Temporal variations in fishing of shore anglers targeting cuttlefish were also little influenced by season, with autumn being the least favoured season by fishers (67%) and in winter 100% fished (Figure 2). Conversely, recreational boat fishing is very seasonal: only 10% of boat fishers targeting squid and 27% of boat fishers targeting cuttlefish fished during the spring, whereas up to 90% of fishers targeting squid and 77% targeting cuttlefish fished in autumn (Figure 2). Due to the prohibition of fishing by boat during the night (Xunta de Galicia, 2009), the regular schedule for their operations is from 07.00 a.m. to 13.00 p.m.

From the information provided by the fishers in the interviews, it was estimated that 99.7 ± 6.3 shore anglers targeting squid and only 2.5 ± 0.1 shore anglers targeting cuttlefish operate regularly in the Ría of Vigo (Table 1). The fishing grounds of anglers targeting squid were homogeneously distributed throughout the study area, while the shore-based cuttlefish fishery is concentrated in a single fishing ground (Table 1). Accordingly, it was estimated that 91.6 ± 7.5 boats fish for squid and 156.3 ± 3.8 target cuttlefish in the area (Table 1). The boats fishing for squid were mainly distributed around fishing grounds located in the outermost part of the Ria of Vigo while the boats targeting cuttlefish use fishing grounds mostly in the inner part of the ría (Table 1).

Although their fishing journeys were somewhat shorter, annual fishing days reported for shore anglers was doubled that of

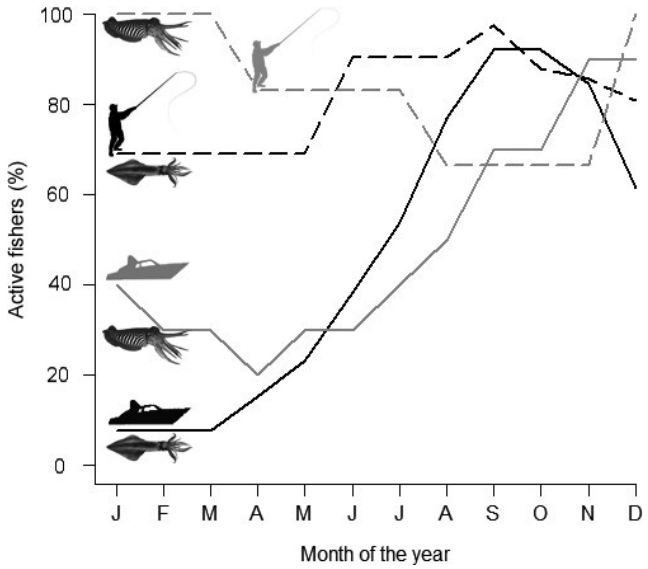

FIGURE 2 Annual temporal variation of recreational fishers for squid (in black colour) and cuttlefish (in grey colour) in the Ría of Vigo. Shore anglers (broken lines) and boat fishers (solid lines) are also showed

boat fishers (Table 2). Consequently, overall annual fishing effort for shore anglers fishing for squid (649.6 ± 505.6 h/year) and cuttlefish (400.0 ± 134.9 h/year) were higher than that of the boat fishers fishing for squid (391.9 ± 242.0 h/year); no information for boat fishers targeting cuttlefish was obtained. The annual catches per fisher declared in the interviews by shore anglers targeting squid and cuttlefish were lower than that reported by boat fishers (Table 2).

Taking into account the mean number of anglers and boats fishing in the Ría of Vigo (Table 1) and their mean catch (Table 2), it was estimated that 7.58 t of squid and 11.32 t of cuttlefish are caught annually in the area by recreational fishers. Most of the squid (67%) and almost all the cuttlefish (99.7%) were taken by boat fishers (Table 2).

3.2 | Using recreational fishers' knowledge to identify the modalities of the fishery

According to the perception of the recreational fishers interviewed, the health of their fishery is not good. They consider the abundance of cephalopods has been decreasing in the Ría of Vigo during the last decades (they reported a mean of 4.25 ± 0.48, where 1 = strong increase and 5 = strong decrease).

Among the variables that influence the recreational catches, the fishers stated that the temperature of the water (59% of the fishers), the availability of food (38%) and the moon phase (28%) are of great relevance for their activity (the moon phase is not relevant for boat fishers because they only operate during the day). To a lesser extent, other factors like the strength of the currents (15%), the rain (13%), the state of the tide (11%), the turbidity of the water (7%), the avidity for the lures (6%), the activity of predators (5%) and the overfishing of the area (4%) also influence their catches (Figure 3). Notably, the type of substrate is of great importance for boat fishing, especially when fishing for cuttlefish (100% of the fishers), whereas the zone of fishing has a relatively high relevance for boat fishers fishing for cuttlefish (70%) and somewhat lower for boat fishers fishing for squid (23%; Figure 3).

3.3 | Using recreational fishers' knowledge in the mapping of their fishing grounds

Through the mapping of recreational fisheries, shore anglers indicated 11 fishing grounds located in the main port facilities of the Ría of Vigo (Figure 4a), while the boat fishers indicated that they operate over a fishing area of 29.95 km^2. In this fishing area, boat fishers identified 12 fishing grounds for squid over an area of 27.25 km^2 located in the middle and outer zone of the Ría of Vigo. Boat fishers also identified 10 fishing grounds for cuttlefish over an area of 24.81 km^2, distributed in the inner zone of the study area (Figure 4b).

3.4 | Monitoring the squid and cuttlefish recreational boat fishery

A fishing monitoring programme for MRF was performed by two of the boat fishers operating in the Ría of Vigo. These fishers provided complete information on CPUE and GPS positions of 18 fishing journeys performed between October and December 2014 in the study area. Fishers visited, on average, 2.32 ± 1.42 fishing locations per fishing journey, and they reported 16.70 kg of squid and 72.90 kg of cuttlefish in the logbooks, with a yield of 0.06 ± 0.08 kg/line-hr for squid and 0.45 ± 0.29 kg/line-hr for cuttlefish. Based on the information on the fishing journeys provided by the fishers, the intensity of the fishing effort was greater around the mussel farms of the northwest coast (Cangas) than in other fishing grounds of the Ría of Vigo

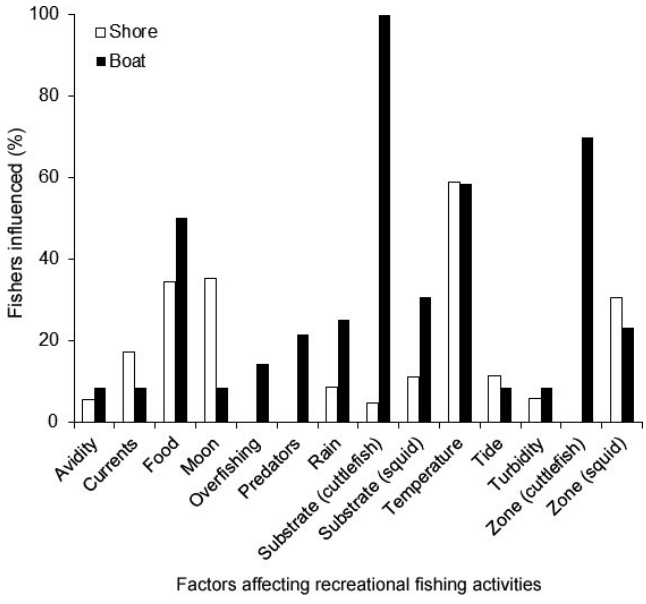

FIGURE 3 Modulators by fishing modality of the squid and cuttlefish recreational fishery in the Ría of Vigo

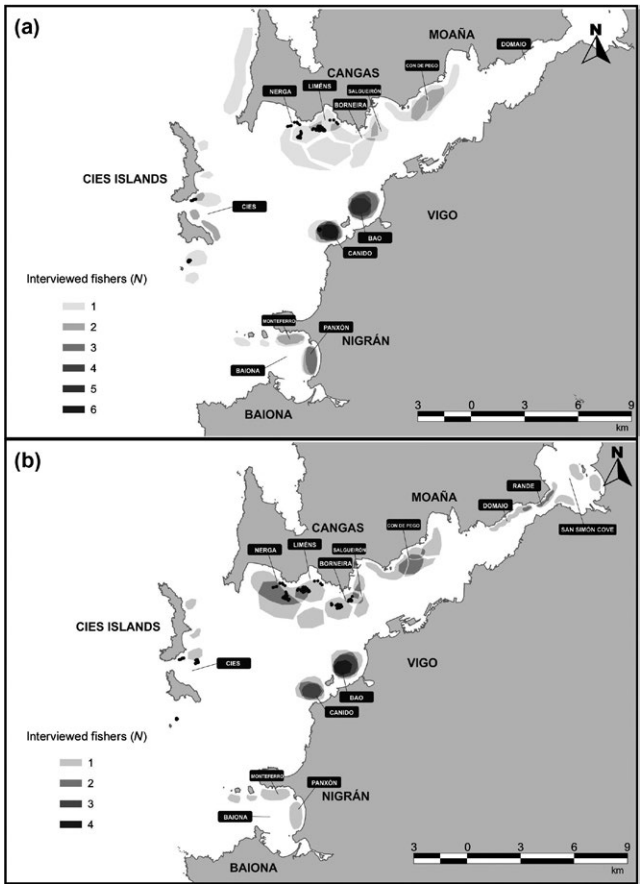

FIGURE 4 Recreational fishing grounds of squid (a) and cuttlefish (b) in the Ría of Vigo, based on the fishers' knowledge. The number of informants for each of the identified areas is also indicated

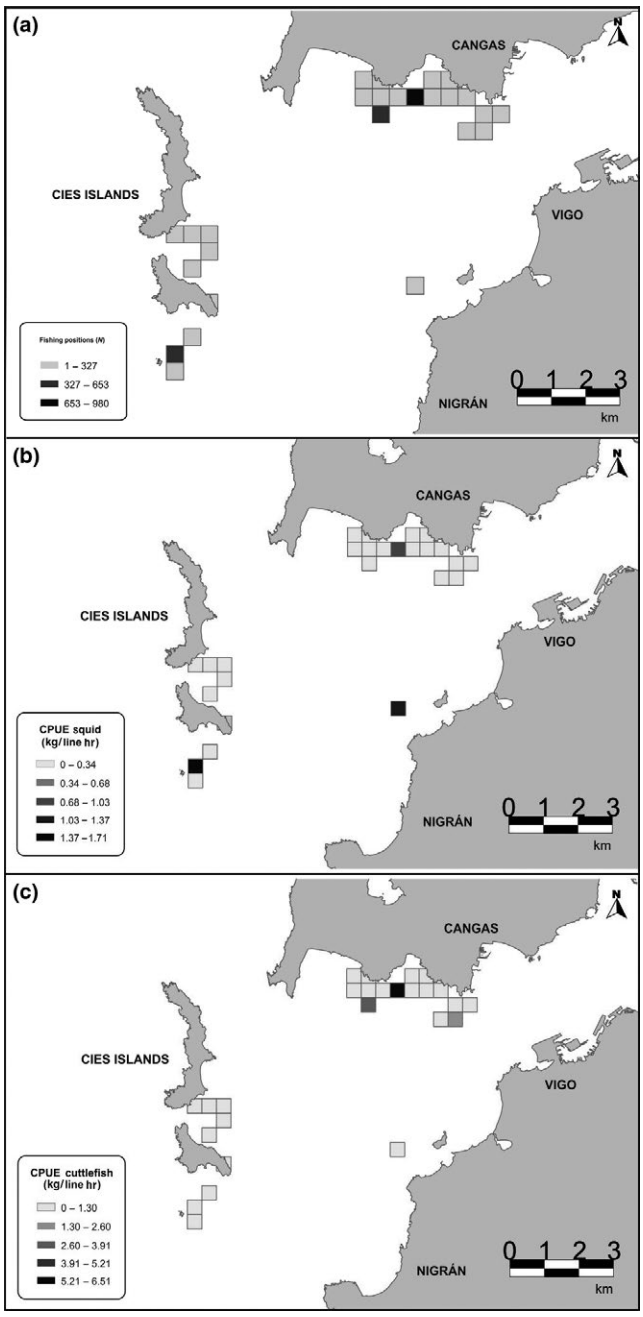

FIGURE 5 Distribution of fishing effort as the number of fishing positions for squid and cuttlefish obtained in on-board GPS data loggers by 500 × 500 m cells (a), and estimated CPUE (kg/line-hr) of squid (b) and cuttlefish (c) obtained in on-board GPS data loggers by 500 × 500 m cells

(Figure 5a). The catches of cuttlefish were also higher in the fishing grounds of Cangas, where they reached up to 6.51 kg/line-hr, while catches of squid were higher in the outer part of the Ría of Vigo, that is the Cíes Islands and Canido, where they achieved up to 1.71 and 1.27 kg/line-hr, respectively (Figure 5b).

4 | DISCUSSION

Some of the estimates derived from the information collected in the interviews (effort, catches and expenditures) could be influenced by typical biases of recreational fisheries surveys (i.e. recall, representativeness, non-response and declaration) and should be treated with care. Furthermore, due to the low participation, the effort and CPUE distribution obtained in the fisheries monitoring programme could be affected by differences between fishers (see Cabanellas-Reboredo et al., 2017). However, the sampling design followed in this study identified both the main key informants and their access points. Thus, approximately 16% of the recreational fishers operating in the Ría of Vigo were interviewed (Table 1). Also, the number of interviews performed ($N = 57$) is well above the number of interviews (≈20) from which the results of in-depth questionnaires do not usually improve significantly (Morgan, 2002; Tashakkori & Teddlie, 2010). In addition, the result of the fisheries monitoring (Figure 5) was coincident with the cartography of the fishing grounds obtained in the interviews with maps (Figure 4). Consequently, the results are considered consistent and representative of the squid and cuttlefish fishery in the Ría of Vigo.

As in nearby regions (Cabanellas-Reboredo, 2014; Rangel & Erzini, 2007; Zarauz et al., 2013), this recreational fishery has important social, economic and ecological implications for the coastal ecosystems and people living on them. Indeed, its impact on the

fishing stocks is comparable to similar fisheries in the north of Spain (Cabanellas-Reboredo, Alós, Palmer & Morales-Nin, 2012; Zarauz et al., 2013). Annual catches (estimated in 19 t; Table 2) represent 11% of total catches in the area (13% of landed squid and 10% of cuttlefish), based on mean annual commercial landings (for the period 2013–2015) in the ports of the area are 55 t for squid and 101 t for cuttlefish (Xunta de Galicia, 2016a). Consequently, this fishery should be assessed in-depth, as suggested in this and nearby areas (Pita & Freire, 2016; Rangel & Erzini, 2007; Zarauz et al., 2015) and be managed in conjunction with commercial and other recreational fisheries.

It is also important to highlight that management of these fisheries is conditioned by the seasonality of the life cycle of squid (Cabanellas-Reboredo, Alos, Palmer, March & O'Dor, 2012; Cabanellas-Reboredo, Alós, Palmer & Morales-Nin, 2012; Moreno, da Cunha & Pereira, 1994) and cuttlefish (Guerra, 2006a; Guerra & Castro, 1988), mainly related to their high rate of population renewal and reproductive behaviour (Otero et al., 2015; Roura et al., 2013; Sánchez & Martín, 1993). In particular, the complex reproductive cycle of European squid means this species is dependent on environmental conditions, which has important implications for fisheries management (González, Otero, Pierce & Guerra, 2010; Guerra, Allcock & Pereira, 2010; Roura et al., 2013). The peak abundance of squid in Galicia is between July and December (Guerra & Rocha, 1994), the same peak period for recreational fishers in this study (Figure 2), and also in nearby regions (Zarauz et al., 2013). In the Ría of Vigo, squid is more abundant in autumn and winter in the external part (Guerra, 1984), which is targeted by recreational boat fishers (Table 1, Figures 4 and 5a,b).

Juveniles of different cohorts but also adult breeding squid (Guerra, Rocha, Casas & Fernández, 1992; Rocha & Guerra, 1999) penetrate into the Ría of Vigo in spring and summer (Guerra, 1984). Shore anglers are active in these areas and seasons (Table 1, Figure 4), and, although their overall catch is lower than that of boat fishers (Table 2), they potentially target immature and spawning adults (Guerra et al., 1992). Thus, their activity should be regulated because factors influencing recruitment are particularly important in short-lived species such as squids, in which there is a complete turnover of biomass every 1–2 years (Guerra, 2006b).

By contrast, the recreational cuttlefish fishery is mainly carried out from boats (Tables 1 and 2). The peak season for boat fishers begins in summer, the period in which the mature cuttlefish migrate to the innermost areas to spawn (Guerra, 1984, 2006a; Guerra & Castro, 1988). Therefore, the temporary closures imposed in these areas (Xunta de Galicia, 2016b) are a positive management measure that could be applied in other areas relevant to the reproduction of this species.

Although individual expenditure is lower than that of recreational fishers of other regions of the north of Spain (Morales-Nin, Cardona-Pons, Maynou & Grau, 2015; Zarauz et al., 2013), the direct economic expenditure of shore anglers and boat fishers in the Ría of Vigo (more than 260,000 €/year) contributes significantly to the development of the local economy. This contribution should be recognised by policy makers and integrated into decision-making models for the regulation of public resources.

This fishery is carried out by middle-aged men, a quarter of whom are already retired. As in the Basque Country (N Spain), the proportion of retired people is especially high among boat fishers (Zarauz et al., 2013). As a consequence, fishers have been operating in the studied area for many years (25.3 ± 8.1 years) collecting an important knowledge of the area and species harvested. This expert fishers' knowledge, if properly collected and translated (see Close & Hall, 2006; FAO, 2013), can be used as an alternative information source to map fishing grounds (Figure 4) and to provide other useful evidence for fisheries management (Figure 3).

Fishers also pointed out that the substrate and the zone are important for the distribution of squid and cuttlefish (Figure 3). As shown by the distribution of the fishing grounds in the Ría of Vigo (Figure 4), cuttlefish select sandy substrata with seagrass meadows in the San Simón Cove (Guerra & Castro, 1988), while the presence of artificial substrates for spawning, like the mussel farms of Cangas, are important for squid (Cabanellas-Reboredo et al., 2014). Moreover, high fishing effort and CPUE were found in the proximity of mussel farms of Cangas (Figure 5).

Although a comparison of different methods to collect data on MRF could be of interest, it can be concluded that a combination of mapping fishing grounds based on fishers' knowledge and individual fisher monitoring tools is useful for the management of MRF in cases where official data are lacking. The use of these methods is therefore a cost-effective alternative to carrying out socio-ecological studies in larger areas to obtain reliable information that will facilitate sustainable management of the cephalopod fisheries, both from ecological and socio-economic perspectives.

ACKNOWLEDGMENTS

This research was funded by the Autonomous Government of Galicia, RECREGES project under Grant [ED481B2014/034-0]. We thank Ángel Guerra, from IIM-CSIC of Vigo, for the guidance provided in this work. We also thank the recreational fishers from the Ría of Vigo who provided information about their activity, and in particular to the fishers who participated in the fisheries monitoring.

ORCID

P. Pita http://orcid.org/0000-0001-9273-1481

REFERENCES

Anuchiracheeva, S., Demaine, H., Shivakoti, G. P., & Ruddle, K. (2003). Systematizing local knowledge using GIS: Fisheries management in Bang Saphan Bay, Thailand. *Ocean & Coastal Management*, *46*, 1049–1068.

Arlinghaus, R. (2006). Overcoming human obstacles to conservation of recreational fishery resources, with emphasis on central Europe. *Environmental Conservation*, *33*, 46–59.

Arnáiz, R. (2001). A revisión da Pesca de Baixura en Galicia. In M. Rey, J. Fernández, & M. Izquierdo (Eds.), *IV Foro dos Recursos Mariños e da Acuicultura das Rías Galegas (55–66)*. O Grove.

Aswani, S., & Lauer, M. (2006). Incorporating fishermen's local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania. *Human Organization*, *65*, 81–102.

Cabanellas-Reboredo, M. (2014). *Socio-ecological approach of the recreational squid fishery*. Palma de Mallorca: University of the Balearic Islands.

Cabanellas-Reboredo, M., Alos, J., Palmer, M., March, D., & O'Dor, R. (2012). Movement patterns of the European squid *Loligo vulgaris* during the inshore spawning season. *Marine Ecology Progress Series*, *466*, 133–144.

Cabanellas-Reboredo, M., Alós, J., Palmer, M., & Morales-Nin, B. (2012). Environmental effects on recreational squid jigging fishery catches. *ICES Journal of Marine Science: Journal du Conseil*, *69*, 1823–1830.

Cabanellas-Reboredo, M., Calvo-Manazza, M., Palmer, M., Hernández-Urcera, J., Garci, M. E., González, Á. F., … Morales-Nin, B. (2014). Using artificial devices for identifying spawning preferences of the European squid: Usefulness and limitations. *Fisheries Research*, *157*, 70–77.

Cabanellas-Reboredo, M., Palmer, M., Alós, J., & Morales-Nin, B. (2017). Estimating harvest and its uncertainty in heterogeneous recreational fisheries. *Fisheries Research*, *188*, 100–111.

Castro, B. G., & Guerra, Á. (1990). The diet of Sepia officinalis (Linnaeus, 1758) and Sepia elegans (D'Orbigny, 1835) (Cephalopoda, Sepioidea) from the Ría de Vigo (NW Spain). *Scientia Marina*, *54*, 375–388.

Close, C. H., & Hall, B. G. (2006). A GIS-based protocol for the collection and use of local knowledge in fisheries management planning. *Journal of Environmental Management*, *78*, 341–352.

Cooke, S. J., & Cowx, I. G. (2006). Contrasting recreational and commercial fishing: Searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation*, *128*, 93–108.

Council of the European Union. (2006). *On the European Fisheries Fund*. Brussels: Official Journal of the European Union.

Council of the European Union. (2008). *Concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy*. Brussels: Official Journal of the European Union.

Council of the European Union. (2009). *Establishing a Community control system for ensuring compliance with the rules of the common fisheries policy, amending Regulations (EC) No 847/96, (EC) No 2371/2002, (EC) No 811/2004, (EC) No 768/2005, (EC) No 2115/2005, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007, (EC) No 676/2007, (EC) No 1098/2007, (EC) No 1300/2008, (EC) No 1342/2008 and repealing Regulations (EEC) No 2847/93, (EC) No 1627/94 and (EC) No 1966/2006*. Brussels: Official Journal of the European Union.

Council of the European Union. (2016). *Fixing for 2016 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union fishing vessels, in certain non-Union waters, and amending Regulation (EU) 2015/104*. Brussels: Official Journal of the European Union.

Cycon, D. E. (1986). Managing fisheries in developing nations: A plea for appropriate development. *Natural Resources Journal*, *26*, 1–22.

ESRI. (2015). *ArcGIS Desktop*. Release 10.2.2. Redlands: Environmental Systems Research Institute.

European Parliament and Council of the European Union. (2008). *Establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)*. Brussels: Official Journal of the European Union.

European Parliament and Council of the European Union. (2013). *The Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC. 1380/2013*. Brussels: Official Journal of the European Union.

FAO (2013). Advances in geographic information systems and remote sensing for fisheries and aquaculture. In G. J. Meaden, & J. Aguilar-Manjarrez (Eds.), *FAO fisheries and aquaculture technical paper*. Rome.

Freire, J., & García-Allut, A. (2000). Socioeconomic and biological causes of management failures in European artisanal fisheries: The case of Galicia (NW Spain). *Marine Policy*, *24*, 375–384.

González, Á. F., Otero, J., Pierce, G. J., & Guerra, Á. (2010). Age, growth, and mortality of *Loligo vulgaris* wild paralarvae: Implications for understanding of the life cycle and longevity. *ICES Journal of Marine Science: Journal du Conseil*, *67*, 1119–1127.

Goodman, L. A. (1961). Snowball sampling. *The Annals of Mathematical Statistics*, *32*, 148–170.

Guerra, Á. (1984). Cefalópodos de la ría de Vigo. Resultados preliminares. *Seminario de estudios galegos*, *1*, 333–348.

Guerra, Á. (2006a). Ecology of *Sepia offcinalis*. *Vie et Milieu—Life and Environment*, *46*, 97–107.

Guerra, Á. (2006b). Estrategia evolutiva de los cefalópodos. *Investigación y Ciencia*, *355*, 50–59.

Guerra, Á., Allcock, L., & Pereira, J. (2010). Cephalopod life history, ecology and fisheries: An introduction. *Fisheries Research*, *106*, 117–124.

Guerra, Á., & Castro, B. G. (1988). On the life of *Sepia officinalis* (Cephalopoda, Sepioidea) in the Ria de Vigo (NW Spain). *Cahiers de biologie marine*, *29*, 395–405.

Guerra, A., & Rocha, F. (1994). The life history of *Loligo vulgaris* and *Loligo forbesi* (Cephalopoda: Loliginidae) in Galician waters (NW Spain). *Fisheries Research*, *21*, 43–69.

Guerra, A., Rocha, F., Casas, F., & Fernández, M. (1992). *Loligo vulgaris* and *Loligo forbesi* (Cephalopoda, Loliginidae): Their present status in Galician Fisheries. *ICES CM*: *40*.

Hind, E. J. (2014). A review of the past, the present, and the future of fishers' knowledge research: A challenge to established fisheries science. *ICES Journal of Marine Science: Journal du Conseil*, *169*, 341–358.

Huntington, H. P. (2000). Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications*, *10*, 1270–1274.

Lewin, W. C., Arlinghaus, R., & Mehner, T. (2006). Documented and potential biological impacts of recreational fishing: Insights for management and conservation. *Reviews in Fisheries Science*, *14*, 305–367.

Macho, G., Naya, I., Freire, J., Villasante, S., & Molares, J. (2013). The key role of the Barefoot Fisheries Advisors in the co-managed TURF System of Galicia (NW Spain). *Ambio*, *42*, 1057–1069.

Méndez, G., & Vilas, F. (2005). Geological antecedents of the *Rias Baixas* (Galicia, northwest Iberian Peninsula). *Journal of Marine Systems*, *54*, 195–207.

Molares, J., & Freire, J. (2003). Development and perspectives for community-based management of the goose barnacle (*Pollicipes pollicipes*) fisheries in Galicia (NW Spain). *Fisheries Research*, *65*, 485–492.

Morales-Nin, B., Cardona-Pons, F., Maynou, F., & Grau, A. M. (2015). How relevant are recreational fisheries? Motivation and activity of resident and tourist anglers in Majorca. *Fisheries Research*, *164*, 45–49.

Moreno, A., da Cunha, M. M., & Pereira, J. M. (1994). Population biology of veined squid (*Loligo forbesi*) and European squid (*Loligo vulgaris*) from the Portuguese coast. *Fisheries Research*, *21*, 71–86.

Morgan, M. G. (2002). *Risk communication: A mental models approach*. Cambridge, NY: Cambridge University Press.

Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fischer, J., & Hutchings, J. A. (1999). Fisheries assessment: What can be learned from interviewing resource users? *Canadian Journal of Fisheries and Aquatic Sciences*, *56*, 1949–1963.

Otero, R. (1926). *Guía de Galicia*. Vigo: Galaxia.

Otero, J., Salgado, X. A. Á., González, Á. F., Souto, C., Gilcoto, M., & Guerra, Á. (2015). Wind-driven upwelling effects on cephalopod paralarvae: *Octopus vulgaris* and loliginidae off the galician coast (ne atlantic). *Progress in Oceanography*, *141*, 130–143.

Pawson, M. G., Glenn, H., & Padda, G. (2008). The definition of marine recreational fishing in Europe. *Marine Policy*, *32*, 339–350.

Pita, P., Fernández-Vidal, D., García-Galdo, J., & Muíño, R. (2016). The use of the traditional ecological knowledge of fishermen, cost-effective tools and participatory models in artisanal fisheries: Towards the

co-management of common octopus in Galicia (NW Spain). *Fisheries Research*, *178*, 4–12.

Pita, P., & Freire, J. (2014). The use of spearfishing competition data in fisheries management: Evidence for a hidden near collapse of a coastal fish community of Galicia (NE Atlantic Ocean). *Fisheries Management and Ecology*, *21*, 454–469.

Pita, P., & Freire, J. (2016). Assessing the impact of spear fishing by using competitions records and underwater visual census. *Scientia Marina*, *80*, 27–38.

Pita, P., & Muiño, R. (2014). Participatory mapping. In S. Raicevich, S. Mackinson, R. Magudia, K. Borrow, & T. Maxwell (Eds.), *Methodological toolbox. Experience and tools for participatory actions in research and decision-making* (pp. 24–27). Lowestoft: Centre for Environment Fisheries and Aquaculture Science.

Platteau, J. P. (1989). The dynamics of fisheries development in developing countries: A general overview. *Development and Change*, *20*, 565–597.

R Core Team. (2015). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing.

Rangel, M. O., & Erzini, K. (2007). An assessment of catches and harvest of recreational shore angling in the north of Portugal. *Fisheries Management and Ecology*, *14*, 343–352.

Rocha, F., & Guerra, A. (1999). Age and growth of two sympatric squid *Loligo vulgaris* and *Loligo forbesi*, in Galician waters (north-west Spain). *Journal of the Marine Biological Association of the UK*, *79*, 697–707.

Roura, Á., Álvarez-Salgado, X. A., González, Á. F., Gregori, M., Rosón, G., & Guerra, Á. (2013). Short-term meso-scale variability of mesozooplankton communities in a coastal upwelling system (NW Spain). *Progress in Oceanography*, *109*, 18–32.

Sánchez, P., & Martín, P. (1993). Population dynamics of the exploited cephalopod species of the Catalan Sea (NW Mediterranean). *Scientia Marina*, *57*, 153–159.

Silvano, R. A., & Valbo-Jørgensen, J. (2008). Beyond fishermen's tales: Contributions of fishers' local ecological knowledge to fish ecology and fisheries management. *Environment, Development and Sustainability*, *10*, 657–675.

Simón, F., Rocha, F., & Guerra, A. (1996). The small-scale squid hand-jig fishery off the northwestern Iberian Peninsula: Application of a model based on a short survey of fishery statistics. *Fisheries Research*, *25*, 253–263.

Stephenson, R. L., Paul, S., Pastoors, M. A., Kraan, M., Holm, P., Wiber, M., … Benson, A. (2016). Integrating fishers' knowledge research in science and management. *ICES Journal of Marine Science: Journal du Conseil*, *73*, 1459–1465.

Tashakkori, A., & Teddlie, C. (2010). *Sage handbook of mixed methods in social & behavioral research*. London: Sage.

Villasante, S., Pita, C., Pierce, G. J., Guimeráns, C. P., Rodrigues, J. G., Antelo, M., … Sumaila, U. R. (2016). To land or not to land: How do stakeholders perceive the zero discard policy in European small-scale fisheries? *Marine Policy*, *71*, 166–174.

Weeratunge, N., Béné, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E. H., … Badjeck, M. C. (2014). Small-scale fisheries through the well-being lens. *Fish and Fisheries*, *15*, 255–279.

Xunta de Galicia. (2009). *Orde do 17 de setembro de 2009 pola que se desenvolve o Decreto 211/1999, do 17 de xuño, polo que se regula a pesca marítima de recreo*. Santiago de Compostela: Diario Oficial de Galicia.

Xunta de Galicia. (2016a, January 2017). *Pesca de Galicia* [Estadísticas oficiales de pesca de la Xunta de Galicia]. Available at http://www.pescadegalicia.gal.

Xunta de Galicia. (2016b). *Resolución de 11 de xullo de 2016 da Dirección Xeral de Pesca, Acuicultura e Innovación Tecnolóxica, pola que se establece un período de veda na ría de Vigo para a captura do choco*. Santiago de Compostela: Diario Oficial de Galicia.

Zarauz, L., Prellezo, R., Mugerza, E., Artetxe, I., Roa, R., Ibaibarriaga, L., & Arregi, L. (2013). *Análisis de la flota recreativa y de su impacto socioeconómico y pesquero en Euskadi*. Herrera Kaia: AZTI-Tecnalia.

Zarauz, L., Ruiz, J., Urtizberea, A., Andonegi, E., Mugerza, E., & Artetxe, I. (2015). Comparing different survey methods to estimate European sea bass recreational catches in the Basque Country. *ICES Journal of Marine Science: Journal du Conseil*, *72*, 1181–1191.

How to cite this article: Palas S, Villasante S, Pita P. Combining fishers' knowledge and cost-effective monitoring tools in the management of marine recreational fisheries: A case study of the squid and cuttlefish fishery of the Ría of Vigo (NW Spain). *Fish Manag Ecol*. 2017;24:469–477.
https://doi.org/10.1111/fme.12255