Universidade de Aveiro Departamento de Biologia
Ano 2016/2017

Pedro Manuel Cancela das Neves

Estimating captures and discards of the beach seine conducted in Mira (Coimbra).

Arte Xávega em Mira (Coimbra): avaliação das capturas e rejeições.

DECLARAÇÃO

Declaro que este relatório é integralmente da minha autoria, estando devidamente referenciadas as fontes e obras consultadas, bem como identificadas de modo claro as citações dessas obras. Não contém, por isso, qualquer tipo de plágio quer de textos publicados, qualquer que seja o meio dessa publicação, incluindo meios eletrónicos, quer de trabalhos académicos.

Universidade de Aveiro Departamento de Biologia
Ano 2016/2017

Pedro Manuel Cancela das Neves

Estimating captures and discards of the beach seine conducted in Mira (Coimbra).

Arte Xávega em Mira (Coimbra): avaliação das capturas e rejeições.

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Marinha, realizada sob a orientação científica da Professora Doutora Maria Marina Pais Ribeiro da Cunha, Professora Auxiliar do Departamento de Biologia da Universidade de Aveiro

o júri

presidente

Doutora Ana Isabel Lillebø Batista
investigadora principal do Departamento de Biologia e do Centro de Estudos do Ambiente e do Mar da Universidade de Aveiro

Doutora Cristina Brice Pita
investigadora auxiliar do Departamento de Ambiente e Ordenamento e do Centro de Estudos do Ambiente e do Mar da Universidade de Aveiro

Prof. Doutora Maria Marina Pais Ribeiro da Cunha (Orientadora)
professora auxiliar do Departamento de Biologia da Universidade de Aveiro

acknowledgements

I would like present my sincere gratitude to:

Universidade de Aveiro, for providing me this opportunity.

Professor Marina Cunha, for accepting being my advisor, and for always being there when I needed, providing the essential support and guidance throughout the work progress.

Rui Vieira, for being crucial in all stages of this study. His help was fundamental and I'm much grateful.

The fishermen crews, especially the Portuguese Beach Seine President, Captain José Vieira.

Aldiro Pereira, for the enthusiastic support, aiding me collecting samples and sharing his fish knowledge.

Docapesca – Portos e Lotas S.A. for providing data regarding the landings.

Professor António Luis for helping in seabird's identification.

Pedro Seabra, Vanessa Ferreira, Diana Lopes, Filipe Tártaro, Américo Soares, Hugo Rocha, Guilherme Moura and Carolina Costa, for their precious aid by volunteering to help me collecting and processing the samples.

Inês Louro, for being promptly available to help me when I needed, and for sharing her last year experiences and data,

Mariana Almeida for aiding me in the statistical analysis.

LEME fellows, for holding up with the fish smell in the laboratory.

My friends for being there, giving me the much needed confidence boost.

My family and girlfriend, for their crucial support.

palavras-chave Arte Xávega; Capturas; Rejeições; Pesca acessória; Mira

resumo

Os recursos pesqueiros são uma fonte vital de nutrientes, e Portugal apresenta um dos maiores consumos de peixe da Europa (61.77 kg de peixe per capita em 2007). Sendo reconhecida como uma atividade importante a nível mundial, a pesca induziu graves depleções de stocks pesqueiros devido à sobrepesca e à falta de gestão adequada. Outra questão relacionada com as pescarias são as capturas ilegais, não reportadas e não regulamentadas, representando uma fração que é extraída do oceano e não é conhecida. Esta fração inclui as capturas acessórias e, consequentemente, os espécimes rejeitados que não são reportados. O conhecimento das rejeições é crucial para avaliações mais precisas dos stocks, bem como para medidas de otimização do uso e comercialização do pescado. A Arte Xávega é um tipo de pesca artesanal que é conduzida na costa Portuguesa. Existe pouca informação disponível relativamente à sua atividade. Devido à sua prática, os impactos da sua atividade no ecossistema necessitam de uma avaliação adequada, especialmente ao nível da quantidade de rejeições produzidas. Para analisar esta questão, este trabalho tem como objetivo as capturas e rejeições produzidas pela Arte Xávega que decorre na Praia de Mira (Coimbra, Portugal) durante o Verão de 2016 (Junho-Setembro, semanas 22 a 36 – W22 a W36) de quatro companhas. Dados das capturas foram fornecidos pela Docapesca, enquanto os dados relativos às rejeições (obtidos através da análise de treze lances) foram apenas recolhidos para uma companha. Dados relativos às capturas de 2015 foram também estudadas com o objetivo de avaliar as diferenças anuais. Diferenças nas Desembarques Por Unidade de Esforço (DPUE) das quatro companhas entre os dois anos foram detetadas. Resultados também indicam que 99.53 toneladas (23 taxa) de recursos marinhos (incluindo peixes, lulas e crustáceos) foram desembarcados e leiloados durante o período estudado de 2016 (W22-W36), o que representa um decréscimo quando comparado com os dados de 2015 (219.00 toneladas, 24 taxa, no mesmo período). *Trachurus trachurus* (Linnaeus, 1758) foi a espécie mais leiloada nos dois anos (127 toneladas em 2015 e 69 toneladas em 2016), representando também a espécie onde os pescadores obtiveram maiores rendimentos. Após ajustamento dos dados, uma média de 50 kg de recursos marinhos por lance foram rejeitados, representando tipicamente 15-60% do total capturado. A anchova *Engraulis encrasicolus* (Linnaeus, 1758) foi a espécie mais rejeitados, sumarizando um total de 1.9 toneladas. Outras espécies rejeitadas abundantes incluem o *T. trachurus*, *Sardina pilchardus* (Walbaum, 1792), *Trisopterus luscus* (Linnaeus, 1758) e o caranguejo-pilado *Polybius Henslowii* Leach, 1820. Estas últimas três espécies tiveram uma taxa de rejeição por lance estimada de 100%, enquanto a taxa do *T. trachurus* encontrava-se usualmente abaixo dos 3%, exceto em quatro lances. Possíveis razões para a ocorrência das diferenças anuais e motivos para a rejeição foram discutidos. A baixa contribuição desta pescaria no cenário nacional (estimada em 0.46% da pesca polivalente) não reflete a importância desta na comunidade local. Um decréscimo do número de companhas a exercer esta atividade é esperado. Para prever esta ocorrência, estudos deverão ser feitos com o objetivo de aumentar a sua sustentabilidade.

keywords

Beach seine; Captures; Discards; Bycatch; Mira

abstract

Fishing is a vital source of nutrients for human consumption, and Portugal yields one of the highest fish consumption per capita in Europe (61.77 kg per capita in 2007). Being recognized as a worldwide important activity, fisheries have induced serious depletions in natural fish populations due to overexploitation and lack of adequate management. Another issue related with fisheries are the IUU (Illegal, Unreported and Unregulated) captures, which represents a portion of what is extracted from the ocean that it is not known. This includes unreported bycatch and, consequentely, discarded specimens. The knowledge of discards is crucial for more adequate management. Beach seine is an artisanal fishery conducted in the Portuguese coast. Little information is available regarding its activity. Due to its practice, the impacts on the ecosystem needs proper assessment, especially due to large amount of discards that it generates. To address this issue, the present work aims to analyse captures and discards from beach seine fisheries occurring at Praia de Mira (Coimbra, Portugal) during the summer season of 2016 (June-September, week numbers 22 to 36 – W22 to W36) of four crews. Captures data were provided by Docapesca, while discards data (obtained upon analysis of thirteen samples) were only collected from one vessel. Data on captures of 2015 were also studied to assess yearly variations. Differences in Landings Per Unit Effort (LPUE) of the four crews were detected between both years. Results also shows that 99.53 tons (23 taxa) of marine resources (including fish, squids and crustaceans) were landed and auctioned during the study period of 2016 (W22-W36), which was a lower amount when comparing landings from 2015 (219.00 tons, 24 taxa, within the same period). *Trachurus trachurus* (Linnaeus, 1758) was the most auctioned species in both years (127 tons in 2015 and 69 tons in 2016), also representing the species where fishermen got their most profits. After proper data adjustment, an average 50 kg of marine resources per haul were discarded, representing typically 15-60% of the total captured. The anchovy *Engraulis encrasicolus* (Linnaeus, 1758) was found to be the most common discarded species, making up to a total of 1.9 tons. Other abundant discards included *T. trachurus*, *Sardina pilchardus* (Walbaum, 1792), *Trisopterus luscus* (Linnaeus, 1758) and the Henslow's crab *Polybius henslowii* Leach, 1820. These last three species had an estimated 100% discard rate per haul, while *T. trachurus* was usually below 3%, except in four hauls. Possible reasons for yearly differences to occur and motives for discarding were discussed. The low contribution of this fishery on the national scenario (estimated 0.46% of multi-gear captures) does not reflect its importance to the local community. Further decrease on operating beach seine crews on a national scenario is expected. To prevent this occurrence, proper assessments should be performed in order to increase its sustainability.

Index

List of Figures

List of Tables

Introduction

Fishing has been an important source of food for humanity, with plenty of socio-cultural benefits for those engaged with the activity. Recently, it was thought that marine resources were limitless. However, with increased scientific knowledge and fisheries development this perspective is now changed: these resources, although renewable are not infinite, and therefore require proper management (FAO 1995).

A record of erroneous management and lack of scientific support led traditional fishing zones to become overexploited (Castillo and Mendo 1987; Myers *et al.* 1997; Watson and Pauly 2001). Currently, fishing fleets threat most areas of the ocean, destroying the last natural refuges which, in the past, have acted as population and ecosystem buffer zones, now exposing populations to an increasing risk of collapse and decreased ecosystem resilience (Pauly *et al.* 2005).

Fisheries' management and policy

In 1950, the newly founded Food and Agriculture Organization (FAO) of the United Nations began its operational activity, collecting and analysing the global statistics on fisheries.

In the mid-1950s, quantitative models were developed as the basis of fisheries' management. These were mainly single-species management models, and the recommended control mechanisms were simply the selection of optimum or minimum size to be captured. This was known as the selective fishing method but recently, the concept changed; the requirement is not only avoiding undesirable sizes of target species, but also avoiding protected species and those without or with very little economic value. However, gear technology advances could not fulfil these requirements. Furthermore, this method does not take into consideration relevant fisheries' impacts on habitat alteration, trophic interactions and other ecosystem components (Hall *et al.* 2000).

The growth in fishing capacity led to the creation by the European Union of the Common Fisheries Policy (CFP), in 1983, last updated in 2014. The main objective of the CFP is to ensure that the European fishing industry is sustainable and does not threaten, over the long term, the fish populations' persistence and productivity. In Portugal, the General Management of the Maritime Natural Resources, Security and Services (*Direção Geral dos Recursos Naturais, Segurança e Serviços Marítimos – DGRM*, Portuguese Ministry of Agriculture and Sea) is responsible for implementing the measures established by the European Commission.

Among the major constraints on fisheries, from an economic, environmental and management point-of-view, are the Illegal, Unreported and Unregulated (IUU) captures. The occurrence of IUU captures means that only a portion of what is being extracted from the ocean is known (FAO 2016). To reduce the IUU captures, the last CFP reform established a discarding prohibition and introduced the landing obligation. This management tool was introduced on the 1st January of 2015; it stated that all the captures of species that are regulated by Total Allowable Catches (TACs) must be landed. Landing obligation has a phased implementation: it started with pelagic fisheries and fisheries in the Baltic Sea and will be extended to other fisheries in the EU by 2019. For the fisheries under this tool, all captures of all species that are managed through TACs, quotas and minimum sizes, must be landed. Minimum landing sizes were also changed into minimum conservation reference sizes, remaining largely the same, except for Baltic cod and anchovy in the South-Western waters. The Regulation (EU) No. 1380/2013, of December 11, of the European Parliament and of the Council, on its article No. 15, clause 11, states that fish that does not reach the minimum conservation reference size can be sold for purposes other than human consumption, such as to fishmeal, fish oil, animal food, food additives and pharmaceutical and cosmetic products.

Another approach to manage fish stocks and fishing communities is being tested, and it relies on an ecosystem-based analysis, implemented by the Ecosystem Principles Advisory Panel (1999). Ecosystem-based management is an environmental management approach that recognizes the full range of interactions within an ecosystem, including humans, rather than considering single issues or species. Some examples of the use of this method are described in Witherell *et al.* (2000) and Kaufman *et al.* (2004) reports for Alaska groundfish fisheries and California's nearshore fisheries, respectively. Although not considering a political perspective, Pauly *et al.* (2002)

acknowledge that the solution to enable ecosystem restoration and reduce excess fishing is simple: the creation of large scale natural refuges, with permanent no-take zones and the elimination of illegal incentives.

The European Commission also proposes some possible solutions to reduce bycatch and discards. The voluntary departure from fishing grounds when high quantities of low-sized fish are being caught is a good example of what happens in Norwegian waters (not an EU member). Making better use of low-value fish is important since they are inevitably caught (i.e. non-target species could be used as fishfeed in aquaculture). The reduction of TAC/quotas-related discards and monitoring discards levels are other examples of the proposals by the European Commission (CEC 2002).

Bycatch and discards

Bycatch and discards are among the most significant issues affecting marine fisheries management. Most fishing operations, whether they employ towed or fixed gears, capture organisms that are not the primary target of the activity. These may include individuals of target species under the minimum conservation reference size (stipulated through the Council Regulation (EC) No. 850/98, of 30 March, and amended by the Council Regulation (EC) No. 812/2015, of 20 May) or for which the quota level as been reached, and species that have little or no commercial value (Hall *et al.* 2000).

The European Commission distinguishes the consequences of bycatch and discards in three categories: biological, economical and related to stocks assessment and fisheries management (CEC 2002). Organisms' mortality and increased availability of biomass for scavengers is the most evident biological consequence. A decade ago, Kelleher (2005) estimated that 7.3 million tonnes of resources are dumped back to the ocean per year, where trawl fisheries for shrimp and demersal finfish account for over 50% of total estimated discards. The role of fishery discards as a supplementary food supply for scavenging seabirds is well recognized (Garthe *et al.* 1996; Votier *et al.* 2004; Carniel and Krul 2012). Since the growth potential of fish is decreased due to intense capture of the small individuals (Pauly *et al.* 2005), the obvious economic consequence is that profits are smaller than they would be if the fish were left in the sea to be caught at a mature age. For stock assessments, the major issue is that realistic fishing mortality rates are uncertain since the effectively discarded values are often unknown. For better management, the knowledge of these quantities is crucial. Therefore, scientific monitoring of discards is extremely important, and should be enhanced (CEC 2002).

In Portugal, between 2007 and 2014, it was possible to observe a growing trend in the fraction of discarded resources at auction (Figure 1). Noteworthy is that these numbers are only representing what is not sold at auction or was unfit for consumption, not including marine resources that are left at the beach, or dumped back into the ocean. Therefore, the values of the actual discards are clearly underestimated. Since 2013, the total rejected biomass decreased, which may be related to a corresponding decrease in landings (INE 2015; INE 2016). However, fished resources characterized as unfit for consumption increased to almost 100 tons in 2015.

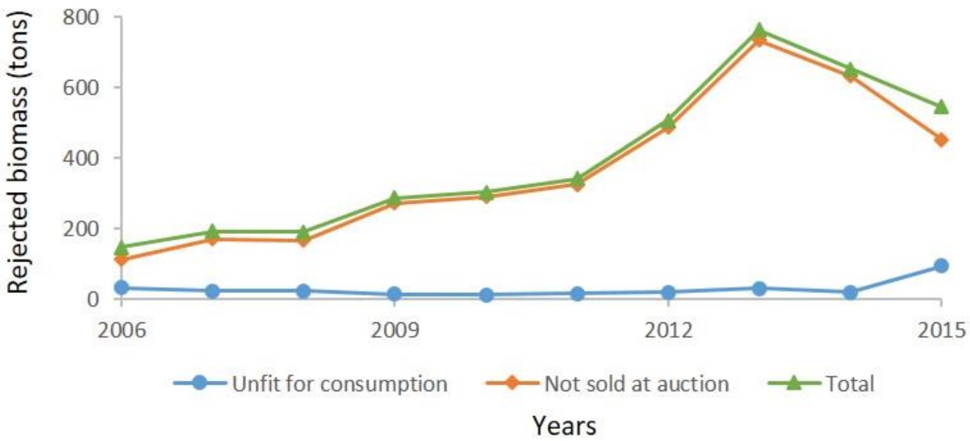


Figure 1. Statistics provided by the Portuguese Statistics Institute (INE), regarding the rejected biomass between 2006 and 2015. Total sums up what was rejected at auction and labelled as unfit for consumption. Source: INE 2007 - 2016.

For the Southern coast of Portugal, Borges *et al.* (2001) estimated discards as 20% of the total catches for demersal and pelagic purse seining, 13% for trammel nets, and 62% and 70% for fish and crustacean trawls, respectively. Other studies have reported higher values: 90% for crustacean trawl fishery in the Algarve (Monteiro *et al.* 2001) and 31.1% for trammel nets in European small-scale fisheries (including the Algarve; Gonçalves *et al.* 2007). However, there has been much less focus on small-scale beach seine discards and how to manage their impacts (Gray and Kennelly 2003).

Portuguese fisheries

In Portugal, fishing is a common practice since the medieval times (Pereira *et al*. 2015). However, the first comprehensive study about the state of fisheries was only published on 1892, by the Captain António Artur Baldaque da Silva (da Silva 1892). The average fish consumption *per capita* in Portugal (estimated as 61.77 kg per capita in 2007) is the highest in the European Union (Source: Eurostat). This reflects the importance of fisheries in Portugal, and how substantial the demand is. Portugal is geographically in a favourable position for fisheries, with one of the largest Exclusive Economic Zone (EEZ; total area of approx. 1.7 million km^2) in the European Union, 18 times larger than its land territory (Pereira *et al.* 2015).

According to DGRM, the main marine resources exploited by the Portuguese fleet are small pelagic species such as sardines, horse mackerel, especially *Trachurus trachurus* (Linnaeus, 1758), and mackerel (mostly, but not exclusively, from the family Scombridae), however, the most important, from an economic point-of-view, are the demersal species, such as octopus, hake, prawns and cuttlefish. Other species include the black and white scabbardfish.

The national fleet consists predominantly of small vessels (about 91% with an overall length of less than 12 meters) operating with different fishing gears, such as gill and trammel nets, traps and longlines, usually sailing up to 6 miles from the coast (Source: DGRM). In 2015, 4 188 fishing vessels had fishing licenses, the lowest number since 2006. This constitutes a reduction on the fishing fleet, with less capacity and less power engine (INE 2016).

In 2015, the average price of fish traded in auction was 1.81€/kg. This represents a decrease in relation to 2014, that according to the statistical records showed the highest average price of fish traded in auction (2.02 €/kg). This difference may be related to the total amount of fish traded in auction (119 890 tons in 2014 and 140 831 tons in 2015; INE 2016); the price change reflects the total fish traded in auction, where the decrease in quantities landed lead to an inflation of marketed fish prices and an increase in landings tends to decrease its value.

Beach seine fisheries

According to FAO, the fishing activity is extremely diversified. Fisheries can be classified as industrial, small-scale and recreational. Industrial is a form of intensive fishing where the vessels have advanced fish finding devices and navigational equipment. When the capture of fish is for sport or own consumption, with no commercial trading is involved, it is classified as recreational. The classification of small-scale fisheries is uncertain and may include artisanal fisheries. The differences in small-scale and artisanal fisheries are subtle, and they take into account several characteristics concerning the explored region and type of vessel (McGoodwin 2001).

Nearly 95% of the world's fishermen, representing over 20 million primary producers, are involved in small-scale fisheries. More than 40 million people worldwide are employed within the small-scale sector, including small-scale processors, marketers and distributors. All captures made by small-scale fisheries are suitable for human consumption, whereas around a third of the large-scale fisheries are subsequently processed and used mainly for animal feed (McGoodwin 2001).

Beach seine is an artisanal fishing activity that has been used for thousands of years throughout the world (Gabriel *et al.* 2005). Usually, the seine has buoys on the head rope at the top of the net and weights attached to the footline at the bottom of the net. This provides a way of keeping the net vertically open when pulled through the water, trapping the resources (Tietze *et al.* 2011)(Figure 2). Certain regions where beach seining is employed use motor-powered boats to set the net, while other fishing regions use non-motorized boats (such as in Sri Lanka and India, where the majority of the boats are human-handled). When preparing the haul, one of the hauling lines is fastened onto the shore, and the shoreward wing, seine body and seaward wing are set out in a wide semi-circular arc (Tietze *et al.* 2011). The hauling may be carried out either manually, with the help of bulls, or using two tractors, one for each rope end. For these reasons, beach seining is only possible to occur in coastal areas with sandy beaches that are sufficiently long to facilitate the necessary net and vessel manoeuvres (Pereira *et al.* 2015).

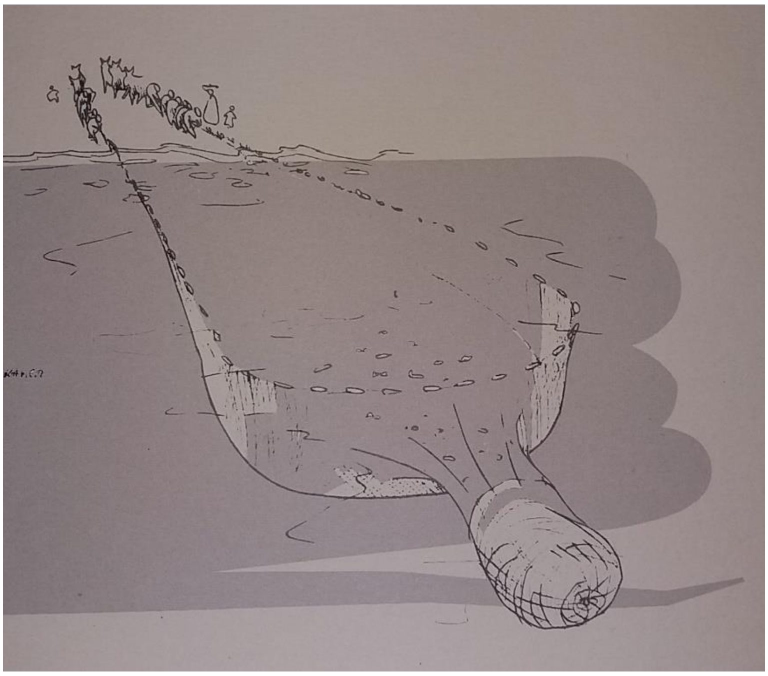


Figure 2. Beach seine net trapping resources. Source: adapted from Fernandes (1984)

Beach seine is one of the most important artisanal fisheries in Portugal (Pereira *et al.* 2015) and, due to its geomorphologic requirements, it can only be executed in the Central Coast and the Algarve region (Figure 3).

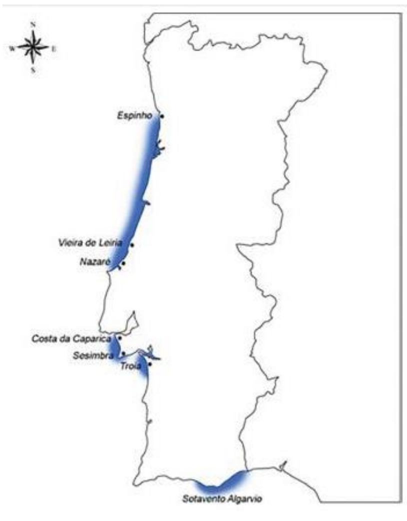


Figure 3. Portuguese beach seine geographical locations. Source: Pereira *et al.* (2015).

Two theories could explain beach seine introduction in Portugal, both assuming that it derived from a Mediterranean practice. The first suggests that the implementation of this fishing practice started in the region of Ria de Aveiro (Figure 4a). The second assumes that the arrival of Catalan fishermen to the Algarve, marked the beach seine beginning in Portugal (Figure 4b) (Pereira *et al.* 2015). Martins *et al.* (2000) and Franca and Costa (1979) support the latter theory stating that the first report of beach seining in Portugal is dated from the year 1405, for the Algarve region. The Portuguese fishermen were later responsible for the introduction of the beach seine expertise in South Africa (Lamberth *et al.* 1997).

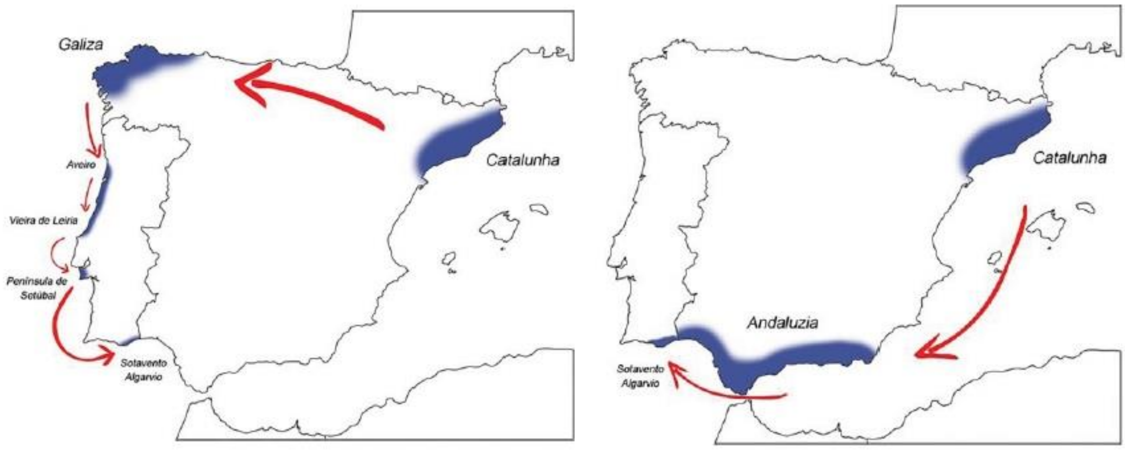


Figure 4. Introduction of the beach seine in Portugal through Ria de Aveiro (left) and the Algarve region (right). Source: Pereira *et al.* (2015).

It is known that artisanal fishery is exceptionally important for local communities, contributing with the supply of good quality fish (Viegas and Tedim 2012), and in 1973 the Portuguese Government introduced the Regulamentation for Artisanal Fisheries, through the Ordinance No.4/1973, of 6 January. In 1996, the Ministerial Order No.488/1996 of 16 September, approved the Seine Fishery Regulamentation, where proper characterization of this activity is made, describing its operating zones and specific restrictions, such as the minimum authorised mesh size, which is 20mm for the codend. This practice is currently the only seine-surrounding type of fishery in Portugal, defined by the Regulatory Decree No.7/2000, of 30 May, and standardized by the Ordinance No.1102-F/2000, of 22 November.

Beach seining is a seasonal fishery, operating usually between March and October (Jorge *et al.* 2002). According to Cabral *et al.* (2003), the main target species in Portugal are small pelagic fish such as the mackerel, *Scomber japonicus* Houttuyn, 1782, anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), horse mackerel, *T. trachurus* and sardine, *Sardina pilchardus* (Walbaum, 1792). The mackerel, anchovy and horse mackerel represent up to 95% of the landings (Martins *et al.* 2000; Jorge *et al.* 2002; Antunes 2007; Louro 2016)

In order to be auctioned, the resources caught must fulfil the legal requirements and must have market potential. The value of resources auctioned at the market may be highly variable and so is the fishermen's income that is based on the value of the landing (Antunes 2007). These characteristics are not attractive for the young fishermen, specially due to the instable salary (Antunes 2007; Santos *et al.* 2012) and as in other artisanal fisheries, Portuguese beach seine workforce is characterized by the predominance of males but especially in older age groups.

Beach seine impacts

In developing countries, beach seines are an important source of income and employment, supporting the livelihoods of numerous coastal communities. Benin and Togo, in West Africa, and Mozambique, in east Africa, have a less developed fisheries sector, where beach seining accounts up to 70% and 80% of the total captures, respectively (Tietze *et al.* 2011). However, over the last two decades, beach seining became controversial because of the potential negative environmental impacts of this practice on the habitats, namely on nursery and breeding grounds, and on fish stocks through the capture of juveniles. Some countries have introduced new regulations, while others proceeded to ban fishing with beach seines (Tietze *et al.* 2011). The dilemma is how to balance peoples' livelihoods and food security with the need to re-establish and maintain a healthy ecosystem towards an increase of fisheries productivity, but this dilemma is not unique to beach seine.

Artisanal fisheries are known for using several fishing gears and affecting different fish stocks, although to a lesser degree than industrial fisheries. In Europe, studies on beach seine impacts are scarce (Cabral *et al.* 2003). Towards a better beach seine management, it is important to gather valid scientific knowledge around its real impacts, so no unjustified restrictions are imposed (e.g., ban of beach seine in False Bay surf zones, South Africa; Clark *et al.* 1994).

The grounds of this fishery are coastal shallow sandy areas. Although there are few studies on the structure and dynamics of fish assemblages for the Portuguese coast, some studies have highlighted the importance of these locations because they may act as nursery grounds for fish (Gibson 1994; Andrades *et al.* 2012; Ellis *et al.* 2012).

According to this, beach seine is expected to have impacts on juveniles. Furthermore, this fishery is characterized by a large amount of discards, since it uses a low selectivity fishing gear (Lamberth *et al.* 1997; Cabral *et al.* 2003; Akel and Philips 2014; Louro 2016). Several other problems concerning beach seine impacts on benthic organisms could be addressed, such as bottom trawling (e.g.: de Groot 1984, Prena *et al.* 1999), however, Lamberth *et al.* (1995) study has shown that beach seine did not produce significant impacts in the benthic fauna and flora.

Accidental captures of marine mammals, although rare, are of particular concern and attract the media attention. On the 22nd of July of the present year[1], a group of 150 dolphins were accidentally caught in Praia de Mira's beach seine, however, fishermen were successful at saving 133. The number of casualties was not higher due to the fact these fishermen partially destroyed their nets, despite the high financial and practical costs of such damage. There are previous records of dolphins getting trapped in nets, but the number of events may be decreased with the use of sensors that produces a low frequency signal (International Whaling Commission).

Due to the low commercial value of most of the catch and to minimum reference conservation size, beach seine fishery is responsible for a large quantity of discards (Cabral *et al.* 2003). In Fonte da Telha (Setubal, Portugal), it was estimated that the discards from beach seine activity were high for most species, especially the ones with low commercial value (Cabral *et al.* 2003). However, not all species were discarded according to its market value. Sardines and mackerels were sold at a low commercial value, but still had low rejection percentages. It has been also shown that discards, for some species, depends on season, while others were highly discarded in all seasons (Cabral *et al.* 2003). In Costa da Caparica (Lisbon, Portugal), Antunes (2007) has observed that discards represented 13% of the total captures. Discards were essentially species with no or little market potential and juveniles, and varied according to species. Dominant discarded species in Praia de Mira (Coimbra, Portugal) monitored during 2015

---

[1] Golfinhos morrem nas redes de pesca. Jornal de Notícias, 2016. http://www.jn.pt/local/noticias/coimbra/mira/interior/dezassete-golfinhos-mortos-em-captura-acidental-de-pescadores-5300540.html (accessed on 09/08/2016)

included the European anchovy, the tub gurnard, sardines, pouting and the Henslow's swimming crab. Total discards typically accounted for 20 to 40% of the total biomass captured (Louro 2016)

Objectives

Scientific information regarding the Portuguese beach seine activity is available, but limited, especially regarding its pressures and, ultimately, ecological impacts. The main objective of this work is to make an assessment of the captures and discards from beach seine fishery in Praia de Mira (Central Portugal). Specific aims include:

1. Characterization of captures in terms of target and non-target species using auction and field data, respectively;
2. Assessment of abundance and biomass of the dominant discarded species;
3. Temporal analysis of captures and discards;
4. Discussion of possible solutions to avoid discards or to comply with the landing obligation.

Materials and Methods

This study was conducted in Praia de Mira (Figure 5), between June and September of 2016. Beach seine is a traditional practice in this region[2], and has a local market coordinated by Docapesca – Portos e Lotas, S.A., where landings are auctioned.

Figure 5. Location of the study area. Reference point: Docapesca – Portos e Lotas, S.A. (GPS: 40°27'30.12"N, 8°48'8.72"W). Source: Google Earth v.7.1.5.1557.

There are 5 actively working fishermen beach seine crews in Mira's region, where 4 operate in Praia de Mira and the other in Poço da Cruz beach. Each crew is constituted by ca. 16 fishermen, usually 10 are involved in each haul operation, rotating frequently. Although there are specific operation zones for each vessel, no conflicts arise between fishermen if they fish in areas other than their own. Furthermore, Mira's coastal management plan was approved through the Ministerial Council No.142/2000, of 20 October, and clearly defines zoning with adequate fishing and bathing areas. Hauls can go as far as 3 nautical miles (5.56 km) offshore, but the samples reported herein were from hauls that reached approximately 1.07-1.34 nautical miles (2.0-2.5 km).

[2] Turismo do Centro. Praia de Mira. http://www.turismodocentro.pt/pt/produtos_.2/praia_de_mira_.a496.html (accessed on 15/08/2016)

Vessel characterization

To study the discards from beach seine activity in Praia de Mira, one crew (V1) was followed from June to September 2016. The vessel characteristics are within the typical ones for the Portuguese small-scale fisheries fleet: over 10 years old vessels with a total length of approx. 12 meters. Plus, the vessel has 4.5 tonnes of gross tonnage and it is equipped with a motor with approx. 90 horse power. Each crew uses its own nets (Figure 6), which may vary in total size and its mesh. The net used by this crew is characterized in Table 1.

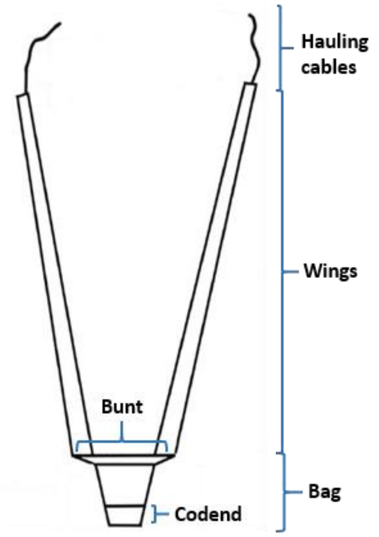


Figure 6. Schematization of the net structure. Source: Adapted from: Pereira *et al.* (2015).

Table 1. Settings of the net employed by V1. Total length and mesh size are described for each net section.

	Length (m)	Mesh size (mm)
Hauling cables	2500 (each)	-
Wings	390 (each)	600-200
Bag	43	160-2
Codend	4	2

Sampling

Beach seining in Praia de Mira in 2016 started in the end of May and field work was conducted from June to September. Since in this region beach seining is a seasonal activity, no samples were collected in the winter. One random sample of ca. 20 kg of the discarded portion of the capture was collected each week. Sampling day varied according to weather and sea conditions. A total of 13 samples were collected (Table 2). Preliminary sorting and identification of the species was carried out on site. The less common species were stored individually in suitable containers. The total biomass of each abundant species was weighted on site and, afterwards, three sub-samples of 30 individuals randomly selected were weighted, allowing for subsequent estimates of the average individual biomass and abundance. Lastly, 30 randomly selected specimens of each dominant species were stored for lab processing. To conclude field work, all the non-selected organisms were returned to the sea.

Table 2. Sample metadata. Start and End pertain to the haul operation. A code was used to identify each sample, where the number is regarding to the week number of the current year (2016).

Sample	Date	Start (approx.)	End (approx.)	Code
1	02/06/2016	06h00min	08h30min	S22
2	09/06/2016	09h00min	11h00min	S23
3	24/06/2016	06h30min	08h40min	S25
4	30/06/2016	05h15min	08h10min	S26
5	07/07/2016	06h00min	08h30min	S27
6	21/07/2016	12h30min	16h00min	S29
7	25/07/2016	07h00min	11h00min	S30
8	03/08/2016	06h15min	08h30min	S31
9	08/08/2016	08h00min	09h30min	S32
10	16/08/2016	03h30min	07h00min	S33
11	23/08/2016	07h30min	10h40min	S34
12	30/08/2016	06h20min	08h30min	S35
13	06/09/2016	07h20min	08h50min	S36

Sample processing

Total and fish standard sizes (Figure 7, ± 0.1 cm) and fresh weight (± 0.01 g) were obtained. Muscle tissue samples of almost all species (around four organisms per species per sample, whenever possible) were collected and stored at -18ºC for future stable isotope analysis (trophic ecology) and molecular studies. Selected specimens were included in the Biological Research Collection (Departamento de Biologia, Universidade de Aveiro).

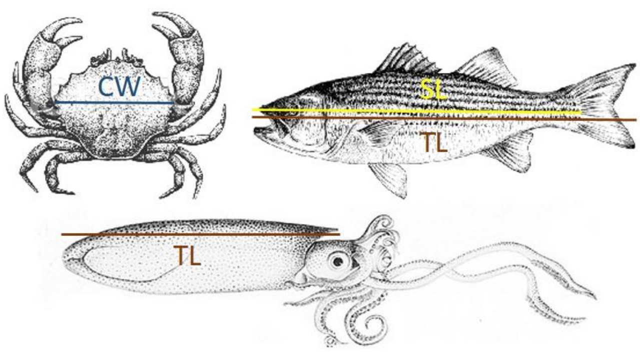


Figure 7. Crustacean, cephalopod and fish measuring method. TL: total length; SL: standard length; CW: carapace width.

Data analysis: Landings

Official records of landings (biomass in kg) from 2015 and May to September of 2016, regarding the four beach seine crews of Praia de Mira, were provided by Docapesca – Portos e Lotas, S.A.. Care should be taken when interpreting the following analyses, since the official statistics only include species that were sold, while there is a lack of information on the pre- and post-auction discards. Based on these data, total landings were estimated for the considered sampling period (week 22 to week 36). Knowing the activity days through Docapesca data, an assessment of Landings Per Unit Effort (LPUE) was made, defined as biomass landed per activity day per vessel. The average price per kilogram of the main auctioned species was also estimated. The percentage of discarded biomass was assessed from estimates of the discarded biomass (values obtained from sampling) and landed biomass (inferred from data from Docapesca) in each sampled haul.

For the multivariate analysis the total weekly biomass data of the landed species by each of the four studied crews was organized in a matrix (28 species vs. 120 samples corresponding to 15 weeks x four crews x two years). Non-metric Multidimensional Scaling (nMDS) was performed using the Bray–Curtis similarity measure, after square root transformation of the biomass data, allowing to decrease differences between abundant and less abundant species (Field *et al*. 1982). The analysis of similarities by randomization/permutation tests (ANOSIM) was performed to assess for: i) differences among the landings of the four crews during the study period of 2016, using a one-way layout; ii) inter-annual variations and differences in the landings of the four crews over 2015 and 2016 using a two-way crossed layout (Clarke 1993). The two-way crossed layout means that the tests for differences between "Year" groups are averaged across all "Vessel" group and vice-versa (Clarke 1993). By using two-way crossed layout, the effect of inter-annual variation can be assessed against differences between vessels. SIMPER (Similarity Percentages – species contributions) analyses were performed to assess the percentage contributions of each landed species to the similarity within and dissimilarity between the groups. For all tests, the statistic R is presented; R values give an absolute measure of how separated the groups are, on a scale of 0 (indistinguishable) to 1 (all similarities within groups are less than any similarities between groups) (Clarke and Gorley 2006). The significance of all tests was expressed as a percentage (P). PRIMER v6 software (Clarke and Gorley 2006) was used for these multivariate analyses.

Data analysis: Discards

Discarded organisms were categorized as target (TS) and non-target (NTS) species, according to its market potential. Target species include the ones who were discarded due to other reasons rather than its commercial stance, whereas the ones classified as non-target had no market value. Discarded organisms were identified whenever possible to species level, and their frequencies of occurrence over the sampling period were recorded. Community structure was characterized by estimating abundance, taxa richness and k-dominance (abundance-biomass curves, Lambshead *et al.* 1983) per sample. The software PRIMER v.6.1.13 was used to estimate Species Richness (S) and Shannon-Wiener diversity index (H', ln), Pielou's evenness index (J') and Hulbert's Expected Number of Species ($ES_{(n)}$) (Clarke and Gorley 2006). The estimation of the number of hauls per day allowed the analyses of the discard rate per haul, and per species.

Dominant discarded fish species were selected for a more detailed analysis regarding its demographic structure and condition. Size-class frequency distributions were graphically analysed through histograms. Temporal variation of the Individual Mean Biomass (IMB) was also studied. Fish condition was assessed through the analysis of weight-length relationships. These were estimated by fitting an exponential curve ($W=a*TL^b$) to the data. Parameters *a* and *b* of the exponential curve were estimated by linear regression analysis over log-transformed data:

$$\log(W) = \log(a) + b*\log(TL),$$

where W is the weight (g), TL is the total length, *a* is the intercept and *b* is the regression coefficient. The degree of association between TL and W is given by the coefficient of association R^2.

According to Froese (2006), it is possible to infer that if:

- $b < 2.948$, it indicates a tendency towards negative-allometric growth (decrease in relative body thickness or plumpness);

- $2.948 \leq b \leq 3.075$, it indicates a tendency towards isometric growth (fish body weight increases with the length isometrically);
- $b > 3.075$, it indicates a tendency towards positive-allometric growth (increase in relative body thickness or plumpness).

Results

Landings

Landings from June until early-September of the four crews operating in Praia de Mira are shown in Figure 8, where the landings for V1 are also plotted separately. A careful interpretation should be made, since landings data from Docapesca only consider auctioned resources, and do not include pre- and post-auction discards. In this period (W22 to W36), a total of 99.53 tons of organisms were landed. Also, V1 and V2 crews landed the most, reaching 34.93 and 46.19 tons, respectively. Total landings included 23 different taxa, (Annex I) from which 19 species of bony fishes accounting for 96.32 tons landed for the considered period. The remaining species were one cartilaginous fish (*Raja clavata* Linnaeus, 1758) and three cephalopods (*Alloteuthis* sp., *Loligo vulgaris* Lamarck, 1798, and *Sepia officinalis* Linnaeus, 1758). The Atlantic horse mackerel *T. trachurus* was the most landed species (68.97 tons) with large quantities being landed throughout the study period, except for July (W28 to W30). The second most frequent species (15.53 tons), the anchovy *Engraulis encrasicolus* (Linnaeus, 1758), was landed mainly after W29, with 52% of those landings made by V1.

Weekly landings of V1 crew ranged from 71.1 kg (only 2% of the total landings in W35) to 5 526.3 kg (35% of the total landings in W31); *T. trachurus*, *E. encrasicolus*, *Alloteuthis* sp. Wülker, 1920, and *Scomber japonicus* Houttuyn, 1782, were the most landed species, corresponding to a total of 18 890.3, 8 028, 883.6 and 618.0 kg, respectively. The V1 landings of *E. encrasicolus* and *T. trachurus* accounted for 52% and 28%, respectively, of the total biomass landed for these species. The salema, *Sarpa salpa* (Linnaeus, 1758), was landed essentially by V1. However, the landings for *Sardina pilchardus* (Walbaum, 1792), one of the most important target species, was rather low (only 28 kg during the study period).

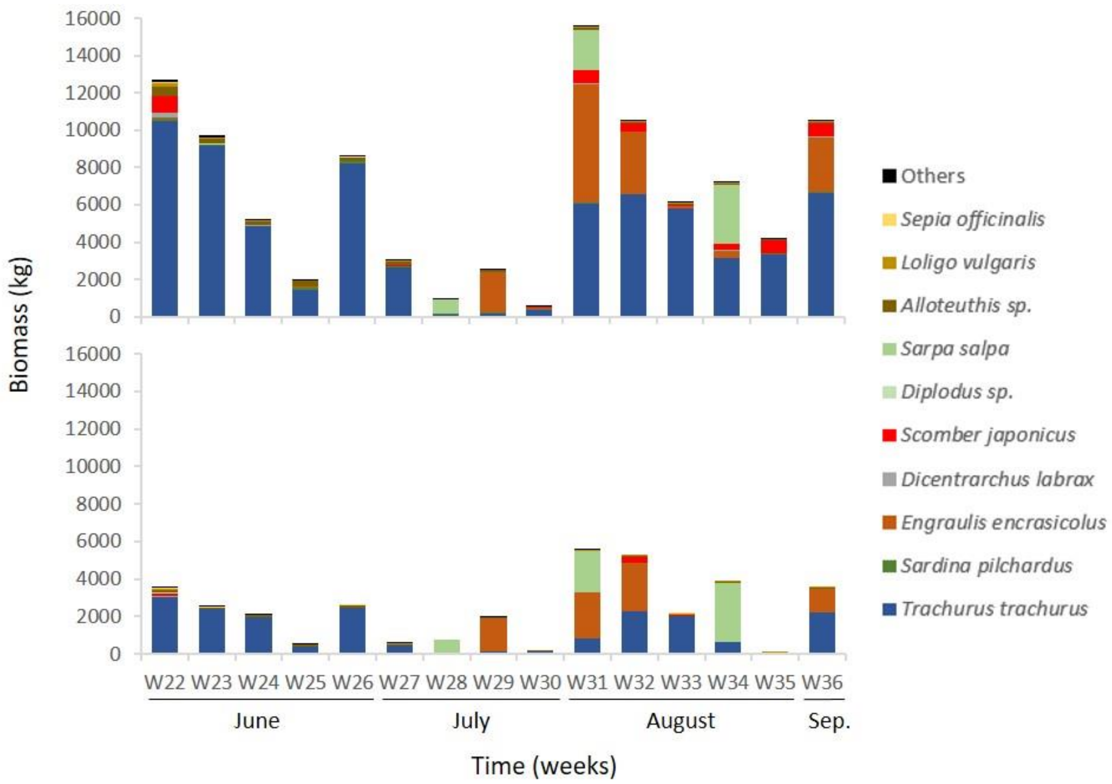


Figure 8. Total landings over the weeks of the four beach seine crews operating in Praia de Mira (on top) and V1 landings (bottom).

The total landings of the four crews were compared using a multivariate analysis (Annex II). The results of the ANOSIM test showed significant differences among crews (R=0.206; P=0.1%) that were explained mainly by variations in the total biomass landed of the dominant species (*T. trachurus*, *E. encrasicolus* and both squids – *L. vulgaris* and *Alloteuthis* sp.). Besides the contributions of these dominant species, *S. salpa* was also a major driver for dissimilarities between V1 and other crews. V3 and V4 showed consistently lower landed biomass for all species, with the exception of the tub gurnard, *Chelidonichthys lucerna* (Linnaeus, 1758), for V4, which led to increased dissimilarities between this crew and the others (results of the SIMPER analysis in Annex II).

The number of hauls per day, carried out by V1, ranged from one to four, but were typically two to three. This crew performed one to seven days a week. The number of activity days in V1 was one of the highest among the Praia de Mira crews: 65 days close to V2 with 64 days while the records for V4 and V3 were only 50 and 56 days, respectively.

The V1 crew LPUE (landings per unit effort, expressed as landings per activity day, Figure 9, right) ranged from 23.7 to 789.5 kg.d^{-1}, in W35 and W31 respectively, while LPUE for V2 varied from 80.6 kg.d^{-1} (W28) to 1310.4 kg.d^{-1} (W26). V3 and V4 landings ranged 17.0-635.5 kg.d^{-1} and 20.4-742.7 kg.d^{-1}, respectively. Typically, V1 and V2 had consistently higher biomass records than the other two.

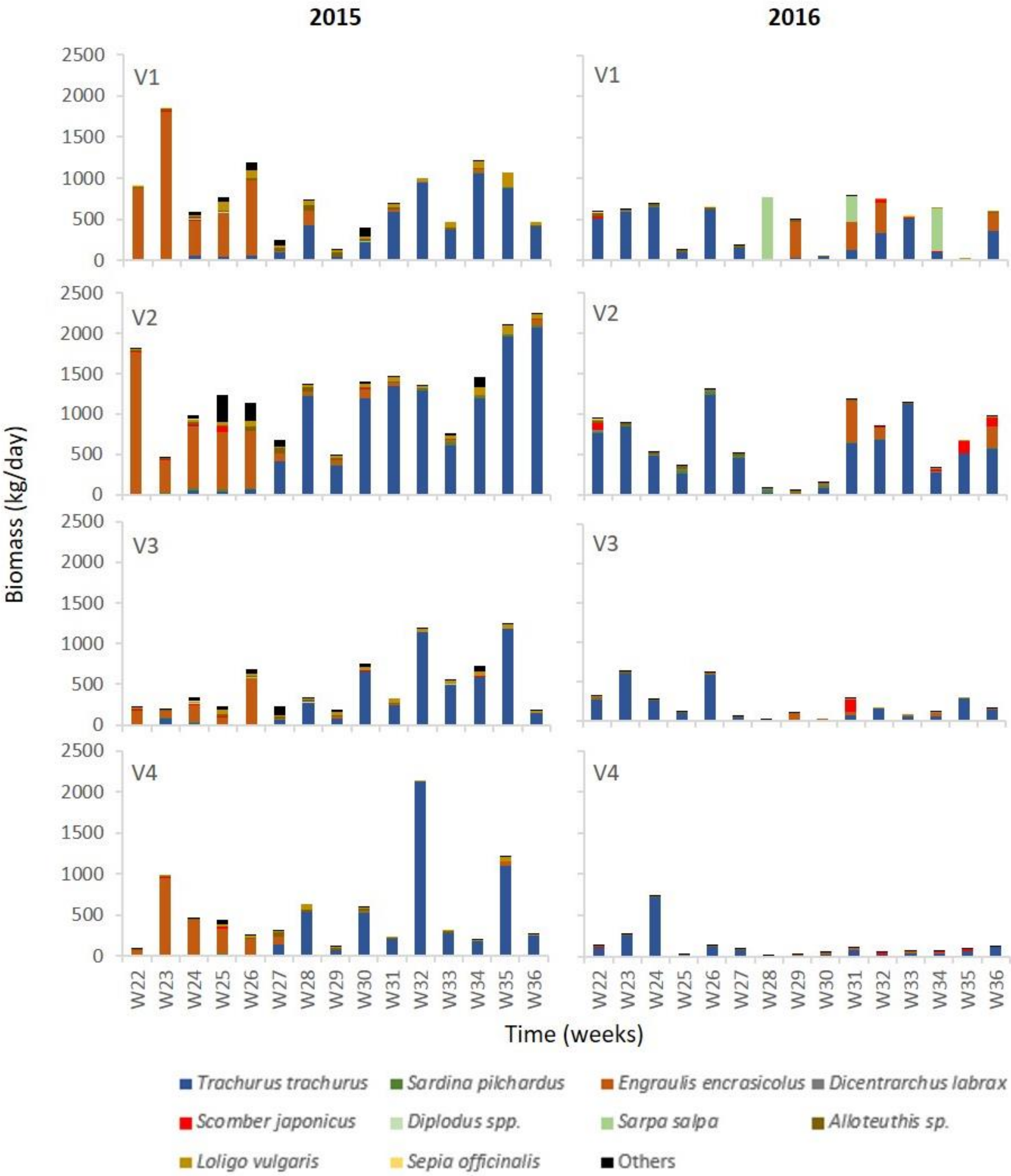


Figure 9. LPUEs (biomass landed per activity day) of the four Praia de Mira crews, in 2015 (left) and 2016 (right) (activity day ranged from 1 to 7 days per week).

The Atlantic horse mackerel was landed almost on a daily basis by all crews, making up to a significant portion of the landings per activity day. Maximum LPUE of this species were reached in June and the minimum in July (V1 and V2 in the same week). Regarding V1, LPUE of this species ranged from 31.3 to 650.0 kg.d^{-1} (W29 and W24, respectively, and excluding W28 when there were no landings reported). V2 LPUE for the Atlantic horse mackerel ranged from 6.5 to 1 241 kg.d^{-1} (W29 and W26, respectively). The higher LPUEs of anchovy *E. encrasicolus* were obtained by V1 and V2: 12.3-438.0 kg.d^{-1} and 3.3-520.1 kg.d^{-1}, respectively.

Fluctuations in the average price per kilogram in auction for the considered sampling period are shown in Figure 10. This data only takes into consideration the earnings of V1 and V2, since they represent 81% of the total landed for this period. Only two species, *Alloteuthis* sp. and *T. trachurus,* were consistently auctioned every week during the study period. The three most valued species were the Loliginidae squids and the European seabass. Some fluctuations in prices per kilogram were observed for *L. vulgaris*, and *Dicentrarchus labrax* (Linnaeus, 1758), however they were consistently above 5 €/kg. The price per kilogram of the European squid *L. vulgaris* varied from 5.15 to 11.86 €/kg, and *D. labrax* ranged from 6.00 to 8.68 €/kg (excluding W22 when the price was 3.92 €/kg). Minor fluctuations throughout the sampling period were observed for *Alloteuthis* sp. price per kilogram that varied from 5.06 to 7.08 €/kg. Other fishes were less valued with average prices over the study period, ranging between 0.72 €/kg for *E. encrasicolus* and 2.04 €/kg for *T. trachurus*.

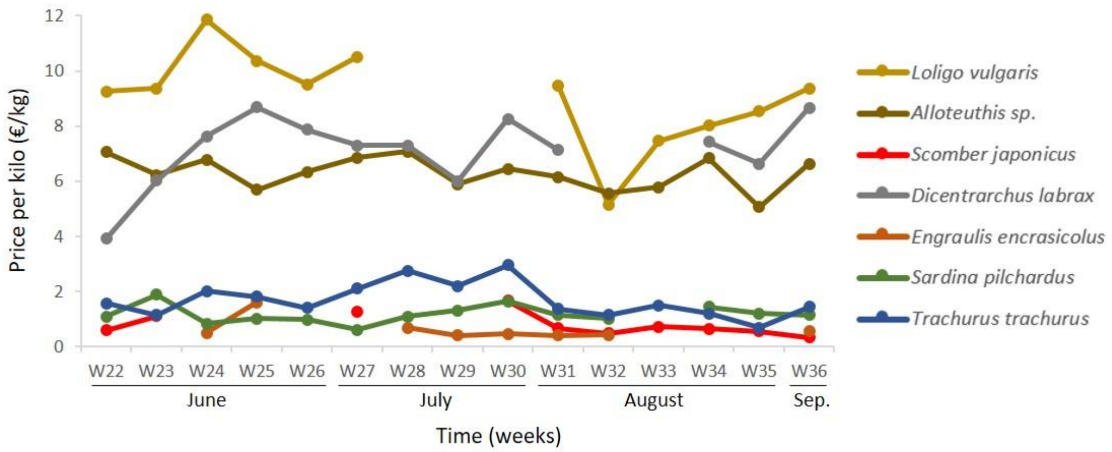


Figure 10. Average fish price per kilogram in the considered period (W22-W36).

A comparison between the contributions of the different species to the total biomass auctioned and total earnings (Figure 11) revealed that *T. trachurus* was one the main sources of the fishermen's income. More than 75% of their total earnings in the study period of 2016 were based on this species' captures. Squids, due to their higher price per kilogram, represented a considerable portion of the total earnings in the study period, even with relatively low landings in terms of biomass. As for the anchovies, they were the second most landed species (23% and 13% for V1 and V2, respectively), however, its low market value resulted in only 9% and 4% earnings for V1 and V2, respectively. Other high-valued species were caught irregularly and in relatively low biomasses, but still representing 3% of total earnings for both crews. Species of this group included the seabream *Diplodus* sp., wedge sole *D. cuneata*, boe drum *Pteroscion peli* (Bleeker, 1863) and the cuttlefish *S. officinalis*.

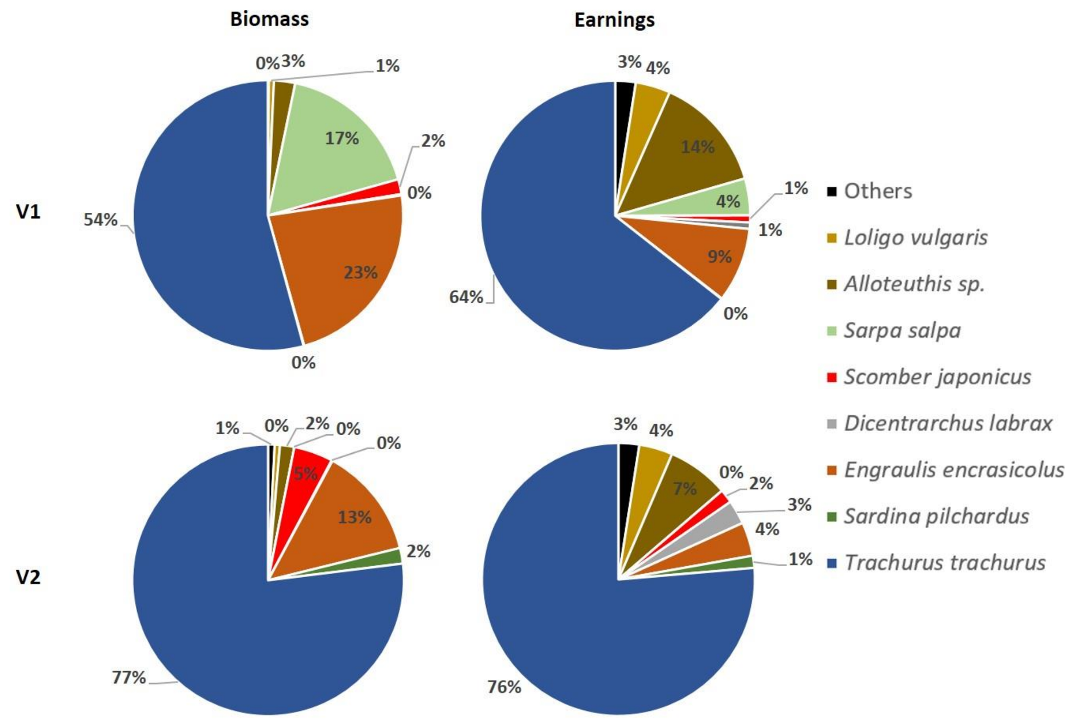


Figure 11. Species relative contribution per biomass and earnings. Top row regards V1 activity, while bottom represents V2.

Inter-annual variations on landings

A total of 347.15 tons of marine resources, ascribed to 24 taxa, were landed and auctioned in 2015 by the four Praia de Mira crews. In 2016, 149.03 tons were recorded since the beginning of the fishing activity (May) until September (data available for the present work). Assuming that this fishery could be conducted until November with similar LPUE, total landings for 2016 can be estimated as 268.64 tons. This represents a decrease of nearly 80 tons in relation to 2015 (ca. 23% decrease). The data provided by Docapesca for the four crews between weeks W22 and W36 in both years were compared in detail (Figures 9 and 12).

A total of 219 tons of resources were auctioned in the considered period of 2015 (Figure 12, top). This is more than twice the landings in the same period of 2016 (99.5 tons), which reflects an overall decrease in landings per week in this year (Figure 12, bottom). The number of activity days in the considered period of all crews were higher than in the current year for the considered period (V1: 79 activity days; V2: 79; V3: 70; V4: 59). The main landed species in 2015 were *T. trachurus*, with 127.16 tons, and *E. encrasicolus*, with 59.97 tons, followed by *L. vulgaris*, with 11.61 tons. These landings peaked in weeks W25, W34 and W35, with 18.79, 21.30 and 25.72 tons, respectively (Figure 12). V1 and V2 represented around 72% (59 and 100 tons, respectively) of the total landings in the considered period of 2015. In 2016, the same crews landed lower biomasses however contributing to a higher percentage of the total landings (81%).

Data for 2016 indicates that the LPUE peaked in W26, with 1310 $kg.d^{-1}$ landed by V2 crew (Figure 9, right). This was not much higher than their average LPUEs in 2015, which were 1266 $kg.d^{-1}$ throughout the study period (Figure 9, left). In 2015, V1 crew LPUE were in average 781 $kg.d^{-1}$, while only 499 $kg.d^{-1}$ in 2016. Analysing the other two crews average LPUEs, the result is similar (from 550 $kg.d^{-1}$ in 2015 to 133 $kg.d^{-1}$ in 2016 for V4, and from 493 to 216 $kg.d^{-1}$ for V3). In both years the lowest landings were observed during July.

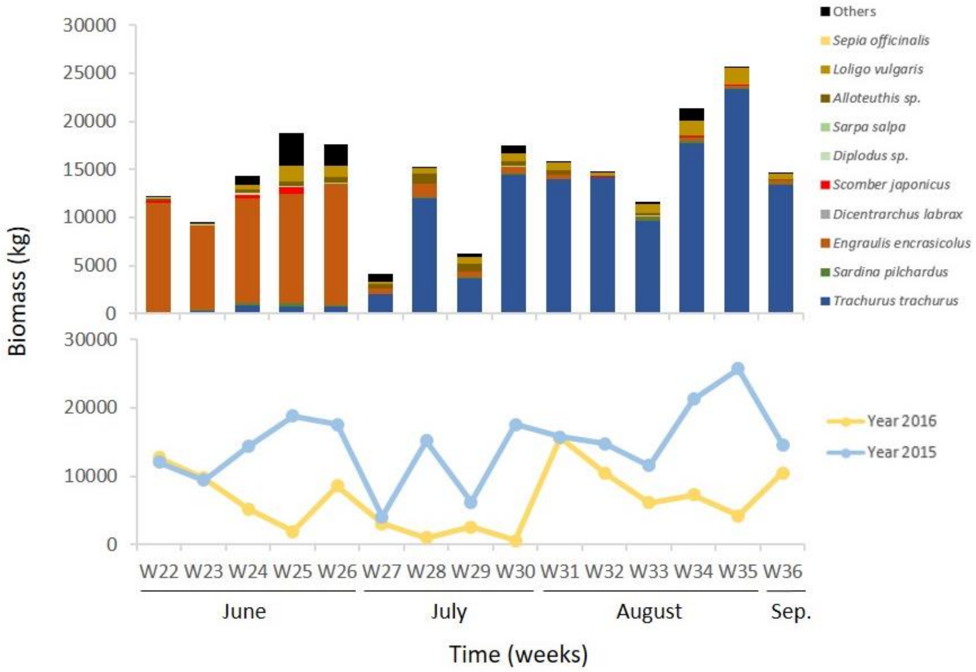


Figure 12. Total biomass auctioned in between W22 and W36 of 2015 (top). Comparison with the data of 2016 was also made (bottom).

The weekly landings of the four crews in 2015 and 2016 were compared using a MDS analysis (Figure 13). A two-way crossed ANOSIM test, confirms the significance of differences in landings between years (R=0.264, P=0.1%) and vessels (R=0.140, P=0.1%). The higher R value relative to the "Year" factor indicates that inter-annual changes in the species landed were more important than differences between "Vessel" factor (reflecting differences between species landed by each vessel). This is most obvious when observing the MDS plot (Figure 13) where the segregation between samples of the two years is much clearer than the segregation of samples from different vessels. Pairwise tests further indicate that V1 and V2 are different from each other and from the other crews (Annex III). However, no significant differences were found between V3 and V4 (R: 0.038, P=12.5%), the two crews with substantially lower landings observed in both years.

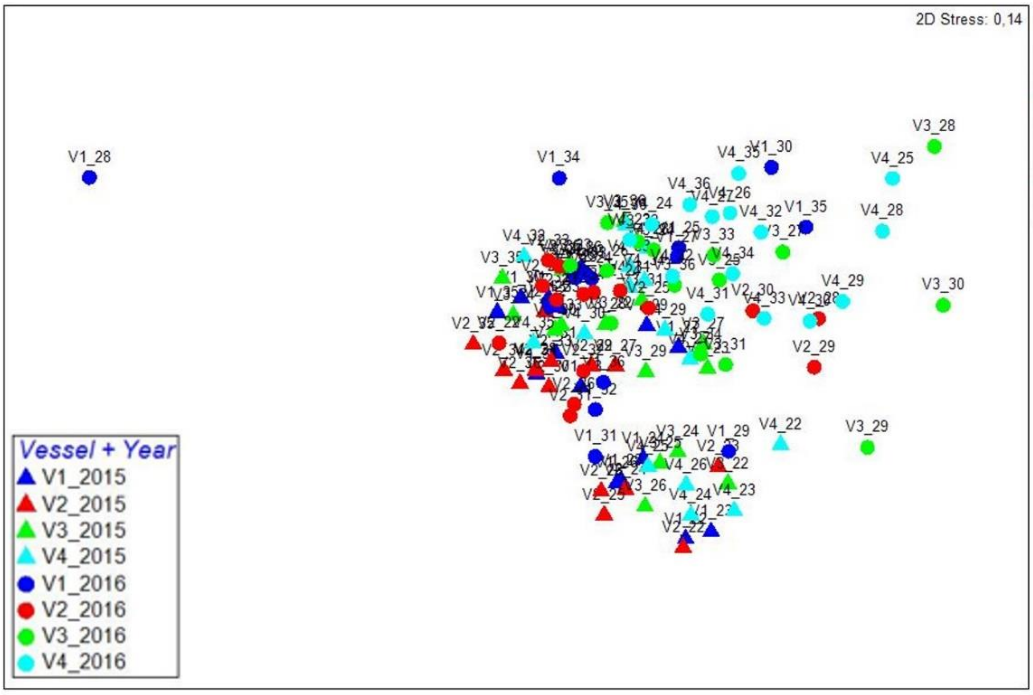


Figure 13. Multidimensional Scaling (MDS) of the landings, plotted according to the year and vessel.

The results of the SIMPER analyses (Annex III) show that these differences are essentially due to *T. trachurus*, *E. encrasicolus* and *L. vulgaris*, with an average dissimilarity 60.91% between 2015 and 2016. An overall decrease from 2015 to 2016, was observed on these species landings (127.16 to 68.97 tons of *T. trachurus*, 59.97 to 15.53 tons of *E. encrasicolus* and 11.61 to 0.62 tons of *L. vulgaris*)

Data from 2015 reveals a clear transition between seasons, where, in the early-summer (W22-W26) landings were characterized by a higher biomass mainly of *E. encrasicolus* and, after W27 *T. trachurus* became the dominant species (Figure 11, top). This is also reflected in the two segregate groups of samples for 2015 in the MDS plot (Figure 13, group of samples in the bottom right corresponds mostly to weeks 22-26, year 2015). Landings shifted from an average of 11.01 tons of anchovies per week until W27 to 0.49 tons per week, while *T. trachurus*, which had an average capture per week of 0.54 tons, shifted to 12.44 tons per week after W27. However, no clear patterns were observed in 2016, where *T. trachurus* was the most landed species throughout the considered period (note that there are no clear groupings of 2016 samples in the MDS plot, Figure 13).

The differences in earnings between the considered periods of 2015 and 2016 were analysed only considering V1 and V2 profits, since they auctioned a considerable higher amount of resources than the other two crews (these two crews had earnings four times higher than V3 and V4 in 2016 and three times higher in 2015 with $V2_{profits}>V1_{profits}$ in both years). Overall, due to a lower volume of auctioned organisms, earnings were cut down to half in 2016. The *T. trachurus* was the main source of income for the considered period in 2015 for V2 (41% of the total earned), and the squid *L. vulgaris* was the most profitable resource for V1 (37%). For 2016, *T. trachurus* was the main source of profits for both crews. The most valued species were still the same (*L. vulgaris* and *Alloteuthis* sp.), however, their market value increased from averages of 8.19 and 5.24 €/kg in 2015 to 9.07 and 6.29 €/kg in 2016, for *L. vulgaris* and *Alloteuthis* sp., respectively. This is probably due to lower quantities of these species captured in 2016, leading to a rise on its value. Even though the increased value of the cephalopods in 2016, it did not balance the lower landings, resulting in earnings obtained from these species more than 10 times lower than in 2015. The sardine and Atlantic horse mackerel had an average price per kilogram in the considered period of 2016 of 1.09 and 1.69 €/kg, respectively. While *T. trachurus* price per kilogram increased from 1.41 €/kg, *S. pilchardus* decreased from 1.09 €/kg. Furthermore, this price increase in *T. trachurus* resulted in an increasing in profits by 20% in the current year, even with lower landed biomass. The anchovies had the lowest rating in 2016, with a minimum of 0.3 €/kg. A similar occurrence was observed for 2015 (0.77 €/kg).

Discards

A list of the discarded species recorded during this study is presented in Table 3. A total of 36 species were recorded as discards for the thirteen hauls (Table 3, Figure 14). Bony fish species occurred frequently throughout the study period, especially *E. encrasicolus* and *T. trachurus,* both occurring in 92.3% of the samples, and clupeids (84.6%). Other species with frequent occurrence (Table 4) include the pouting *Trisopterus luscus* (Linnaeus, 1758), with 76.9%, *Liza aurata* (Risso, 1810), 69.2%, *Echiichthys vipera* (Cuvier, 1829) and *C. lucerna*, both with 61.5%. Single time occurrence was observed for *Callionymus lyra* Linnaeus, 1758, *Merluccius merluccius* (Linnaeus, 1758), *Pagrus pagrus* (Linnaeus, 1758), *S. salpa* and nearly all seabreams.

Table 3. Species found in the thirteen samples. FO: absolute value of Frequency of Occurrence; percentage is also represented. TS: Target Species; NTS: Non-target Species; *NTS: Non-target Species, occasionally sold at auction.

Taxa		Common name	FO	%	Status
Bony fishes					
Ammodytidae	*Ammodytes cf. tobianus*	Small sandeel	1	7.7	NTS
Atherinidae	*Atherina presbyter*	Sand smelt	6	46.2	NTS
Belonidae	*Belone belone*	Garfish	4	30.8	NTS
Bothidae	*Arnoglossus laterna*	Mediterranean scaldfish	3	23.1	TS
Callionymidae	*Callionymus lyra*	Common dragonet	1	7.7	NTS
Carangidae	*Trachinotus ovatus*	Pompano	3	23.1	NTS
	Trachurus trachurus	Atlantic horse mackerel	12	92.3	TS
Clupeidae	*Alosa* sp.	Allis shad / Twaite shad	11	84.6	NTS
	Sardina pilchardus	Sardine	11	84.6	TS
Engraulidae	*Engraulis encrasicolus*	European anchovy	12	92.3	TS
Gadidae	*Trisopterus luscus*	Pouting	10	76.9	NTS*
Merlucciidae	*Merluccius merluccius*	European hake	1	7.7	NTS
Moronidae	*Dicentrarchus labrax*	European seabass	2	15.4	TS
Mugilidae	*Liza aurata*	Golden grey mullet	9	69.2	NTS
Scombridae	*Scomber japonicus*	Chub mackerel	2	15.4	TS
	Scomber scombrus	Atlantic mackerel	3	23.1	TS
Sparidae	*Boops boops*	Bogue	5	38.5	NTS
	Diplodus annularis	Annular seabream	1	7.7	TS
	Diplodus sargus sargus	White seabream	1	7.7	TS
	Diplodus vulgaris	Common two-banded seabream	2	15.4	TS
	Pagrus pagrus	Red porgy	1	7.7	NTS
	Sarpa salpa	Salema	1	7.7	TS
	Spondyliosoma cantharus	Black seabream	1	7.7	TS
Trachinidae	*Echiichthys vipera*	Lesser weever	8	61.5	NTS
Triglidae	*Chelidonichthys lucerna*	Tub gurnard	8	61.5	NTS*
Cnidarians					
Medusozoa und.		Jellyfish	2	15.4	NTS
Crustaceans					
Cirolanidae und.		Pill bug	2	15.4	NTS
Corystidae	*Corystes cassivelaunus*	Masked crab	1	7.7	NTS
Crangonidae	*Crangon crangon*	Sand shrimp	1	7.7	NTS
Gammaridae	*Gammarus* sp.		1	7.7	NTS
Polybidae	*Liocarcinus* sp.		1	7.7	NTS
	Polybius henslowii	Henslow's swimming crab	12	92.3	NTS
Molluscs					
Loliginidae	*Alloteuthis* sp.		10	76.9	TS
	Loligo vulgaris	European squid	9	69.2	TS
Mytilidae	*Mytillus* sp.	Mussel	1	7.7	NTS

Other specimens were discarded irregularly (ie. *Atherina presbyter* Cuvier, 1829, in 46.2% of the samples, *Boops boops* (Linnaeus, 1758) in 38.5%, and *Trachinotus ovatus* (Linnaeus, 1758) in 23.1%). Regarding molluscs, amongst four analysed species, Loliginidae were the most frequent (76.9% for *Alloteuthis* sp., followed by *L. vulgaris* with 69.2%), while others only appeared once. Of all the crustaceans sampled, *Polybius* *henslowii* Leach, 1820, occurrence is almost constant (92.3% of the samples). The presence of cnidarians was highly irregular, occurring once in June and in August.

The most specious group was the bony fishes, with 25 different species. Higher taxa richness per sample was observed in June, except for S22. However, after peaking at S23 with 19 different species, a decreasing trend was observed, reaching a minimum of seven species in late-July, at S30 and maintaining values below 15 species throughout the remaining sampling period.

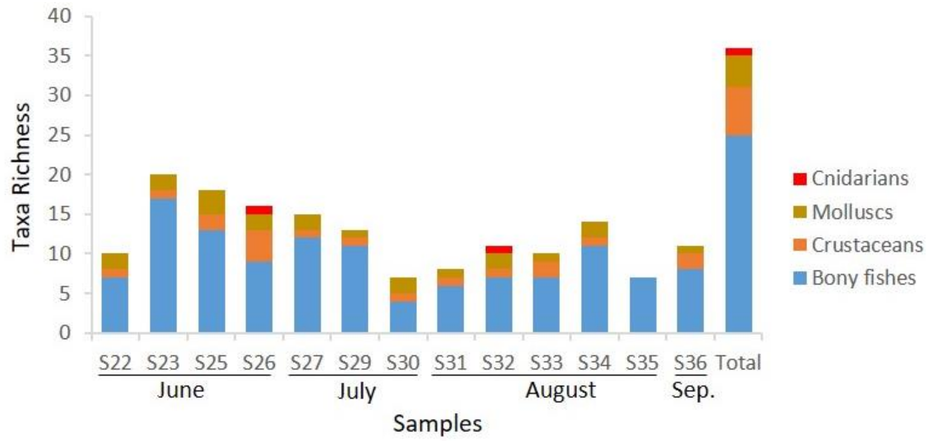


Figure 14. Overview of the number of identified species in each taxonomic group within each sample. Total richness reveals the taxonomic composition of the thirteen samples.

Table 4. Data corresponding to a more in-depth sample richness analysis. "✓" marks the occurrence of a species in a sample. The total number of species per sample is indicated in the bottom row.

	S22	**S23**	**S25**	**S26**	**S27**	**S29**	**S30**	**S31**	**S32**	**S33**	**S34**	**S35**	**S36**
	June				**July**			**August**					**Sep.**
Bony fishes													
T. trachurus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Alosa sp.		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
S. pilchardus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
E. encrasicolus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
T. luscus	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓
L. aurata	✓	✓	✓		✓	✓			✓		✓	✓	✓
C. lucerna	✓	✓	✓	✓	✓	✓				✓	✓		
Others	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Crustacea													
P. henslowii	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Others			✓	✓						✓			✓
Mollusca													
L. vulgaris	✓	✓	✓	✓	✓		✓		✓	✓	✓		
Alloteuthis sp.	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		
Others			✓										✓
Cnidaria													
Medusozoa und.				✓					✓				
No. of species	10	20	18	16	15	13	7	8	11	10	14	7	11

The 36 species here reported represent a total of 178 101 organisms and 2 533 kg (values estimated from the samples taken) discarded from the thirteen hauls sampled (Figure 15, note the logarithmic scales in the top graphs; Tables 5-6). Bony fishes were the dominant group, making up 92% of the total discarded abundance and biomass (163 762 individuals, 2330 kg). The number of discarded individuals per haul ranged from 52 to 130 764 (typically 2000-7000 individuals per haul) and the biomass from 11 to 1883 kg (typically 30-90 kg per haul), with lower abundances and biomasses discarded late in the summer and an exceptionally high discards observed in W31 (Figure 15, top; Tables 5-6).

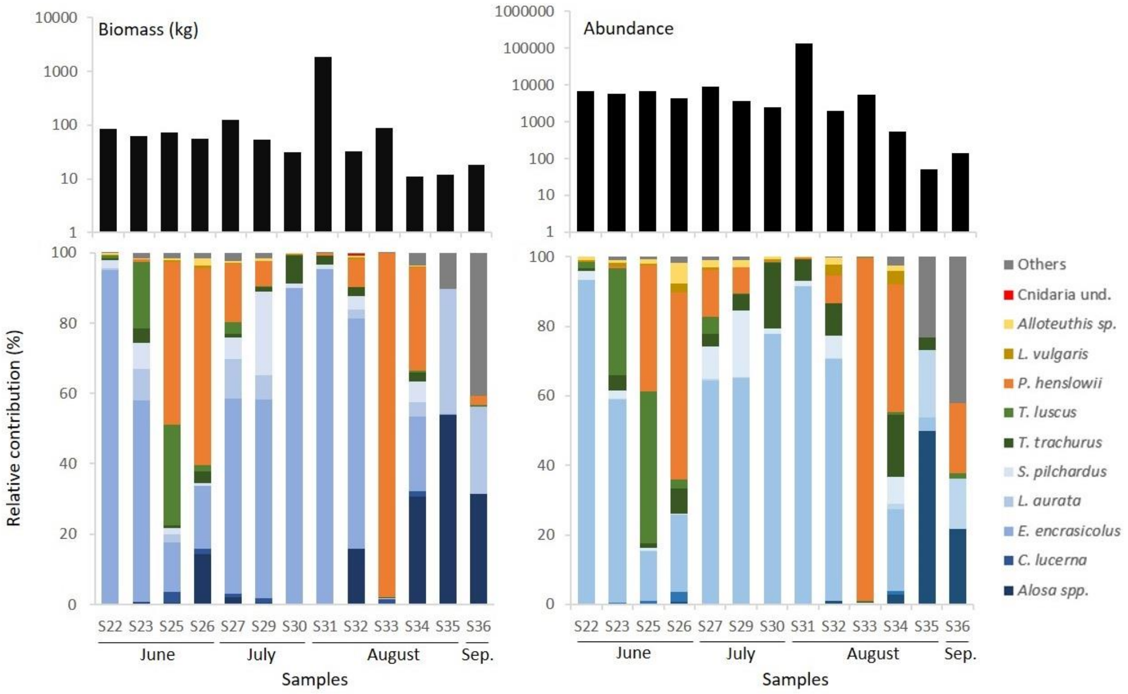


Figure 15. Discards biomass (left) and abundance (right) for the sampling period. Absolute data on top, while relative contribution per species is represented on bottom.

Amongst discarded species, *E. encrasicolus* is highlighted; in average this species accounted for 48.6% of the individuals and 47.4% of the biomass discarded in each haul. This species was dominant in the discards throughout the summer, until mid-August representing typically 50-95% of the discards in each haul (Figure 15, bottom, Tables 5-6). Up to 119 745 anchovies (1796 kg) were discarded in a single haul in S31 (67% of the total abundance and 71% of the total biomass discarded in the 13 hauls sampled). Other frequent discards of target species included the sardine, *S. pilchardus* (in average 4.8% of the individuals but only 4.9% of the biomass discarded in each haul), and the Atlantic horse mackerel, *T. trachurus* (in average 6.5% of the individuals but only 2.2% of the biomass discarded in each haul). The horse mackerel was discarded especially after S26. The inverse occurred for *T. luscus* (in average 8.6% of the individuals and 5.5% of the biomass discarded in each haul), that was essentially captured and discarded until S26. Other non-target fish species were captured and discarded less frequently but whenever present, they represented a considerable fraction of the discards especially later on the summer: *L. aurata* (in average 4.1% of the abundance and 10.8 % of the biomass) and *Alosa spp*. (in average 7.0% of the abundance 13.6% of the biomass) (Tables 5-6). The crustacean *P. henslowii* was the main non-target species in the discards (in average 23.0% of the individuals and 22.8% of the biomass discarded in each haul), peaking in S33 (88 kg of it discarded).

The k-dominance curves are an ecological indicator of the size structure of the discarded assemblage (Figure 16). In almost all plots, abundance and biomass curves nearly overlap in their fully extent, revealing that essentially small-sized individuals are being discarded. An exception to this is found on samples S35 and S36, where the biomass curve is above the abundance one, indicating that larger individuals (e.g. species with low market potential, such as *Alosa spp*., *L. aurata* and *S. salpa*) were also discarded elevating the percentage contribution of the biomass.

The high values of the y-intersect (most above 60%) reflect the fact that the discards were frequently dominated by only one species: this was usually the anchovy *E. encrasicolus* that was dominant throughout the summer until late-August, replaced occasionally by other species (e.g. *P. henslowii* in S26).

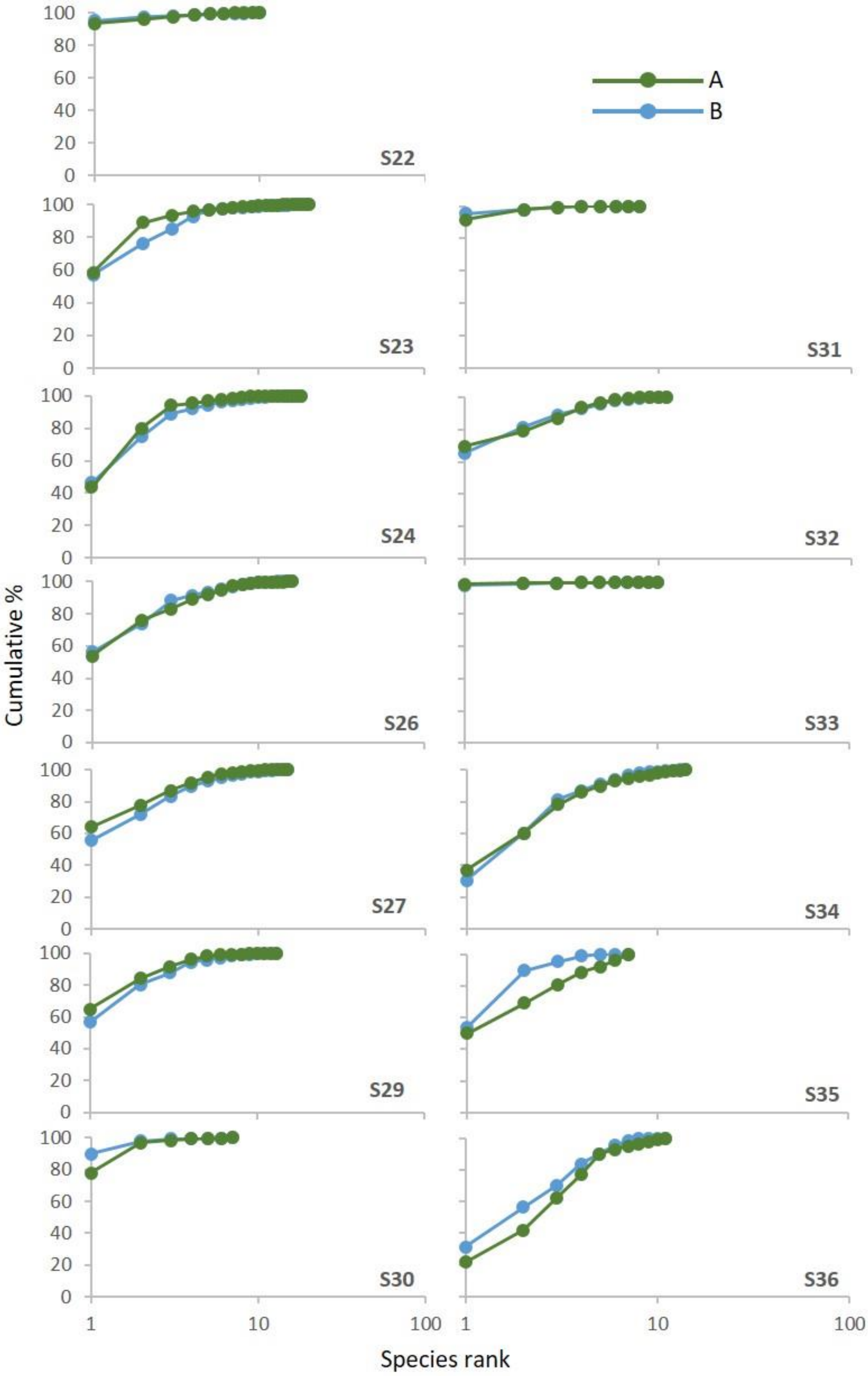


Figure 16. Plotted ABC curves for species abundance (A) and biomass (B). Results are presented per sample.

Table 5. Relative abundance (% in each sample) of the discarded species. The estimated total number of individuals discarded per haul is indicated in the bottom row.

	S22	S23	S25	S26	S27	S29	S30	S31	S32	S33	S34	S35	S36
	June				July			August					Sep.
Bony fishes													
T. trachurus	0.63	4.33	1.30	7.13	3.60	4.52	19.04	6.09	9.49	0.45	17.69	3.85	0.00
Alosa sp.	0.00	0.27	0.03	0.76	0.07	0.03	0.00	0.01	1.04	0.02	2.89	50.00	21.74
S. pilchardus	2.59	2.45	0.78	0.41	9.37	19.29	1.49	1.57	6.46	0.06	7.94	0.00	0.00
E. encrasicolus	93.44	58.43	14.34	22.15	64.06	64.85	77.87	91.57	69.53	0.13	23.47	3.85	0.00
T. luscus	1.73	30.61	43.62	2.49	4.91	0.24	0.24	0.00	0.00	0.26	0.72	0.00	1.45
L. aurata	0.01	0.29	0.13	0.00	0.43	0.24	0.00	0.00	0.20	0.00	1.44	19.23	14.49
C. lucerna	0.01	0.23	0.96	2.90	0.22	0.24	0.00	0.00	0.00	0.18	1.08	0.00	0.00
Others	0.01	0.99	0.48	1.41	1.02	1.03	0.00	0.02	0.20	0.06	2.53	23.08	39.86
Crustacea													
P. henslowii	0.12	0.52	36.23	53.81	13.61	7.46	0.16	0.69	7.95	98.58	36.82	0.00	20.29
Others	0.00	0.00	0.13	0.25	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	1.45
Mollusca													
L. vulgaris	0.40	1.09	0.70	2.67	0.76	0.00	0.40	0.00	3.18	0.19	3.97	0.00	0.00
Alloteuthis sp.	1.04	0.80	1.26	6.00	1.95	2.08	0.80	0.05	1.89	0.00	1.44	0.00	0.00
Others	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72
Cnidaria													
Medusozoa und.	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Total (No. ind.)	**6938**	**5658**	**6902**	**4223**	**9214**	**3680**	**2491**	**130764**	**2012**	**5474**	**554**	**52**	**138**

Table 6. Biomass relative contribution of the discarded species. Total biomass, in kilograms, per sample is described below.

	S22	S23	S25	S26	S28	S29	S30	S31	S32	S33	S34	S35	S36
	June				July			August					Sep.
Bony fishes													
T. trachurus	0.31	3.99	0.87	3.21	0.84	1.18	8.00	2.42	2.59	0.24	2.66	0.05	0.00
Alosa sp.	0.00	0.45	0.47	14.22	2.01	0.42	0.00	0.04	15.93	0.37	30.59	54.00	31.41
S. pilchardus	2.40	7.27	1.82	0.72	6.16	23.83	1.28	1.27	3.79	0.19	5.69	0.00	0.00
E. encrasicolus	95.17	57.29	14.11	17.91	55.63	56.49	89.93	95.38	65.39	0.08	21.22	0.12	0.00
T. luscus	0.80	19.10	28.54	1.78	3.44	0.16	0.21	0.00	0.00	0.22	0.38	0.00	0.53
L. aurata	0.39	9.05	2.35	0.00	11.24	6.83	0.00	0.00	2.58	0.00	4.24	35.52	24.80
C. lucerna	0.01	0.29	2.98	1.73	0.96	1.49	0.00	0.00	0.00	1.06	1.58	0.00	0.00
Others	0.06	1.47	1.49	1.42	2.36	1.65	0.00	0.10	0.21	0.00	3.62	10.30	40.79
Crustacea													
P. henslowii	0.11	0.68	46.28	56.03	16.56	7.30	0.16	0.77	7.81	97.69	29.41	0.00	2.46
Others	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Mollusca													
L. vulgaris	0.19	0.01	0.43	0.80	0.22	0.00	0.11	0.00	0.51	0.14	0.46	0.00	0.00
Alloteuthis sp.	0.55	0.41	0.62	2.01	0.57	0.64	0.32	0.02	0.56	0.00	0.16	0.00	0.00
Others	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cnidaria													
Medusozoa und.	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00
Total (kg)	**84.02**	**63.48**	**73.25**	**56.56**	**126.15**	**53.51**	**31.64**	**1883.17**	**32.33**	**87.69**	**11.07**	**12.09**	**18.18**

Diversity and evenness indexes are presented in Table 7. Most Pielou's values were below 0.50, while Shannon-Wiener diversity ranged from 0.10 in S34 to 1.93 in S36. These overall low diversity and evenness values reflect the high dominance of a few discarded species such as the anchovy and the Henlow's crab. Samples S34, S35 and S36 are the ones with the highest diversity and evenness indexes ($ES_{(100)}$ reaches 10.7 in S34 and J'= 0.74 in S36) corresponding to low captures of these two species. Similar results were obtained for biomass.

Table 7. Diversity and evenness indexes for each sample for abundance and biomass data. S: Species Richness; N: Estimated number of individuals; B: Estimated biomass; J': Pielou's index; H': Shannon-Wiener index; ES_{100}: Expected number of species upon analysing 100 individuals; A: Abundance; B: Biomass.

		S	N	B (kg)	J'_A	H'_A	J'_B	H'_B	ES_{100}
S22	June	10	6938	84.02	0.15	0.34	0.12	0.27	4.37
S23		20	5658	63.48	0.38	1.13	0.45	1.36	7.11
S25		18	6902	73.25	0.45	1.29	0.51	1.46	6.89
S26		16	4223	56.56	0.53	1.47	0.50	1.40	9.02
S27	July	15	9214	126.15	0.46	1.26	0.54	1.47	7.77
S29		13	3680	53.51	0.44	1.12	0.51	1.30	6.39
S30		7	2491	31.64	0.34	0.66	0.21	0.40	4.05
S31	August	8	130764	1883.17	0.17	0.36	0.12	0.24	3.37
S32		11	2012	32.33	0.47	1.12	0.49	1.18	6.91
S33		10	5474	87.69	0.04	0.10	0.07	0.15	2.28
S34		14	554	11.07	0.67	1.78	0.65	1.72	10.70
S35		7	52	12.09	0.76	1.49	0.54	1.04	7.00
S36	Sep.	11	138	18.18	0.80	1.93	0.74	1.77	10.48

Results from both previous analyses indicate that the discarded portion is clearly dominated by small-sized species, until S34. From that point, those species are captured and discarded in substantially lower quantities being replaced by more frequent captures of larger species, such as *L. aurata* and *Alosa spp.,* which have low market potential.

Dominant discards of this activity, for the considered sampling period, include target and non-target species. Target species include *E. encrasicolus*, *T. trachurus* and *S. pilchardus*, while *T. luscus* and *P. henslowii* were classified as non-target species. Fish demographic structure and weight-length relationships, as well as the ratio between landed/discarded per dominant species are presented below. The latter includes the squids due to their relevance when considering fishermen earnings.

Discards per haul

An estimative of the discard rate per haul was made (Figure 17). Again, it should be noted that the interpretation of these data must be cautious since the available data from Docapesca only covers the auctioned biomass and therefore the overall percentage of discards may be underestimated as it includes only the biomass left on the beach or dumped back to the sea previous to the auction; the rejected biomass after auction cannot be included because it is not recorded.

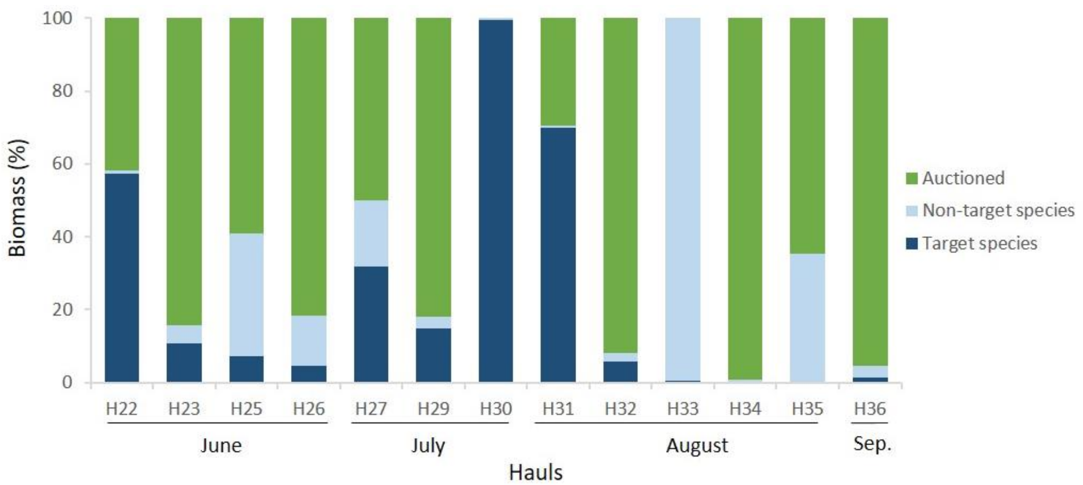


Figure 17. Discard rate per haul. Discards sums target and non-target species biomass

Three of the sampled hauls showed more than 70% discard rate, however differences can be found regarding the species that were discarded. In hauls H22, H30 and H31 *E. encrasicolus* accounted for almost all the discarded biomass (95.17%, 89.93% and 95.38%, respectively). Furthermore, for the day in which H30 occurred, there are no official records on its auctions, so it is assumed either the biomass landed was not sold and was posteriorly discarded or the fishermen opted for discarding all the capture. No resources were landed in H33, resulting in a haul with 100% of the biomass (mainly *P. henslowii*) being discarded. Discard rates ranged from 0 to 100% but were typically 15-60% of the captured biomass. Overall, an average of 194.86 kg/haul were discarded, ranging from 11.07 (H34) to 1883.17 (H31) kg/haul. However, a much lower mean of 54.16 kg/haul is estimated if H31 sample is considered as an outlier. Species discard rate per haul are shown in Table 9. The target species (TS), *E. encrasicolus* and *S. pilchardus,* discard rates are always remarkably high. The anchovy was captured throughout the summer in large quantities, and was fully discarded in most of the hauls. The sardines were rejected with a 100% discard rate in the considered period, with a discarded biomass ranging from 0.41, in H30, to 23.85 kg, in H31 (Figure 18). While *E. encrasicolus* specimens from H29 and H31 were landed and auctioned, the sardines were never sold, resulting in a 100% discard. The squids and the Atlantic horse mackerel had the lowest discard rate. They were only 100 % discarded in the H30 and H33, when no landings were recorded for those hauls. The European squid had 100% discard rate as well in H32, however this represented a very low biomass captured (around 0.16 kg), and subsequently discarded. The non-target species (NTS) were always entirely discarded by the crew monitored in the present study. NTS higher biomasses made up to 197 and 40 kg of *P. henslowii* and *T. luscus*, respectively. The first species was captured especially in the mid-June until H33, while the latter was captured only in the beginning of the summer.

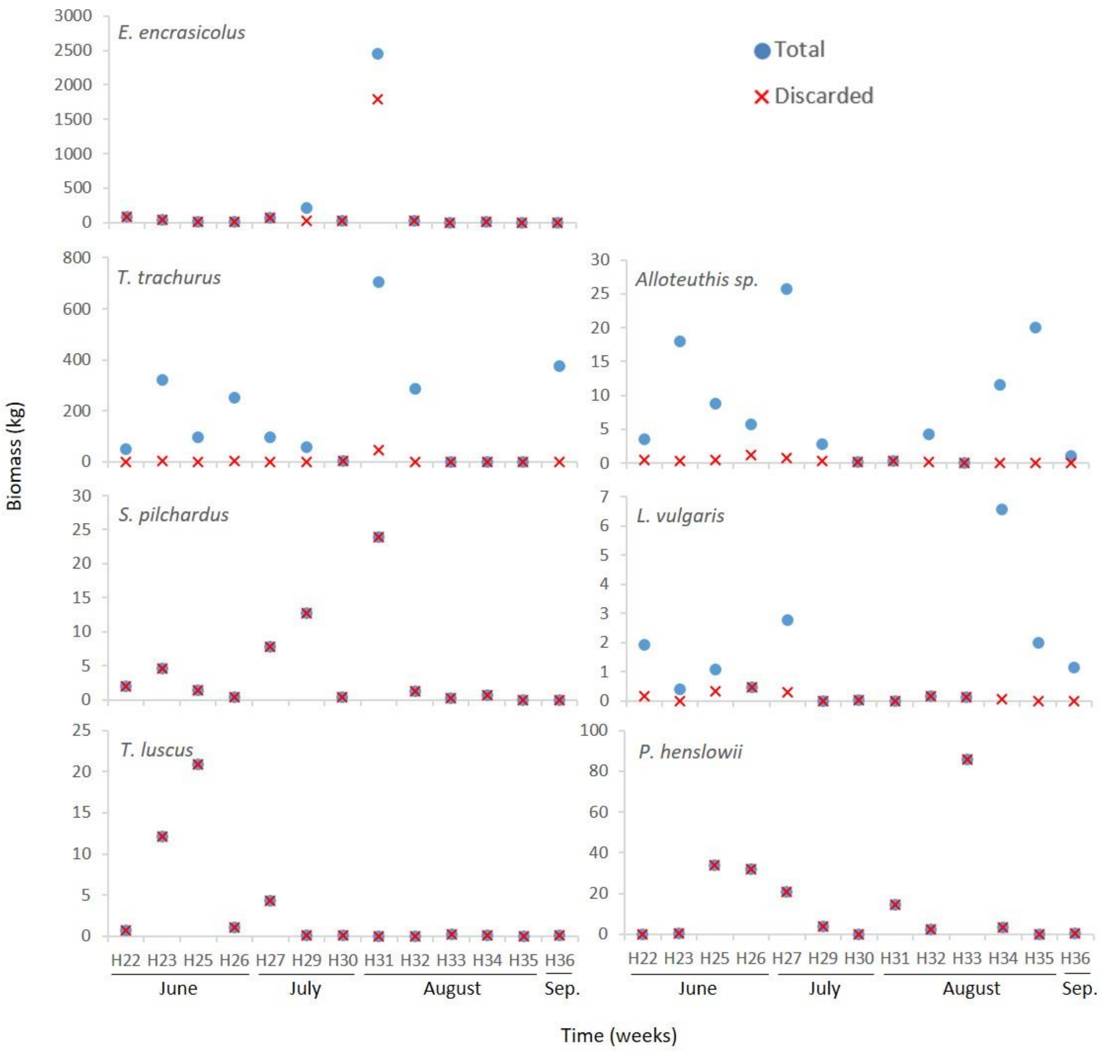


Figure 18. Ratio between landed and discarded per haul for the dominant species. Last row includes Non-target species (NTS), while the rest regards Target Species (TS).

Table 8. Target (TS) and Non-target (NTS) species discard rate (%) per haul. The total discarded percentage per haul is shown in the bottom row.

		H22	H23	H25	H26	H27	H29	H30	H31	H32	H33	H34	H35	H36
		June				**July**			**August**					**Sep.**
TS	*Trachurus trachurus*	1.07	1.57	1.32	2.85	1.11	2.11	100,00	25.95	0.29	100.00	100.00	100.00	0.00
	Sardina pilchardus	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-
	Engraulis encrasicolus	100.00	100.00	100.00	100.00	100.00	25.14	100.00	73.13	100.00	100.00	100.00	100.00	-
	Alloteuthis sp.	23.57	2.82	9.99	49.62	2.81	21.54	100.00	100.00	4.31	100.00	0.30	0.00	0.00
	Loligo vulgaris	15.28	2.09	45.83	100.00	10.05	-	100.00	-	100.00	100.00	1.54	0.00	0.00
NTS	*Trisopterus luscus*	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	-	100.00	100.00	-	100.00
	Polybius henslowii	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-	100.00
Discards per haul		**58.24**	**15.68**	**40.87**	**18.27**	**50.15**	**18.17**	**100.00**	**70.45**	**8.08**	**100.00**	**0.69**	**35.47**	**4.55**

Size-class analysis

Of the most abundant fish discards, two species, pouting (*T. luscus*, Figure 19) and horse mackerel (*T. trachurus*, Figure 20), were mainly represented by individuals that did not reach the minimum conservation reference size to be auctioned: 17 and 15 cm, respectively. Pouting was usually discarded with the length of 8-9 cm (full range: 6-21 cm). The histograms (Figure 19) show a small modal-class shift from 8 to 9 cm from S22 to S27. The discarded individuals of the Atlantic horse mackerel, ranged from 5.0 to 15.6 cm, but were usually within the 6-7 cm, size-classes which is below their legal limit.

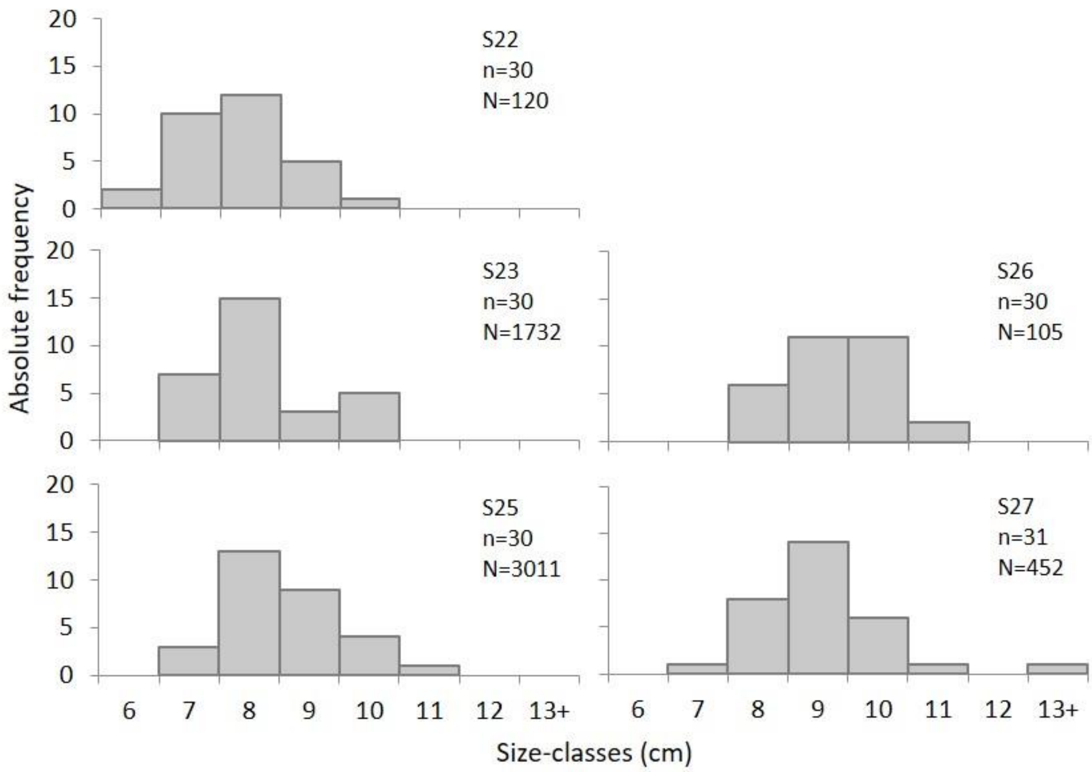


Figure 19. Size-class frequencies for *T. luscus*. Minimum conservation reference size: 17cm. n: number of analysed individuals; N: Estimated number of specimens.

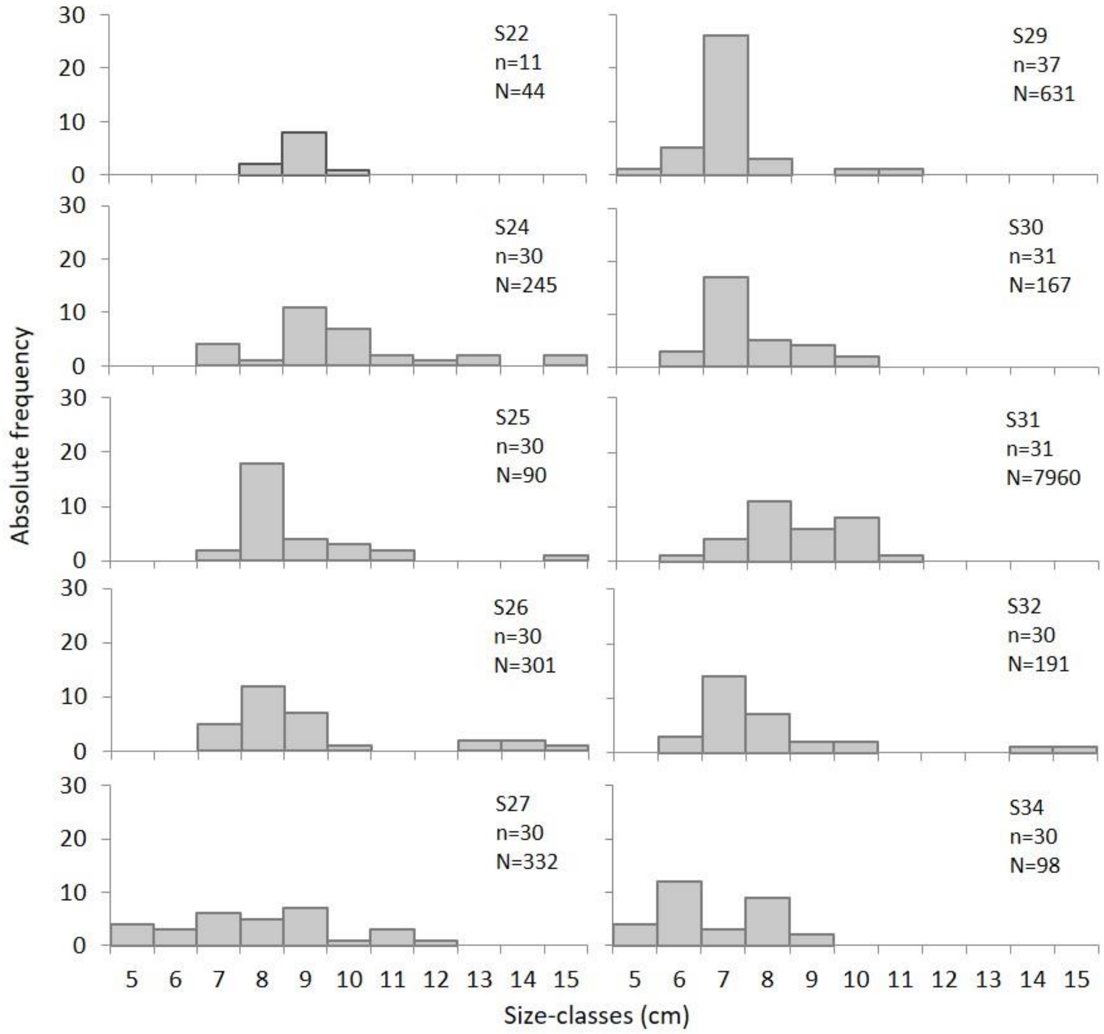


Figure 20. Size-class frequencies for *T. trachurus*. Minimum conservation reference size: 15cm. n: number of analysed individuals; N: Estimated number of specimens.

The same did not occur with *S. pilchardus* and *E. encrasicolus* specimens. Although captured specimens were well above their minimum conservation reference size, they were not landed either because the total biomass was too low, or, has it occurred especially for *E. encrasicolus*, the fishermen were aware of the lack of interest from the buyers on this particular species (this information was obtained directly from the crew). The sardines were usually discarded with the length of 11-12 cm, (full range: 6-22 cm, Figure 21) which is just above the legal limit (11 cm). Anchovy discards were mainly composed by individuals within 12-14 cm length (full range: 9-17 cm, Figure 22). A small shift in the modal class can be observed for *E. encrasicolus* specimens, from 12-13 cm before the first week of August (S31) to 13-14 cm in the following samples.

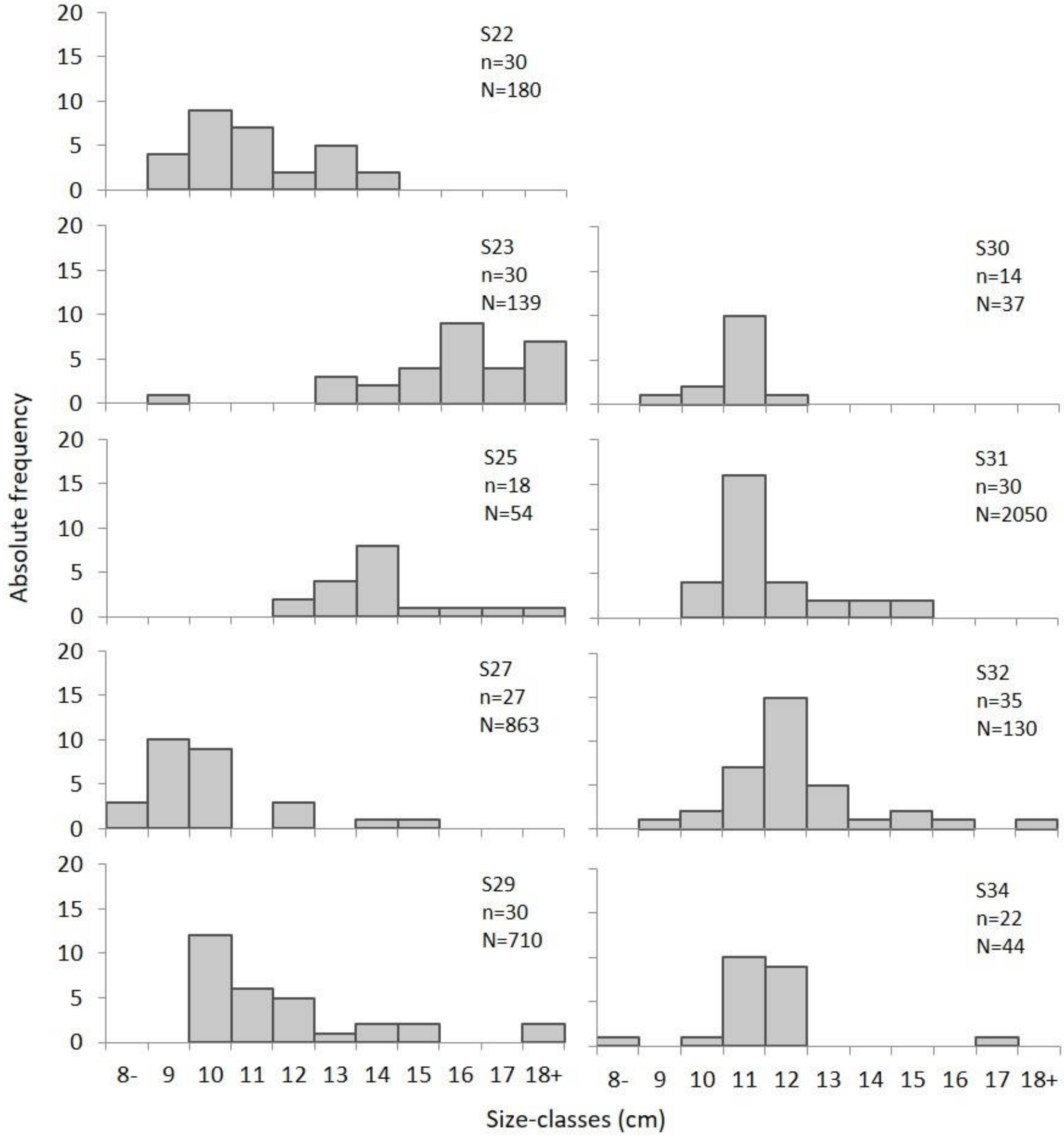


Figure 21. Size-class frequencies for *S. pilchardus*. Minimum conservation reference size: 11cm. n: number of analysed individuals; N: Estimated number of specimens.

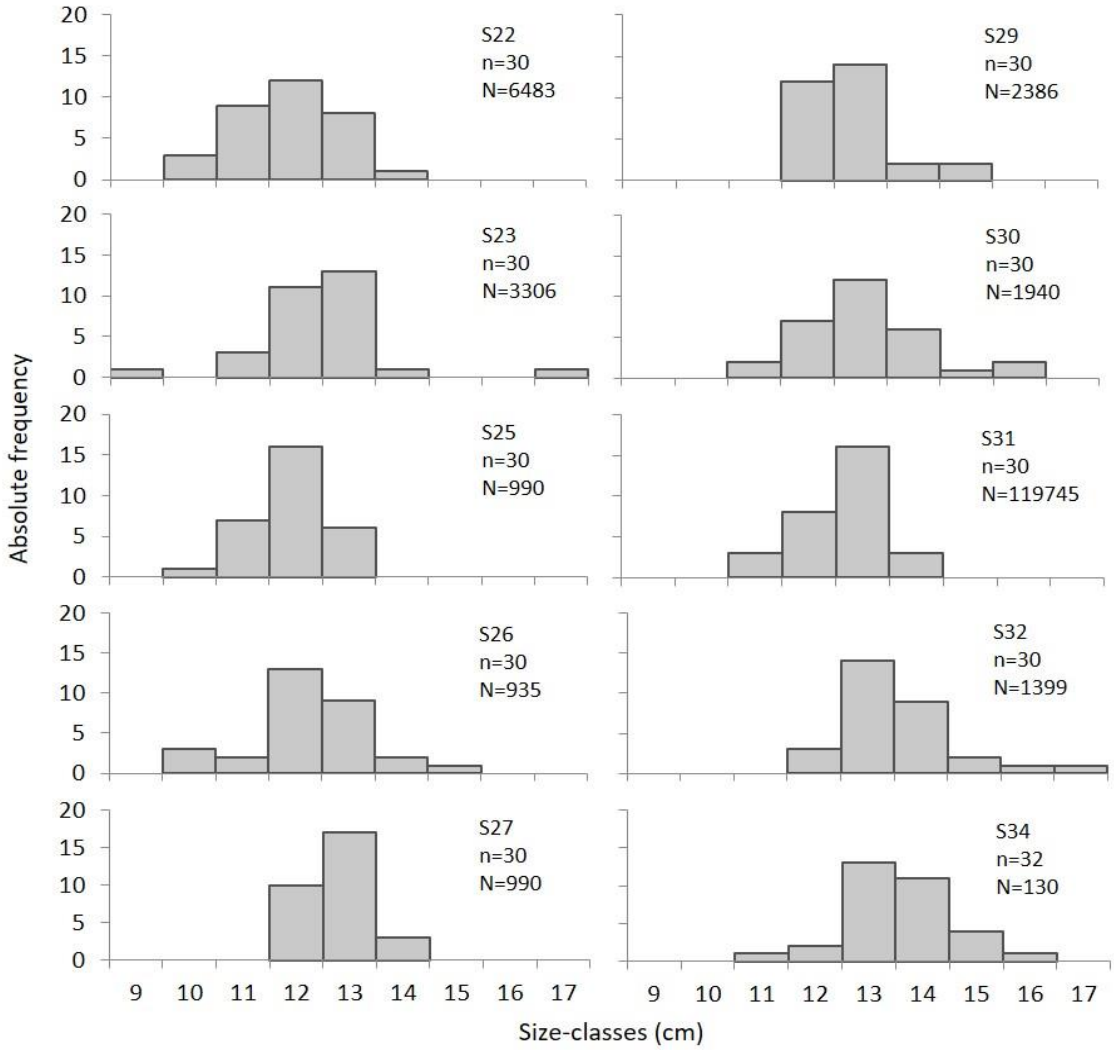


Figure 22. Size-class frequencies for *E. encrasicolus*. Minimum conservation reference size: 12cm. n: number of analysed individuals; N: Estimated number of specimens.

Weight-length relationships

Dominant discarded species were also selected to determine weight-length (W-L) relationships. In this case, *C. lucerna*, a non-target species, was also included since the number of individuals (n=82) is sufficient for analysis (Figure 23). The sample size and minimum and maximum of weight and length for each species are presented in Table 9, as well as the W-L relationships, the coefficient of determination (R^2), the confidence interval (CI) of *a* and *b*, and growth type.

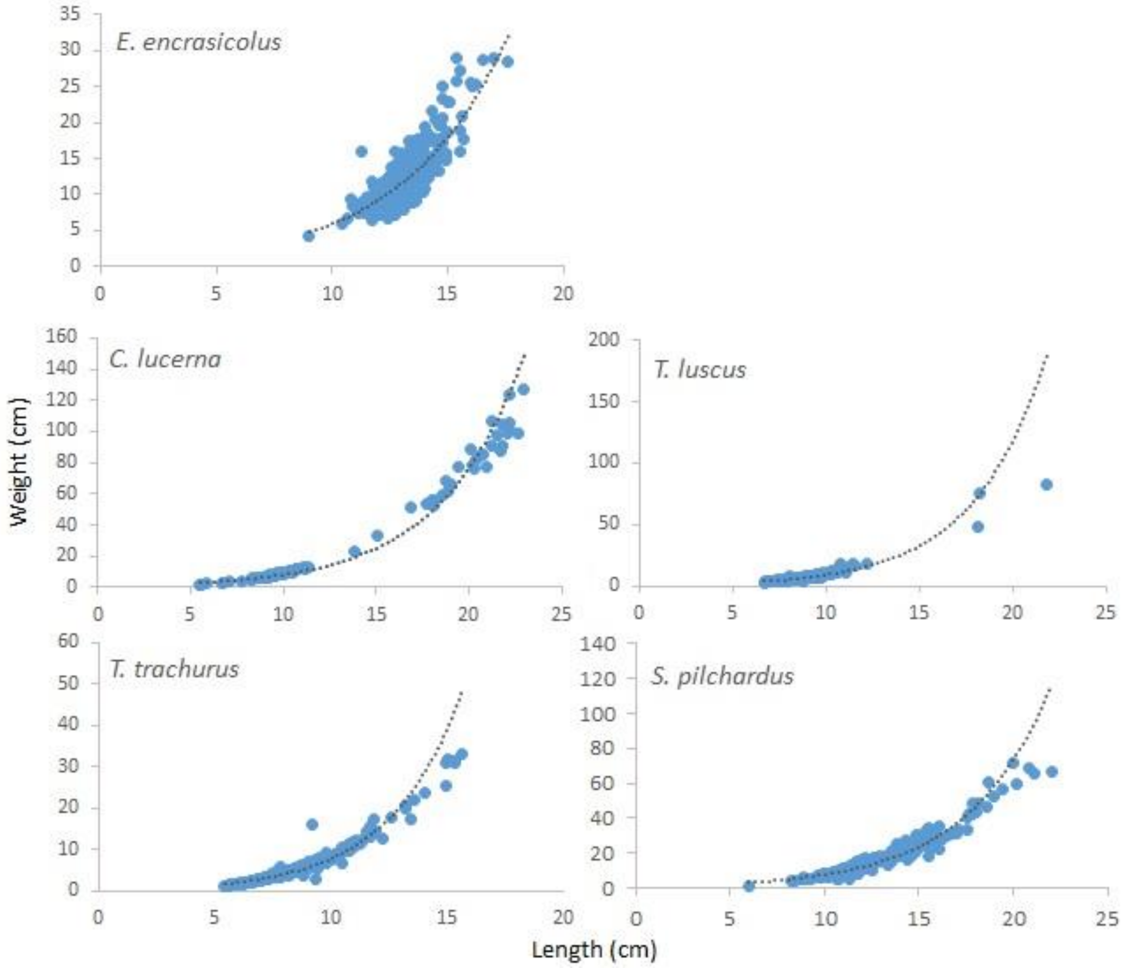


Figure 23. Weight-length relationships for the selected fish species.

All linear regressions were statistically highly significant (p<0.01) and the coefficient of association (R^2) ranged from 0.652 for the anchovy to 0.996 to the tub gurnard. Exponent b of the selected fishes ranged from a minimum of 2.917 to a maximum of 3.064 indicating isometric growth for the horse mackerel, the sardine and the tub gunard and a slight decrease in relative body thickness or plumpness for the anchovy and the pouting.

Table 9. Weight- length relationships and its descriptive statistics for the five considered species. W_e: Estimated minimum weight for auction.

		Length (cm)		Weight (g)							
Species	**n**	**Min.**	**Max.**	**Min.**	**Max.**	**W-L equation**	R^2	**95% CI of *b***	**95% CI of *a***	**Growth type**	W_e **(g)**
T. trachurus	298	5.50	15.60	1.12	33.08	$W=0.007L^{3.055}$	0.970	2.993-3.117	0.007-0.008	Isometric	27.42
S. pilchardus	242	6.00	22.00	1.13	71.34	$W=0.006L^{3.053}$	0.943	2.958-3.148	0.005-0.008	Isometric	9.07
E. encrasicolus	303	9.00	17.60	4.16	28.92	$W=0.007L^{2.917}$	0.652	2.676-3.159	0.003-0.012	Negative-allometric*	9.84
T. luscus	163	6.70	21.80	2.75	82.25	$W=0.011L^{2.938}$	0.958	2.842-3.034	0.009-0.014	Negative-allometric*	45.34
C. lucerna	82	5.50	23.00	1.56	126.85	$W=0.008L^{3.064}$	0.996	3.022-3.107	0.007-0.009	Isometric	-

* confidence interval within isometric growth type

These weight-length relationships (Table 9) allow the estimation of the species average weight that corresponds in the local fish populations to the minimum conservation reference sizes to be auctioned (Table 9 and orange line in Figure 24). The fluctuations of the estimated mean individual biomass of the discarded specimens throughout the study period show very clearly that the discarded anchovy and sardine specimens were consistently above their minimum conservation reference sizes while the discarded horse mackerel and pouting specimens were clearly small specimens below the marketable sizes (Figure 24). Note that these results refer to average values.

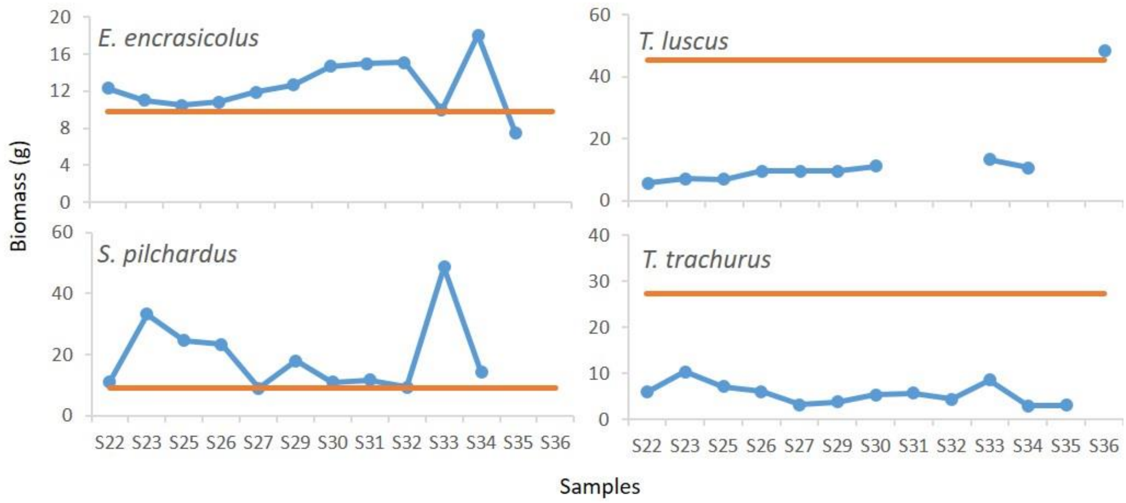


Figure 24. Temporal variation of the individual mean biomass (IMB, blue line) of the dominant discarded fish species. Also represented by the red line is the biomass corresponding to an individual with the minimum conservation reference size, estimated using the weight-length relationships previously obtained.

Discussion

Beach seine is one of the most traditional fishing techniques in Portugal (Pereira *et al.* 2015), carried out by small fishing communities along the Portuguese coast, particularly in the central coast. Jorge *et al.* (2002) stated that in 2001 there were 76 crews actively working in Portugal. In 2013 there were 53 (Santos 2015) and, nowadays, only 43 are licensed[3]. A further decrease in this number can be foreseen for the next years. This may be explained by the hard conditions these fishermen are submitted to. Portuguese beach seine crews are decreasing because this activity does not provide a steady income, and their earnings are strongly dependent on the chances of a good haul, weather conditions, and the buyers' interest. Furthermore, since this is a seasonal fishery, their profits are limited to certain periods of activity (Santos *et al.* 2012).

Artisanal fisheries exhibit a small contribution to the minimum gross national income, however they are locally extremely important in many cultural and socioeconomic aspects, buffering tourism and community identity (Santos *et al.* 2012). Moreover, the importance of projects such as PRESPO[4], which aimed at promoting the sustainability of artisanal fisheries in the Atlantic area by improving management policies, should be highlighted as a major step on the characterization of these fishing communities. Praia de Mira is known by its fishing tradition, especially due to beach seine technique employed for centuries in the region. However, information regarding the pressures exerted by this fishery on biological communities is limited (Cabral *et al.* 2003). Addressing this gap is crucial to develop proper management tools that take into consideration both ecological and socioeconomic trade-offs.

In the context of the national statistics regarding the discarded biomass in four NUTS II regions (Nomenclature of Territorial Units for Statistics), it is possible to observe an increasing trend on the amount of reported discarded fish that peaked in 2013-2014 in the North and Center (Figure 25). Prior to this year, a lower biomass of fish was

---

[3] Pescadores de arte xávega querem venda direta. Jornal Aurinegra, 2016. http://aurinegra.pt/pescadores-de-arte-xavega-querem-venda-directa/ (accessed on 04/08/2016).

[4] Project PRESPO. http://atlanticprojects.ccdr-n.pt/project-area/prespo (accessed on 09/12/2016)

discarded. Statistics from Algarve show that reported discards are very low or practically inexistent after 2012. However, in Lisbon, after 2011, the recorded discards increased, peaking in 2014. In 2015 a decreasing in the biomass discarded is observed in almost all NUTS II regions. Overall only a small portion was considered unfit for consumption. Statistics from Alentejo, Madeira and Azores were not presented due to lack of data in some years.

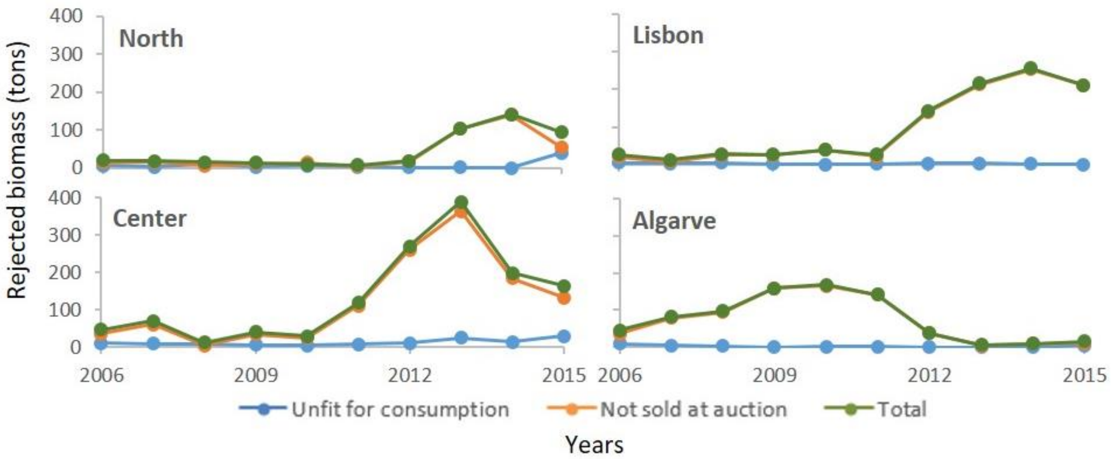


Figure 25. Official statistics regarding the discarded biomass after auction per NUTS II Portuguese regions. Source: INE (2007-2016).

Around 2300 tons were reported as discards in the NUTS II Center and Lisbon regions combined, from 2006 until 2015, which is a third of the total rejected portion recorded in official statistics for the same period. However, these are minimum values, since it only represents what was discarded as unfit for consumption and by the lack of buyers, with no information regarding pre-auction discards. For this reason, the scientific monitoring of these discards is extremely important. A measure – landing obligation – is being implemented by the Common Fisheries Policy to reduce the Illegal, Unreported and Unregulated (IUU) catches, which includes discards. By 2019, fishing crews must land all fish they capture of species that have management standards (TACs, minimum conservation size and quotas). This is a first step towards a better comprehension on the subject, because an increased control on discarded quantities will provide a tool for more realistic statistics and more accurate stock assessments. However, it could affect the viability of some fisheries, especially in the small-scale sector, due to increased fishermen burdens, without proper incentives being given (Veiga *et al.* 2016). A total of 85 744 registered fishing vessels were operating in EU waters, where small-scale fisheries represent a crucial portion of this total. According to this, it is important to properly evaluate the challenges this industry will suffer upon the implementation of this tool. Also, the ecological consequences of landing obligations (e.g. removal of large quantities of biomass from the ecosystem; issues related to subsequent disposal of the biomass) must be further examined.

Inter-annual variations

According to FAO (2016), around 81.5 million tonnes of fish were captured in 2014. For that year, the Portuguese fleet only captured 0.15% of this value, 119 890 tons (INE 2015). From those quantities, almost 50 % for the same year was covered by a series of small-scale fisheries included in the multi-gear category (“Polivalente”). In 2015, a 2.5% increase (to 57 470 tons) of the total biomass was verified. Multi-gear fisheries incorporates several fishing techniques, such as beach seine, as well as gillnets and trammel nets, catching a wide range of species, targeted or non-targeted.

Beach seine performed by the four crews in Praia de Mira contributed to about 0.60% of the total Multi-gear fishery landings (value estimated using official multi-gear fisheries’ statistics of 2015 from the Portuguese Statistics Institute, INE 2016). For the present year (2016), data are not available yet but considering last years’ data (57 470 tons, INE (2016)) as a reference, beach seine in Praia de Mira contributed only to 0.46% of the total captured and auctioned, which represents an estimated decrease of approximately 80 tons in the amount of resources auctioned in 2015.

Knowing that nets with the same legal minimum meshes were employed in the different periods, the reason for this decrease may be related to a decreased fishing effort in 2016 (which may have occurred, according to data provided by Docapesca) but also to decreased LPUEs. In fact, crews landed and auctioned considerably less resources. Inter-annual variations on the availability of fishery resources are often observed. Moreover, Watson and Pauly (2001) showed that, upon correcting the massive over-reporting of marine fisheries by the People’s Republic of China, world fisheries landings have, in fact, been slowly declining since the late 1980s, by about 0.7 million tonnes per year, rather than increasing at a rate of 0.33 million tonnes per year, as previously thought.

The environmental shifts that may have also influenced differences between captures per year to occur were not determined, however, biological (i.e. species interactions, food availability) and physical constraints (i.e. turbulence, sea surface temperature) affect larval survival and pelagic fish recruitment, where subtle shifts can alter populations due to their sensitivity to biological and physical processes (Agenbag *et al.* 2003; Cury and Roy 2011). Leitão (2015b) suggested that studies regarding environmental parameters affecting species landings should be conducted to each International Council for the Exploration of the Sea (ICES) sub-Division, since they are affected by different environmental conditions, leading to different heterogeneous of some stocks.

<u>Atlantic horse mackerel</u>

The Atlantic horse mackerel *T. trachurus* is one of the most important species in terms of commercial importance. Another study on beach seine activity conducted in Praia de Mira reported the Atlantic horse mackerel as the most captured species between 1997 and 1999, representing 60%, 80% and 70% of the total biomass for each year, respectively (Jorge *et al.* 2002). It was also one of the main resources auctioned in 2015 and 2016 during the study period (W22-W36) reported herein. The Atlantic horse mackerel is classified by the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species as a species of Least Concern. However, it is important to consider that, *Trachurus* spp. stocks are difficult to assess, due to its spasmodic recruitment (Roel and de Oliveira 2007), characterised by varying strong and low-frequency recruitments without a clear periodicity. Data provided by the FAO (Fishstat) indicate that there is a global decrease in horse mackerel captures, from 559 882 tons in 1995 to 161 054 tons in 2014. From the beach seine data provided by Docapesca, a decreasing pattern was also observed in the transition from 2015 to 2016 in this fishery (127 to 69 tons, between W22-W36). On the other hand, an ICES report for Division IXa (Atlantic Iberian Waters) showed that the Spawning-Stock Biomass (SSB) has been relatively stable in this region due to strong recruitments in 2011 and 2012, which indicates that stocks are also stable over the last years (ICES 2016a). Additionally, the INE (2016) report reveals an increase on the Portuguese captures of this species in 2015, when comparing with the previous year. The decrease on *T. trachurus* captures in Praia de Mira in 2016 may be related to a decreased fishing effort as well as nter-annual fluctuations in environmental factors. Leitão (2015b) showed that, for the sub-Division IXa Northern Coast of Portugal, the upwelling index, which is a measure of the water volume that upwells along the coast, northerly winds occurrence and wind magnitude is a good proxy for relating environmental conditions with the landings of this species.

Anchovy

The anchovy *E. encrasicolus* is an oceanodromous species that forms large schools, occurring mainly in coastal waters. Its populations also show large fluctuations depending on environmental conditions (Pethybridge *et al.* 2013). When considering the global scenario, FAO data (Fishstat) indicates a similar pattern from 2011 to 2014, where it the global reported captures shifted from 607 118 to 271 488 tons. A considerable decline of this species auctions was verified between years in the considered period (W22-W36), from 59.97 tons in 2015 to 15.53 tons in 2016. However, upon analysing the data for captures per haul, summing discards plus auctioned specimens (not including eventual, unknown post-auctions rejections of this species), a total of 2.93 tons of this fish were captured in the thirteen hauls analysed herein, while a previous study in the same area conducted by Louro (2016) revealed that approximately 0.80 tons were estimated as captures in eleven hauls, which may reveal an overall increase on this species captures that is not shown in the official data. ICES published a stock advice for the anchovy in Division IXa, revealing that this species biomass stock indicators for 2016 are the highest ones within their historical series (ICES 2016b). Also, INE (2016) states an increase of this species captures in Portugal waters, when comparing to 2014 (817 tons in 2014 to 2 531 tons in 2015). This been said, a shift on environmental variables in Praia de Mira region might also justify this increase. A study conducted by Martín *et al.* (2008) on the Catalan coast (NW Mediterranean) has showed that the environmental conditions in winter, which precedes the reproduction period, and by the end of the summer of previous year, affecting larvae growth and survival, strongly influence landings per unit effort of this species. Additionally, a variation on the *T. trachurus* captures may have been followed by shift on *E. encrasicolus* captures. A clear species transition is observed from last years' data, and for this year, a presumable increase on anchovies captures might have been followed by a decrease on *T. trachurus* biomass.

European squid

Regarding the European squid *L. vulgaris*, which is also a major contributor for dissimilarities between the two years, a considerable decrease in the amount of biomass auctioned was also observed: from 11.61 to 0.62 tons. According to Moreno *et al.* (2014), a recent decrease on the Portuguese landings of this species has been verified. This species is reported to lay eggs in clusters attached to hard substrates, natural or fishing devices and marine debris. It was found that several egg masses of this species were hauled from the sea attached to fishing gear throughout the Portuguese coast. Since major nursery and spawning grounds of *L. vulgaris* were detected close to Praia de Mira (Moreno *et al.* 2014), this highlights the fact that the deployment of static fishing gear could act as a major threat to the spawning success of this species. Moreover, a study conducted by Moreno *et al.* (2009) showed that Sea Surface Temperature (SST) was a major environmental factor determining this species' seasonality and distribution, with lower SST linked to higher abundances and broader distributions.

Sardine

Sardines were the most landed species in Portugal between 1938 and 2009 (Leitão 2015). The sardines are considered as target species of this fishery, however, the estimated captures in 2015 to 2016 (W22-W36) were low and the biomass auctioned also declined from 2015 to 2016 (2.02 tons in 2015 and 0.92 tons in 2016). When assessing the stock development over the years provided by ICES for Divisions VIIIc and IXa (which includes the Cantabrian Sea and the Atlantic Iberian Coast), their captures have, in fact, declined considerably, along with the recruitment (age 0) and biomass at age 1 and older, being the latter close to the historical low (ICES 2016c). The low captured biomasses of sardine in both years are in agreement with these ICES reports.

Other species

Two fish species, salema *S. sarpa* and chub mackerel *S. japonicus* should also be highlighted. The salema was one of the species that had an increase on biomass auctioned from 0.17 tons in 2015 to 6.08 tons in 2016 (W22-W36). These differences where essentially due to V1 landings; the crews' Captain was able to find an interested buyer for this species which avoided its discard. In 2014 and 2015, the chub mackerel was the most landed fish in the Portuguese waters (29 543 and 46 430 tons, respectively. The slight increase on the biomass auctioned reported herein (1.55 to 3.84 tons in the considered periods of 2015 and 2016) followed the national trend.

Another factor that may contribute to inter-annual differences is the unknown portion of captures that are discarded after auction. For stock assessments, the total discards quantities (especially on the small scale sector) are often limited (CEC 2002). To understand the differences between years, available data on pre and post-auction discarded quantities would be crucial to provide more accuracy.

Earnings

Regarding the average price per kilogram of *T. trachurus*, *E. encrasicolus* and *S. pilchardus* in 2016, a similar situation occurred when considering the national scenario. The price changes reflects the total traded in auction, where the decrease in quantities caught may lead to price inflation, while an increase in captures tends to decrease its value (INE 2015). Analysing the 2015 national average price per kilogram for these three fish species, the Atlantic horse mackerel was the only species that had a higher than average price per kilogram (national average of 1.01 €/kg, INE 2016), while others were below. The anchovy is a highly abundant species, however, since this fish is not so appreciated by the local community, their price per kilogram tend to be lower. Fishermen do not control the minimum selling price per kilogram of their fish. It is decided by intermediates that provide the link between the fishermen and the rest of the fishing industry. For this reason, their earnings rely on the quality of each landing and on market demand.

Discards

Comparison between years

Data provided by Louro (2016) on the discards of beach seining in Praia de Mira is available enabling to compare the results from 2015 and 2016 once the same methodology was employed in this study. The previous study targeted two crews (V1 and V3) and only eleven samples were collected, while the present work only focused V1, with thirteen samples. Louro (2016) reported that discard rates per haul were typically 20-40% and, for the present study, more variable rates (to about 15-60%) were obtained. In fact, an increase occurred, from an average 136.00±140.57 in 2015 to 194.86±508.39 kg of discards per haul in 2016 (from an estimated total of 1.36 tons in 2015 to 2.53 tons in 2016). The standard errors for these estimates are high: 31% in 2015 and 72% in 2016. After performing an adjustment of the data, excluding odd hauls such as the one from week 25 in 2015 (capture and subsequent discard of 0.52 tons of resources), and the one from week 31 in 2016 (capture and subsequent discard of 1.88 tons of resources) the mean discarded quantities per haul were 93.44 kg ± 42.93 in 2015 and 54.16 kg ± 35.11 in 2016 with a standard error below 20% in both periods, providing a more robust comparison of the data.

Discard composition and structure (biomasses) in 2015 and 2016 did not show significant differences (ANOSIM results: R: 0.002; P=39.9%; MDS plot in Annex IV). The total captures per haul (sum of landings and beach discards) in both years showed that higher percentage of discards occurred whenever *E. encrasicolus* was the dominant captured species.

The W–L relationships estimated in this study were compared with previously obtained relationships for the same species (Louro 2016) discarded in Praia de Mira (Table 10) showing slightly higher values of *b* in 2016 than in 2015 for all species except the sardine. The parameters of the W-L relationship may vary significantly according to season (Bagenal and Tesch 1978), changes in *b* can be used as indicating fluctuations in the physiological condition of the individuals (appropriate statistic test can be used but are beyond the scope of the present study.

Table 10. Comparison of weight-length relationship parameters obtained by Louro (2016) for discarded specimens in 2015.

	Present work			Louro (2016)		
Species	**n**	**W-L equation**	R^2	**n**	**W-L equation**	R^2
T. trachurus	298	$W=0.007L^{3.055}$	0.970	275	$W=0.009L^{2.937}$	0.990
S. pilchardus	242	$W=0.006L^{3.053}$	0.943	299	$W=0.003L^{3.354}$	0.876
E. encrasicolus	303	$W=0.007L^{2.917}$	0.652	324	$W=0.021L^{2.553}$	0.959
T. luscus	163	$W=0.011L^{2.938}$	0.958	233	$W=0.010L^{2.981}$	0.991
C. lucerna	82	$W=0.008L^{3.064}$	0.996	203	$W=0.014L^{2.849}$	0.991

According to Mendes *et al.* (2004), the physiological condition can reflect temporal variation in food availability and growth. Individual fish within the same sample vary considerably, and the average condition of each population varies seasonally and inter-annual. As a consequence of the discarding selection process, the resulting coefficients were based on limited length ranges and do not reflect all the size spectra of the populations (Mendes *et al.* 2004). Accordingly, the use of weight-length relationships should be limited to the size ranges used in the estimation of the fitted regression (Petrakis and Stergiou 1995).

A poorer fit was obtained for *E. encrasicolus*, and subsequently monthly data were analysed separately to investigate for possible changes in *b* over the summer but the results were not conclusive.

<u>The motives for discarding</u>

From the analysed samples, a high proportion of juveniles amongst discarded specimens was expected. High discard rates can be observed if the fishery is located in a nursery area (Morizur *et al.* 2004). It has been shown before that coastal areas are important nursery grounds for fish (Gibson 1994; Andrades *et al.* 2012; Ellis *et al.* 2012) and, migration towards deeper marine areas occurs as fish grow (Murta and Borges 1994; Hyndes *et al.* 1999).

Target species were discarded for five reasons. The first could be related to the species unfulfilment of the legal minimum landing size (Table 11). This was observed essentially for *T. trachurus* and *T. luscus*. The second could be justified by the lack of interest by potential buyers, which was also observed in the previous study during 2015 (Louro 2016). The main reason for the occurrence of anchovy discards is due to this reason, however, some of the specimens where also bellow legal thresholds. This species is not much appreciated in Praia de Mira region.

Table 11. Minimum conservation reference size to be auctioned per species. Species average size was included, as well as size range Source: Ordinance No. 27/2001. MCRS: Minimum Conservation Reference size to be auctioned; SAS: Species Average Size.

Species	Common Name	MCRS (cm)	SAS (cm)	Range (cm)
T. trachurus	Atlantic Horse Mackerel	15	8.66±1.81	5.00-15.60
S. pilchardus	Sardine	11	12.66±2.60	6.00-22.00
E. encrasicolus	Anchovy	12	13.19±1.09	9.00-17.60
T. luscus	Pouting	17	9.24±1.78	6.70-21.80

Another reason for discarding might be related to the fact that, even though species have commercial value, the low volume of captures does not warrant sale. This occurred specially for *S. pilchardus*. This species has market potential, however, low biomasses were usually captured and, in the only sample that could have resulted in auctioning (S33), the majority of the specimens were below the legal size for auction. Accidental discarding might be considered another reason, especially for the squids. Their high price per kilogram indicates that it is one of the most valued species of this fishery, but accidental discarding may occur because smaller specimens may be easily overlooked during sorting. The last reason for discarding is related with the TACs. During the study period this happened only once for the Atlantic mackerel *S. scombrus:* since this mackerel fisheries were closed on the 17th of May 2016 (Source: DGRM), this species could not be auctioned. However, only 1.8 kg of this species were estimated as discards in the thirteen hauls. As it occurred for other species, fishermen may sell a small fraction of the resources to tourists and local consumers immediately after their capture, before discarding them. A similar situation was described by Cabral *et al.* (2003).

Despite the pressures that beach seining can have on organisms, Clark *et al.* (1994) suggested that the high mortality rates induced by this fishery reach only 10% of the natural mortality rates. However, in the beach seine at False Bay where that study was carried out, discards are almost immediately returned to the sea, which may decrease mortality rates. To the author of the current study knowledge, this does not occur in Praia de Mira, nor at other locations along the Portuguese coast (Cabral *et al.* 2003). Captures are sorted on the beach and only after discards are returned to the sea, when organisms are already dead, leading to close to high mortality rates in discarded specimens. Higher survival rates of discarded crustaceans are often observed (CEC 2002; Leitão *et al.* 2014) and this also occurred for *P. henslowii* in Praia de Mira.

The percentage of discards in crustacean trawl fisheries was estimated as 70 % of the total capture by Borges *et al.* (2001), and as 90% by Monteiro *et al.* (2001). Borges *et al.* (2001) also estimated that discard rates of 20% for demersal and pelagic purse-seining and 13% for trammel nets. Typical discard rates of 20-40% were reported in the study by Louro (2016) for beach seining, while this study has shown typical discard rates of 15-60%. This is generally higher than the ones previously obtained by Jorge *et al.* (2002) for

Praia de Mira (10%, 1997-1999). Antunes (2007) estimated an average of 37.9 kg of discards per haul (a 13% discard rate per haul) in Costa da Caparica (Setubal, Portugal) beach seine, which is lower than what was estimated in the present study (54.2 kg of discards per haul, excluding H31). Gray *et al.* (2001) and Gray and Kennelly (2003) also reported a high discarded fraction of the total captured by the beach seine fleet (both in Australia): 38% in Botany Bay (1998-1999) and 57% in two Australian barrier estuaries.

Towards a solution

In order to minimize unwanted catches and to contribute for an effective management of fisheries, proper estimates of the discards should be provided. There are several ways of estimating them, however one of the most effective solutions includes the presence of observers (Morizur *et al.* 2004).

The two main approaches regarding this subject is how to reduce discards, and, preferably, how to increase the utilization of non-target species (Kelleher 2005). According to Hall *et al.* (2000), to achieve bycatch reduction, and, consequently, decreased discards quantities, there are two levers that should be moved: fishing effort and bycatch per unit effort (BPUE). A reduction in fishing effort can be a direct solution, but costly to the fishermen. Reductions in BPUE can be achieved through technological changes in gear and other equipment, as well as in deployment and retrieval methods, by training actions targeting fishermen and management actions such as selective licensing and economic advantages for the best performers. In large-scale fisheries and certain small-scale fisheries, a volunteer departure from a fishing area if bycatch rates are high can be implemented. For beach-seine, fishermen have small and restricted fishing areas, and the departure from the fishing area implies that they cannot perform their activity. However, in Praia de Mira, the crews often stop their activity for that day if a bad haul occurs (high rates of bycatch, or species that cannot be landed because of minimum conservation reference sizes or TACs but also low overall captures).

The low impact of beach seine fisheries on a national scenario does not reflect its socioeconomic relevance for the small local communities where this technique is traditionally employed. This fisheries needs a proper management plan, especially, to provide alternatives to the generated discards. Besides the inability to assess real fishing efforts, a considerable portion is sold directly after capture (Cabral *et al.* 2003). This should also be taken into consideration, in order to find proper solutions.

Care should be taken when considering landing obligation as a tool to optimize small-scale fisheries such as beach seine. Firstly, the unwanted catch can be sold, but not for human consumption (Source: EC). Del Pazo *et al.* (2014) reveals possible alternatives for the discarded species. They include producing fish meal, producing compounds for pharmacy and cosmetics and food supplements, however these are logistically much more complex solutions. The local market should provide a way to store large quantities of these resources. Also, would end up increasing fishermen burdens, due to increased time on sorting and processing the resources (Veiga *et al.* 2016). This, added to the fact that beach-seine have typically a low number of fishermen per crew, with generally low income, the landing obligation tool might represent a threat for these communities, and crews in Praia de Mira are no exception. Moreover, the process of landing all the previously discarded resources would end up in increased costs due to the need of its proper disposal (Veiga *et al.* 2016). The long exposure to heat of marine resources discarded by beach seining would also make them more easily perishable. An exemption of beach seine to the landing obligation could be considered, however it may be perceived as unfair by other fishing fleets if that measure is not properly supported.

Projects such as the *Cabaz do Peixe* (Fish Basket), implemented in Sesimbra by local associations, should be enhanced and used as an example to be followed. Its main objective is to reduce fishing wastes, while decreasing the gap between fishermen and consumer, eliminating intermediaries, through the process of selling 3 kg of fresh fish at 20 € each[5]. It is a well-accepted measure implemented in Sesimbra, boosting local artisanal fisheries without increasing the fishing effort.

In Praia de Mira, the anchovy was captured and discarded in substantial quantities (especially in 2016), calling for a solution for this situation. Spain is one of the largest consumer of this species (23% of the EU consumers), and has a high demand of ready-

[5] Cabaz do peixe.
http://www.cabazdopeixe.pt/ (accessed on 28/10/2016)

to-eat preserved and prepared anchovy products (Eurofish International Organization 2012). This could be a potential solution for the unwanted captures of this species if adequate commercial relationships could be implemented and regulated.

The mackerel *S. japonicus* was one of the main discards of the Algarve's fleet. In an effort to decrease its impacts, the collaboration between Center of Marine Sciences (*CCMar – Centro de Ciências Marinhas*) and other institutes developed Project Cavala, where its main objective is to promote the divulgation of innovative and traditional recipes, whose main ingredient is the mackerel[6]. The same could be implemented for *E. encrasicolus*, at least locally, appealing for its use throughout the community, resulting in an increase of its market potential, and reducing discards.

When discussing solutions for this fishery discards, it is also important to highlight the fact that discards are considered as a key source food for several groups, such as the opportunistic seabirds (Votier *et al.* 2004; Carniel and Krul 2012), and other scavengers (Catchpole *et al.* 2005). It is expected that seabirds' populations will suffer an increase in areas of high proportion of discards from fisheries. The opportunistic seabird yellow-legged gull *Larus michahellis* Naumann, 1840, was frequently observed in Praia de Mira, scavenging for food after each haul. Besides the discarded fish they consume, the portunid crab *P. henslowii* was found amongst the preferred preys. According to Arcos *et al.* (2008), sea birds exploit over 80% of the discards available. Due to this, a decrease on the discards availability might drive an increased predation of the seabirds (such as *L. michahellis*) on other species (Ramos *et al.* 2009), which may raise concerns over this fishery.

[6] Projeto Cavala.
http://www.cavala.pt/ (accessed on 28/10/2016)

Final remarks

It is already known that fish are considered one of the most important source of nutrients, being crucial part of the human diet. In developing countries, it provides about 50% of the animal protein (Finegold 2009). For this reason, it is important to maintain their sustainability. Fisheries are posing a high threat to the resources they depend upon, since they have been explored at or above their optimum capacity (Morizur *et al.* 2004). This will drive inevitably to their depletion over time. The collapse of the main world's fisheries in the past (i.e. Myers *et al.* (1997)), represents the failure of management programs. Moreover, the almost full access to the oceans, the same fisheries being managed by different plans and the increase on fishing capacity per vessel are posing additional threats to its resources (Pauly *et al.* 2002). An improvement of current management plans is much needed, and for that to happen, a strong cooperation between the politicians, scientific community and others involved must be established. It is crucial to understand that the ocean will not be able to provide for these large quantities for much long, especially with the growing global human population (Pauly *et al.* 2002). Pauly *et al.* (2002) advises that if these trends are to be reversed, a significant reduction on fishing capacity must be put in action, along with the decommissioning of the fishing fleet, and management plans must incorporate the precautionary principle, appealing to scientific consensus.

Along with this alarming scenario, fisheries are even at greater risk due to the discards quantities that it generates. Since many of the world's most important fisheries are in great risk of collapsing (Pauly *et al.* 2002), the importance given to impacts has risen. For decades, the discards issue was overlooked, since it was not visible and thought to be in small magnitude (Hall *et al.* 2000). It is now known that it constitutes a large wastage of fisheries resources, culminating, once more, in the inability in managing these vital resources. Resolutions from the United Nations enhanced the attention that is needed to be given towards this subject, in order to assess a more realistic perspective of the fisheries impacts. Kelleher (2005) estimated that about 7.8 million tonnes of resources are considered suboptimal and, consequently, discarded. The main fisheries that contribute the most to these critical proportions are the shrimp and demersal finfish trawls, with more than 3.9 million tonnes of discards being generated by their activity, representing only 22% of the total landings. Small-scale fisheries usually generate lower discard rates (weighted discard rates of 3.7%, Kelleher 2005). However, a decreasing trend in its occurrence is being observed, especially in developed countries, due to increase in their use, and better management plans. Still, discards information is highly variable, and that is unsuitable for proper assessments (Kelleher 2005). The on-board observer provides the least variation, being crucial for increased accuracy.

In response to this problem, the new Common Fisheries Policy reform introduced the landing obligation, as a way to tackle this problem. Captures from EU fisheries managed under the CFP have to be landed, and not returned to the sea, and counted against the quotas. This started in 2015, and will be fully implemented by 2019, for all commercial species under TACs or minimum conservation reference sizes (Source: EC). This tool will be used to provide more accuracy on stock assessments, and force fishing to be more selective. However, the applicability of this tool to small scale fisheries should be carefully analysed.

It is known that small-scale fisheries have an important contribution in nutrition and sustainable livelihoods[7], being found worldwide. Local fisheries tend to engage their activity in the presumed "peak abundance" season, while undertaking another work in between. However, little is known about its practice (Salas *et al.* 2007). For example, more information is available regarding large-scale fisheries, since it is easier to collect data from large volumes of resources than in small-scale fisheries. Moreover, large-scale fisheries have major impacts in the gross national income. Fewer efforts are being made in small-scale fisheries towards a systematic data collection (Salas *et al.* 2007). Small-scale fisheries, which compose a large portion of the Portuguese fishing fleet, are in need to the development of these plans to enhance their sustainability and decrease their impacts. For example, crustacean trawls produce large amounts of discards (70% were estimated in Borges *et al.* (2001), while 90% was obtained by Monteiro *et al.* 2001).

[7] FAO. Importance of small-scale fisheries.
http://www.fao.org/fishery/ssf/en (accessed on 27/10/2016)

According to (Pereira *et al*. 2015), beach seine is one of the most important traditional fishing practices in Portugal. It is usually known by the use of the seines along with the use of animals, especially bovines, to provide brute force in dragging their nets towards the beach. Nowadays, it employs a mechanical alternative, through the use of tractors. Due to its traditional background, this artisanal fishery has been submitted to be under the National Immaterial Cultural Heritage. It is also known for providing high quality and nutritional food for the local communities (Viegas and Tedim 2012). This practice, besides defining the cultural identity of the region where it is conducted, is a source of tourism (Santos *et al.* 2012). However, little information is available regarding its activity (Cabral *et al.* 2003). For proper management of this traditional fisheries it is crucial to gather accurate data on its activity. The low contribution of beach seine to the overall captures at national level (estimated 0.46% of the multi-gear captures) does not reflect the remarkable importance for the local community. Due to its special characteristics, this traditional fishery is very attractive to tourists in Praia de Mira, especially in July and August. Many of these tourists as well as some local consumers are eager to immediately acquire the fresh fished resources. Also, beach seine represents a considerable portion of the economic income of some families.

Through this study, three major constraints may be identified for the fishermen. The first is related to variations in fishing effort, which could directly influence fishermen income. Second regards to the environmental uncertainties, where changes in environmental conditions possibly affect resource availability. The other is related to the economic uncertainties, since fishermen do not control the minimum price that resources are auctioned, being strictly decided by potential buyers. This expresses the variability in fishermen income.

The Code of Conduct for Responsible Fisheries explicitly mentions the importance that small-scale fisheries, such as beach seine, have in poverty alleviation and food security (FAO 1995). This highlights the fact that it is important to balance local communities' needs, while maintaining healthy ecosystems. Accurate assessments and measures to decrease discard rates are crucial tools for a better management of beach seine fisheries, contributing to the conservation of marine habitats and improving the sustainability of this activity.

Literature cited

Agenbag JJ, Richardson AJ, Demarcq H, *et al* (2003) Estimating environmental preferences of South African pelagic fish species using catch size- and remote sensing data. Prog Oceanogr 59:275–300.

Akel EHK, Philips AE (2014) Fisheries and biodiversity of the beach seine catch from the Eastern Harbor, Alexandria, Egypt. Egypt J Aquat Res 40:79–91.

Andrades R, Bolzan MS, Contaifer LS, *et al* (2012) Evidence of sandy beaches as growth grounds for commercial fish in the south-western Atlantic. Panam J Aquat Sci 7:107–110.

Antunes M (2007) Caracterização da pesca com arte de xávega na zona costeira adjacente ao estuário do Tejo. Universidade de Lisboa

Arcos JM, Louzao M, Oro D (2008) Fisheries ecosystem impacts and management in the Mediterranean: seabirds point of view. Am Fish Soc Symp 49:1471–1479.

Bagenal TB, Tesch FW (1978) Age and Growth. In: Bagenal T (ed) Methods for Assessment of Fish Production in Fresh Waters. IBP Handbook No. 3. Blackwell Scientific Publications, pp 101–136

Borges TC, Erzini K, Bentes L, *et al* (2001) By-catch and discarding practices in five Algarve (Southern Portugal) métiers. J Appl Ichthyol 17:104–114.

Cabral H, Duque J, Costa MJ (2003) Discards of the beach seine fishery in the central coast of Portugal. Fish Res 63:63–71.

Carniel VL, Krul R (2012) Use of artisanal fishery discards by seabirds on the Paraná Coast in Brazil. Mar Ornithol 40:57–62.

Castillo S, Mendo J (1987) Estimation of Unregistered Peruvian Anchoveta (*Engraulis ringens*) in Official Catch Statistics, 1951 to 1982. In: Pauly D, Tsukayama I (eds) The Peruvian Anchoveta and its Upwelling Ecosystem: Three Decades of Change. IMARP, GTZ and ICLARM, pp 109–116

Catchpole TL, Frid CLJ, Gray TS (2005) Discards in North Sea fisheries: Causes, consequences and solutions. Mar Policy 29:421–430.

CEC (2002) Communication from the Commission to the Council and the European Parliament on a community action plan to reduce discards of fish.

Clark BM, Bennett BA, Lamberth SJ (1994) Assessment of the impact of commercial beach-seine netting on juvenile teleost populations in the surf zone of False Bay, South Africa. South African J Mar Sci 14:255–262.

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. Aust J Ecol 18:117–143.

Clarke KR, Gorley RN (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E. Plymouth

Council Regulation (EC) No.850/98. Technical measures for the protection of juveniles of marine organisms.

Cury P, Roy C (2011) Optimal Environmental Window and Pelagic Fish Recruitment Success in Upwelling Areas. Can J Fish Aquat Sci 46:670–680.

da Silva AAB (1892) Estado atual das pescas em Portugal. Imprensa nacional

de Groot SJ (1984) The impact of bottom trawling on benthic fauna of the North Sea. Ocean Manag 9:177–190.

Del Pazo TO, Antelo LT, Franco-Uría A, *et al* (2014) Fish discards management in selected Spanish and Portuguese métiers: Identification and potential valorisation. Trends Food Sci Technol 36:29–43.

Ecosystem Principles Advisory Panel (1999) Ecosystem - Based Fishery Management. Washington, DC

Ellis JR, Milligan SP, Readdy L, *et al* (2012) Spawning and nursery grounds of selected fish species in UK waters. Sci Ser Tech Rep 147:56.

Eurofish International Organization (2012) Overview of the world's anchovy sector and trade possibilities for Georgian anchovy products.

FAO (1995) Code of Conduct for Responsible Fisheries. Food and Agriculture Organization of the United Nations, Rome

FAO (2016) The State of World Fisheries and Aquaculture. Rome

Fernandes, L (1984) Artes de Pesca Artesanal. Secretaria Regional da Agricultura e

Pescas. Região Autónoma dos Açores

Field JG, Clarke KR, Warwick RM (1982) A practical strategy for analysing multispecies distribution patterns. Mar Ecol - Prog Ser 8:37–52.

Finegold C (2009) The importance of fisheries and aquaculture to development. In: Wramner P, Cullberg M, Ackefors H (eds) Fisheries, sustainability and development. The Royal Swedish Academy of Agriculture and Forestry, Stockholm,

Franca MLP, Costa FC (1979) Nota sobre as Xávegas da Costa da Caparica e Fonte da Telha. Bol do Inst Nac Investig das Pescas 1:37–69.

Froese R (2006) Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22:241–253.

Gabriel O, Lange K, Dahm E, Wendt T (2005) Von Brandt's fish catching methods of the world. Blackwell Publishing, New Delhi

Garthe S, Camphuysen K, Furness RW (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Mar Ecol Prog Ser 136:1–11.

Gibson RN (1994) Impact of habitat quality and quantity on the recruitment of juvenile flatfishes. Netherlands J Sea Res 32:191–206.

Gonçalves JMS, Stergiou KI, Hernando JA, *et al* (2007) Discards from experimental trammel nets in southern European small-scale fisheries. Fish Res 88:5–14.

Gray CA, Kennelly SJ (2003) Catch characteristics of the commercial beach-seine fisheries in two Australian barrier estuaries. Fish Res 63:405–422.

Gray CA, Kennelly SJ, Hodgson KE, *et al* (2001) Retained and discarded catches from commercial beach-seining in Botany Bay, Australia. Fish Res 50:205–219.

Hall MA, Alverson DL, Metuzals KI (2000) By-catch: Problems and solutions. Mar Pollut Bull 41:204–219.

Hyndes GA, Platell ME, Potter IC, Lenanton RCJ (1999) Does the composition of the demersal fish assemblages in temperate coastal waters change with depth and undergo consistent seasonal changes? Mar Biol 134:335.

ICES (2016a) Horse mackerel (*Trachurus trachurus*) in Division IXa (Atlantic Iberian Waters). In: ICES Advice 2016, Book 7.

ICES (2016b) Anchovy (*Engraulis encrasicolus*) in Division IXa (Atlantic Iberian waters). In: ICES Advice 2016, Book 7.

ICES (2016c) Sardine (*Sardina pilchardus*) in divisions VIIIc and IXa (Cantabrian Sea and Atlantic Iberian waters). In: ICES Advice 2016, Book 7.

INE (2007) Estatísticas da Pesca 2006. Lisbon, Portugal

INE (2008) Estatísticas da Pesca 2007. Lisbon, Portugal

INE (2009) Estatísticas da Pesca 2008. Lisbon, Portugal

INE (2010) Estatísticas da Pesca 2009. Lisbon, Portugal

INE (2011) Estatísticas da Pesca 2010. Lisbon, Portugal

INE (2012) Estatísticas da Pesca 2011. Lisbon, Portugal

INE (2013) Estatísticas da Pesca 2012. Lisbon, Portugal

INE (2014) Estatísticas da Pesca 2013. Lisbon, Portugal

INE (2015) Estatísticas da Pesca 2014. Lisbon, Portugal

INE (2016) Estatísticas da Pesca 2015. Lisbon, Portugal

Jorge I, Siborro S, Preciosa Sobral M (2002) Contribução para o conhecimento da pescaria da xávega da zona centro. Relatórios Científicos e Técnicos Inst Investig das Pescas e do Mar 85:1–22.

Kaufman L, Heneman B, Barnes JT, Fujita R (2004) Transition from low to high data richness: An experiment in ecosystem-based fishery management from California. Bull Mar Sci 74:693–708.

Kelleher K (2005) Discards in the world's marine fisheries. An update. FAO Tech Pap 131.

Lamberth SJ, Bennett AB, Clark BM, Janssens PM (1995) The impact of beach-seine netting on the benthic flora and fauna of False Bay, South Africa. South African J Mar Sci 15:115–122.

Lamberth SJ, Sauer WHH, Mann BQ, *et al* (1997) The status of the South African beach-seine and gill-net fisheries. South African J Mar Sci 18:195–202.

Lambshead PJD, Platt HM, Shaw KM (1983) The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. J Nat Hist 17:859–874.

Leitão F (2015) Time series analyses reveal environmental and fisheries controls on Atlantic horse mackerel (*Trachurus trachurus*) catch rates. Cont Shelf Res 111:342–352.

Leitão F, Range P, Gaspar MB (2014) Survival estimates of bycatch individuals discarded from bivalve dredges. Brazilian J Oceanogr 62:257–263.

Louro I (2016) Avaliação da biodiversidade e biomassa nas capturas e rejeições da arte xávega operada em Mira - Coimbra. Universidade de Aveiro

Martín P, Bahamon N, Sabatés A, *et al* (2008) European anchovy (*Engraulis encrasicolus*) landings and environmental conditions on the Catalan Coast (NW Mediterranean) during 2000-2005. Hydrobiologia 612:185–199.

Martins R, Carneiro M, Rebordão F, Sobral M (2000) A pesca com a Arte de Xávega. Relatórios Científicos e Técnicos Inst Investig das Pescas e do Mar 48:1–32.

McGoodwin JR (2001) Understanding the cultures of fishing communities: a key to fisheries management and food security. Rome

Mendes B, Fonseca P, Campos A (2004) Weight-length relationships for 46 fish species of the Portuguese west coast. J Appl Ichthyol 20:355–361.

Ministerial Council No. 142/2000. Approval of the Coastal Zone Management Plan for Ovar-Marinha Grande.

Ministerial Order No.488/1996. Beach-Seine Fishery Regulamentation.

Monteiro P, Araújo A, Erzini K, Castro M (2001) Discards of the algarve (southern Portugal) crustacean trawl fishery. Hydrobiologia 449:267–277.

Moreno A, Chaves C, Lourenço S, *et al* (2014) Nursery and spawning grounds of the squid Loligo vulgaris on the Portuguese shelf. In: ICES CM. p 18

Moreno A, dos Santos A, Piatkowski U, *et al* (2009) Distribution of cephalopod paralarvae in relation to the regional oceanography of the western Iberia. J Plankton Res 31:73–91.

Morizur Y, Caillart B, Tingley D (2004) The problem of discards in fisheries. Encycl Life Support Syst @UNESCO-EOLSS, Arch Arch institutionnelle l´Ifremer 17.

Murta AG, Borges MF (1994) Factors affecting the abundance and distribution of horse mackerel *T. trachurus* (Linnaeus, 1758) in Portuguese waters. ICES C 1999/H:20:16.

Myers RA, Hutchings JA, Barrowman NJ (1997) Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecol Appl 7:91–106.

Ordinance No.9/1973. Artisanal Fishery Regulamentation.

Ordinance No. 27/2001. Species minimum size for auction.

Ordinance No.1102-F/2000. Seine-surrounding Fisheries Regulamentation.

Pauly D, Christensen V, Guénette S, *et al* (2002) Towards sustainability in world fisheries. Nature 418:689–695.

Pauly D, Watson R, Alder J (2005) Global trends in world fisheries: impacts on marine ecosystems and food security. Philos Trans R Soc Lond B Biol Sci 360:5–12.

Pereira ONA, Dias JA, Bastos MR (2015) Considerações sobre a arte xávega em Portugal: sua introdução, desenvolvimento e teorias inerentes. O Homem e as Zo Costeiras 121–139.

Pethybridge H, Roos D, Loizeau V, *et al* (2013) Responses of European anchovy vital rates and population growth to environmental flutuations: An individual based modeling approach. Ecol Modell 250:370–383.

Petrakis G, Stergiou KI (1995) Weight-length relationships for 33 fish species in Greek waters. Fish Res 21:465–469.

Prena J, Schwinghamer P, Rowell TW, *et al* (1999) Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: Analysis of trawl bycatch and effects on epifauna. Mar Ecol Prog Ser 181:107–124.

Ramos R, Ramírez F, Sanpera C, *et al* (2009) Diet of Yellow-legged Gull (*Larus michahellis*) chicks along the Spanish Western Mediterranean coast: The relevance of refuse dumps. J Ornithol 150:265–272.

Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013. European Parliament and Council of the European Union.

Regulatory Decree No.7/2000.

Roel BA, de Oliveira JAA (2007) Harvest control rules for the Western horse mackerel (*Trachurus trachurus*) stock given paucity of fishery-independent data. ICES J Mar Sci 64:661–670.

Salas S, Chuenpagdee R, Seijo JC, Charles A (2007) Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. Fish Res 87:5–16.

Santos BMP (2015) Notas Para a Compreensão Da Arte Notas Para a Compreensão Da. Universidade de Coimbra

Santos MPN dos, Seixas S, Aggio RBM, *et al* (2012) A Pesca enquanto Atividade Humana: Pesca Artesanal e Sustentabilidade. J Integr Coast Zo Manag 12:405–427.

Tietze U, Lee R, Siar S, *et al* (2011) Fishing with beach seines. FAO Fisheries and Aquaculture, Rome

Veiga P, Pita C, Rangel M, *et al* (2016) The EU landing obligation and European small-scale fisheries: What are the odds for success? Mar Policy 64:64–71.

Viegas M do C, Tedim F (2012) Pequenas comunidades piscatórias nas paisagens litorais do Norte de Portugal : da lenta “Agonia” à revitalização. In: O Mar: patrimónios, usos e representações.

Votier SC, Furness RW, Bearhop S, Crane JE (2004) Changes in fisheries discard rates and seabird communities. Nature 427:727–730.

Watson R, Pauly D (2001) Systematic distortions in world fisheries catch trends. Nature 414:534–536.

Witherell D, Pautzke C, Fluharty DL (2000) An ecosystem-based approach for Alaska groundfish fisheries. ICES J Mar Sci 57:771–777.

Annexes

Annex I

AI.1. List of the captured species by the four crews in 2016 (W22 to W36). FAO code and the Portuguese common name is also represented.

FAO	Species	Common name (EN)	Common name (PT)	Total (kg)
Bony fishes				
HOM	*Trachurus trachurus*	Atlantic horse mackerel	Carapau	68966.3
ASD	*Alosa alosa*	Allis shad	Sável	2.8
IL	*Sardina pilchardus*	Sardine	Sardinha	916
ANE	*Engraulis encrasicolus*	European anchovy	Biqueirão	15529.0
GRA	*Parapristipoma octolineatum*	African striped grunt	Riscado	22.1
BSS	*Dicentrarchus labrax*	European seabass	Robalo legítimo	448.9
PLE	*Pleuronectes platessa*	European plaice	Solha-legítima	2.0
DRS	*Pteroscion peli*	Boe drum	Rabeta-africana	119.2
BON	*Sarda sarda*	Atlantic bonito	Sarrajão	24.5
MAS	*Scomber japonicus*	Chub Mackerel	Cavala	3841.5
TUR	*Scophthalmus maximus*	Turbot	Pregado	9.0
CET	*Dicologlossa cuneata*	Wedge sole	Língua	133.3
SOS	*Pegusa lascaris*	Sand sole	Linguado-da-areia	3.0
SOL	*Solea solea*	Common sole	Linguado-legítimo	2.0
SWA	*Diplodus sargus sargus*	White seabream	Sargo-legítimo	87.8
SRG	*Diplodus spp.*	Sargo breams nei	Sargos	9,1
SLM	*Sarpa salpa*	Salema	Salema	6079.0
SBG	*Sparus aurata*	Gilthead seabream	Dourada	13.5
GUU	*Chelidonichthys lucerna*	Tub gurnard	Ruivo	179
Cartilaginous fishes				
RJC	*Raja clavata*	Thornback ray	Raia-lenga	54.2
Molluscs				
OUM	*Alloteuthis media*	Midsize squid	Lula-bicuda-curta	2265.4
SQR	*Loligo vulgaris*	European squid	Lula-vulgar	615.4
CTC	*Sepia officinalis*	Common cuttlefish	Choco-vulgar	205.9

Annex II

AII.1. Average similarities among each crew in 2016. Species that contributed the most are also represented.

V1 *(Average similarity: 42.76%)*

Species	Av.Biomass	Av.Sim	Sim/SD	Contrib%	Cum.%
T. trachurus	30.59	26.56	1.45	62.11	62.11
Alloteuthis sp.	6.92	7.44	1.41	17.40	79.51
L. vulgaris	3.09	2.59	1.06	6.07	85.58
E. encrasicolus	11.84	2.11	0.24	4.94	90.52

V2 *(Average similarity: 56.37%)*

Species	Av.Biomass	Av.Sim	Sim/SD	Contrib%	Cum.%
T. trachurus	43.76	32.49	1.87	57.64	57.64
S. pilchardus	6.88	6.14	1.36	10.9	68.54
Alloteuthis sp.	6.53	5.67	2.22	10.05	78.60
E. encrasicolus	10.16	2.28	0.47	4.04	82.63
D. labrax	3.52	2.06	1.11	3.65	86.29
S. japonicus	7.32	2.04	0.53	3.62	89.91
L. vulgaris	3.54	2.01	1.07	3.56	93.47

V3 *(Average similarity: 45.58%)*

Species	Av.Biomass	Av.Sim	Sim/SD	Contrib%	Cum.%
T. trachurus	22.47	30.98	1.86	67.96	67.96
E. encrasicolus	5.59	5.4	0.66	11.84	79.80
Alloteuthis sp.	3.97	4.08	1.01	8.95	88.75
L. vulgaris	1.84	2.08	0.88	4.56	93.32

V4 *(Average similarity: 50.69%)*

Species	Av.Biomass	Av.Sim	Sim/SD	Contrib%	Cum.%
T. trachurus	14.85	29.45	2.46	58.11	58.11
Alloteuthis sp.	3.35	7.1	1.71	14.01	72.12
C. lucerna	2.01	4.36	1.4	8.61	80.73
D. cuneata	1.08	2.22	0.87	4.39	85.12
S. japonicus	2.92	1.99	0.36	3.93	89.05
E. encrasicolus	2.61	1.53	0.3	3.02	92.06

AII.2. Average dissimilarities between crews in 2016. Species that contributed the most are also represented.

V1 & V2 *(Average dissimilarity: 54.82%)*

Species	Group V1 Av.Biomass	Group V2 Av.Biomass	Av.Diss	Diss/SD	Contrib%	Cum.%
T. trachurus	30.59	43.76	17.74	1.26	32.35	32.35
E. encrasicolus	11.84	10.16	9.90	0.93	18.06	50.41
S. salpa	8.68	0.12	5.25	0.48	9.57	59.99
S. japonicus	3.59	7.32	4.65	0.94	8.49	68.47
S. pilchardus	0.69	6.88	4.56	1.38	8.32	76.80
Alloteuthis sp.	6.92	6.53	2.69	1.15	4.91	81.71
L. vulgaris	3.09	3.54	1.80	1.15	3.28	84.98
D. labrax	1.40	3.52	1.79	1.18	3.27	88.25
C. lucerna	0.24	1.73	1.35	0.97	2.47	90.72

V1 & V3 *(Average dissimilarity: 59.16%)*

Species	Group V1 Av.Biomass	Group V3 Av.Biomass	Av.Diss	Diss/SD	Contrib%	Cum.%
T. trachurus	30.59	22.47	20.3	1.35	34.31	34.31
E. encrasicolus	11.84	5.59	11.99	0.97	20.27	54.59
S. salpa	8.68	0.00	7.36	0.46	12.44	67.03
Alloteuthis sp.	6.92	3.97	5.00	1.10	8.46	75.48
S. japonicus	3.59	2.90	4.14	0.76	6.99	82.48
L. vulgaris	3.09	1.84	2.37	1.07	4.01	86.48
D. cuneata	0.34	1.11	1.32	0.70	2.23	88.71
S. officinalis	1.14	0.72	1.28	0.96	2.16	90.87

V2 & V3 *(Average dissimilarity: 57.00%)*

Species	Group V2 Av.Biomass	Group V3 Av.Biomass	Av.Diss	Diss/SD	Contrib%	Cum.%
T. trachurus	43.76	22.47	22.2	1.58	38.96	38.96
E. encrasicolus	10.16	5.59	8.01	0.96	14.06	53.01
S. pilchardus	6.88	0.49	5.64	1.44	9.90	62.91
S. japonicus	7.32	2.90	5.54	0.88	9.72	72.63
Alloteuthis sp.	6.53	3.97	3.61	1.19	6.33	78.95
D. labrax	3.52	0.41	2.42	1.31	4.25	83.21
L. vulgaris	3.54	1.84	2.14	1.34	3.75	86.95
C. lucerna	1.73	0.51	1.66	0.99	2.92	89.87
S. officianalis	1.56	0.72	1.29	0.99	2.25	92.13

V1 & V4 *(Average dissimilarity: 62.47%)*

Species	Group V1 Av.Biomass	Group V4 Av.Biomass	Av.Diss	Diss/SD	Contrib%	Cum.%
T. trachurus	30.59	14.85	20.97	1.55	33.56	33.56
E. encrasicolus	11.84	2.61	10.5	0.77	16.82	50.38
S. salpa	8.68	0.15	7.93	0.48	12.69	63.07
Alloteuthis sp.	6.92	3.35	4.95	1.40	7.92	70.99
S. japonicus	3.59	2.92	4.34	0.90	6.95	77.94

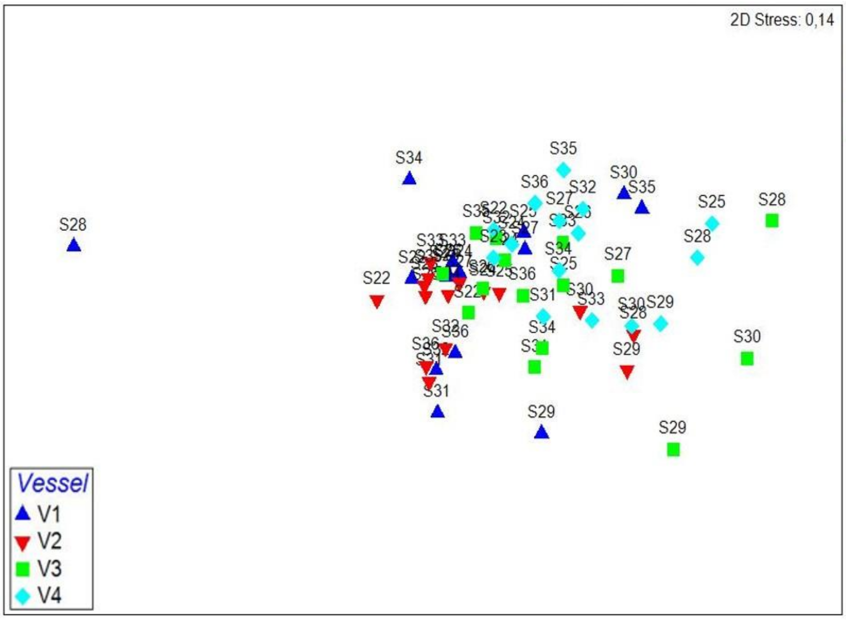
L. vulgaris	3.09	0.97	2.63	1.25	4.21	82.15
C. lucerna	0.24	2.01	2.14	1.23	3.43	85.58
D. labrax	1.40	1.18	1.52	1.14	2.43	88.01
P. peli	1.04	0.78	1.38	0.87	2.22	90.22

V2 & V4 *(Average dissimilarity: 60.26%)*

	Group V2	**Group V4**				
Species	**Av.Biomass**	**Av.Biomass**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
T. trachurus	43.76	14.85	25.09	1.96	41.64	41.64
E. encrasicolus	10.16	2.61	7.58	0.84	12.57	54.22
S. pilchardus	6.88	0.54	5.89	1.56	9.77	63.99
S. japonicus	7.32	2.92	5.73	1.00	9.51	73.50
Alloteuthis sp.	6.53	3.35	3.23	1.22	5.37	78.87
L. vulgaris	3.54	0.97	2.35	1.56	3.90	82.77
D. labrax	3.52	1.18	2.32	1.28	3.85	86.62
S. officianalis	1.56	0.50	1.31	0.97	2.18	88.80
C. lucerna	1.73	2.01	1.28	1.24	2.12	90.92

V3 & V4 *(Average dissimilarity: 54.59%)*

	Group V3	**Group V4**				
Species	**Av.Biomass**	**Av.Biomass**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
T. trachurus	22.47	14.85	19.61	1.40	35.93	35.93
E. encrasicolus	5.59	2.61	8.45	0.96	15.49	51.41
S. japonicus	2.90	2.92	5.86	0.81	10.74	62.15
Alloteuthis sp.	3.97	3.35	4.34	1.40	7.96	70.11
C. lucerna	0.51	2.01	2.82	1.29	5.17	75.28
L. vulgaris	1.84	0.97	2.36	1.11	4.33	79.61
D. cuneata	1.11	1.08	1.91	1.13	3.50	83.11
D. labrax	0.41	1.18	1.63	0.92	2.99	86.09
P. peli	0.36	0.78	1.38	0.78	2.53	88.62
S. pilchardus	0.49	0.54	1.19	0.59	2.18	90.81



AII.3. nMDS that plots landings of the four crews in the study period.

Annex III

AIII.1. Two-way crossed analysis between Year and Vessel groups. Pairwise tests are represented bellow.

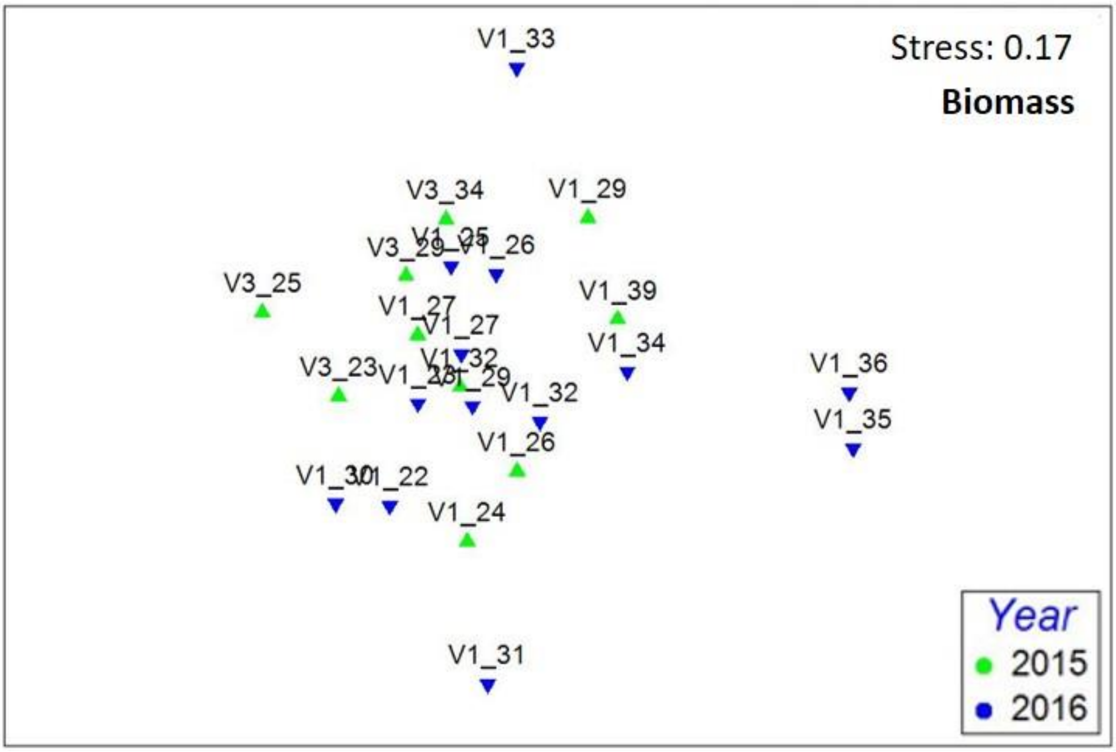
Tests for differences between Year groups (across all Vessel groups)
Global test
Sample statistic (Global R): 0.264
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Tests for differences between Vessel groups (across all Year groups)
Global test
Sample statistic (Global R): 0.14
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise tests

Groups	**R Statistic**	**Significance Level %**	**Possible permutations**	**Actual permutations**	**Number ≥ Observed**
V1, V2	0.079	1.8	Very large	999	17
V1, V3	0.048	7.1	Very large	999	70
V1, V4	0.174	0.2	Very large	999	1
V2, V3	0.186	0.1	Very large	999	0
V2, V4	0.333	0.1	Very large	999	0
V3, V4	0.038	12.5	Very large	999	124

Annex IV



AIV.1. Multidimensional Scaling (MDS) of V1 and V3 discarded biomass data, in the considered period of 2015 (green dots) and 2016 (blue dots, only V1 data). Data represented according to the year, separated by each sampling week.