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UNIVERSIDADE DO ALGARVE

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Mestrado em Biologia Marinha

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Declaração de autoria de trabalho

Declaro ser o(a) autor(a) deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída

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Abstract

Marine recreational fishing has a great diversity of activities which can be linked to one another. Such is the case of shore-based angling and the use and harvest of live bait. The quantity and economic value referring to this activity is unsupervised in many parts of the world, especially in Europe, creating a "parallel economy" difficulting the assess of these characteristics. Most of these resources are marine polychaetes, but significant use and harvest of small crustaceans and sipunculids for their use in marine recreational fishing is observed globally. As several taxonomic groups are used all over the world, this study aimed to explore the preference, perceptions, quantities and expenditures of marine recreational rod shore-based anglers on live bait species, destined to increase the information needed to better understand the ecologic and socioeconomic impacts and help the development of management measures that can ensure the sustainability of harvesting activity. Interviews to rod shore-based anglers in main fishing location around the Algarve were conducted during summer months and was found that anglers preferred the use of both native and exotic live bait in their recreational fishing activity, mainly the *Diopatra neapolitana*, *Perinereis sp.*, and *Solen marginatus* mostly obtained through local live bait shops. Extrapolation of direct expenses on live bait was estimated to be approximately 2.2 million €, of which comprised around 1.2 million € of native polychaete marine worms, 354000 € of the exotic *Perinereis sp.*, 290000 € of *S. marginatus*, and 200000 € ghost shrimps (*Upogebia sp.*). The results of this study indicate that polychaete harvesting should be given equivalent attention to other fisheries, the need of research on the biology and densities of the most used polychaetes in Ria Formosa lagoon, efforts to provide updated information to recreational anglers and the continuous assessment of the live bait harvesting activity.

Keywords: Marine recreational fishing; Live bait; Polychaete worms; Shore-based angling; Live bait harvesting; Direct expenditure.

Resumo

A pesca recreativa de mar é uma actividade praticada por milhões de pessoas em todo o mundo. A importância cultural, social e economica desta actividade pode ser observada pela alta participação em certas zonas, proporcionando milhares de postos de trabalho e gastos economicos em diversas categorias entre os quais podem ser mencionados equipamentos, iscos, permissões, embarcações, combustível e acomodação. Devido à sobreexploração de certos stocks de recursos marinhos e com a degradação de seus habitats, conflitos entre a pesca comercial e recreativa são frequentes e sendo a pesca comercial normalmente mais mencionada por estes impactos negativos sobre as espécies alvo. Contudo, estudos que têm como foco a pesca recreativa começam a emergir com indicações que esta também pode ter impactos que ajudam à depleção de stocks de espécies de interesse comercial. No entanto, os impactos economicos e biológicos da pesca recreativa ainda não são integrados na gestão dos recursos. Das diferentes actividades referidas como pesca recreativa, a apanha de poliquetas encontra-se intrissicamente ligada a vários modos de pesca como a pesca costeira marinha, em que vários organismos como os poliquetas anelídeos, pequenos crustáceos e bivalves são usados como isco. Apesar de ser uma das categorias significativas no total gasto dos pescadores recreatvios nesta actividade, em muitas partes do globo a avaliação económica destes recursos é dificil de ser averiguada por raramente se encontrarem declarados com IVA, criando assim uma "economia paralela". O mesmo acontece em Portugal, e desde 2000 foram implementadas legislações que procuram regular a apanha de isco, mas devido à reduzida informação relativa à sua biologia e ecologia, estes recursos podem presentemente não ser regulados sustentavelmente. O aumento da procura de poliquetas para utilização de isco ou como ração em aquacultura levantou preocupações na comunidade científica e gestores de recursos devido ao risco de sobreexploração e impactos que a actividade de apanha e a utilização de iscos exóticos pode criar nos ecossistemas. Para uma melhor compreensão dos impactos ecologicos e socioeconomicos da apanha de isco vivo para a utilização na pesca recreativa de mar e para o desenvolvimento de medidas necessárias para assegurar a exploração sustentável desta actividade, este estudo teve como objectivo identificar as preferências, percepções de uso, gastos e quantidades usadas por pescadores recreativos em isco vivo na região do Algarve.

Para obtenção de dados, foram realizadas entrevistas pessoais a pescadores recreativos usando cana nas regiões de Faro, Albufeira, Quarteira, Vilamoura e Vila Real de Santo António, durante os meses de Verão de 2019 (inicio de Junho a final de Agosto) e foram obtidos 140 questionários válidos com informações relativas à pesca realizada em 2018. Dos dados obtidos foi realizada posteriormente uma extrapolação para a região do Algarve utilizando registos na literatura para o número de pescadores recreativos existentes nesta região. O questionário incluíu três temas principais: (i) experiência dos pescador, (ii) percepção da utilização e potenciais impactos de isco vivo, (iii) informação sociodemográfica do pescador.

A população de pescadores amostrada mostrou permanecer com as características sociodemograficas registadas em estudos passados sendo ainda caracterizada por ser maioritariamente constituída por pescadores masculinos (94.3%) com idade média de 51.6 anos. Pescam durante todo o ano e são profissionalmente activos com rendimento familiar mensal relativamente baixo. Praticam na sua grande maioria apenas pesca recreativa costeira de cana.

Relativamente à preferência de isco, o uso de poliquetas anelídeos ambos nativo e exótico foi o mais utilizado em conjunto com bivalves, maioritariamente obtido através de lojas de isco. As espécies mais utilizadas foram as poliquetas denominadas por Casulo (*Diopatra neapolitana*), a Koreana (*Perinereis sp.*) e o bivalve Lingueirão (*Solen marginatus*). Ente outros iscos usados podem ser realçados as poliquetas como o Parchal (*Marphysa sp.*), a Minhoca Branca (*Nephthys sp.*) e o pequeno crustáceo Ralo (*Upogebia pusilla*). De todas as espécies mencionadas pelos pescadores apenas as poliquetas Koreana, Americana (*Glycera dibranchiata*) e o sinpunculídeo denominado por Bibis ou Titas (*Sinpunculus sp. 2*) não são nativos de Portugal continental.

Os pescadores amostrados preferem o uso de isco vivo comparativamento a isco morto ou artificial sendo o principal motivo mencionado para esta escolha devido a melhores resultados na pesca, ou seja, maior eficácia na apanha do pescado. No entanto, os pescadores argumentam que a utilização dos diversos tipos de isco varia conforme a estação do ano, modalidade de pesca, espécies alvo da pescaria e os diferentes estados do seu ciclo de vida. A falta de conhecimento relacionado com a utilização de espécies exóticas de isco vivo é notório assim como o hábito de descartar isco não usado para o local de pesca e, por estes motivos, este estudo considera a população amostrada como um potencial vector de introdução de espécies exóticas e organismos ou patogénicos por estes associados. A importância de uma comunidade de pescadores bem informada deve

ser realçada, dado que proporciona aos pescadores a oportunidade de tomar decisões sustentáveis que podem simultaneamente beneficiar e salvaguradar a sua experiência de pesca recreativa.

O valor médio gasto anual em isco vivo pelos pescadores amostrados foi de 208.3 €, que realizam em média 52.1 saidas de pesca por ano, corresponedendo a uma valor médio gasto de 4 € por saída de pesca. Estes valores são semelhantes aos observados na Europa Ocidental variando em média entre 100 a 350 € anuais gastos em isco vivo. As espécies de isco vivo onde os pescadores do Algarve referiram gastar monetariamente mais foram o Casulo (*D. neapolitana*), a Koreana (*Perinereis sp.*) e o Lingueirão (*S. marginatus*), que quando extrapolados para a região do Algarve utilizando o preço de venda em lojas de isco Algarvias, correspondem a 432000 €, 354000 € e 290000 € em despesas directas anuais respectivamente. Outras espécies com valores significativos foram as poliquetas Minhoca Branca (*Nephthys sp.*) e Parchal (*Marphysa sp.*), e o pequeno crustáceo Ralo (*U. pusilla*) correspondendo a 318000 €, 256000 €, 200000 € em despesas directas anuais respectivamente. Foi calculado que aproximadamente 11.2 toneladas anuais de poliquetas nativas (*D.neapolitana*, *Marphysa sp.*, *Nephthys sp.*, *Hediste diversicolor* e *Halla parthnopeia*) foram utilizadas pelos pescadores recreativo da região do Algarve.

Este estudo conclui que a apanha de isco vivo e o seu uso na pesca recreativa de mar é uma actividade social e economicamente relevantes e que apesar dos esforços nos últimos 20 anos que levaram à caracterização desta actividade, informação relativa à biologia, ecologia e densidade das espécies usadas como isco vivo, assim como os impactos de apanha nas principais zonas de apanha como é o caso da Ria Formosa ainda são escassos. De modo a assegurar a exploração sustentada destes recursos, é sugerida a consideração de implementação de períodos de defeso rotativos em áreas de intensa apanha, esforços para informar os pescadores recreativos sobre potenciais impactos da utilização de isco vivo exótico e a contínua avaliação de dados relativos à pesca recreativa de mar assim como da actividade de apanha uma vez que o isco vivo são recursos que podem sofrer flutuações biológicas.

Palavras-Chave: Pesca recreative de Mar; Isco vivo; Poliquetas; Pesca recreativa costeira; Apanha de isco; Despesas diretas.

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Introduction

Marine recreational fishing (MRF) is an ancient activity practiced near the coastline all around the world. From the feeling of satisfaction and unwinding to connection to nature and challenging experiences, diverse are the reasons that motivate anglers to engage in recreational fishing (Arlinghaus et al. 2002; Hunt and Grado 2010). A global estimate of the number of marine recreational anglers is difficult, but is thought that there are almost 9 million in Europe generating mean annual expenses of around 6 € billion and creating thousands of jobs for this sector with recognized social and economic relevance (Arlinghaus et al. 2002; Toivonen et al. 2004; Armstrong et al. 2013; Hyder et al. 2018; Pita et al. 2018). Still, is believed that the number of recreational anglers is underestimated for many countries and the high participation rate for some regions show the social and cultural importance given by people to recreational fisheries (Arlinghaus et al. 2002; Toivonen et al. 2004; Monkman et al. 2015).

The decreasing of fish stocks and an overall increase in pressure on marine natural resources due to overexploitation (Zeller et al. 2008) and/or habitat degradation has caused conflicts between the recreational and commercial fisheries sectors (Tisdell 2003) that frequently compete for the same species (Cooke and Cowx 2006) and/or are in disagreement with some management restrictions applied to their own sector (Tisdell 2003). With the exception of a few countries such as USA and Australia, which divide quotas for some stocks between both recreational and commercial sectors (Ryan et al. 2016), MRF has always been neglected as there is a common perception that this activity is too small to be significant, especially when compared to commercial fisheries (Gartside et al. 1999; Cooke and Cowx 2004, 2006). However, as MRF data starts to emerge, it is becoming clear that for some target species, recreational fishing captures equal, or even surpass, its commercial counterparts (Gartside et al. 1999; Coleman et al. 2004; Morales-Nin et al. 2005; Zeller et al. 2008). This is relevant, since there are few studies focussing on MRF and this sector is not subject to long-term monitoring programs such as those targeting the commercial fisheries sector; as so its biological and economic impacts are not comprehensively integrated when management decisions are taken.

This shortage of knowledge extends not only to fishing effort and target species but also to other marine recreational fisheries activities such as the harvest of polychaete worms (for bait or aquaculture feeds) or the harvest of bivalves. In fact, harvest and purchase of live bait is intrinsically linked to some MRF activities such as shore based

fishing (Cunha et al. 2005; Fidalgo e Costa et al. 2006; Sá et al. 2017; Watson et al. 2017; Cole et al. 2018) and studies have shown that it can represent significant expenditure to recreational anglers (Henry and Lyle 2003; Armstrong et al. 2013; Font and Lloret 2014; Lovell et al. 2017; Hyder et al. 2018; Pita et al. 2018). Unfortunately, economic valuation of these resources is difficult to assess since sales are seldom declared for VAT purposes creating a "parallel economy" (Olive 1993; Cunha et al. 2005; Fidalgo e Costa et al. 2006; Carvalho et al. 2013a), and there is little knowledge with regard to species biology and population dynamics as well as little understanding of harvesting impacts on live bait species populations (Cole et al. 2018; Cabral et al. 2019).

The live baits used in MRF are mainly marine invertebrates where polychaetes appear to be the dominant taxonomic group, but other groups such as small crustaceans and sipunculids are also used frequently (Wynberg and Branch 1991; Brown 1993; Gambi et al. 1994; Hodgson et al. 2000; Henry and Lyle 2003; Cunha et al. 2005; Sypitkowski et al. 2008, 2009, 2010; Napier et al. 2009; Carvalho et al. 2013a, 2013b; Saito et al. 2014; Baust et al. 2015; Watson et al. 2017; Pita et al. 2018; Cole et al. 2018). In some countries, the exploitation of polychaetes has already required the implementation of management measures such as license requirement, logbooks completion, maximum catches and restriction of tools allowed to both recreational and commercial harvesters to ensure the sustainability of harvest activity in response to prior overexploitation (Brown 1993; Henry and Lyle 2003; Miller and Smith 2012; Lovell et al. 2017; Cabral et al. 2019). This can be seen for the bloodworm *Glycera dibranchiata* in the USA (Sypitkowski et al. 2008, 2009, 2010) and Canada (Cole et al. 2018) where the above mentioned restrictions were imposed following overexploitation (Miller and Smith 2012). The same situation was observed in Australia regarding beachworms from the genus *Australonuphus* (*A. parateres* and *A. teres*) and the *Hirsutonuphis mariahirsuta* (Henry and Lyle 2003; Cole et al. 2018). However, there are locations such as in South Africa where information regarding commercial harvesting is unknown, that has considerable subsistence and recreational harvest activity of polychaetes from Nereididae, Eunicidae and Sabellidae families (Wynberg and Branch 1991; Baust et al. 2015; Cole et al. 2018) as well small crustaceans such as *Callianassa kraussi* and *Upogebia africana* (Hodgson et al. 2000; Napier et al. 2009). There is no legislation for the management of these resources, but research has already highlighted the need for careful attention to the exploitation of these resources that in many cases are not being harvested sustainably and could be on the brink of collapse (Britz et al. 2001; Sowman 2006).

In Europe, bait harvesting is a widespread activity practiced along several Atlantic and Mediterranean coastal systems, targeting species from Arenicolidae, Nereididae, Onuphidae, Eunicidae and Nephtyidae families (Watson et al. 2017; Cole et al. 2018). Despite the great diversity of harvested polychaete families, the European supply for these resources is not enough to meet the current demand (Fidalgo e Costa et al. 2006; Sá et al. 2017; Font et al. 2018), especially from recreational anglers and for aquaculture feeds of high value commercial fishes (Olive 1993), and live bait is therefore imported from Asian markets (Fidalgo e Costa et al. 2006; Sá et al. 2017). According to Cole et al. (2018) the greatest diversity of polychaete worms is harvested in Asian countries from the families Nereididae, Onuphidae, Sabellidae, Eunicidae and Serpullidae. These polychaetes are harvested from both wild and cultured stocks and are destined for both local and international markets (Saito et al. 2014; Cole et al. 2018). The main target polychaetes are from the genus *Perinereis*, mostly harvested in Korea, China and Japan since the 80's, however, its harvest quantities have been decreasing probably due to management decisions, although information related to the sustainability of this fishery are scarce (Saito et al. 2014; Cole et al. 2018). Nonetheless, management measures such as closed seasons and rotativity of harvesting grounds are mentioned to have helped the regeneration of highly exploited wild stocks and contribute to more sustainable fisheries (Cole et al. 2018).

In Portugal, studies focusing on live bait and polychaete species have increased during the last decade concerning diverse topics that range from the characterization of the harvest activity in estuaries and lagoons (Costa et al. 2015; Fidalgo e Costa et al. 2016; Cabral et al. 2019), socioeconomic assessments for the harvesting activity of the species *Diopatra neapolitana* (Cunha et al. 2005; Freitas et al. 2011; Aleixo et al. 2014) and the ragworm *H. diversicolor* (Carvalho et al. 2013a), market features of imported polychaete species (Fidalgo e Costa et al. 2006) and assessment of impacts associated to the introduction of exotic species through live bait trading (Sá et al. 2017). There are several polychaete worm species harvested and used for bait in Portuguese MRF and, although taxonomic identification is still under revision, the species reported to be the main targets of harvesters are *D. neapolitana* ("casulo"), *Marphysea sp.* ("ganso"), and the ragworm *H. diversicolor* (Cunha et al. 2005; Carvalho et al. 2013a; Costa et al. 2015; Fidalgo e Costa et al. 2016; Cabral et al. 2019). Additionally, the use of the native groved razor shell *Solen marginatus* in MRF has been mentioned (Veiga et al. 2008; Pontes 2019) as well as the non-native species such as the bloodworm *G. dibranchiata* and several species

of the *Perenereis* genus, which are also widely used by Portuguese recreational anglers (Fidalgo e Costa et al. 2006; Veiga et al. 2008). The harvest of polychaetes for live bait is mainly carried out in estuaries and lagoons throughout the year, but more intensively during warmer months (Costa et al. 2015; Fidalgo e Costa et al. 2016; Cabral et al. 2019). The live bait harvested from the national estuaries and lagoons (Ria de Aveiro, Ria Formosa, Sado estuary, Tejo estuary) was estimated to be around 90 tonnes in 2015 (Costa et al. 2015) and approximately 120 tonnes in 2019 (Cabral et al. 2019). Its majority is destined for MRF sold to anglers through local retail shops or private companies.

Socioeconomic valuations of these resources have only been performed individually for two species: *D. neapolitana* in Ria de Aveiro (Cunha et al. 2005; Freitas et al. 2011; Aleixo et al. 2014) and for *H. diversicolor* in the Douro estuary (Carvalho et al. 2013a). *H. diversicolor* was the only species reported to be harvested in this region (Carvalho et al. 2013a), while *D. neapolitana* in Ria de Aveiro is harvested among many other species, (including species from the genus *Nephthys* and *Marphysa*), for which there is no data available (Cunha et al. 2005). According to Direcção-Geral de Recursos Naturais, Segurança e Serviços Marítimos (DGRM), Portuguese polychaete worms landings (designated as worms/minhocão) varied between 0,3 tonnes in winter months to 1 tonne in summer ones, with mean landing value between 2 €/kg to 30 €/kg, between the years of 2008 and 2015.

Since 2000 onwards, there has been an effort to regulate bait harvesting at the national level, introducing permits for harvesters, gear requirements and maximum weights per daily capture (ex. Portaria n. º 1102-B/2000, Portaria n.º 1228/2010, Portaria n.º 14/2014). Other management measures, such as harvesting closure for specific species (*H. diversicolor*, *D. neapoltitana* and *Marphysa sp.*) have been put in place in the Sado estuary (Portaria nº576/2006) (Costa et al. 2015). Nonetheless the effectiveness of such measures for resource management has been questioned since such regulations are not totally aligned with the species biology (e.g. recruitment and reproduction times) (Pires et al. 2012; Costa et al. 2015; Cabral et al. 2019). This also emphasizes the shortage of knowledge regarding species biology and ecology, undermining efforts to sustainably manage these resources.

The use of live bait, especially polychaete worms, in shore-based angling is fairly widespread in MRF worldwide (Watson et al. 2017; Cole et al. 2018). Like other aspects of MRF (fishing effort, target species, impact on fish stock) little is known about the value and volume of polychaetes species used in MRF as well recreational anglers' preferences

and perceptions regarding the use of these species. The increase in demand for these resources has raised concerns within the scientific community and decision makers due to the risk of overexploitation and habitat degradation associated to this activity. To prevent this, a better understanding of the ecologic and socioeconomic impacts of live bait harvesting for MRF and the development of comprehensive management measures are needed to ensure the sustainability of this activity. This study aims to contribute towards this goal by exploring the following aspects for MRF in the Algarve, focusing on bait harvesting in the Ria Formosa lagoon:

(i) Identify recreational anglers' preferences for live bait species;

(ii) Explore recreational anglers' perceptions on the use of live bait;

(iii) Estimate recreational anglers' expenditure and quantities used for live bait species.

Material and Methods

2.1. Study Site

The Ria Formosa lagoon is situated in the south of Portugal in Algarve (36° 59' 31.46" N 7° 55' 21.90" O) protected by five barrier islands (Barreta, Culatra, Armona, Fuseta and Tavira), two small peninsulas (Ancão and Cancela) and is connected to the Atlantic Ocean by six inlets (Ancão, Faro-Olhão, Armona, Fuzeta, Tavira and Lacém) (Mudge et al. 1999; Newton and Mudge 2003; Ceia et al. 2010; Guimarães et al. 2012). It is the biggest lagoon of Portugal with approximately 55 km extension and maximum 6 km wide and a surface area of approximately 80 km^2, presenting a mesotidal regime with 3 m average channel depth and amplitude ranging from approximately 1.3 m to 3.5 m, at neap and spring tides respectively (Cabaço et al. 2010; Ceia et al. 2010; Guimarães et al. 2012). Water exchange with the ocean is high, corresponding to 50-75% of the total volume of water inside the lagoon being exchanged daily, which plays a crucial role in limiting the impact of nutrients and pollution within the system. This exchange is possible due to occasional dredging done to inlets during the present and last century to avoid their closure by natural migration of the barrier islands in response to ocean and coastal processes (e.g. storms, tidal currents, overwash and sediment transportation) and to improve water circulation within the lagoon (Amaro and Cancela da Fonseca 2006; Cabaço et al. 2010; Ceia et al. 2010). Due to great oceanic influence, low input from freshwater inflows (the great majority dry up during warmer months) and high surface evaporation, the water is saline and varies slightly from 32 to 38 ‰, with lower salinity detected at inner zones and higher at outer zones of the lagoon (Mudge et al. 1999; Amaro and Cancela da Fonseca 2006).

This natural semi protected system has a great variety of habitats such as salt marshes, saltwater channels, exposed sand, mud banks and seagrass meadows which provide shelter to several species (Ceia et al. 2010; Cravo et al. 2014; Müller and Erzini 2016). Among this diversity are many species of economic value that use the protection and food areas of inner waters to reach full development or for spawning events (Ribeiro et al. 2006)

Ria Formosa is a protected area of major importance for migratory birds as it is used for resting, feeding and nesting (Amaro and Cancela da Fonseca 2006; Ceia et al. 2010) and has extensive seagrass meadows, considered one of the most productive and

threatened ecosystems in the world (Guimarães et al. 2012). It also provides an important nursery site for numerous resident and migratory marine species (Müller and Erzini 2016). These meadows are comprised by subtidal *Cymodocea nodosa* and *Zoostera marina*, and intertidal *Zoostera noltii*, which are key species intrinsically linked to this coastal ecosystem, its productivity and biodiversity (Guimarães et al. 2012).

Anthropogenic pressure is intense in Ria Formosa lagoon given that important population clusters (i.e. Faro, Olhão and Tavira) are in its vicinity. The lagoon supports several extractive activities, including salt extraction, bivalve production/harvest, fisheries, aquaculture, and recreational activities such as canoeing, kite surfing, fishing, and bird watching. Therefore the lagoon is full of activity throughout the year but with more intensity in warmer months due to a significant increase in tourism (Ceia et al. 2010; Guimarães et al. 2012).

The harvesting of marine organisms, especially bivalves such as *Ruditapes decussatus*, *Solen marginatus*, *Cerastoderme edule*, *Spisula solida*, *Venerupis aurea* among others, as well as the harvest of polychaetes is intense in the Ria Formosa throughout the year (Gaspar 2011). The impacts associated to harvesting activity have been studied around the world, showing changes in sediment composition, biotic community, and biogeochemical properties, as well as decrease of biomass and biotic diversity after disturbance. However, none of the conclusions could generalize these impacts as the effects of harvesting activity, since they could be related to the physical, biological and chemical features of each location (Brown and Herbert Wilson 1997; Ellis et al. 2000; Gutiérrez et al. 2004; Cabaço et al. 2005; De Juan et al. 2007; Constantino et al. 2009; Birchenough 2013; Carvalho et al. 2013b; Garmendia et al. 2017). Assessment of this activity in Ria Formosa has been carried out related to impacts on macrobenthic assemblages (Carvalho et al. 2013b), in *Zoostera noltii* beds (Cabaço et al. 2005) and harvest of razor clams using salt (Constantino et al. 2009), showing recovery rates of 4 days after perturbation for macrobenthic assemblages and one month for seagrasses beds, as well as no physical damage from the use of salt to harvest razor clams, especially when compared to hand tools or other mechanized methods.

2.2. The questionnaire

Due to the lack of data regarding live bait harvest, anglers' preferences for live bait species and expenditure on live bait species at Algarve, several methodologies were

developed and put in place to obtain this information. As a first approach to quantify harvest effort, associated value and target species, a survey, operationalized by personal interviews targeting recreational and professional harvesters took place from October to December 2016, and from May to July 2017 (Annex I). A total of 42 field trips were conducted. To survey the Ria Formosa evenly, the lagoon was divided in 15 different zones and a route was assigned to each zone (Fig. 1).

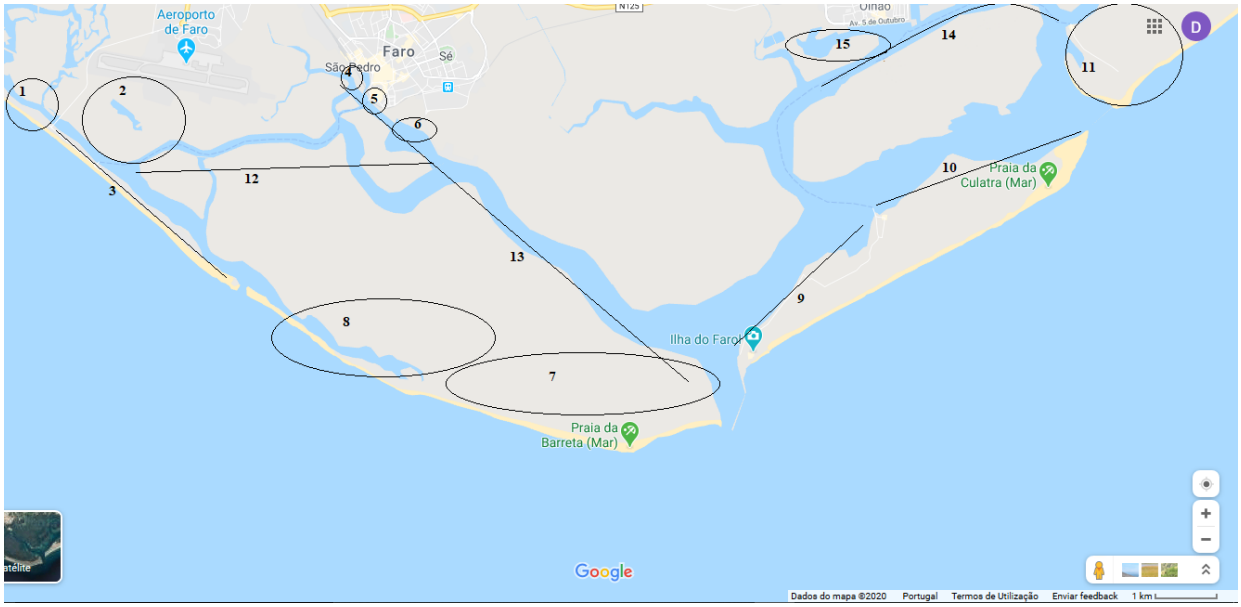

Figure 1- Locations surveyed along the Ria Formosa lagoon to quantify harvest effort, associated value and target species divided in 15 zones. 1-Faro beach to Quinta do Lago, including Ludo location; 2-Airport interior zone: From Faro Beach to Ramalhete; 3-From Faro beach to Barrinha; Three different routes in Faro: 4-Faro A, 5-Faro B, 6-Faro C situated from Marine to Historic Center; Two routes in Deserta Island: 7-Deserta A, 8-Deserta B; 9-Farol island; 10-Culatra island; 11-Armona; 12-From Faro to Faro beach, route done by boat; 13-From Faro to Deserta Island, route done by ferry; 14-From Olhão to Armona, route done by ferry; and 15-Olhão Marina.

The questionnaire asked about live bait target species, vegetation type, tool used, sediment type, harvested volume/quantity, and frequency of digging activity. In addition, this survey also aimed to gather information to quantify the nursery service provided by the Ria Formosa. Global Positioning System (GPS) coordinates were recorded every time a questionnaire was completed and/or every time someone was observed harvesting but impossible to approach (e.g. sighting of a harvester on the other side of the canal, harvester running away, etc.). These surveys usually took place before the low tide to survey the period when this activity occurs, as it ends when the tide rises, and the mudflat is covered (Annex II).

Unfortunately, a significant number of harvesters were not available to share information with us and the few who agreed to talk with us did not always provide reliable

information. As a result, the data gathered within this survey was insufficient to fulfil the objectives of this study. A second survey was developed, aiming to target fishing equipment/ bait shops. This survey sought information on live bait species, volume/quantities of live bait species sold and revenues. Several shops were contacted and invited to participate in the survey. Except for one, all the shops contacted stated that they would not participate in the survey and that would like to maintain the required information private. Finally, a third survey was developed, this time targeting recreational anglers to understand their preferences for live bait species, expenditure, and perception on live bait use. To make the questionnaire available to a wider number of anglers, an online survey was set up, using google forms application[1], and promoted through angler's associations and sport fishing magazines. The online survey was made available to the angling community in January 2019. However, despite the efforts to publicize it, only 6 surveys were completed over a 5-month period. Due to the limited number of responses received from the online survey, it was decided to present the questionnaire survey through face-to-face interviews.

The questionnaire (Annex III) started with an introduction explaining the aims of the survey, its promotors and information about the data treatment and storage. Respondents were also requested to give their consent to participate in the survey and share their data. The questionnaire survey included three main themes: (i) anglers experience, (ii) angler's perception on live bait use and potential impacts, and (iii) sociodemographic information. In the first part, the survey sought information about location of the fishing events, frequency, fishing season, type of bait used, bait source and expenditure. The second section assessed the angler's awareness of potential impacts of live bait use, fishing practices and opinions on live bait demand in Algarve. The sociodemographic part focused on information necessary to characterize the sociodemographic profile of the anglers who answered the survey (e.g. age, household, occupation, and income.).

[1] https://docs.google.com/forms/d/1gFnmleMbesa7S2WRXmJTdvG0o8BMKnSajmKW_rAAdBM/viewform?edit_requested=true

2.3. Sampling and data treatment

A total of 180 questionnaires were completed through face-to-face interviews from June to August 2019. Of those, 40 questionnaires were excluded due to incomplete or incoherent responses, leaving a total of 140 valid surveys. To help reach the biggest number of anglers, the Federação Portuguesa de Pesca Desportiva (FPPD) was contacted and helped disseminate this questionnaire during fishing competition events in the south and centre of Portugal. In addition to these surveys done by FPPD, surveys were also performed in the inward main channel of Ria Formosa, south of Faro, and jetties of Albufeira, Vilamora, Quarteira, Farol Island and Vila Real de Santo António (Fig. 2).

These locations were chosen due to the fact that during the summer months, fishing in concessional beaches is forbidden, leading marine recreational anglers to fish predominantly in jetties or to outside the hours of concession (from 9am to 9pm) (Veiga et al. 2008). The anglers were approached when practicing the activity and after a short briefing on the survey, if receptive, the interview would take place. Unfortunately, occasionally anglers were not available to share information to perform the survey, stating that rod fishing was an escape from the daily stress, and that they wanted to enjoy their time without being bothered. This increased the sampling effort and stretched the time survey longer than anticipated. When possible, interviews were also done performed individually to avoid possible bias from other anglers.

We used the data on our sample to estimate mean expenditure on live bait per fisher per year and then extrapolate this value to the total number of anglers in the Algarve (n = 10 929) as estimated by (Pontes 2019). We also provided estimates of expenditure per species of live bait.

$$E_{SLB} = [\text{Mean } E_{\text{per fisher/per year}}] \times [\text{Nº of anglers in Algarve}]$$

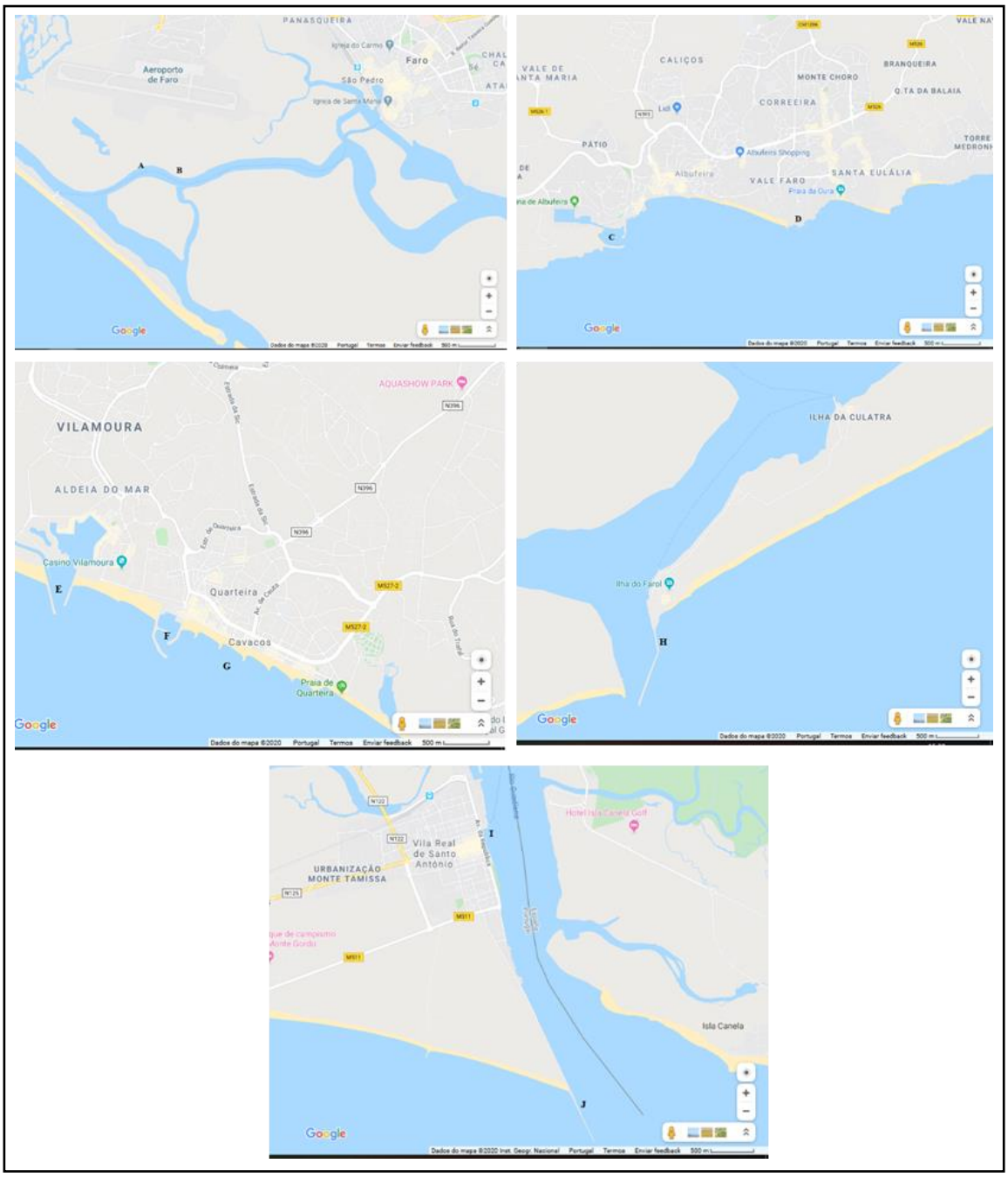

Figure 2- Location of the surveys performed in: A-Inward main channel of Ria Formosa; B- Near Ramalhete station; C-Jetty of Albufeira; D- East of Albufeira Jetty; E- Near Vilamoura Jetty; F-Quarteira Jetty; G-Quarteira Beach; H-Farol Island Jetty; I-Vila Real de Santo António; and J-Vila Real de Santo António Jetty.

Results

3.1. Anglers' socio demographic characteristics and fishing experience

A total of 140 (N =140) recreational anglers practicing rod fishing from shore were interviewed in the Algarve region. This activity was mainly practiced by males (94.3%) with a mean age of 52 years (s.d. = 14.7), employed (58.0%), with a mean household structure of 2.9 (s.d. = 1.2) people and mean monthly income between 1000 and 1500 € (Tab.1).

The great majority of anglers were from the Algarve region (82.9%) and around 10% were from the centre and north of Portugal (Tab.1) and claimed to mainly practice MRF in this region when participating in sport fishing competitions.

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Table 1 - Sociodemographic profile of the recreational anglers sampled in Algarve. Note: NA – Not answered questions.

		N	%
Gender			
	M	132	94.3%
	F	6	4.3%
	NA	2	1.4%
	Total	140	100%
Age Class (years)			
	[20-30]	10	7.1%
	[31-40]	26	18.6%
	[40-50]	29	20.7%
	[51-60]	26	18.6%
	[61-70]	26	18.6%
	[71-80]	11	7.9%
	[80-90]	3	2.1%
	NA	9	6.4%
	Total	140	100%
	Mean	51.6	
Professional activity			
	Retired	31	22.1%
	Unemployed	15	10.7%
	Employed	83	59.3%
	NA	11	7.9%
	Total	140	100%
Family household			
	1	23	16.4%
	2	26	18.6%
	3	34	24.3%
	4	35	25%
	5	9	6.4%
	6	1	0.7%
	NA	12	8.6%
	Total	140	100%
Household Income (€)			
	0	5	3.6%
	[1-500]	9	6.4%
	[501-1000]	38	27.1%
	[1001-1500]	29	20.7%
	[1501-2000]	20	14.3%
	[2001-2500]	12	8.6%
	[2501-3000]	5	3.6%
	> [3000]	2	1.4%
	NA	20	14.3%
	Total	140	100%
Residence			
	Aveiro	1	0.7%
	Beja	2	1.4%
	Canada	1	0.7%
	Coimbra	1	0.7%
	Evora	1	0.7%
	Faro	116	82.9%
	Leiria	1	0.7%
	Lisboa	2	1.4%
	Porto	3	2.1%
	Santarem	2	1.4%
	Setubal	1	0.7%
	Spain	4	2.9%
	NA	5	3.6%
	Total	140	100.0%

The sampled anglers practiced MRF in all seasons (80.7%), yet some revealed they preferred specific seasons of the year, with summer being the most preferred season (10%) (Tab.2).

Table 2 – Anglers' period of activity during the year according to seasons. W-Winter; S-Spring; F-Fall; Su-Summer

Period of activity	N	%
All Year	113	80.7%
W+S+F	1	0.7%
W+Su	1	0.7%
W+F	3	2.1%
S+Su	8	5.7%
Su	14	10.0%
Total	140	100.0%

Algarve has fishing grounds favourable for several types of MRF yet most of the respondents (75,7%) practiced mainly rod fishing from shore (Table 3)

Table 3 – Types of MRF activities practiced by interviewed anglers and respective percentages. SF-Rod fishing from shore; BF-Rod fishing from boat; HLB-Harvest of invertebrates; S-Spearfishing.

Fishery practiced	N	%	Nº Fishing activities	Nº Fishing activities (%)
SF+BF+HLB+S	1	0.7%	4	0.7%
SF+BF+HLB	2	1.4%	3	1.4%
SF+BF	21	15%	2	21.4%
SF+HLB	8	5.7%		
SF+S	1	0.7%		
SF	106	75.7%	1	75.7%
None	1	0.7%	0	0.7%
Total	140	100.0%		100.0%

3.2. Recreational anglers' bait preferences

Results show that while most anglers prefer to use live bait (83.6%), dead bait was used by 9.7% and artificial lures by 6.7% of the interviewed anglers (Fig.3).

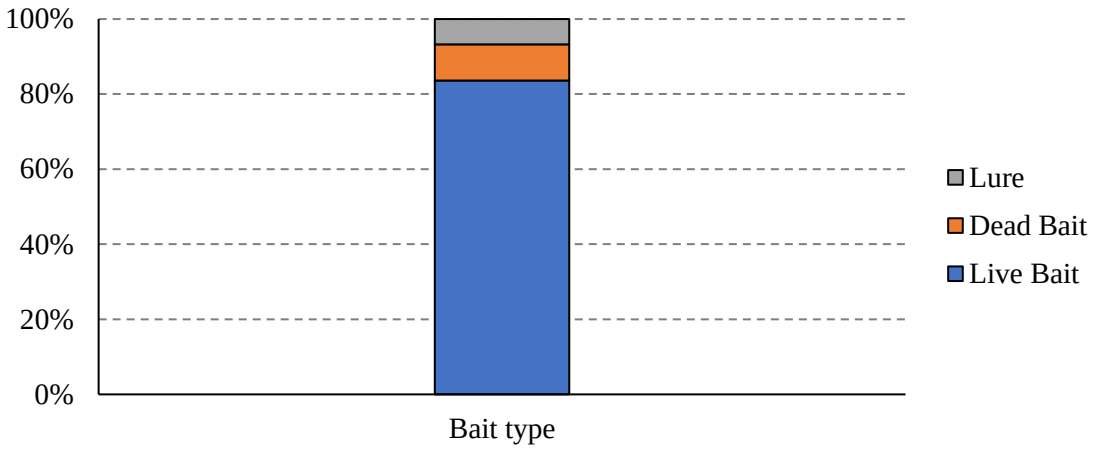

Figure 3- Anglers' use (%) for different types of bait (lure, dead bait and live bait) in Algarve.

Recreational anglers sampled mainly get their live bait from local bait shops (73.2%). With less frequency, some anglers also stated they obtained live bait by self-harvesting (20.8%) or purchased it from professional harvesters (6.0%) (Fig.4).

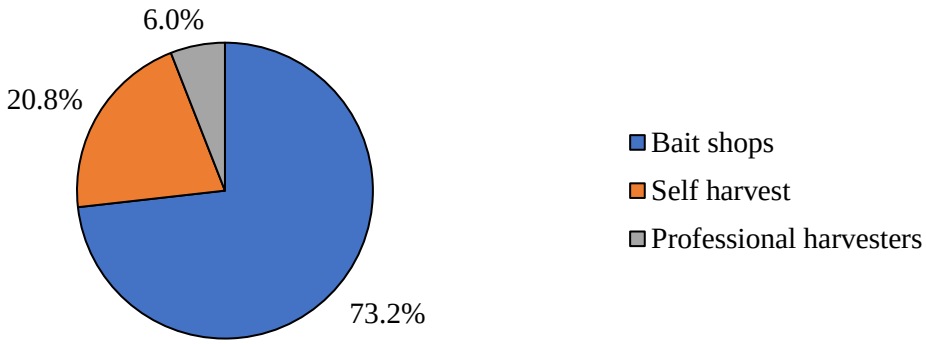

Figure 4 -Anglers' sources (%) of live bait.

Forty-four per cent of the respondents stated to prefer to use native live bait species and 40% used both native and exotic species in their fishing trips (Fig. 5).

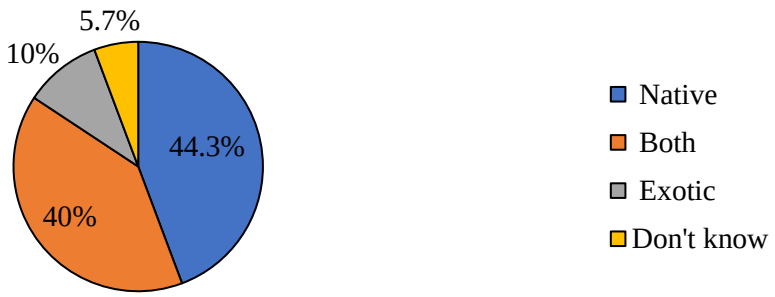

Figure 5 – Anglers' preferences (%) for exotic or native live bait species in Algarve.

When asked about the species used as bait, sampled anglers reported the use of 14 species of live bait, of which 11 were native and 3 were exotic. The native species comprised 7 polychaetes, 2 crustaceans, 1 bivalve and 1 sipunculid whereas the exotic species comprise 2 polychaetes and 1 sipunculid (Tab.4). Anglers usually used more than one species of bait, averaging 3.9 different species (s.d. = 2.2), with a maximum of 10 and a minimum of one species stated to be used throughout the year in their MRF.

Table 4 – Species of live bait stated to be used in MRF by the interviewed anglers with their common and scientific name, Algarve live bait shop sale price and their status (native/exotic).

Common name (Portuguese/English)	Genus/Species	Price (€/100 g)	Price (€/ ind.)	Price (€/box)	Taxonomic Group	Status
Casulo / Tube worm	*Diopatra neapolitana*	7				
Parchal / Native bloodworm	*Marphysa sp.*	8				
Minhoca branca / Catworm	*Nephthys sp.*	15				
Minhoca da lama / Ragworm	*Hediste diversiclor*			1.5	Polychaetes	
Minhocao /	*Halla parthnopeia*		20			
Borracheira /	*Glycera convoluta*					
Tiagem /	*Scoletoma impatiens*					Native
Lingueirão or Navalha / Grooved razor shell	*Solen marginatus*	1			Bivalvia	
Ralo / Mud shrimp	*Upogebia pusilla*		0.12		Crustacea	
Caranguejo verde / Green crab	*Carcinus maenas*		0.15			
Salsicha / Peanut worm	*Sinpunculus nudus*		2.2		Sipunculid	
Coreano /Corean ragworm	*Perinereis sp.*			2.5	Polychaetes	
Americana / American bloodworm	*Glycera dibranchiata*			3.5		Exotic
Bibis or Titas / Peanut worm	*Sinpunculus sp. 2*			3.9	Sipunculid	

From these species, the two most used by recreational anglers in their fishing trips were the native *D. neapolitana* (N=89 anglers) followed closely by the exotic *Perinereis sp.* (N=85), and the native grooved razor shell (N=77) and *Marphysa sp.* (N=74). Moderately used were the natives *Nephthys sp.* (N=55) and *U. pusilla* (N=54) (Fig.6).

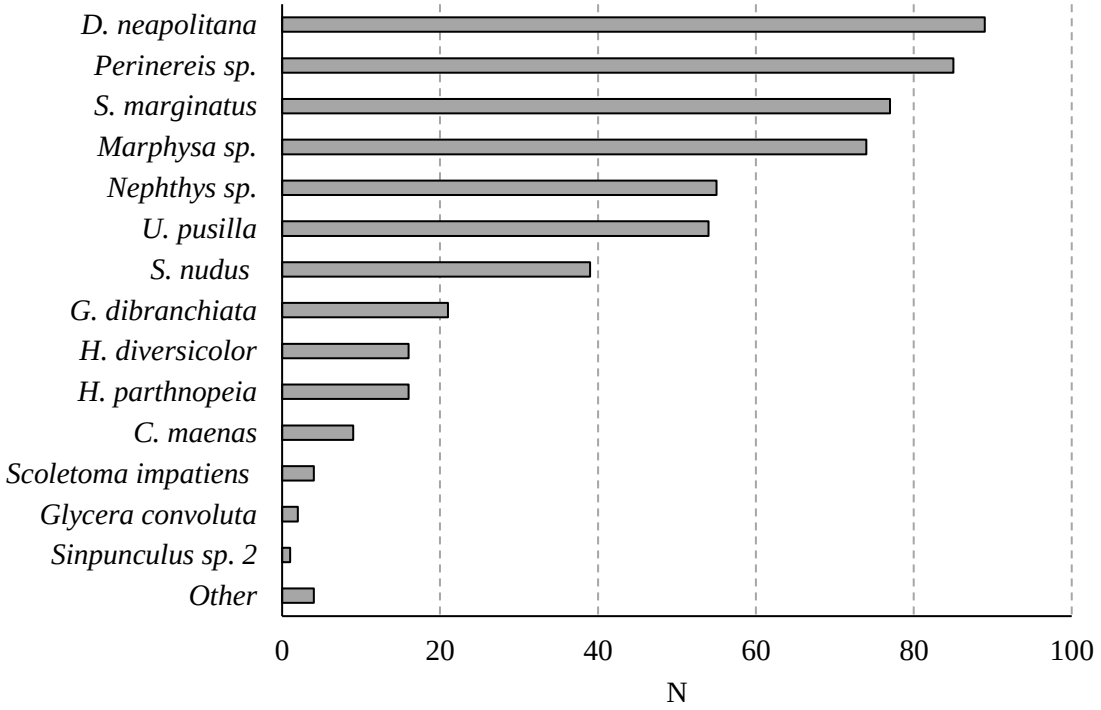

Figure 6 – Numbers of surveyed recreational anglers using the different live bait species in fishing trips.

Although the number of recreational anglers using the native polychaete *D. neapolitana* is higher than the ones using the exotic *Perinereis sp.*, when asked the most important species used during their fishing trip, sampled anglers answered the exotic polychaete *Perinereis sp.* (Fig. 7).

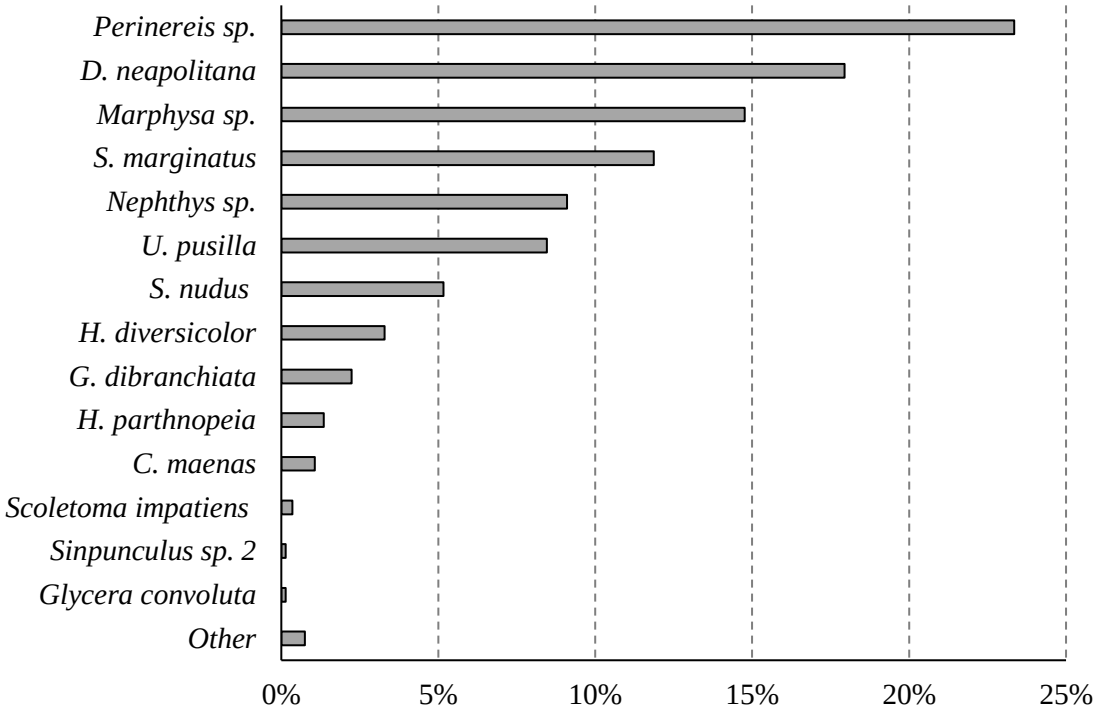

Figure 7 – Numbers of surveyed recreational anglers using the different live bait species in fishing trips.

Sampled anglers appear to prefer the use of live bait, both native and exotic, comprised mainly of polychaetes and razor clams, but also small crustaceans and sipunculids.

3.3. Anglers' perceptions on live bait use

The questionnaire also contained questions aiming to assess anglers' perceptions on the use of live bait species in Algarve MRF, including motives underlying anglers' preferences for live bait species, perceptions regarding the evolution of live bait market in Portugal and anglers' awareness of potential ecological impacts associated to exotic live bait use.

When asked about their motives when choosing live bait species, the majority of anglers stated that "better fishing results" (75.3%) was the main reason underlying their choices for specific live bait species while only 20.8% of anglers stated cost (i.e. preference for cheaper species) as the key reason. (Fig.8).

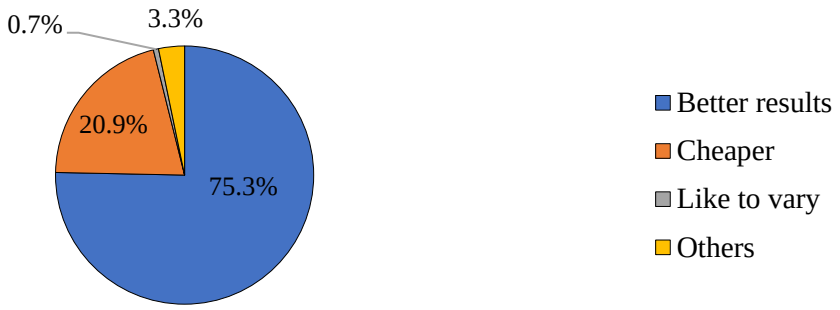

Figure 8 – Anglers' motives (%) for live bait species used in MRF.

Regarding the anglers' awareness of possible impacts on the local ecosystem associated with the use of exotic species, the survey revealed that the sampled anglers were mainly unaware of the potential negative ecological impacts (72.1%) (Fig. 9A). From those who stated they were aware of possible negative impacts (27.1%), the one with most recognition was the introduction of exotic species (40.0%) followed by the introduction of parasites/bacteria (22.2%) (Fig. 9B).

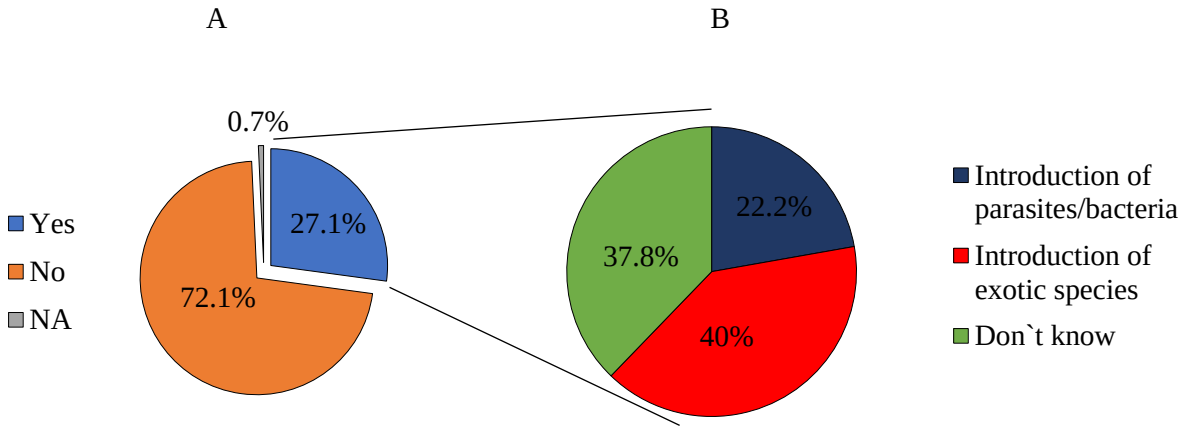

Figure 9 – Anglers' awareness (%) of possible ecological impacts on the ecosystem associated to the use of exotic live bait species (A), and most recognized ecological impacts by aware anglers (B).

Recreational anglers were questioned about the practice of discarding live bait at the end of a fishing trip and the majority affirmed that they sometimes discarded leftover live bait (37.9%). Thirty-two percent stated that always perform this practice and 18.6% reported to never discard live bait (Fig.10).

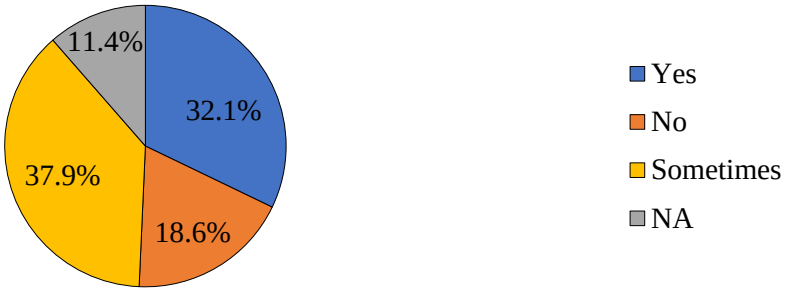

Figure 10 – Recreational anglers' answers (%) when asked if they discard live bait at the end of the fishing trip.

When asked to consider the scenario for the use of only native live bait species, almost half of all anglers seemed willing to accept (47.1%) and 20.0 % showed to be against it. However, a significant percentage of people did not answer this question (32.9%) (Fig.11).

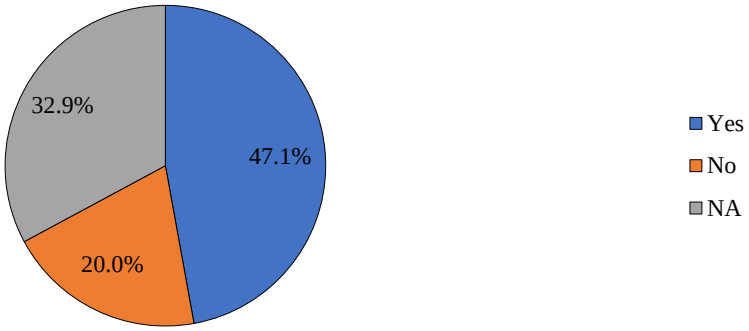

Figure 11 – Anglers' responses (%) if they were willing to use only native live bait species in their MRF.

Recreational anglers are of the opinion that the quantity of native live bait available on the market is enough to meet their demand (37.9%) while only a small percentage of them disagrees (15.0%). However, almost 50% of the sampled anglers preferred not to answer (Fig. 12).

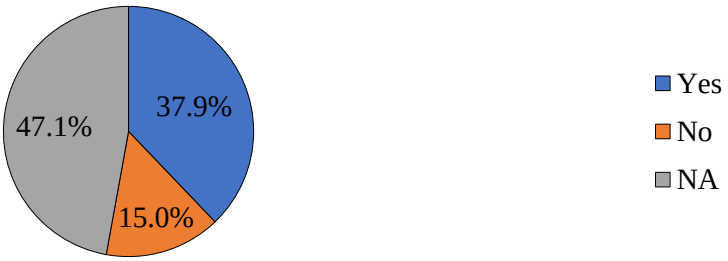

Figure 12 – Anglers opinion (%) if the quantity of native live bait is enough for the demand from recreational anglers.

Regarding the angler's perception on the evolution of the demand for live bait species over the last ten years, the majority are of the opinion that demand has increased (47.1%) (Fig. 13).

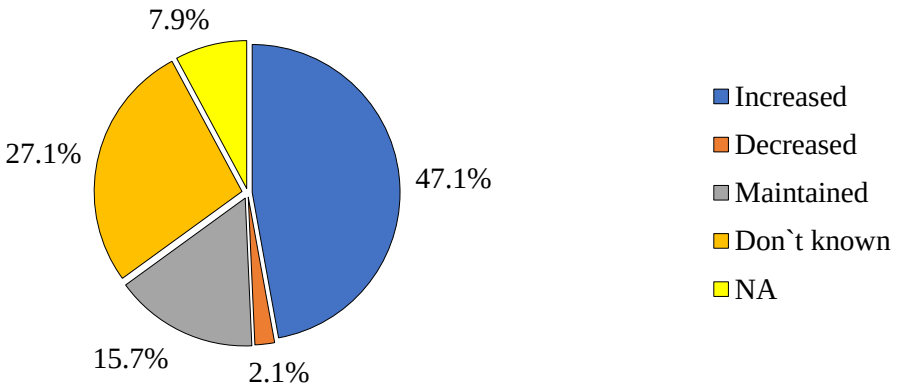

Figure 13 – Anglers answers (%) for the evolution of recreational anglers' demand for live bait over the last ten years.

3.4. Recreational anglers' expenditure on live bait in Algarve.

This section will present the economic value stated to be spent on live bait for the year 2018 by sampled anglers and an extrapolation estimate for the region of the Algarve considering the sampled anglers' mean expenditure per fishing trip, mean number of fishing trips, stated economic expenditures on the different species of live bait, and an estimate of the total number of shore recreational anglers in Algarve adapted from the literature (Pontes 2019).

Sampled anglers are estimated to spend a mean of 208.3 € (s.d. = 293.5) on live bait per year, performing a mean of 52.1 fishing trips (s.d.=53.8) and spending an average of 4 € in each fishing trip on live bait.

The polychaetes *D. neapolitana* and the *Perinereis sp.* presented the highest expenditure by recreational angler's sampled with a mean of 39.6 € (s.d.=70.4 €) and 32.4 € (s.d.= 68.3 €) per year, respectively (Tab.5). The polychaetes from the genus *Nephthys sp.*, although less used than the polychaetes from the genus *Marphysa sp.* and the grooved razor shell *S. marginatus*, presented the third highest mean expenditure of 29.1 € (s.d.=66.0 €) per year per angler, due to their high sale price value.

Species	**Mean value spent by each angler sampled on each live bait species per year (€)**	**s.d.**	**Estimated extrapolated annual direct expenditure (€)**	**Status**
D. neapolitana	39.6	70.4	432867	Native
Nephthys sp.	29.1	66.0	318034	
S. marginatus	26.6	67.0	290399	
Marphysa sp.	23.4	54.3	255660	
U. pusilla	18.3	53.5	200235	
S. nudus	13.8	52.1	151132	
H. diversicolor	9.4	36.6	102264	
H. parthnopeia	6.6	25.6	72600	
C. maenas	1.0	6.4	10929	
Scoletoma impatiens	0.9	6.2	9368	
Total			1843488	
Perinereis sp.	32.4	68.3	354022	Exotic
G. dibranchiata	6.4	35.2	62477	
Sinpunculus sp. 2	0.1	1.7	1560	
Total			418059	
Others	0.7	8.5	7810	-
Total for all species			2269357	

Considering the mean value stated to be spent by sampled anglers on each live bait species, and through the considered number of recreational anglers for the Algarve

(10 929) (Pontes 2019), was estimated that Algarve recreational anglers spent around 433000 € on the purchase of *D. neapolitana* and over 354000 € on the *Perinereis sp.* which were the two most used species of live bait. The polychaeta *Nephthys sp.* was estimated around 318000 € and the grooved razor shell *S. marginatus* 290000 € in direct expenses. With lower expenditures are the species *Marphysa sp.* and the crustacean *U. pussilla* which were estimated to be worth 256000 and 200000 € respectively (Tab.5).

The mean economic value spent on live bait for the Algarve region was estimated by multiplying the mean economic value spent in live bait per year by sampled anglers by the total number of shore recreational anglers in Algarve (N=10929) (Pontes 2019). For this region, this study estimated that recreational anglers spent around 2.3 € million on live bait to use in shore based MRF.

Discussion

4.1 Anglers' socio demographic description and fishing experience

Recreational anglers sampled were in their vast majority male (94.3%) and mostly ranging from ages between 31 and 70 years (76.4 %). The male predominance is recurring in Portuguese MRF (Marta et al. 2001; Oliveira 2003; Veiga et al. 2008; Diogo and Pereira 2013; Pontes 2019) and has been observed in many locations around the world (Vigliano et al. 2000; Zeybrandt and Barnes 2001; Pawson et al. 2007; Pita et al. 2018). The high male participation in this activity for this region has been pointed out to remain constant over the years (Veiga et al. 2008), and the results of this study agree with an unchanged mostly male angler population. The mean age of anglers of 51.6 years does not show differences in comparison to past studies targeting angler populations in this region except that no children (less than 18 years old) were observed practicing MRF (Veiga et al. 2008; Pontes 2019).

Anglers showed to be a professionally active population with low monthly household income, considering the number of people comprising their household. The last century belief that Portuguese anglers were mostly professionally inactive has begun to change by recent studies supporting otherwise (Oliveira 2003; Veiga et al. 2008; Pontes 2019) and sampled anglers support a professionally active angler population.

Most sampled anglers were from Algarve (82.9 %) with few from other locations of the country (10 %) or foreigners (3.6 %). Veiga et al. (2008) and Pontes (2019) have reported significant encounters with national anglers not residing in Algarve, especially those on vacation with families, however, sampled anglers were most usually alone or with other anglers. This may not mean this kind of anglers are rare but were probably not detected by the sampling procedure because it occurred in high angler density locations and anglers on vacation could preferer less crowded fishing spots.

Sampled anglers claim to fish all year around (80.7 %) and perform a mean of 52.1 fishing events per year that is not very different from past results, where Algarve anglers fished a mean 44 days/year in 2017 (Pontes 2019), and a mean of 65 days/year in 2006/07 (Veiga et al. 2008). Compared to other countries, sampled anglers show higher avidity than angler populations from European Nordic countries (Toivonen et al. 2004; Hurkens and Tisdell 2006), France (Herfaut et al. 2013), USA (Lovell et al. 2017) and Canada (Fisheries and Oceans Canada 2019) which together make up a mean number of fishing events ranging among 12 and 18 per year. Despite this high avidity there are

countries such as Spain which have angler populations reported to perform a mean 90 fishing trips per year (Pita 2018).

The practice of shore rod fishing together with other recreational fishing activities such as spearfishing, boat fishing and bait harvest, is not uncommon around the world (Pradervand and Baird 2002; Fielder 2004; Younsi et al. 2010; Monkman et al. 2015; Fisheries and Oceans Canada 2019). However, sampled anglers mostly practice solely shore rod fishing (75.71 %) as their only recreational fishing activity. The sociodemographic features of sampled anglers show that this population does not show any considerable differences from past studies, still being characterized by a mainly male resident shore angler population, fishing all year around, directing their MRF mostly to shore rod fishing, and are employed but with relatively low household income.

4.2. – Recreational anglers' bait preferences

Within the diversity of MRF, the use of live bait can be observed globally (Gambi et al. 1994; Fielder 2004; Fidalgo e Costa et al. 2006; Lewis and Karageorgopoulos 2008; Younsi et al. 2010; Font and Lloret 2011; Miller and Smith 2012; Saito et al. 2014; Watson et al. 2017). For this region, anglers have been reported to have high preference for live bait still fitting in this description (Veiga et al. 2008; Pontes 2019).

Algarve recreational anglers seem to rely on live bait in most of their fishing events especially through live bait shops. As in many countries in Western Europe, the local supply of some of these resources, such as polychaetes, is not enough to meet market demand and are imported from North America (USA and Canada) and South-east Asian markets (China, Korea, Vietnam and Taiwan) into local shops where it increases anglers' choice and access to different species of live bait (Olive 1993; Fidalgo e Costa et al. 2006; Saito et al. 2014; Sá et al. 2017; Font et al. 2018). Live bait shops clearly play an important social and economic role on the accessibility of live bait to sampled anglers, however, information regarding these establishments is scarce and sales are not declared for VAT (Olive 1993; Cunha et al. 2005) .

Self-harvesting of bait is not uncommon among anglers (Fielder 2004; Monkman et al. 2015). In Wales, there are registries of anglers harvesting 50% of all live bait used in their MRF (Monkman et al. 2015) and in Fraser Island, Australia, this practice was considered the main source of live bait for competitive anglers (Fielder 2004). Although only 8 % of sampled anglers stated to also practice the harvest of live bait together with

shore rod fishing, 20.8 % stated that harvesting is one of their sources of live bait. This difference may be due to anglers harvesting live bait less frequently compared to rod fishing and may not consider the harvesting as other marine fishing activity due to only being performed from time to time or may even consider it to be a complementary practice to shore rod fishing.

The presence of professional harvesters supplying bait shops is also not new (Olive 1993; Cunha et al. 2005), and a small number of anglers reported purchasing live bait directly from these professional harvesters which indicates that in the Algarve the three types of bait collection defined by Olive 1993 (Type I – anglers catching their own bait to use in MRF; Type II – local semi-professional bait diggers; and Type III – professional harvesters) are still practised. The harvesting of live bait in Portugal is still poorly studied, but the scientific community seems to agree with an increase interest in this activity since the last century with studies suggesting the need for better description of its social, economic, biological and ecological features (Olive 1993; Cunha et al. 2005; Costa et al. 2015; Cabral et al. 2019). Watson et al. (2017) empirically assessed the polychaete fishery in the U.K and combined with analysis of published literature around the world estimated significant biomass removal and economic value associated to these resources, suggesting the need of urgent action to ensure harvest sustainability and minimize impacts on coastal ecosystems.

The use of exotic live bait species has become a frequent practice among anglers from Northeast Atlantic and Mediterranean countries (Fidalgo e Costa et al. 2006; Arias et al. 2013; Watson et al. 2017; Cole et al. 2018; Font et al. 2018). In Costa Brava, Spain, there is high preference for the exotic species *G. dibranchiata* and *P. linea* which were the most commercialized live baits species in 2015 in that region (Font et al. 2018). The use of exotic species, specially polychaetes, have been pointed out in the past as one of the preferred live baits in Algarve (Pontes 2019). In this study two distinct groups of anglers were detected, the ones that prefer the use of native live bait (44.3 %) and the ones who shift between native and exotic live bait in their MRF (40.0 %).

Many of the live baits used in Algarve MRF can be seen in the Northeast Atlantic coast and in Mediterranean, where polychaetes from the genus *Diopatra sp.*, *Marphysa sp.*, *Nephthys sp.*, and *Arenicola sp.* have been reported to be commonly used (Olive 1993; Gambi et al. 1994; Fadlaoui et al. 1995; Cunha et al. 2005; Cappell and Lawrence 2006; Rodrigues et al. 2009; Carvalho et al. 2013a, 2013b; Watson et al. 2017; Cole et al. 2018). The most used species by sampled anglers, despite not being considered the most

important, was the native "casulo" (*D. neapolitana*). This species is harvested in many Mediterranean estuaries (Pires et al. 2010, 2012; Arias and Paxton 2015) and is one of the few regulated by Portuguese legislation, requiring anglers to possess a license, proper gear and limited daily catch. In previous studies for this region, this species has always been mentioned and it is also harvested in other coastal systems of Portugal, especially in the Ria de Aveiro where it is the most harvested polychaete (Cunha et al. 2005; Veiga et al. 2008; Costa et al. 2015; Cabral et al. 2019).

Another favourite polychaete used was the exotic worm known as the "Korean ragworm" (*Perinereis sp.*), used by fewer anglers compared to the "casulo" but considered to be the most important species used during their MRF activities. This live bait species is used all over the world and is exported from Asian countries such as China, Korea and Japan (Fidalgo e Costa et al. 2006; Saito et al. 2014; Cole et al. 2018). However, the term "Korean ragworm" is thought to harbour several cryptic species (Fidalgo e Costa et al. 2006; Font et al. 2018) and settlement out of their natural range has been observed in the Mediterranean raising concerns regarding the introduction of this species linked to its use in MRF (Arias et al. 2013).

The grooved razor shell *S. marginatus* has been mentioned to be used in Algarve by anglers (Veiga et al. 2008; Pontes 2019) and it seems to have remained a main choice by sampled anglers. This species is harvested in Ria Formosa lagoon, usually by salting (Constantino et al. 2009), and it was found more commonly used among highly avid anglers.

The polychaetes species from *Marphysa sp.* have been in recent years under taxonomic revision in Europe (Lavesque et al. 2017), Africa (Lewis and Karageorgopoulos 2008), Asia (Wang et al. 2018), and Australia (Zanol et al. 2007, 2016; Glasby and Hutchings 2010) as the believed cosmopolitan species *Marphysa sanguinea* firstly identified in U.K had been proved to be many times wrongfully identified around the world. In Portugal, polychaetes from this genus have been denominated as *M. sanguinea* (Garcês and Pereira 2011) but there is the possibility of other cryptic species of this genus to also be present or be another species altogether. These species are also regulated by the same management policies applied to *D. neapolitana*, and is the primary species harvested in the Sado estuary (Costa et al. 2015; Cabral et al. 2019).

The polychaetes from the genus *Nephthys* are also found in several coastal systems around Europe (Rainer 1991; Hutchings et al. 2012; Pires et al. 2013; Zanol et al. 2016; Lavesque et al. 2017) and have been reported to be harvested and used in MRF

in Portugal together with the species *D. neapolitana* and *Marphysa sp.* (Cunha et al. 2005; Veiga et al. 2008; Costa et al. 2015; Pontes 2019; Cabral et al. 2019). However, records concerning their exploitation are absent, and there is no legislation concerning their harvest activity.

Algarve recreational anglers seem to prefer the use of both exotic and native live bait in their MRF, specially the polychaetes *D. neapolitana*, and *Perinereis sp.*, and the grooved razor shell *S. marginatus*. This angler population seems to rely heavily on local bait shops to obtain live bait and it is important to highlight the need to understand the social and economic relevance of these establishments, which in Ria de Aveiro have been reported to belong to local families that depend heavily of the income of this activity (Cunha et al. 2005; Freitas et al. 2011) and the same may happen in other coastal systems of Portugal.

4.3. Anglers' perceptions on live bait use

Angler's perceptions on the use of live bait are essential for implementing regulations that can ensure sustainable and continuous practice of live bait harvest, and its use in MRF. As anglers can be very mobile when practicing MRF their opinions on the state of live bait are crucial to obtain updated information of such widespread activity. Hence, anglers' preferences, awareness, practices, and their opinions on possible changes to these resources can provide crucial information to the scientific community and help decision makers.

Despite being more expensive than other types of bait, live bait is preferred and more frequently used by Algarve anglers. "Better fishing results" was the most stated answer for this preference but no other study was found with reliable information on success catch rate among types of bait. Besides, this is a question with low consensus among anglers as many argue that the best type of bait can vary according to species, season, fishing modality and on the different stages of the target fish's life cycle. For Algarve anglers, the success rate from the use of live bait appears to be the key motive behind their preference.

Introduction of exotic species is known to potentially affect the stability of whole ecosystems, often leading to local ecologic and economic losses (Galil 2007; Arias et al. 2013; Çinar 2013). The exotic Korean ragworm, as one of the most preferred and used species by sampled anglers may potentially affect the local coastal systems where they

can become established with unknown consequences. The awareness of anglers on this subject becomes essential to mitigate possible already unknown settlement areas, as well avoid the introduction of new exotic species. It was found that sampled anglers were mainly unaware of potential ecological impacts of the use of exotic live bait and added to the significant practice of live bait discarding, this angler population may present an important vector that facilitates the introduction of exotic species into local coastal systems.

MRF participants have been increasing in recent years, and in many Western European countries, such as Portugal, the local supply of live bait is insufficient to meet its demand (Fidalgo e Costa et al. 2006; Sá et al. 2017; Font et al. 2018). This trend may possibly increase the quantity of exotic live bait demand, specially under the present conditions of its access, relatively low price and increased resistance compared to native live baits (Fidalgo e Costa et al. 2006, 2016; Carvalho et al. 2013a, 2013b; Font et al. 2018). The scenario of using only native live bait in MRF to help mitigate this impact, although accepted by half the sampled anglers, may raise concerns among different angler communities due to limiting their choices of bait, being economically unaffordable or/and by already being a good established standard live bait choice in Portuguese MRF. Furthermore, the high preference for exotic species from a considerable part of anglers sampled suggests that Algarve angler population would possibly show resistance with this scenario.

The increase in both demand and commercial value of these resources in the future has been suggested by Cole et al. (2018), which highlights the main obstacles to sustainable polychaetes fishery to be the gaps in knowledge of species biology and population dynamics, the scarce understanding of harvest impacts, reliability on wild stocks and biosecurity problems such as introduction of invasive species. As main demanders of these resources, recreational anglers sampled do not appear to be sufficiently informed about the possible consequences of using exotic live bait. The importance of a well-informed angler community needs to be highlighted, as it can help tackle issues by providing anglers with the opportunity to perform sustainable decisions that could simultaneously benefit their recreational experience and safeguard it.

4.4. Recreational anglers' expenditure on live bait in Algarve.

MRF expenses can vary greatly even among angler individuals and it can be either a very expensive or cheap activity (Armstrong et al. 2013). Although main expenses may differ among angler populations, expenses associated with travel cost (fuel, public transportation, etc.), accommodation, fishing equipment (rods and reels), boats and respective fees, and bait are often mentioned (Henry and Lyle 2003; Cappell and Lawrence 2006; Prior and Beckley 2007; Font and Lloret 2011; Armstrong et al. 2013; Herfaut et al. 2013; Lovell et al. 2013; Pita et al. 2018). Anglers expenditure on baits can be as limited as the 2% of total expenditure as reported for 2000 in Australia (Henry and Lyle 2003) or as substantial as 58% as found in Cap de Creus, Spain in 2007 (Font and Lloret 2011) and 52.8% reported for the Algarve in 2006/07 (Veiga et al. 2008). However, information regarding bait is not usually differentiated among the different types of bait, and estimates tend many times to cluster this information all in one single category. This facilitates the comparison to where different angler populations direct their expenses but do not detect specific direct expenses on each species or tool used as bait which, in the case of natural resources without supervision such as live bait, can lead to undetected overexploitation and parallel economies (Olive 1993; Cunha et al. 2005; Carvalho et al. 2013b). In Portugal, these resources are not supervised, and management policies are only applied to maximum harvest of annelid species, and to the closed season of *Marphysa* species, *D. neapolitana* and *H. diversicolor* in Sado estuary, Setúbal (Portaria nº 576/2006) (Cabral et al. 2019). Therefore, anglers demand and their expenses on live bait can help reveal gross estimates and setting a baseline to its social and economic value.

Expenditures of sea angling on bait are mostly gathered with small equipment or food expenses and mostly associated with angler's expenditure on trips (Font and Lloret 2011; Armstrong et al. 2013; Herfaut et al. 2013; Lovell et al. 2017). Considering the reduced number of studies providing information, specifically on live bait, comparison between angler expenses from literature with the ones obtained on live bait by sampled anglers can help understand the economic relevance that live bait displays in these bait expenses, given how costly some of these resources can be, such as the case of some polychaetes (Sá et al. 2017; Watson et al. 2017; Font et al. 2018).

Hyder et al. (2018) provided average estimates of annual expenses from recreational anglers in European countries estimating an average expenditure of 680 € annually per angler on MRF activities, and Portugal anglers were mentioned to spend above this average (796€). Veiga et al. (2008) reported similar results for Algarve region in 2006/07 with 865 € spent annually per angler on MRF, of which 39.9% were bait expenses, corresponding to approximately 344.7 € annually per angler on bait. In Galicia, northwest Spain, recreational anglers were found to spend on average 256 € annually on different types of bait, of which around 44% was live bait, mostly polychaete worms (Pita et al. 2018). Still in Northeast Atlantic coast, Armstrong et al. (2013) reported that English recreational anglers spent a mean of £761 annually on angler trip expenses in 2012, mainly on accommodation, food and drink, bait and charter/boat hire which altogether make up around 75% of the total angler trip expenses, and shared similar expenditures, with bait corresponding roughly to a little over than £100 annually per angler. In Cape de Creus, Mediterranean coast of Spain, anglers in 2007 were estimated to spend on average 350 € per year on bait and tackle (Font and Lloret 2011). Sampled Algarve anglers' expenditures on live bait (208.3 €) do not differ much from the above-mentioned studies and appear to fit in with other West European countries, with mean individual angler annual expenses on bait ranging from 100 € to 350 €. These values are possible to compare with Canadian expenditures of 2015, where 9% of total direct expenses were attributed to lures, lines, tackle, bait and other fishing supplies resulting in average annual expenditures of 65.8 $ by anglers (Fisheries and Oceans Canada 2019). Unfortunately, data from countries that regulate their recreational fisheries such as USA and Australia do not present these values in this format (annual expenditure per angler) making it difficult to compare expenditures at the angler level (Henry and Lyle 2003; Lovell et al. 2017). However, it appears that sampled anglers such as other European countries are willing to spend a higher percentage of their MRF expenses on bait compared to North American countries and Australia.

Although annual bait expenditures appear to not differ much among Western European countries, fishing frequency does. This leads to expenses on these resources per angler trip to be more expensive for angler populations with low fishing frequency compared to more avid ones. In Algarve, expenditures on bait per fishing trip have been reported to be on average 5.3 € in 2006/07 (Veiga et al. 2008), 6.9 € in 2017 (Pontes 2019) and 4 € in this study. In Galicia, Spain, anglers were reported to spent on average 14 € on bait per trip between 2015 and 2017 (Font and Lloret 2011). Iberian Peninsula angler

communities have shown to perform a lot of fishing trips annually, and compared to angler populations of France and England, which perform significantly fewer fishing trips, a higher expenditure on bait with an average of 23 € on bait per trip in France in 2006 (Herfaut et al. 2013) and ranging from 36 to 167 £ per fishing trip in England in 2012 was observed (Armstrong et al. 2013). Compared to the USA in 2016/17, expenditures per trip on bait ranged from 1.2 USD$ (s.d. = 0.3 $) in the state of Maine to 18.1 USD$ (s.d. = 3.1 $) in the state of Louisiana (Lovell et al. 2017). The average expenditure per trip per angler on bait for all states was around 6.6 $, like Iberian Peninsula anglers and significantly less than the ones observed in other European countries. However, care must be taken when comparing from USA, as the bait reported in Lovell et al. (2017) does not describe this as live, dead or artificial bait (lures). As can be seen, the acquisition of bait is economically significant and can sometimes be very expensive items in MRF and, therefore, it becomes relevant to specify the economic value of species used as bait to provide some transparency over these unsupervised resources until better management measures are established and to better understand the preferences at the local level as several species are found to be commercialized.

D. neapolitana has been mentioned several times in Portugal as the most targeted polychaete for harvest (Cunha et al. 2005; Freitas et al. 2011; Aleixo et al. 2014; Costa et al. 2015; Xenarios et al. 2015; Cabral et al. 2019) and to its use in MRF as live bait (Veiga et al. 2008; Pontes 2019). Three studies have assessed quantities harvested of this species and its respective economic value in Ria de Aveiro and was found that the quantity harvested has decreased from 45 tonnes in 2001/02 (Cunha et al. 2005) to 29 tonnes in 2007/08 (Freitas et al. 2011) and to only 9 tonnes in 2012/13 (Aleixo et al. 2014). This study estimated that approximately 6 tonnes were used by recreational anglers, only a little less than the quantities reported to be harvested in Ria de Aveiro. The reasons of the decrease in quantities harvested are still unclear, but the possibility of overexploitation, decrease in harvest effort and biological and environmental fluctuations has been considered by Aleixo et al. (2014). The economic valuation of this resource in Ria de Aveiro has fallen from 327000 € in 2001/02 (Cunha et al. 2005) to around 224000 € in 2007/08 (Freitas et al. 2011) and, considering the same first selling price of the two studies before (approximately 7.2 €/kg), to around 64800 € in 2012/13 (Aleixo et al. 2014). Prices of polychaete worms are known to fluctuate according to the current supply, demand and economic conditions of consumer groups of the countries of these establishments (Watson et al. 2017), but through the information gathered in this study from local live

bait shops in Algarve, *D. neapolitana* was sold to recreational anglers at 7 € per 100 grams (70 €/kg) in 2018, and was estimated that approximately 6 tonnes were sold to Algarve recreational anglers corresponding to around 432000 € in direct expenses. If taken in consideration the sell price in Cunha et al. (2005) the resulting income from harvesting would be around 43200 €.

Several species from the genus *Perinereis sp.* have been mentioned in the literature to be imported into Portugal, usually by airplane, arriving at Porto and Lisbon airports from wild and cultured stocks of China (Fidalgo e Costa et al. 2006; Costa et al. 2015; Sá et al. 2017). The taxonomic identification of these species is not always clear, but at least three species have been reported to arrive from China at Lisbon airport: the *Perinereis aibuhitensis*, in 2002 and 2003 (Fidalgo e Costa et al. 2006), and *Perinereis linea* and *Perinereis cultrifera* in between 2012 to 2015 (Sá et al. 2017). According to its size and coloration, *P. linea* is commercialized under different common names such as "coreano", "coreano XL" and "red coreano" (Sá et al. 2017; Font et al. 2018). In 2002 and 2003, landings of *P. linea* and *P. cultrifera* were around 35 tonnes each year, and in 2013 to 2015 a significant decrease of quantities exported was detected, ranging from around 8 to 15 tonnes (Sá et al. 2017). However, according to Fidalgo e Costa et al. (2006) 60% of the *P. aibuhitensis* landed in Lisbon Airport went by road to Spain in 2002 and 2003 and the same could happen in more recent years. The only economic valuation in literature was given by Fidalgo e Costa et al. (2006) for *P. aibuhitensis* in 2003 at Lisbon airport of 718180 US $ representing a little over 19 tonnes. In Algarve, these worms can cost between 2 to 3 € per box (each box containing 8 to 12 worms) in 2018, and it was estimated that recreational anglers spent around 354000 € in direct expenses in this live bait.

The grooved razor shell *S. marginatus* is a species both sold for live bait and for consumption (Gaspar 2011). In the 90's, Portugal was the major exporter of razor clams (*E.siliqua* and *S. marginatus*), followed by the collapse of these resources in Spain in the 80's (*E.siliqua*, *Ensis arcuatus* and *S. marginatus*) (Gaspar 2011). In order to meet the demand of Spanish markets, there was an overexploitation of *E. siliqua*, with landings reaching over 1000 tonnes during most of the 90's followed by the collapse of natural stocks, which promoted the development of studies to better understand its biology, ecology and impacts on the ecosystems (Gaspar et al. 1998; Chícharo et al. 2002; Falcão et al. 2003) consequently leading to implementation of razor clams fishery legislation (Gaspar 2011). In Portugal, DGRM provided quantities and economic data of landings of

"longueirões", which comprise the species *E. siliqua* and *S. marginatus*, being observed an increase of the economic value of these species from 2.5 €/kg in 2008 to 3.9 €/kg in 2018 in Continental Portugal. On the other hand, quantities landed suffered fluctuations during the same time reaching a minimum landed in 2011 of 64.1 tonnes and its maximum in 2016 of 227.7 tonnes. In 2018, quantities landed has decreased to 181.7 tonnes. In Algarve, these resources have been showing an increase in the economic value of 3.6 €/kg in 2015 to its maximum recorded in 10 years of 5.5 €/kg in 2018, with quantities landed showing a negative correlation with its price, as landings have been decreasing from the maximum landed of 25 tonnes in 2015 to 18.6 tonnes in 2018. Still, this almost doubles the quantities landed between 2008 and 2013 of around 10 tonnes. Information gathered from harvesters and live bait shops in Algarve confirm that the species many times used as bait is the *S. marginatus*, but some recreational anglers admit acquiring this live bait sometimes at local supermarkets. In live bait shops in Algarve, this live bait was sold at 1 €/100 g (10 €/kg) corresponding, when extrapolated from this value, to 290000 € spent by recreational harvesters or 29 tonnes used in Algarve MRF, 4 tonnes more than the maximum quantity ever recorded by DGRM statistics for both species of razor clams in Algarve. However, it must be highlighted that *S. marginatus* landings share the same problem as polychaetes, and a great portion of the landings are not declared (Gaspar 2011).

Polychaetes from the genus *Marphysa* are the second native worm most demanded in Portugal territory, especially in Sado estuary where is the most harvested species (Costa et al. 2015; Cabral et al. 2019). Registries from DGRM in Portugal for this resource are available since 2007 to 2014 where minimal landings fluctuated from 25 kg in 2014 and maximal landings of 1.3 tonnes in 2012 (Costa et al. 2015; Sá et al. 2017). Furthermore, according to Cabral et al. (2019), in 2014 the largest sport store in Portugal sold approximately 19200 packages of *Marphysa sp*. However, the values reported from DGRM landings are underestimated, as a significant part of this business is suspected to occur through a parallel economy (Olive 1993; Cunha et al. 2005; Costa et al. 2015; Cabral et al. 2019). In France, it was estimated that around 1.3 to 2.5 tonnes of *Marphysa sp.* corresponding to approximately 400000 worms sold to French recreational anglers in 2011. In Queensland, Australia, a decrease was detected in the harvest of several *Marphysa* species from 12 million worms in the late 90's to only 5 million in recent years (Cole et al. 2018). Species from this genus were known to be the most valuable polychaete in Italy and were commercially harvested in Italy coastal systems being posteriorly

imported to the USA and Korea at the price of 4 US $ per box in 1992 (Gambi et al. 1994). In Portugal, the economic value of these polychaetes were available from Garcês and Pereira (2011) referring that the price per litre has fluctuated between 150 and 200 € in 2007, and between 250 and 300 € in 2008, with annual sales oscillating from 600 and 750 thousand € between 2007 and 2009. In live bait shops in Algarve, *Marphysa sp.* was being sold at 8 € per 100 g in 2018 and it was estimated that approximately 3.2 tonnes of this polychaetes were sold to Algarve anglers, corresponding to 256000 € in direct expenditures.

The species commonly named "Minhoca branca" or "Bicha branca" in Portugal is usually assigned to the species *Nephthys hombergii* (Cunha et al. 2005; Ravara 2010), however, there is the possibility of this species not being the only one harvested of this family. Although it was not one of the most used polychaetes, this live bait has a fairly expensive retail price when compared to other live bait species, being only outpriced by the polychaete known in Algarve as "Minhocão" (not to be confused with *Marphysa. sp*) that is sold individually instead of by weight. Considering the sale price of 15 €/ 100g in live bait shops in 2018, it was estimated that Algarve anglers spent approximately 318000 € in worms from *Nephthys sp.* for live bait in MRF, corresponding to nearly 2 tonnes. As far as can be told, this estimate appears to be the first attempt at an economic valuation of this resource, and it should be used as an indicator for comparison in future studies.

The harvest of the ghost shrimp known as "ralo" for its use in MRF is recurrent in Algarve (Veiga et al. 2008; Pontes 2019). According to Pontes (2019) this live bait was one of the most used baits in this region, and sampled anglers still reasonably rely on it during a good percentage of their fishing trips. Compared to polychaete worms, the ghost shrimp (*Upogebia sp.*) is also considerably cheaper costing 0.12 € per each shrimp in Algarve live bait shops in 2018. Although the harvest for bait was not mostly directed to the use of these small estuarine and lagoon crustaceans in Algarve, there are places such as Knysna Estuary and Langebaan Lagoon in South Africa where species of the *Upogebia* genus are extremely popular as bait (Wynberg and Branch 1991; Hodgson et al. 2000; Napier et al. 2009). The main species harvested in Knysna Estuary in 2000 and 2009 was the *Upogebia africana* (Hodgson et al. 2000; Napier et al. 2009), harvested by both subsistence fishers and recreational anglers, and according to Napier et al. (2009) 44 % of the 600000 mud prawns harvested annually. In communication with a live bait shop in Algarve it was reported that in summer approximately 10 000 ghost shrimps per month were sold to be used in MRF. Considering the sale price mentioned above (0,012 €) it

was estimated that around 1.6 million ghost shrimps were sold to recreational anglers in Algarve corresponding to approximately 200000 € in direct expenses.

There were polychaetes such as the native ragworm *H. diversicolor* and the exotic *G. dibranchiata*, and the sipunculids *S. nudus* ("salsicha") and *Sinpunculus sp. 2* ("Titas") that were also mentioned in previous studies as being commonly used in Portuguese MRF (Veiga et al. 2008; Carvalho et al. 2013a; Pontes 2019). However, *H. diversicolor* popularity appears to have declined partly to the use of the Korean ragworm which is cheaper and more durable (Carvalho et al. 2013a; Fidalgo e Costa et al. 2016; Font et al. 2018), and the use of sipunculids, especially the exotic ones, were not detected frequently. Nonetheless, anglers sampled use a great variety of native live bait and the exotic *Perinereis sp.*, and in the Algarve, this study estimated that approximately 2.3 million € was spent on live bait for the purpose of MRF. This value is similar to the estimate by Pontes (2019) of 1.6 million € in 2018 and to the one estimated by Veiga et al. (2008) of 2.2 million € in 2006/07, both for the Algarve region. This value is also lower than the one reported by Cabral et al. (2019) that estimated a mean harvesting of the species *D. neapolitana*, *Marphysa sp.*, and *H.diversicolor* to be 24.1 tonnes in Ria Formosa lagoon. In the USA in 2004 the landed values for polychaete fisheries of *G. dibranchiata* and *A. virens* was valuated at approximately 7.5 million USD$ and in 2007 in Nova Scotia, Canada *G. dibranchiata* economic valuation was around 900000 USD$, that is not too different from the economic valuation of the polychaetes inhabiting in Portugal found in Algarve MRF (*D. neapolitana*, *Marphysa sp.*, *Nephtys sp.*, *H. diversicolor* and *H. parthnopeia*) at around 1.2 million € corresponding to approximately 11.2 tonnes. This quantity is also comparable to quantities harvested in Australia, according to Henry and Lyle (2003) in 2000 that estimated the annual harvest of beachworms to be less than 10 tonnes. However, care must be taken when considering this value, as no correction factor was applied in information relative to number of fishing trips considered by sampled anglers, since recreational anglers are known to be propitious to recall bias or memory error that can lead to overestimation (Connelly and Brown 1995). Nonetheless, the quantity and economic value of live bait species estimated to be used in Algarve MRF is substantial and quantity used can rival commercial harvest species in North American countries, Australia, and the polychaete fishery of *A. virens* in U.K. Furthermore, the harvest of ghost shrimps has no records in the literature regarding its exploitation, and its popularity in MRF in Algarve revealed to be far greater than other crustaceans mentioned in the past like the green crab *C. maenas* (Veiga et al. 2008; Pontes 2019). Therefore,

efforts in the assessing the natural stock of this resource should be made in the future to understand the current intensity of exploitation. Considering the expenditures, quantities used of live bait as well the sell price of some polychaetes, this study agrees with Watson et al. (2017) that some species of these resources, especially polychaetes, should be given equivalent attention as other supervised fisheries so overexploitation that has been observed in the past for some species (e.g. *E. siliqua*) is not repeated.

Conclusion

Live bait harvesting is a relevant social and economic activity practiced in all major Portuguese coastal systems. Although studies in the past 20 years have characterized this activity, information regarding the biology, density, and assessment of harvest impact of the main species (*D. neapolitana*, *Marphysa sp.*, *Nephtys sp.* and *Upogebia sp.*) harvested in the Ria Formosa lagoon is still lacking. Biological factors such as reproductive and spawning periods as well as densities in main harvested areas of *D. neapolitana* and *Marphysa sp.* are absent, with only information for Ria de Aveiro by Pires et al. (2012) that reported the reproductive period of *Marphysa sp.* to be between March/April to August/September, and *D. neapolitana* to be between May to August. Current closed season legislation in the Sado estuary (1 of November to 30 of April – Portaria nº576/2006) has been shown to not agree with these findings and has been suggested a change of the closed season from April to September with establishment of rotation harvesting grounds to mitigate the socio economic effects of such prolonged closed season. As the main harvest areas in Ria Formosa are in the east part of the lagoon, assessment of density and reproductive seasons of both species should be taking priority on this location before any legislation should be applied.

Regarding biosecurity of the use of exotic species, mitigation measures such as the ones described in Sá et al. (2017) used by private companies keeping imported polychaetes in water tanks after transportation and replacing them in new boxes have shown to reduce the risk of dissemination of hitchhiker species. Furthermore, efforts should be made to educate recreational anglers on the possible impacts as the angler population sampled showed not to be informed.

Live bait shops have shown to have a critical role in the access to live bait of the Algarve recreational anglers. As this activity in the future may become supervised, is urgent that these establishments have a representative of their perceptions, and social and economic barriers. Font et al. (2018) has found that these establishment in Spain were also not aware of biosecurity problems, and the same scenario may be happening in Portugal. It is also important that these establishments can have a voice in the management actions that could be applied, to help prevent the same problems that recreational anglers are receiving towards new legislation, consequently of lack of organizations that can express their perceptions towards the state of recreational fisheries.

Finally, the continuous assessment of live bait harvest should carried out, as is done for recreational fishing in countries such as USA and Australia. Live bait has been shown to be a resource that suffers biological fluctuations needing assiduous monitoring. However, it must be remembered that the application of legislation towards these resources will only help if there is a presence of authority agents that can enforce it.

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Annexes

Annex I – Questionário de esforço de apanha de isco.

Date	Zona	# Apanhador	Coordenadas	Espécie apanhada	Tipo de vegetação	Tipo sedimento	Ferramenta utilizada	Perguntas /Observaçoes
		1						
		2						
		3						
		4						
		5						
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		35						
		36						

Legenda:

Ferramenta utilizada

1 faca de mariscar

2 bomba

3 ancinho

4 enchada

5 sal

6 vareta

Tipo de vegetação

1 Zostera noltei (sebarrinha)

2 Spartina maritima (parchal)

Perguntas/Observaçoes

quantas marés por mês?

quantos exemplares apanha por maré

Annex II – Location, number of trips and dates where questionnaires of harvest effort were performed.

Location	No.	Number of trips	Date
Faro beach to Quinta do Lago, including Ludo location	1	4	17.10.2016 01.11.2016 02.11.2016 15.05.2017
Airport interior zone: From Faro Beach to Ramalhete	2	4	18.10.2016 01.11.2016 10.11.2016 07.12.2016
From Faro beach to Barrinha	3	8	17.10.2016 10.11.2016 11.11.2016 15.12.2016 16.12.2016 12.05.2017 26.06.2017 08.07.2017
Faro A Faro B Faro C	4 5 6	6	 18.10.2016 10.11.2016 16.11.2016 10.07.2017 11.07.2017 12.07.2017
Deserta A	7	1	19.10.2016
Deserta B	8	1	20.10.2016
Farol island	9	1	30.11.2016
Culatra island	10	4	21.10.2016 09.06.2017 06.07.2016 07.07.2016
Armona	11	3	21.10.2016 30.11.2016 16.12.2016
From Faro to Faro beach, route done by boat	12	2	13.05.2017 21.05.2017
From Faro to Deserta Island, route done by ferry	13	1	19.10.2016
From Olhão to Armona, route done by ferry	14	3	21.10.2016 18.11.2016 30.11.2016
Olhão (Marina)	15	4	21.10.2016 09.07.2017 26.07.2017 27.07.2017
Total		42	

Annex III – Questionnaire presented to recreational fishers

Inquérito aos Pescadores Recreativos sobre o isco vivo

Dê o seu contributo para melhor conhecermos a importância do isco vivo para a Pesca Recreativa!

Este inquérito online, decorre no âmbito de um projeto de investigação científica desenvolvido pela Universidade dos Algarve e o Centro de Ciências do Mar (CCMAR). O objetivo deste projeto é recolher informação sobre as espécies, quantidades, valor económico, perceções e a importância do isco vivo para a pesca recreativa. Em paralelo com outras iniciativas, estamos a pedir aos pescadores recreativos que dêem o seu contributo, ao preencher este inquérito, de forma a conhecermos melhor a importância deste sector para a pesca recreativa, bem como, a importância dos nossos ecossistemas costeiros em fornecer este serviço.

Sobre este inquérito online

- A participação é estritamente voluntária e pode desistir a qualquer momento
- As respostas são anónimas e confidenciais e serão utilizadas unicamente de forma agregada e para fins estatísticos. A informação recolhida será armazenada num computador protegido por uma palavra passe e será apenas acessível aos investigadores envolvidos no projeto.
- O inquérito é breve. Tempo de preenchimento entre 2-5 min.
- Se for do seu interesse, pode obter mais informação contactando os investigadores responsáveis: Davide Morais Araújo (a44564@ualg.pt), Karim Erzini (kerzini@ualg.pt) ou Adriana Ressurreição (adriana.ressurreicao@gmail.com).

I. A SUA EXPERIÊNCIA DE PESCA RECREACIONAL

1.Em que parte do país pesca preferencialmente?

◯ Norte (Caminha a Peniche)
◯ Oeste (Peniche a Cabo de S. Vincente)
◯ Sul (Cabo de S. Vincente a Vila Real de S. António)

2.Em que altura do ano pesca?

◯ Todo o ano
◯ Inverno
◯ Primavera
◯ Verão
◯ Outono
Outro: _____

3.Quantas saídas de pesca faz por ano?

_____

4.Quais as modalidades de pesca recreativa que costuma praticar

◯ Pesca de cana a partir de embarcação
◯ Pesca de cana apeada
◯ Apanha de invertebrados
◯ Caça submarina
Outro: _____

5.Que tipo de isco costuma utilizar nas suas saídas de pesca? Indique sff os tipos de isco que utiliza e a importância relativa (%) de cada um, perfazendo um total de 100%.

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Isco natural vivo (ex. ralo)										
Isco natural morto (ex. choco)										
Amostra (ex. rapala)										

6.Por favor indique a proveniência do isco vivo que utiliza. Indique todas as opções que se aplicarem.

◯ Apanho o próprio isco
◯ Compro em lojas de isco
◯ Compro a apanhadores de isco locais/regionais
Outro: _____

7.No caso do isco vivo, prefere utilizar espécies de isco vivo nativas (locais/regionais) ou exóticas?

◯ Nativas
◯ Exóticas
◯ Ambas
◯ Não sei

8.Por favor indique quais as espécies de isco vivo que mais utiliza e a importância relativa (%) de cada espécie, perfazendo um total de 100%. (Faça um círculo à volta da espécie e valor apresentados)

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Casulo										
Parchal										
Ralo										
Salsicha										
Minhoca branca										
Minhocão										
Lingueirão/navalha										
Koreano										
Outros										

8.1. Se optou pela opção "Outros" na pergunta anterior, por favor especifique a espécie de isco vivo com a percentagem correspondente (10%, 20%...) até o máximo de três espécies.

_____

9.Quanto gasta em média (aproximadamente) por espécie de isco vivo por ano (euros)? (Faça um círculo à volta da espécie e valor apresentados)

	20€	50€	100€	150€	200€	300€	400€	500€	>500€
Casulo									
Parchal									
Ralo									
Salsicha									
Minhoca branca									
Minhocão									
Lingueirão/navalha									
Koreano									
Outros									

9.1. Se optou pela opção "Outros" na pergunta anterior, por favor especifique a espécie de isco com a categoria correspondente (0€, 20€,...) até o máximo de três espécies.

_____

10.Quais são as espécies alvo das suas saídas de pesca recreativa?

_____

11.Qual o destino do seu pescado?

◯ Consumo próprio
◯ Devolução ao mar
◯ Oferecer a amigos

Percepções sobre o impacto ecológico do uso de isco vivo

1.Qual a razão pela preferência pelas espécies de isco vivo referidas em cima?

◯ Obtenho melhores resultados
◯ Mais económica
Outro: _____

2.Tem conhecimento que a utilização de espécies de isco vivo exóticas (i.e., não locais/regionais, ex. americano, coreano, etc.) poderá ter um impacto negativo no ecossistema local?

◯ Sim
◯ Não
◯ Não sei

3.Se respondeu sim, na sua opinião quais são os possíveis impactos do uso de espécies de isco vivo exóticas?

◯ Introdução de espécies exóticas no ecossistema local
◯ Introdução de parasitas/bactérias
◯ Não sei
Outro: _____

4.Costuma atirar para o mar o resto do isco vivo após uma saída de pesca?

◯ Sim
◯ Não
◯ Às vezes
◯ Não responde

5.Estaria disposto a utilizar apenas espécies de isco vivo nativas?

◯ Sim
◯ Não
◯ Não responde

6.Na sua opinião a quantidade de espécies de isco vivo nativas é suficiente para colmatar as necessidades atuais dos pescadores recreativos?

◯ Sim
◯ Não
◯ Não responde

7.De acordo com a sua perceção como evoluiu a procura de isco vivo nos últimos 10 anos?

◯ Aumentou
◯ Diminuiu
◯ Manteve
◯ Não sei

Socio-demografia

As seguintes questões sócio demográficas são necessárias apenas para validação dos dados e resultados. No sentido de validar o presente estudo pedimos-lhe que nos responda às seguintes questões. Lembre-se que as respostas são anónimas e confidenciais e os dados serão usados apenas de forma agregada.

1.Género

◯ Masculino
◯ Feminino

2.Ano de nascimento

_____

3.Quantas pessoas fazem parte do seu agregado familiar?

_____

4.Ocupação profissional:

- ◯ Agricultor
- ◯ Pescador/Armador
- ◯ Comerciante
- ◯ Profissão Liberal (advogado, arquitecto, médico, etc.)
- ◯ Funcionário Público (quadro médio)
- ◯ Empregado
- ◯ Quadro superior
- ◯ Estudante
- ◯ Reformado
- ◯ Desempregado

Outro: _____

5.Qual é o rendimento mensal (euros) do seu agregado (após impostos)?

- ◯ 0
- ◯ entre 1 e 500
- ◯ entre 501 e 1000
- ◯ entre 1001 e 1500
- ◯ entre 1501 e 2000
- ◯ entre 2001 e 2500
- ◯ entre 2501 e 3000
- ◯ superior a 3000

6.Onde vive? (Por favor coloque os 4 primeiros números do código de postal)

_____

7.Gostaria de fazer algum comentário a este questionário?

_____

_____

_____

_____