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Regional and temporal patterns of bycatch landings in the purse seine fishery

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Abstract

Purse seine fishing is one of the main fishing methods used in Portugal and targets mainly sardine (*Sardina pilchardus*). Although considered selective for small pelagic fish, a wide range of bycatch species subject to catch limitations, occur in the landings. The value and volume of bycatch are not well understood, making it difficult to assess its ecological impact and regional and temporal trends in catches. This study analysed purse seine fishing landings in mainland Portugal between 2000 and 2022, using data provided by the Portuguese Fisheries Directorate. The data were reorganised and processed in R, with new variables created (type of vessel, date, average price per kilogramme and region). The coast was divided into four regions – North, Centre, Southwest and South – based on their physical, ecological and socio-economic differences. An initial filtering process was performed to select the species representing 90% of the total landings by value, with four small pelagic fish considered target species by legislation standing out: sardine, chub mackerel (*Scomber colias*), European anchovy (*Engraulis encrasicolus*) and horse mackerel (*Trachurus trachurus*). A second phase identified eight more species that were relevant at the regional level. Spatial and temporal trends of landings were analysed using an R application adapted to our data, revealing sales peaks in the summer and consistent quantities by species over the years. The Centre was identified as the most important region in terms of both weight and value of landings, whereas the South contributed less. A LOESS analysis using inflation-adjusted values showed that the real income received in 2022 was similar to or lower than that received in 2000, indicating a decline in the purchasing power of fishermen, despite rising nominal prices. Cross-correlation analyses revealed positive temporal relationships between species, which were more complex in the South. The results also highlighted discrepancies between the importance of certain species and their classification as target or bycatch on the legislation, especially at the regional level, underscoring the need for a legislation reform.

Keywords: Target species, trend, regulation, mitigation measures.

Resumo

A pesca do cerco é definida como qualquer tipo de pesca que utilize uma parede de rede sempre longa e alta, que é largada de forma a cercar e reduzir a capacidade de fuga das presas, estas sendo espécies pelágicas. O valor económico e o volume das capturas acessórias à pesca do cerco em Portugal permanecem insuficientemente caracterizadas. Torna-se, por isso, essencial desenvolver estudos que se foquem nesta temática, a fim de avaliar os potenciais impactos nas populações afetadas e identificar padrões temporais e regionais da pesca destas espécies. Este trabalho tem como objetivo utilizar a informação obtida para poder propor medidas de mitigação à pesca. Estas medidas podem incluir mudanças à legislação atual no formato de limitações à pesca de espécies no tempo e/ou no espaço. Neste estudo foi usada informação disponibilizada pela DGRM (Direção Geral dos Recursos Naturais, Segurança e Serviços Marítimos) relativa a todos os desembarques da pesca do cerco em Portugal continental, no período compreendido entre 2000 e 2022. Uma vez que os dados não possuíam informação estruturada de uma forma adequada para satisfazer todas as necessidades do trabalho, foi necessário prepará-los para que a informação necessária estivesse disponível. Este processo inclui desde a adaptação dos ficheiros para poderem ser lidos corretamente em R, até à criação novas variáveis relevantes para a análise. Foram adicionadas colunas com informação sobre o tipo de embarcação (de acordo com o seu tamanho), o dia da semana, o mês e o ano do desembarque (em colunas separadas), o preço médio por quilograma em cada registo e a região associada ao respetivo porto de desembarque. Posteriormente foi realizada uma seleção das espécies com maior relevância nos desembarques, tanto à escala nacional como regional. Para esse efeito, o território foi dividido em quatro regiões - Norte, Centro, Sudoeste e Sul – reconhecendo-se que a costa portuguesa apresenta heterogeneidade a nível físico, ecológico, económico e cultural. Esta primeira análise permitiu identificar as diferenças existentes entre regiões, tanto em termos de disponibilidade como de preferência por determinadas espécies, bem como constatar que algumas espécies acessórias assumiam maior relevância económica do que certas espécies classificadas como alvo na legislação em vigor. Observou-se uma forte predominância de biqueirão e sardinha na região Norte, onde o biqueirão se revelou mais importante quando comparado com as restantes regiões. Existiram duas fases de filtragem, uma primeira em que se incluíram todas as espécies presentes nos dados ao longo de toda a costa, selecionando-se aquelas que, em conjunto, representavam 90% do valor total dos desembarques. Este critério conduziu à seleção de quatro espécies classificadas pela legislação em vigor como pequenos pelágicos alvo: a sardinha (*Sardina pilchardus*), a cavala (*Scomber colias*), o biqueirão (*Engraulis encrasicolus*) e o carapau (*Trachurus trachurus*). Na segunda filtragem estas quatro espécies foram removidas da base de dados e realizou-se uma nova análise, desta vez por região. Em cada região, incluíram-se as espécies que representavam 55% do valor comercial regional. Deste procedimento, resultou a seleção de mais oito espécies: a safia (*Diplodus vulgaris*), o besugo (*Pagellus acarne*), o sarração (*Sarda sarda*), as tainhas (*Mugil spp.*), o sargo legítimo (*Diplodus sargus*), a corvina legítima (*Argyrosomus regius*), o atum rabilho (*Thunnus thynnus*) e o polvo vulgar (*Octopus vulgaris*). Adicionalmente, as espécies restantes foram aglomeradas numa única categoria designada “outros”. O número foi limitado a doze espécies uma vez que a aplicação *Dailyland*, utilizada para a análise geral das tendências das espécies, foi criada em R, que possui um limite de memória, impossibilitando a análise de um maior número de espécies. A aplicação *Dailyland* permitiu ainda visualizar as tendências nos desembarques da pesca do cerco com uso de gráficos e mapas, oferecendo também a possibilidade de adaptar a informação exibida ao nível da espécie, ano e porto. Os picos de vendas foram observados no verão, tendo o inverno apresentado as menores quantidades e valores vendidos ao longo do ano. A quantidade vendida manteve-se semelhante ao longo dos anos. Como esperado, a maior parte dos desembarques é feita por embarcações maiores – as traineiras – enquanto as tucas-pequenas e as tucas-grandes representam apenas uma pequena percentagem dos desembarques observados. Ao nível das vendas, a região Centro mostrou ser a mais importante, enquanto a região Sul apresentou a menor contribuição

percentual para o total de vendas em Portugal continental, tanto a nível de peso como de valor. Por fim, para analisar tendências ao longo do tempo em termos de valor de desembarque para cada uma das espécies selecionadas, calculou-se um valor médio de desembarque por ano, ajustado à inflação usando o índice de preços no consumidor para produtos alimentares não transformados em cada ano. Este valor foi depois utilizado para criar uma regressão local ou LOESS (*Locally Estimated Scatterplot Smoothing*) apresentando gráficos temporais para cada espécie na análise, em cada região, verificando assim a evolução do valor das mesmas em cada região, relativamente ao custo de vida. Estes gráficos mostraram que, na maioria dos casos, o valor em 2022, quando ajustado à inflação, é igual ou inferior ao observado em 2000, o que significa que apesar do preço por quilograma das espécies ter aumentado ao longos dos anos, os pescadores estão a vender o peixe a um valor que lhes oferece o mesmo, ou até menos poder de compra em 2022 do que em 2000. Para investigar dinâmicas entre espécies que pudessem justificar alterações de mercado no tempo, utilizou-se uma função de correlação cruzada (CCF). Foram selecionadas espécies com base no valor e peso desembarcados pelas espécies, verificados na aplicação *Daily-land*, para cada região, bem como se são exclusivas de uma região, levando a uma análise mais subjetiva e *ad-hoc* em que foram verificadas interações entre um par de espécies para o Norte e para o Centro, dois pares para o Sudoeste e três pares para o Sul, o que seria de esperar uma vez que a riqueza específica aumenta à medida que nos deslocamos do Norte para o Sul do país. Nestes gráficos foi possível observar relações no tempo em todas as regiões, embora umas mais marcadas que outras e na sua maioria relações positivas, ou seja, o aumento de uma espécie levando ao aumento de outra passado um tempo determinado. No final, considerando os resultados obtidos, verificou-se que existem várias espécies designadas como captura acessória, e que, por isso, têm um limite de desembarque de 20% da carga total da embarcação, parecem apresentar uma maior importância e ser preferidas pelos pescadores em comparação com as espécies listadas na legislação como espécies às quais a pesca do cerco é dirigida. Isto sugere uma necessidade de revisão da legislação em vigor para refletir mais fielmente a realidade atual de Portugal continental. Dadas as diferenças entre regiões, é evidente que a forma mais eficaz de propor medidas de mitigação e criar legislação será a nível regional, para garantir uma maior resiliência e eficiência das medidas e da legislação, assegurando que nenhuma região é desnecessariamente prejudicada economicamente por uma avaliação mais global. Este estudo, dada a sua abrangência e singularidade, fornece também uma base e uma direção para futuros estudos mais detalhados sobre este tema, que poderão ajudar a compreender melhor a dinâmica dos desembarques em Portugal continental e a fazer previsões para o futuro, permitindo a criação de medidas preventivas, obviamente mais eficazes que quaisquer medidas reativas.

Palavras-chave: Espécies-alvo, tendência, legislação, medidas de mitigação.

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List of symbols and abbreviations

CCF – Cross-Correlation Function

FAO – Food and Agriculture Organization

LOA – Length Overall

LOESS – Locally Estimated Scatterplot Smoothing

nei – Not elsewhere included

PNAB – *Programa Nacional de Amostragem Biológica*

1. Introduction

Fishing and the consumption of fish are among humanity's oldest traditions, dating back to prehistoric times when people relied on aquatic resources for sustenance. Since then, fishing has evolved into a global industry that is essential for ensuring food security and economic development, while contributing to cultural practices (Taniguchi, 2024). The global consumption of aquatic animal foods has increased by an average of 1.4% annually, rising from 9.0 kg per person in 1961 to 20.5 kg in 2019, with a slight decline in 2020 when 51% of the global production of aquatic animals, – totalling 90 million tonnes – came from capture fisheries (FAO, 2022). This shows the importance of fisheries as a global food source. While fishing is an essential activity, it is important to recognise its significant impact on the marine environment and the well-being of coastal communities. Overfishing, which is defined as extracting fish stocks at a rate that exceeds their reproductive capacity, is widely recognised as the most significant threat to the sustainability of fisheries worldwide, resulting in a decline in fish populations (FAO, 2024). Even when management policies are in place, unreported, unregulated and illegal fishing remains a significant problem (Agnew *et al.*, 2009).

Bycatch and discards present significant challenges for fisheries, as non-target species, undersized fish, and even damaged fish are often caught unintentionally. If these fish are not landed, this can lead to wasted resources and unnecessary mortality. To address these issues, effective fisheries management is therefore essential to preserve healthy fish stocks and ecosystems, while also ensuring a sustainable social and economic balance for fishing communities (FAO, 1995; Costello *et al.*, 2016). Management strategies to achieve this include setting catch limits, regulating the number of vessels, establishing fishing days and closed seasons, setting size limits and restricting fishing gear (FAO, 2024).

A common type of seine net is the purse seine, which gets its name from the rings that run along its bottom edge. A line, known as a purse line, passes through all the rings and, when pulled tight, draws the rings together, preventing the fish from swimming down and escaping the net. This operation is similar to that of a traditional purse with a drawstring. The purse seine technique is preferred for catching pelagic species that live in schools, particularly small pelagic fish, which account for 25% of worldwide landings (FAO, 2018). The main species caught include sardine, mackerel, anchovy and herring, but larger pelagic species such as some species of tuna can also be targeted. However, this fishing method can also catch semi-pelagic and demersal species, landing those with the highest commercial value.

The purse seine is the main fishing gear used for tuna, accounting for 66% of the world's tuna catch by volume (ISSF, 2025). However, these vessels and nets are larger than those used to target small pelagic fish. Tuna purse seine fishing is the subject of many bycatch studies, in which elasmobranchs are classified as the most vulnerable species, also due to their life history characteristics (Duffy *et al.*, 2019). There is also a current problem in that observers tend to largely underestimate the number of sharks captured, which hinders the ability to monitor the impact of the fisheries (Forget *et al.*, 2021).

Reporting discard and bycatch composition and their level and fate are essential if we are to obtain sound scientific advice on ecosystem-based fishery management (Gray and Kennelly, 2018). To avoid bycatch, technologies such as fish aggregating devices (FDA) are often used in tuna fishing (Basurko *et al.*, 2022), as are sonars and echo sounders by purse seiners. These tools allow the target species to be identified, thereby avoiding the capture of undesirable species and reducing bycatch. However, in purse seine fisheries targeting sardine and other small pelagic fish, such as those operating in Portugal, the capture of non-target pelagic fish and interactions with seabirds are important considerations. Unlike tuna purse seine fisheries – where seabirds are generally less affected due to differences in target species and fishing practices – fisheries directed at smaller pelagic fish may pose a greater risk. Seabirds are

attracted to small schooling fish, and their behaviour of diving into and remaining within the net while pursuing sardines increases their susceptibility to entrapment and drowning (Norriss *et al.*, 2020).

The purse seine fishery is one of the most important fisheries in Portugal, accounting for around 50% of the total weight of landings (Feijó *et al.*, 2019). It mainly targets sardine (*Sardina pilchardus*) but catches several other small and medium-sized pelagic species. The fishery regulation in Portugal (Portaria 218/2023 of 19 July) designate the following species of small pelagic fish as additional target species: Atlantic mackerel (*Scomber scombrus*), bogue (*Boops boops*), European anchovy (*Engraulis encrasicolus*), Mediterranean horse mackerel (*Trachurus mediterraneus*), blue jack mackerel (*Trachurus picturatus*) and Atlantic horse mackerel (*Trachurus* spp.). Other pelagic species that can be targeted include seerfishes (*Scomberomorus* spp.), the skipjack tuna (*Katsuwonus pelamis*), the Atlantic bonito (*Sarda sarda*), the grey triggerfish (*Balistes capriscus*), the garfish (*Belone belone*), the bluefish (*Pomatomus saltatrix*) and mullet genera (*Mugil* spp., *Liza* spp., *Chelon* spp.). All other species not listed as target species in the legislation are considered non-target species and may be landed provided that their total weight does not exceed 20% of the vessel's total load for the fishing trip.

In Portugal, purse seining has also been identified as a threat to the critically endangered Balearic shearwater (*Puffinus mauretanicus*) (Oliveira *et al.*, 2015; Calado *et al.*, 2021). However, studies aimed at minimising the impact of bycatch on seabirds by purse seiners are already in place. The same has happened with dolphin bycatch, for which Future Ocean's pingers are now used to avoid bycatch.

Studies of bycatch often focus on a limited number of marine regions, leaving significant gaps in our knowledge of its spatial and temporal patterns (Oliveira *et al.* 2020). Therefore, a broad overview would improve our understanding of the true dynamics across Portugal and inform the direction of future research in this area. There is still a lack of knowledge regarding the volume and value of bycatch landed, as well as how this is distributed across the Portuguese coast over time and space. This study is important for evaluating the impact that purse seine fishing may have on accessory species populations and for proposing measures to regulate fishing.

The aim of this study is to characterise variations in space (by port or area) and time (by month or year) in the landings of the main species from purse seine fishing off the coast of mainland Portugal. This information will also be used to identify common trends among the various species and ports/areas. The ultimate goal is to contribute to the development of proposals for fisheries regulation. These recommendations may include adjusting the percentage of bycatch that can be landed or introducing legislation to limit the capture of certain species that are more affected by bycatch due to their economic value and availability in certain regions and at certain times of the year.

2. Materials and methods

2.1 Data

Data on the daily landings of the purse seine fleet in the period 2000 - 2022 were obtained from the database of the Portuguese Fisheries Directorate (DGRM - *Direção Geral dos Recursos Naturais, Segurança e Serviços Marítimos*) available to IPMA. Each entry contained encoded information on the vessel (coded ID number) that allowed the differentiation of landings made by each vessel while keeping the vessel anonymous; the landing port name and its ID code, the date of sale, the quantity landed and sold in kg, and the corresponding value of the first sale in euros, the ID, FAO code, common name and scientific name for the species, the code (number) referring to the fishing method used, and finally the commercial size category of the fish landed (T: each T number is associated with a range of number of individuals per Kg with T1 corresponding to the largest size). The size range values vary by species. For

example, T1 for sardine corresponds to 1 to 15 individuals per kg and T4 corresponds to 36 to 67 individuals per kg. Using a weight-length relationship, T categories may be converted into length categories (Feijó *et al.*, 2012).

In some cases, there was no distinction at the species level, leading to entries with the “nei” in front of them like “mulletts nei” for example, meaning “not elsewhere included”, a description that includes various types of mullets (*Mugil* spp.) that were not specifically identified by their exact species name.

The original’s database columns allow for a good first view of the data, although for a more precise analysis and connection between species and their trends over time and in different regions, new categories were created and the data was filtered to check for errors.

As the initial data contained information on the port of Funchal, these entries were removed as they do not pertain to Continental Portugal which is the focus of this study. Errors which could hinder the analysis, like the existence of accented names leading to errors when transferred to R were also found and promptly corrected, thus avoiding entries with different names (characters or spaces instead of an accented letter) for the same species. All accented letters were replaced with their unaccented counterparts to prevent errors arising from the use of these special characters in the code.

In order to differentiate different sized vessels, as they will be able to fish different amounts of fish in one trip and in different areas, for example smaller vessels will fish closer to the port while larger vessels tend to travel to more distant areas searching for higher target fish density areas, new information was added using data available on the Fleet Register database (European Commission, DG MARE, *Fleet Register database*, n.d.), a database where all the fishing vessels flying the flag of an EU country as well as all changes made to them have to be registered.

After filtering the information from the database in search for all purse seiners, a division based on the length overall (LOA), obtained by measuring the maximum length of a vessel’s hull parallel to the waterline was made. The small-skiff (*tuca-pequena*) was assumed to be between 0 and 14 meters long, the large-skiff (*tuca-grande*) was assumed to be between 14 and 18 metres, and the purse seiner (*traineira*) was assumed to be longer than 18 metres (Feijó *et al.*, 2012).

The date column was divided into three to be able to analyse the data based on the day of the week, the month and the year in which each entry inserted itself, allowing for an analysis of the most important days, months and years for each species or the overall of purse seine fishing. This could be useful to understand how periodic bans or fishing limits might affect the overall catch of those species and the ones which will be targeted to make up for these bans.

2.2 Study regions

To perform a regional analysis a column was created to categorise the ports by region. This column allocated the existing ports into four different regions across continental Portugal which were North, Centre, Southwest and South (Fig. 2.1). These aforementioned regions have ports assigned to them in accordance with Portugal’s official regional division (European Union, 2023). The regions *Grande Lisboa*, *Oeste e Vale do Tejo*, *Península de Setúbal* and *Alentejo* regions were merged to create the southwest region since these regions are more uniform between one another and justify merging into one region to simplify the analysis. The following arrangements were ports N -> S:

North with the following ports - Matosinhos, Póvoa Do Varzim, Afurada, Viana Do Castelo, Vila Do Conde, Aguda, Angeiras and Espinho.

Centre with the following ports - Nazaré, Peniche, Figueira da Foz and Aveiro.

Southwest with the following ports – Sines, Setúbal, Lisboa, Sesimbra, Cascais, Gambia, Costa da Caparica, Azenha do Mar and Trafaria.

South with the following ports – Quarteira, Olhão, Vila Real de Santo António, Portimão, Lagos, Sagres, Fuzeta, Tavira, Olhos D'Água, Santa Luzia and Armação de Pêra.

The column zone was created manually by associating each port with its respective region.

As the quantity and value sold were included in the main data, the mean value was a variable added simply by dividing the total value sold by the total quantity sold providing a mean value per kilogramme (€/kg) for each entry.



Figure 2.1 - Map depicting the area for the different regions considered for the analysis of this study. (Source: *Instituto Nacional de Estatística (2025), Estatísticas da pesca – 2024, p. 100.*)

2.3 Selection of study species

To identify the most important species landed in the purse seine fishery, the mean and the total quantity-sold, the mean and the total value sold and the mean value per kg in the auction market were calculated. This procedure was carried out for all species with a first selection taking place. Secondly the analysis was repeated without the species defined as target small pelagics by the fishery regulation (Portaria n.º 218/2023, 2023). Finally, this analysis was repeated but further divided into four distinct groups, with each group representing a specific region and another set of species was selected. This analysis was done for the last 10 years of data available (2013 to 2022) so the selection represents more recent trends in landings.

This can be explained in a step-by-step process:

Step 1 – Landing composition

To evaluate the relative importance of each species, the mean percentage of sales was calculated as the average, across years in the study period, of the ratio between each species' annual sales value and the total annual sales value across all species. A threshold value of 90% was selected to represent the cumulative percentage of mean sales indicative of significant species. In this instance, the value of 90% was selected to encompass all the most important species. This resulted in the selection of four species, named “main species”, the sardine, European anchovy, chub mackerel and the Atlantic horse mackerel.

i = species index

$t = 1, 2, \dots, T$ = year index over the total time span

$V_{i,t}$ = sales value of species i in year t

$V_{tot,t} = \sum_i V_{i,t}$ = total sales value (all species) in year t

First - Yearly ratio

For each year t :

$$R_{i,t} = \frac{V_{i,t}}{V_{tot,t}} \times 100 \quad (2.1)$$

Second – Mean percentage of sales over the whole period

$$\bar{R}_i = \frac{1}{T} \sum_{t=1}^T \frac{V_{i,t}}{V_{tot,t}} \quad (2.2)$$

Final formula -

$$\bar{R}_i = \frac{1}{T} \sum_{t=1}^T \frac{V_{i,t}}{\sum_j V_{j,t}} \quad (2.3)$$

Certain species were of significant importance, by looking at their cumulative percentage, in the context of the ordinance, which classified them as 'target small pelagics'. Four species that were included were the four most significant, by a considerable margin (Table 3.1).

Step 2 – Secondary species

To select the most important by-catch species, the analysis was repeated excluding the main species. For the whole study area, sixteen species, mostly sparids, were included within the 90% cut-off level of

cumulative % of landed value assumed to indicate by-catch species (Table 3.2). The species present in this step were the axillary seabream (*Pagellus acarne*), Atlantic bonito, white seabream (*Diplodus sargus*), common two-banded seabream (*Diplodus vulgaris*), gilthead seabream (*Sparus aurata*), mullets nei., common octopus (*Octopus vulgaris*), meagre (*Argyrosomus regius*), black seabream (*Spondyliosoma cantharus*), European seabass (*Dicentrarchus labrax*), common pandora (*Pagellus erythrinus*), sand steenbras (*Lithognathus mormyrus*), salema (*Sarpa salpa*), European squid (*Loligo vulgaris*), annular seabream (*Diplodus annularis*) and common cuttlefish (*Sepia officinalis*).

Step 3 – Region based species

Given the non-homogeneity of the Portuguese coast, the selection was repeated without the main species, but for each of the four regions, with a threshold of 55%, as there was a limit to the number of species that could be integrated into the study. This was due to the memory limits of the R program and the computer used when running the *Dailyland* application

The selected species went as follows:

North species – Mulletts nei. and white seabream. (Table 3.3)

Centre species – Atlantic bonito, meagre, white seabream and Atlantic bluefin tuna (*Thunnus thynnus*). (Table 3.4)

Southwest species – Axillary seabream, Atlantic bonito, white seabream. (Table 3.5)

South species – Axillary seabream, Atlantic bonito, common two-banded seabream and common octopus. (Table 3.6)

Following the completion of all the steps, the selection comprised twelve species: sardine, chub mackerel, European anchovy, Atlantic horse mackerel, common two-banded seabream, axillary seabream, Atlantic bonito, mullets nei., white seabream, meagre, Atlantic bluefin tuna and common octopus. A category was then designated “others” to represent all the species that were excluded from the analysis.

2.4 Temporal variation of landings

A locally weighted estimated scatterplot smoothing was fitted to landings, in weight and value by year and region for each selected species using the R “loess” function. LOESS, is a nonparametric method of smoothing data series; it uses local regression to fit a smooth curve through a scatterplot, providing, for example a clearer view of trends over time (Cleveland, 1979). The intention was to verify the changes that occurred in landings throughout the years for each species in each region. In the case of landings value, the effective value was used and for that it was necessary to account for inflation. The yearly consumer value index for unprocessed food products (Instituto Nacional de Estatística, 2025) was therefore used. Once the values had been converted, a total value was calculated for each year to be included in the data for the smoother, to facilitate reading and processing the graphics, given the immense amount of data being processed.

In addition, an index of the recent trends in landings by species was carried out using the ratio between the mean landings of the two most recent years in the data (2021 and 2022) and the mean of the three years prior to these (2018, 2019 and 2020). Index values lower, equal or higher than one indicate a downward, stable or upward trend of recent landings, respectively.

2.5 Comparison of landings of selected species

Cross-Correlation Function (CCF) analysis was applied to landings, in weight, to search for common regional and temporal patterns between species. CCF is a measure of the similarity between two time series as a function of the lag of one series relative to the other. It helps to identify and quantify the relationship between two variables over time, i.e. when one variable influences the other with a certain delay (Damos, 2016). Given the large number of possible combinations, a few combinations were considered based on the prominence of a species in terms of its value and total quantity sold in each region, and on whether it was unique to a region. The choice was therefore purely subjective and ad-hoc, as it was made using the graphics created with the *Dailyland* application

Each region had its own set of combinations, and these were:

North - European anchovy and sardine.

Centre - Sardine and Atlantic horse mackerel.

Southwest - Chub mackerel and Atlantic horse mackerel; chub mackerel and axillary seabream; common two-banded seabream and Atlantic horse mackerel.

South – Mulletts nei. and axillary seabream; Atlantic bonito and common two-banded seabream.

3. Results

3.1 Overview of landings and species importance

The analysis began with 261 unique entries in the species column (Annex 1). It is possible to have both the specific common name of a species and the common name of a group of fish belonging to a certain genus (e.g. soles) for example, soles nei. (*Solea* spp.) and common sole (*Solea solea*) may be referring to the same species, as sometimes it is not possible to obtain information regarding the species.

Over the course of the 23-year study period, the 364-vessel purse seine fleet of Continental Portugal alone was responsible for catching 1,384,194 tonnes of fish, generating 1,058,223 million euros in first sale value.

3.2 Study species

The first selection step yielded the main species mentioned above (see Table 3.1). One species stands out in particular: the sardine, which accounts for nearly 50% of the total landings in value (€), while the other three species account for between 11% and 18% each.

Table 3.1 – Total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) for the main species caught on purse-seiners in Continental Portugal between 2013 and 2022.

Species	Mean % of landings in value	Total landings in value (€)	Standard deviation (SD)	Cumulative mean % of landings in value
Sardine	49.94	257479.68	6433.11	49.94
European anchovy	17.98	94193.27	5346.43	67.91
Chub Mackerel	14.87	77361.95	2561.01	82.79
Atlantic horse mackerel	11.12	59574.74	2774.15	93.91

The second selection step led to sixteen different secondary species, ranging from cephalopods to small tunas, with seabreams forming the clear majority (Table 3.2). This substantially higher number and diversity of species than in the previous analysis is to be expected, given that purse-seiners have a clear preference for small pelagic fish. This preference leads to fewer and more dispersed landings for all other species.

Table 3.2 - Total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) excluding small pelagic present in Portaria n.º 218/2023, of 19 July (Article 3) between 2013 and 2022.

Species	Mean % of landings in value	Total landings in value (€)	Standard deviation (SD)	Cumulative mean % of landings in value
Axillary seabream	23.05	5229.23	301.77	23.05
Atlantic bonito	15.53	3471.01	164	38.58
White seabream	10.56	2391.46	136.29	49.14
Common two-banded seabream	9.12	1989.78	58.98	58.26
Gilthead seabream	7.77	1703.38	64.87	66.03
Mullets nei	5.76	1168.87	94.79	71.79
Common octopus	3.94	800.44	49.5	75.73
Meagre	3.32	665.8	66.28	79.06
Black seabream	2.37	531.65	27.89	81.43
European seabass	2.07	472.64	30.22	83.50
Common pandora	1.85	409.65	11.76	85.35
Sand steenbras	1.26	280.57	27.98	86.61
Salema	1.26	247.08	15.7	87.87
European squid	1.19	240.34	10.79	89.06
Annular seabream	0.93	198.89	4.07	90.00
Common cuttlefish	0.74	149.65	6	90.74

In the third selection step it is evident that the North (Table 3.3) exhibits reduced variability, reaching the threshold with only two species exhibiting similar percentages. In contrast, the other regions required three to four species to achieve the same goal.

The Centre (Table 3.4) and Southwest (Table 3.5) regions demonstrate a high percentage of total landings in value for a single species in comparison to those present after it, indicating a preference for those species, presumably when the main species are absent. In the South (Table 3.6) this discrepancy is less pronounced, as the species demonstrate comparable percentages of total landings in value.

The heterogeneity of the Portuguese coastline is evident in the species selected for each region, of which thirteen entries included eight unique species. For instance, the mullets nei. are exclusive to the North, the white seabream is present in the North and Centre, and the axillary seabream demonstrated its dominance in the Southwest and somewhat in the South with the highest total landings in value for both regions, with 32.48% and 23.57% respectively. However, it is not represented in the other two regions.

Table 3.3 - Total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) excluding small pelagic present in Portaria n.º 218/2023, of 19 July (Article 3) in the North region between 2013 and 2022.

Species	Mean % of landings in value	Total landings in value (€)	Standard deviation (SD)	Cumulative mean % of landings in value
Mullets nei	30.3847	706700.12	120651.362646771	30.3847
White seabream	26.3900	510043.77	32729.6111787673	56.7748

Table 3.4 - Total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) excluding small pelagic present in Portaria n.º 218/2023, of 19 July (Article 3) in the Centre region between 2013 and 2022.

Species	Mean % of landings in value	Total landings in value (€)	Standard deviation (SD)	Cumulative mean % of landings in value
Atlantic bonito	31.9595	656305.16	61350.7729606249	31.9595
Meagre	10.7832	212812.35	36141.5575621959	42.7427
White seabream	8.4107	164342.98	7806.57188671585	51.1533
Atlantic bluefin tuna	8.1100	33023.5	9173.7399251196	59.2633

Table 3.5 - Total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) excluding small pelagic present in Portaria n.º 218/2023, of 19 July (Article 3) in the Southwest region between 2013 and 2022.

Species	Mean % of landings in value	Total landings in value (€)	Standard deviation (SD)	Cumulative mean % of landings in value
Axillary seabream	32.4809	3073984.12	264034.650382653	32.4809
Atlantic bonito	12.7899	1119111.35	81562.6344443834	45.2708
White seabream	10.4081	951102.52	96187.2089678652	55.6788

Table 3.6 - Total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) excluding small pelagic present in Portaria n.º 218/2023, of 19 July (Article 3) in the South region between 2013 and 2022.

Species	Mean % of landings in value	Total landings in value (€)	Standard deviation (SD)	Cumulative mean % of landings in value
Axillary seabream	23.5673	2110254.6	89163.2885618642	23.5673
Atlantic bonito	16.0251	1578527.16	133674.274948804	39.5924
Common two-banded seabream	10.9862	999425.45	48755.0654023796	50.5786
Common octopus	8.6171	773299.22	48452.3580383115	59.1957

3.3 Species composition in landings by value

The total weight of landings across the 23 study years indicates that the two most important species in purse seine fishing in Portugal are the sardine with 58.09% followed by the chub mackerel (Fig 3.1). These two species consistently account for the highest percentages of landed weight, with the sardine taking the top spot in every region except the Southwest.

The Atlantic horse mackerel is the third most landed species except in the northern region, where it swaps the position with the European anchovy. These results indicate a high level of interest in horse mackerel by purse seiners along the entire Portuguese coast.

As anticipated, the European anchovy is present in greater numbers in the northernmost regions, specifically the northern (Fig. 3.2) and central (Fig. 3.3) regions. In the northern region it exhibits the third highest percentage of landed weight overall with 9.67%, when compared to the other regions.

The category, which comprises all the species with fewer entries and representation, named “others”, presents higher percentages in the two southernmost regions, Southwest (Fig. 3.4) and South with 3.93% and 3.86% respectively and the lowest percentage in the North region with 1.56%.

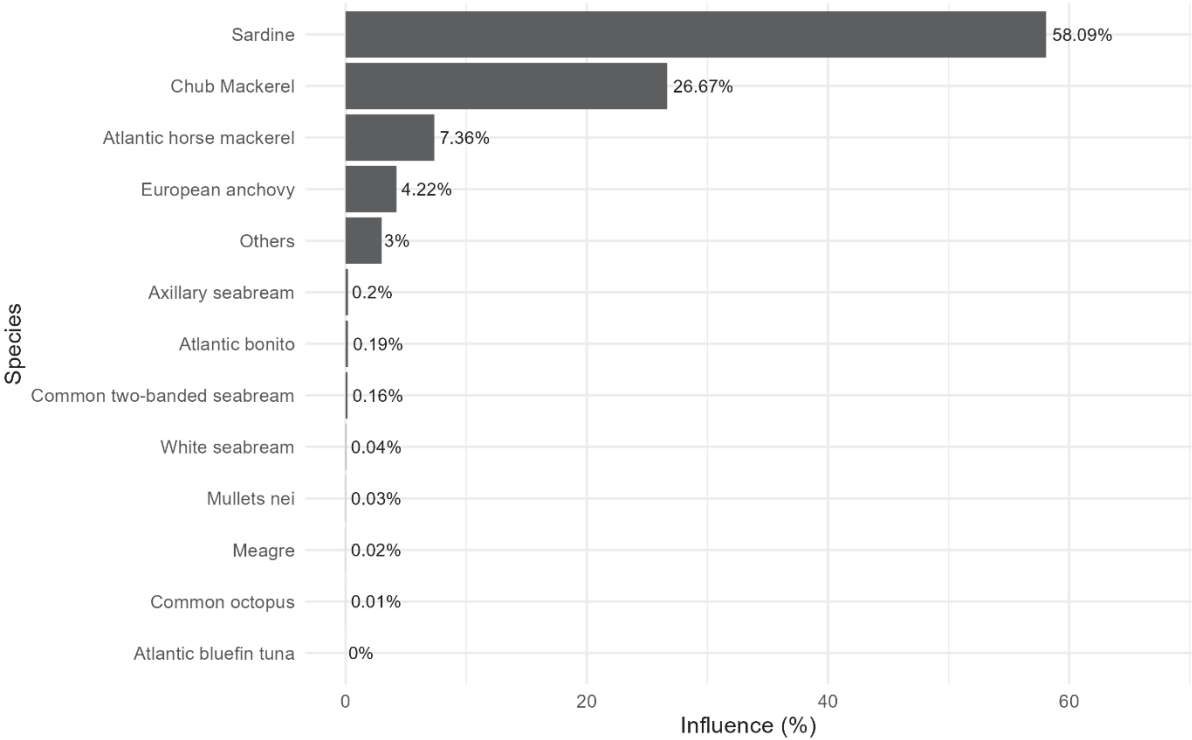


Figure 3.1 – Percentage of the landed weight of the main species and region based species for the whole Portuguese coast from 2000 to 2022.

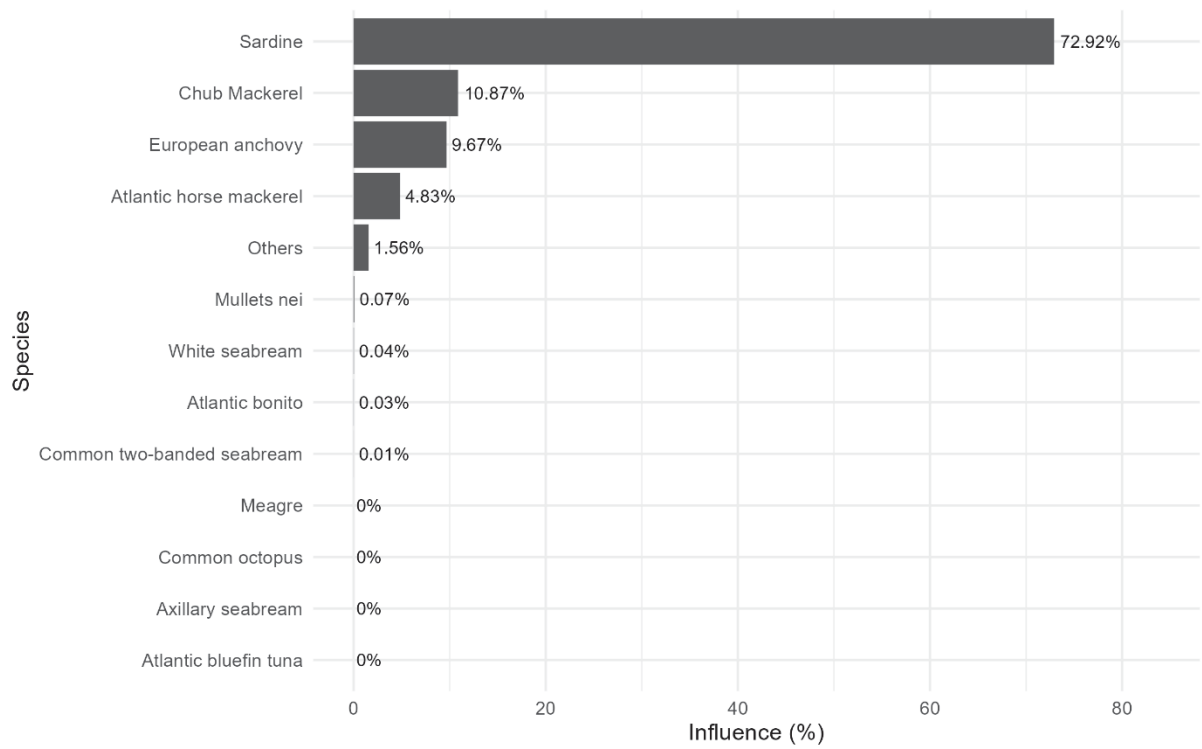


Figure 3.2 – Percentage of the landed weight of the main species and regional species in the North region from 2000 to 2022.

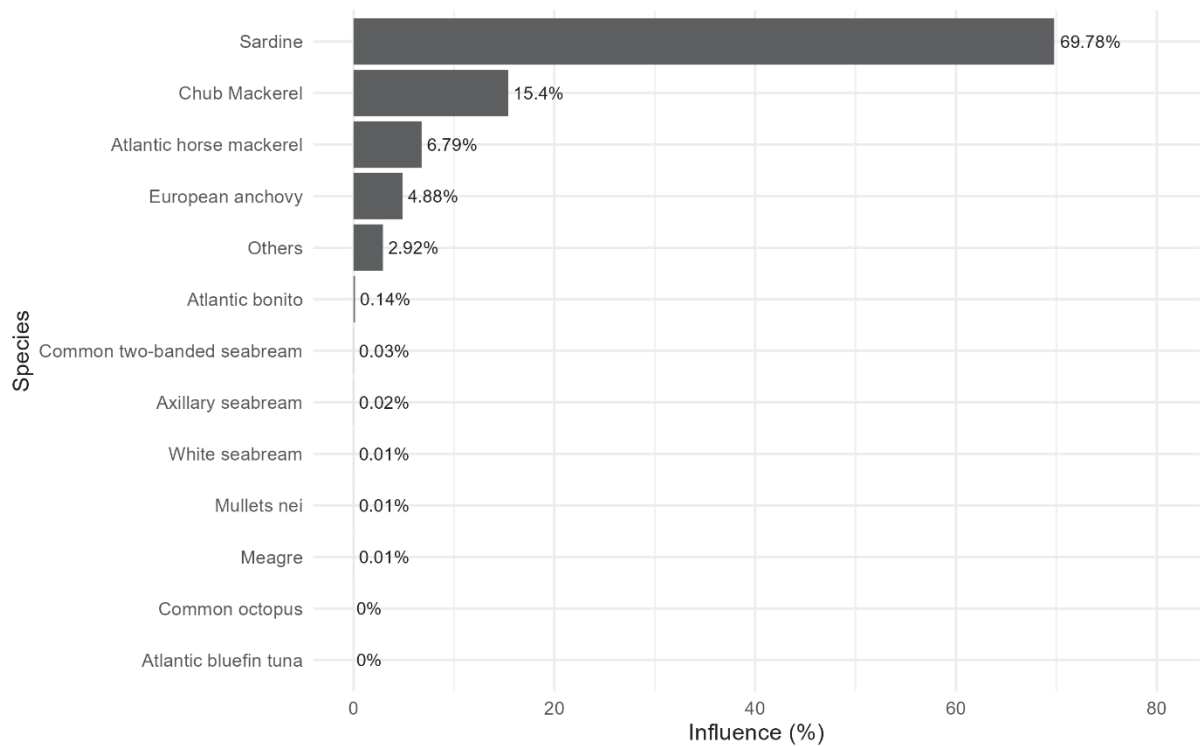


Figure 3.3 – Percentage of the landed weight of the main species and region based species in the Centre region from 2000 to 2022.

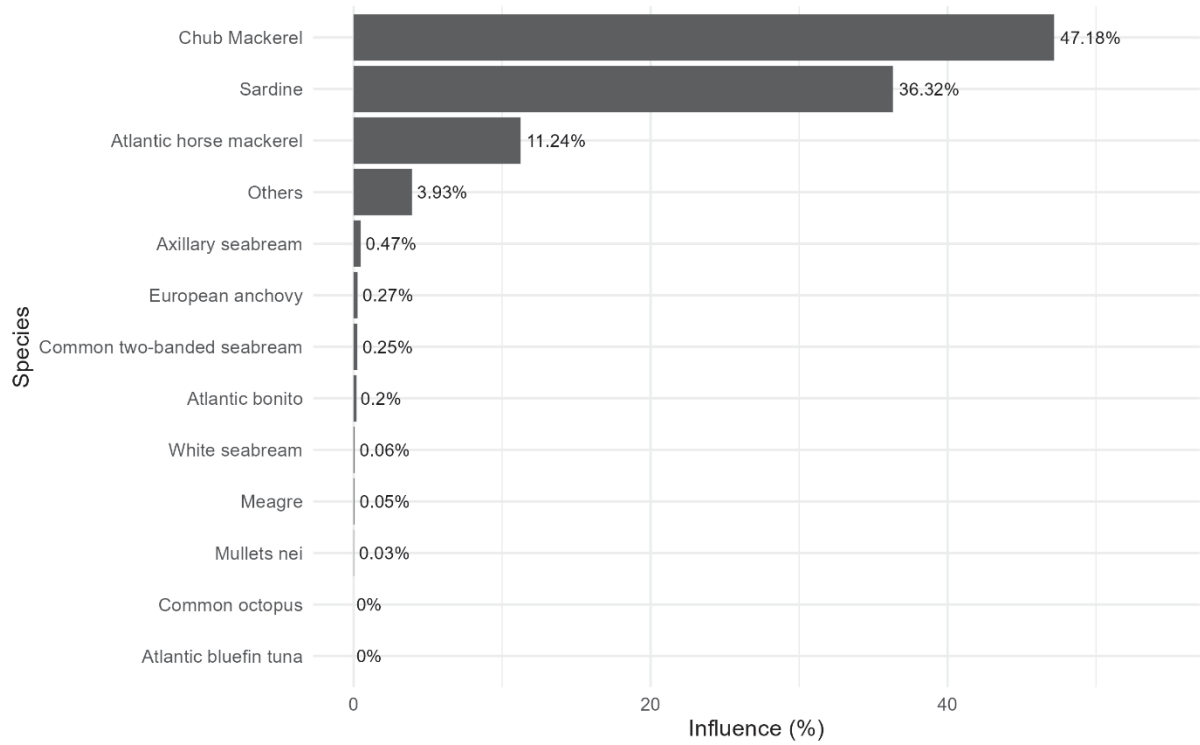


Figure 3.4 – Percentage of the landed weight of the main species and region based species in the Southwest region from 2000 to 2022.

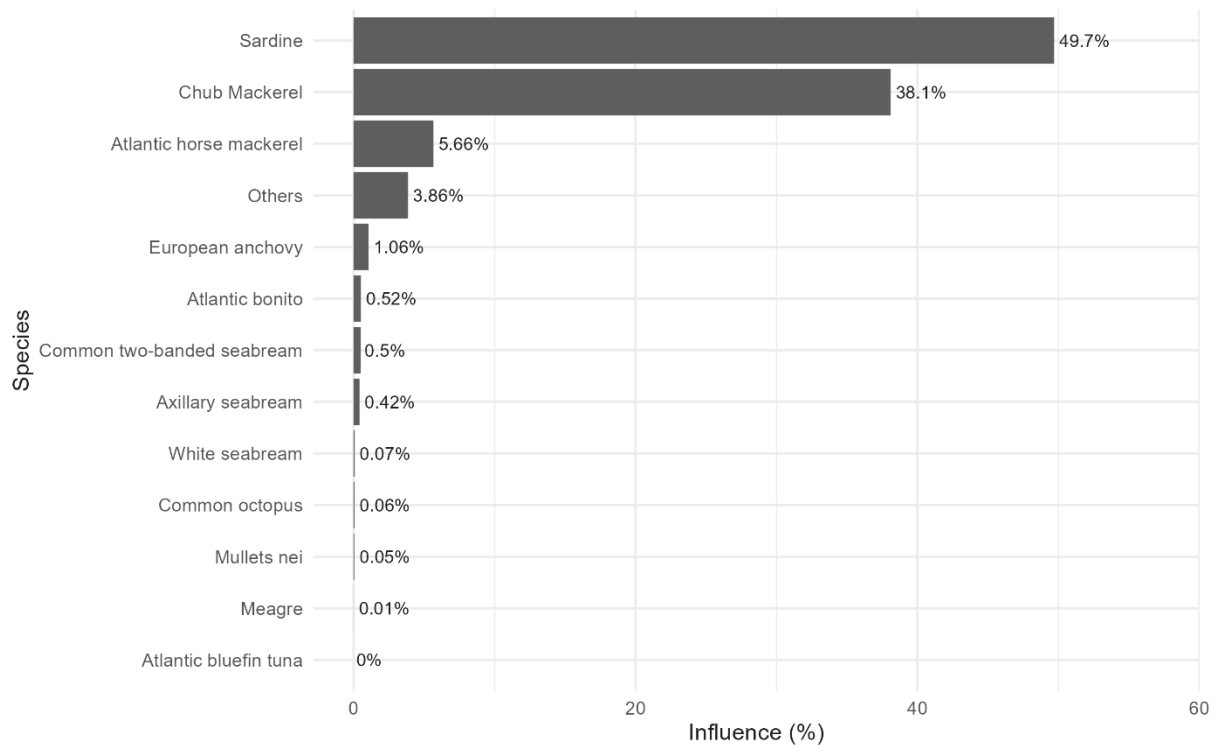


Figure 3.5 – Percentage of the landed weight of the main species and region based species in the South region from 2000 to 2022.

3.4 Overview of the Portuguese purse seine fishery in 2000-2022

The next section is based entirely on the *dailyland* application

The majority of landings by weight and value occurred in the summer period (Figs. 3.6 and 3.7). However, the peak in quantity was achieved in September, while the peak in value occurred in August. This phenomenon occurs during the summer peak season, when demand for fish from consumers is at its highest.

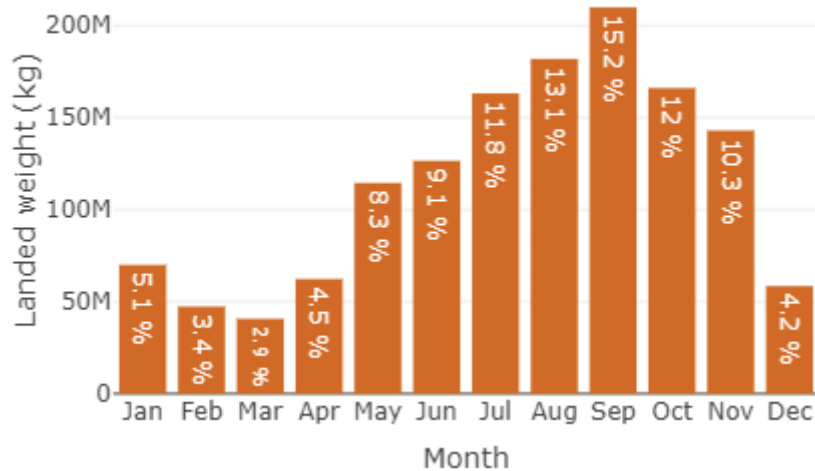


Figure 3.6 - Total quantity of landed weight, in kg, for each month between 2000 and 2022, along with the percentage of the total sold.

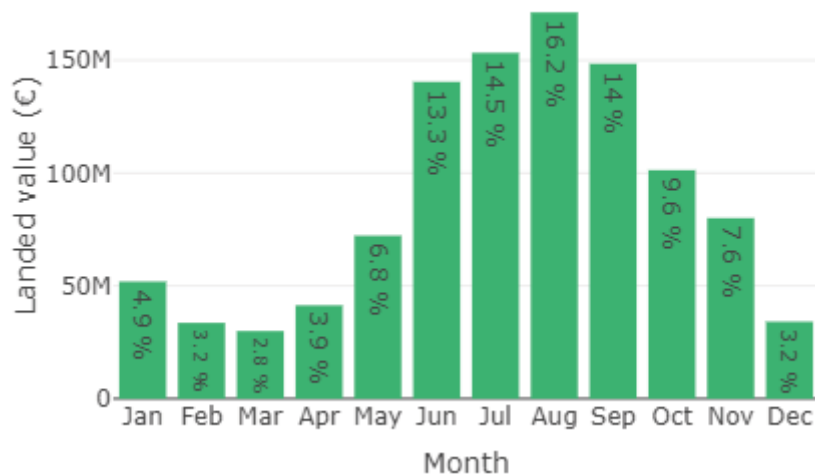


Figure 3.7 - Total value of landed value, in euros, for each month between 2000 and 2022, along with the percentage of the total sold.

The analysis of landings by weight over the years reveals a downward trend until 2006, followed by a relatively stable upward trend, with significant fluctuations in 2014, 2016 and 2020. These fluctuations subsequently returned to the mean value of 60182.34 tons (Fig. 3.8). A similar variation is observed in the value of landings, with higher value of landings achieved in subsequent years (Fig. 3.9), despite a relatively consistent quantity of landings.

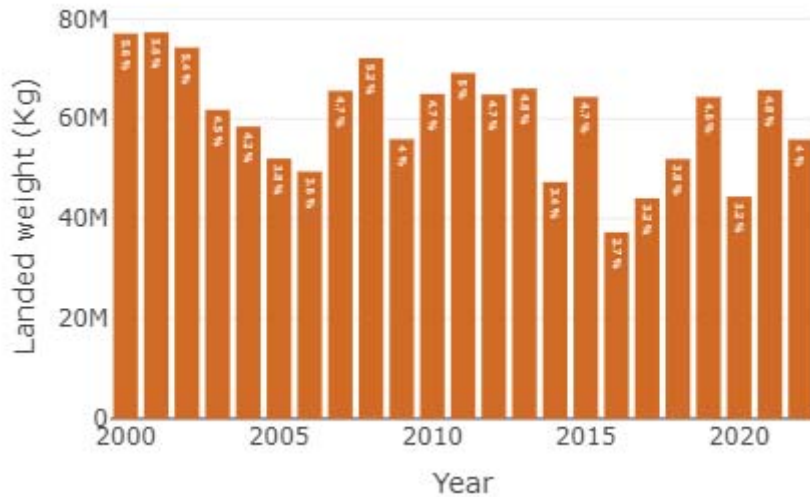


Figure 3.8 - Total quantity of landed weight, in kg, for each year between 2000 and 2022.

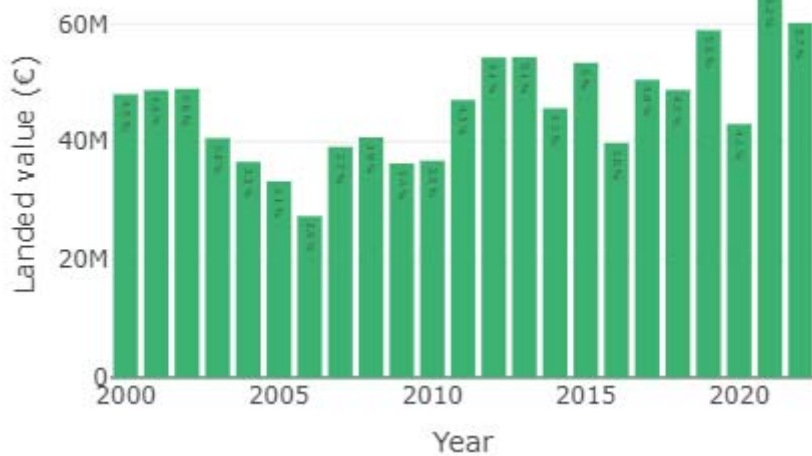


Figure 3.9 - Total value of landed value, in euros, for each year between 2000 and 2022.

It is evident that the majority of purse seine fishing activity is concentrated in the central, southwestern and northern regions in this order (Fig. 3.10), with the southern region accounting for a far lower percentage of the total fishing compared to the others. This is somewhat counterintuitive, given that the central region has fewer ports than other regions. The southwest region is responsible for catching a significant quantity of fish; however, the economic value of this catch is comparatively low in relation to that obtained from other regions.

Purse seiners are the primary source of fish landed (Fig. 3.11). However, the mean price per kg of fish in their landings appears to be lower than that of smaller vessels, mainly small-skiffs. This may be due to the target species, with smaller boats having to prioritise maximum value over maximum quantity on every trip.

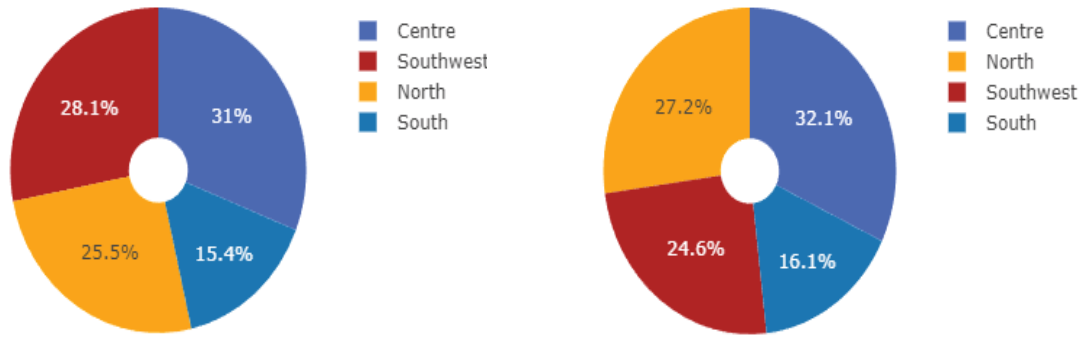


Figure 3.10 - Percentage of the quantity of landed weight (left) and landed value (right) in each region between 2000 and 2022.

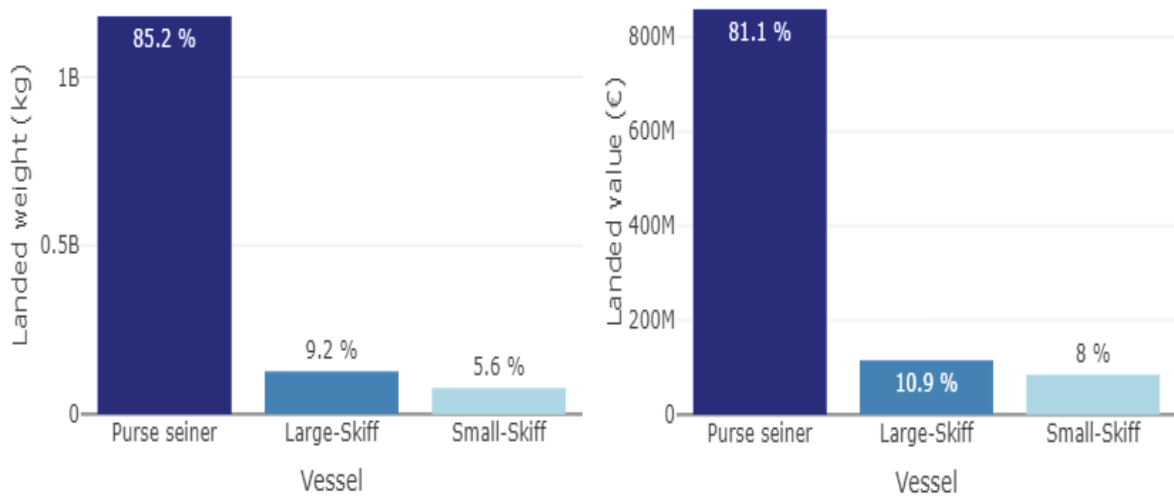


Figure 3.11 - Total quantity of landed weight, in kg (left) and landed value, in euros (right) for each type of vessel between 2000 and 2022 with percentage of total sold.

In the ensuing years since 2013, a marked transition has been observed in the regional dynamics, with the southwestern region commencing the sale of a greater quantity of fish than the central region (Fig. 3.12). However, it appears that the southwestern region continues to sell fish at lower values, consequently yielding an overall sale value that is less than that of the central region and, in the majority of years, even that of the northern region (Fig. 3.13). The southern region remains the area with the smallest number of both quantity and value sold.

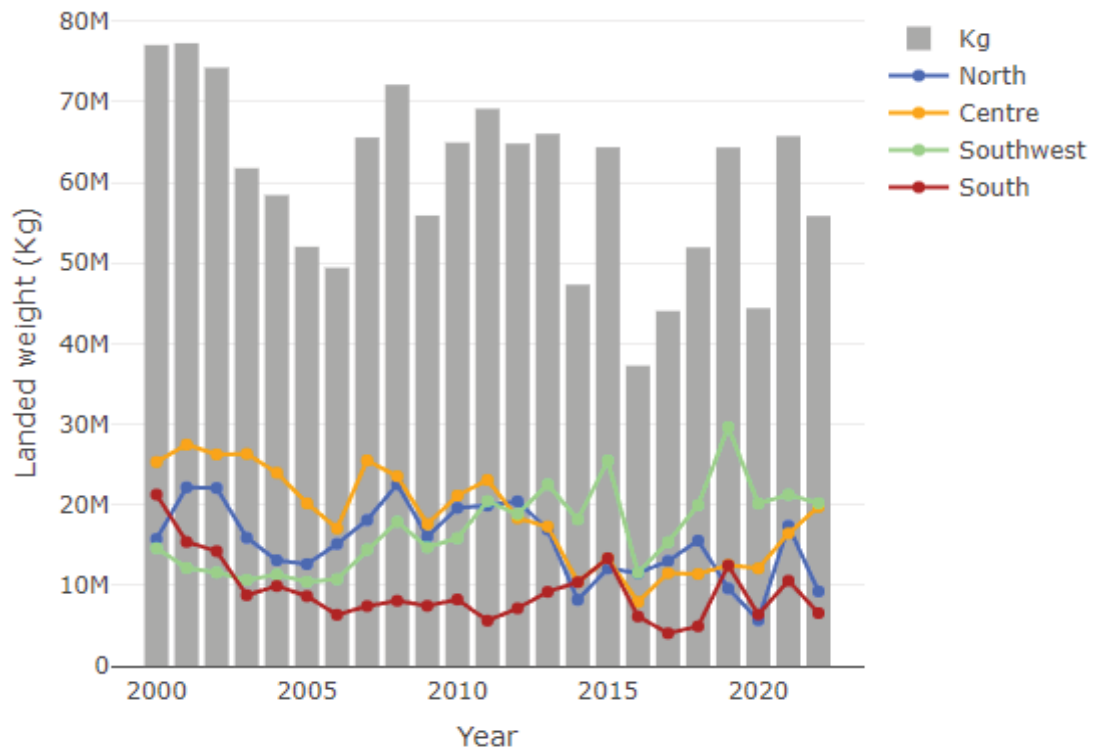


Figure 3.12 - Total quantity of landed weight in each region (dotted lines), in kg, with total amount for all regions combined in each year (grey bars).

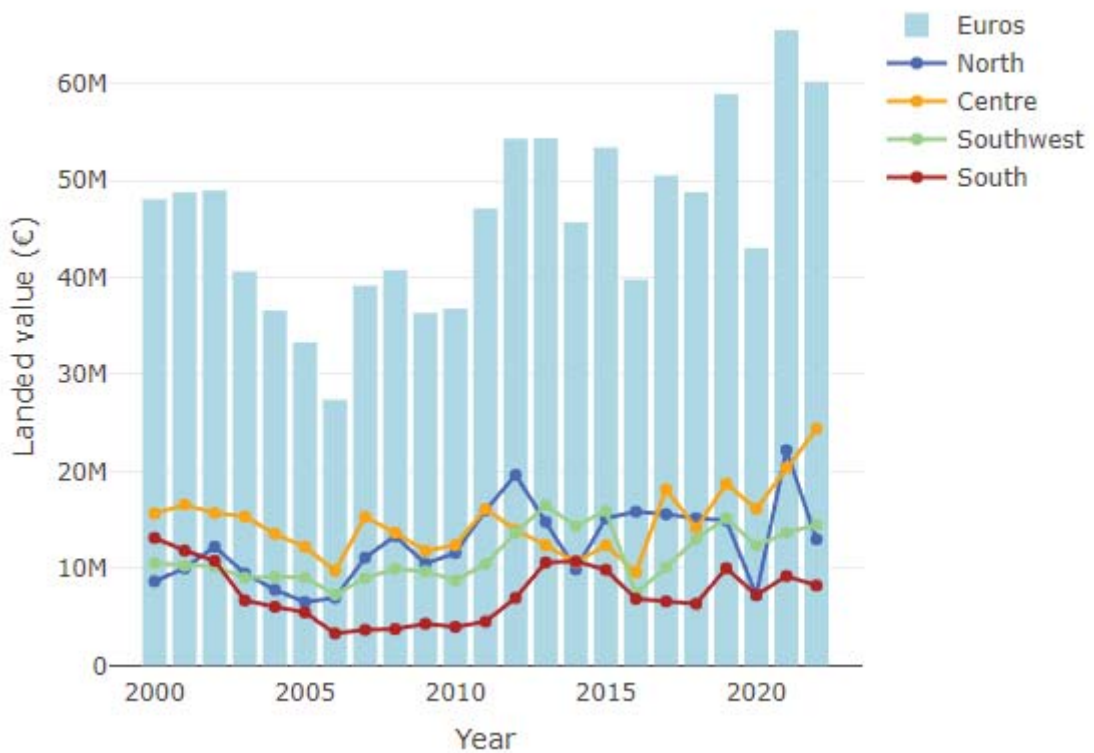


Figure 3.13 - Total landed value in each region (dotted lines), in euros, with total amount for all regions combined in each year (grey bars).

The fishery mainly caught fish in the T2, T3 and T4 size categories. For a long period, from 2000 to 2012, most of the fish caught were T2 size (Fig. 3.14), although in recent years there has been a notable decrease in T2 fish and an increase in the landings of smaller fish, particularly T4 size. A balanced ratio between T2, T3 and T4 has been observed in the last three years.

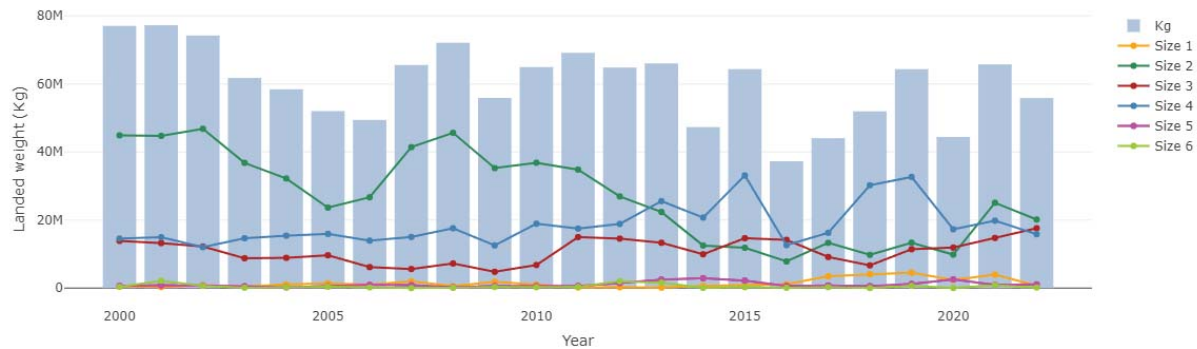


Figure 3.14 - Total landed weight of each size interval (T) (dotted lines), in kg, with total amount for all sizes combined in each year (grey bars).

3.5 Trends of landings by region and species

The smooth trends of landings by weight exhibit different patterns across regions and species. Most species show a wave like trend when looking at the whole of continental Portugal, apart from the Sardine (Fig. 3.15) which shows a steadily decline over the years with only a slight increase since 2019, and the Atlantic horse mackerel which showed a constant increase in weight landed since 2008.

The North region's main catch was sardine until around 2012, when fishers were forced to seek alternatives due to the restrictions in place at the time. This resulted in a notable increase in the presence of European anchovy (Fig. 3.16), chub mackerel (Fig. 3.17), and Atlantic horse mackerel (Fig. 3.18) which shows a very similar global smooth trend to the one drawn by the category others (Annex 14).

The axillary seabream (Fig. 3.19), Atlantic bonito (Fig. 3.20) and white seabream (Fig. 3.21) all had a notable increase since about 2011 with a peak close to 2017. This was followed by a marked decline.

For certain species, there are regions for which data are insufficient to produce a reliable graphic. Such is the case with the Atlantic bonito in the north and southwest, the common two-banded seabream in the north (Fig. 3.22), and the meagre in the north (Fig. 3.23).

Some smooth trends were not possible to read due to lack of data along the study period, this happened for the mullets *nei*. (Annex 15), the common octopus (Annex 16) and the Atlantic bluefin tuna (Annex 17).

The smooth trends observed at a global scale are well represented by the corresponding trends observed at the regional level for each species. This smooth trend is somewhat inverse to the sardine, which has a peak in 2000 and the lowest point in 2017, while the other species, apart from the meagre, have a rise in landings by weight starting around 2010 and peaking close to or at 2017, before slightly decreasing again. The European anchovy and the Atlantic horse mackerel have not experienced a downward trend in recent years, instead maintaining it for the first, and exhibiting signs of further increase for the latter.

In more recent years, the sardine seems to be regaining importance in exchange for lower landings in weight for most species, apart from the European anchovy in the North and Centre, and the chub

mackerel, which lost importance in the North and South regions but has been steadily increasing in landings in the Centre and Southwest regions.

These smooth trends for landings in weight transition well to the smooth trends for landed value, which showed really similar results (Annexes 8 to 20) for almost every species. The sardine however demonstrated a slight increase from 2008 to 2011 where it peaked before decreasing again.

Recent trends indicate an increase in weight landed for eight out of the twelve entries under consideration. As recent data concerning mullets nei. is not available, consequently, they were not included in the analysis (Table 3.7). A marginal increase has been observed in the populations of the European anchovy and Atlantic bluefin tuna, indicating a degree of stability in these species. This works in accordance with what was seen in the preceding trend analysis for the European anchovy. In comparison with the aforementioned species, the Sardine and the Atlantic horse mackerel demonstrate a higher increase, which may suggest a recent escalation in the importance attributed to these species, a resurgence in the case of the sardine.

There has been a relevant increase in the Atlantic bonito and the common octopus; however, the common octopus is less frequently captured which may skew the analysis. A decline in the sale of the meagre, axillary seabream and white seabream, has been observed in recent years, suggesting a potential shift in perceived importance towards species that are higher in value when they are available and/or a decrease in the overall availability of these species. Despite the unfavourable trend exhibited by the chub mackerel, its value remains close that of the recent trend, indicating marginal maintenance of the trend in parallel with the European anchovy and the Atlantic bluefin tuna.

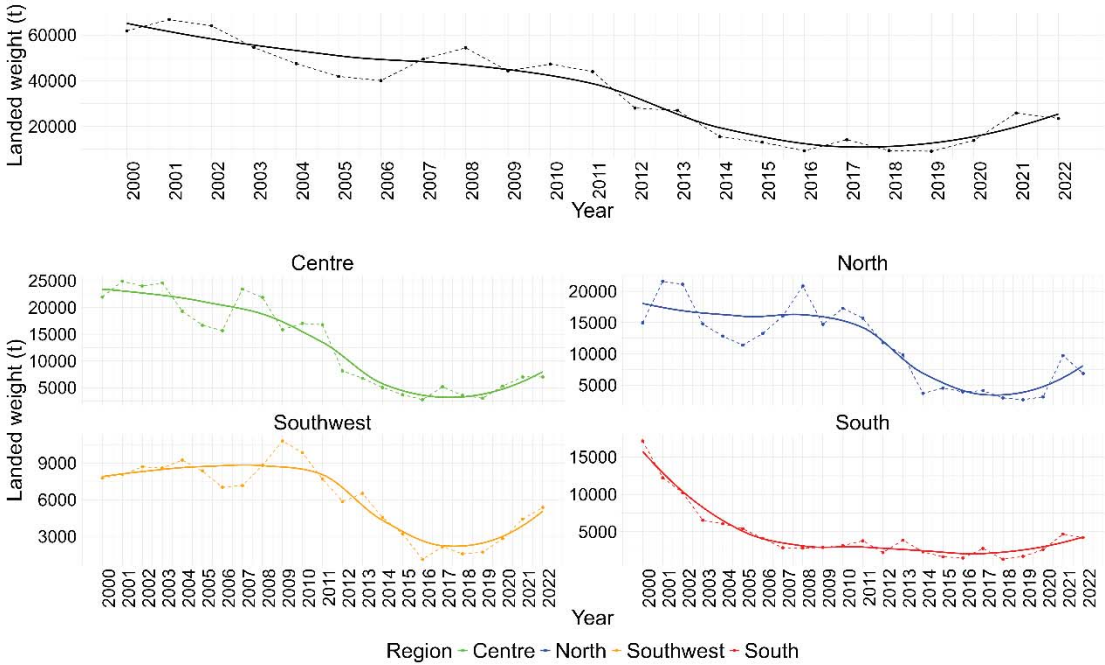


Figure 3.15 - Locally estimated scatterplot smoothing trend for sardines between 2000 and 2022, showing the total weight sold in tonnes per year.

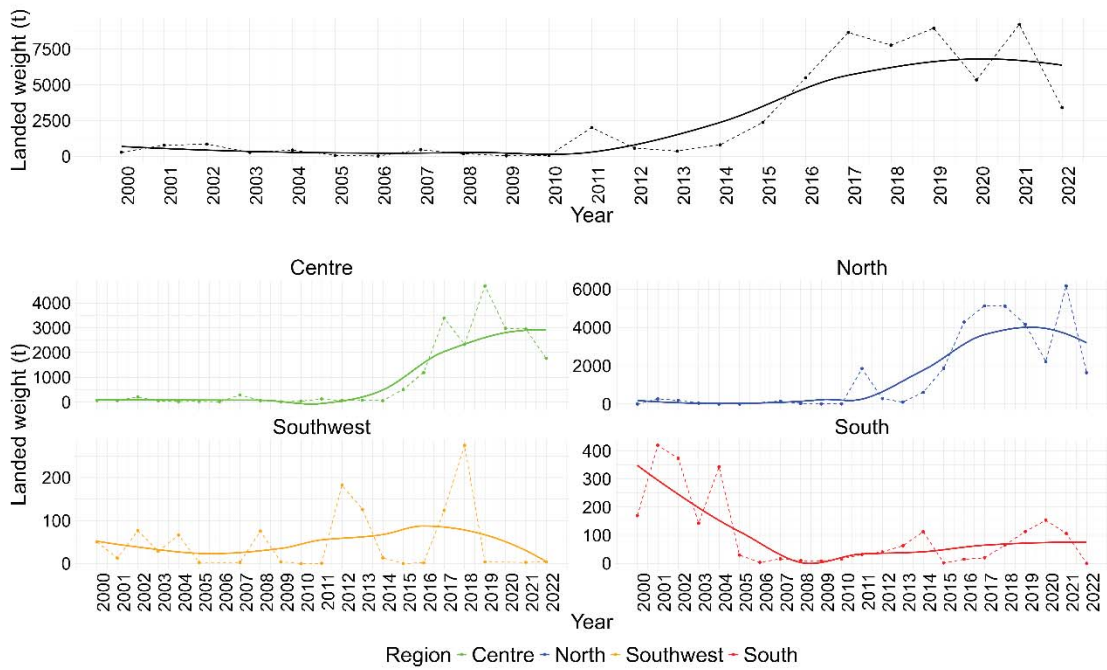


Figure 3.16 - Locally estimated scatterplot smoothing trend for European anchovy between 2000 and 2022, showing the total weight sold in tonnes per year.

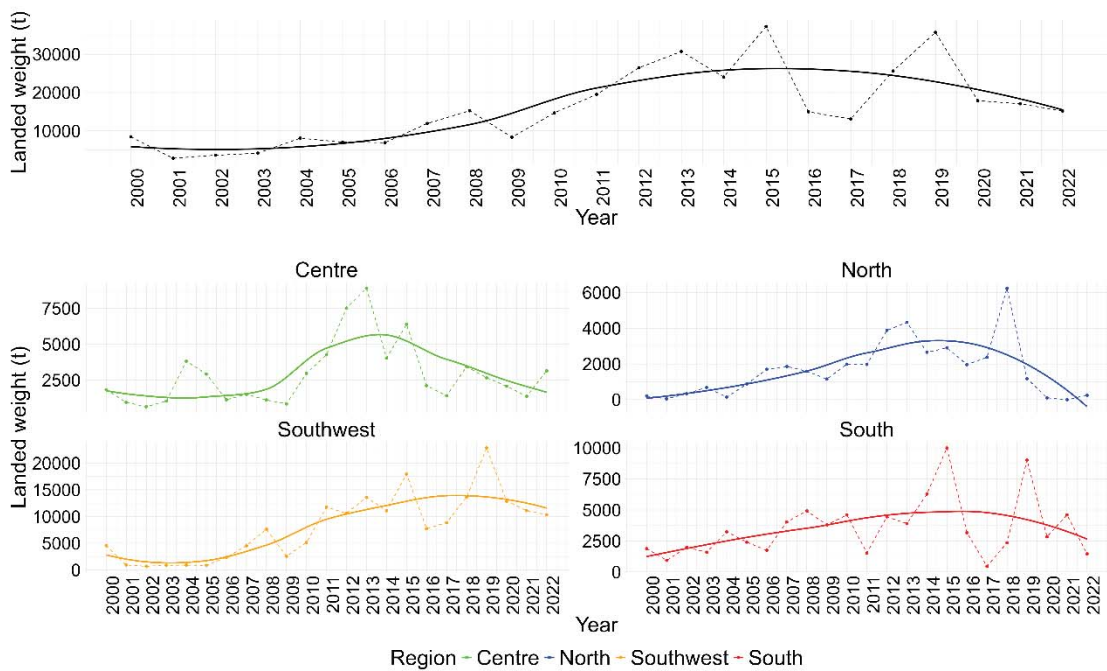


Figure 3.17 - Locally estimated scatterplot smoothing trend for chub mackerel between 2000 and 2022, showing the total weight sold in tonnes per year.

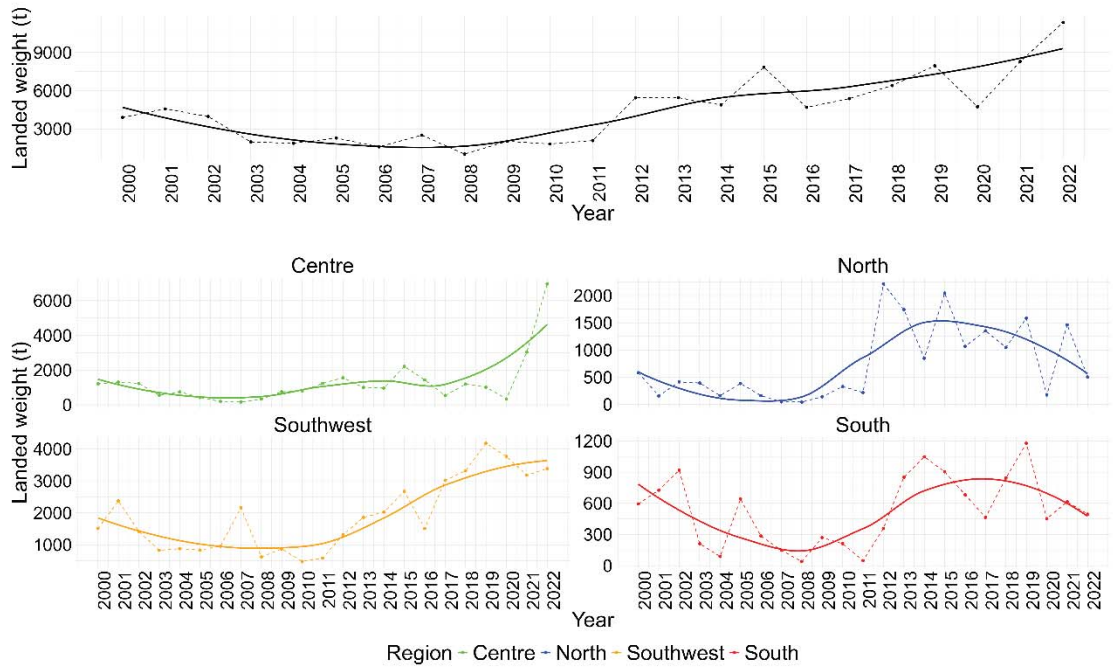


Figure 3.18 - Locally estimated scatterplot smoothing trend for Atlantic horse mackerel between 2000 and 2022, showing the total weight sold in tonnes per year.

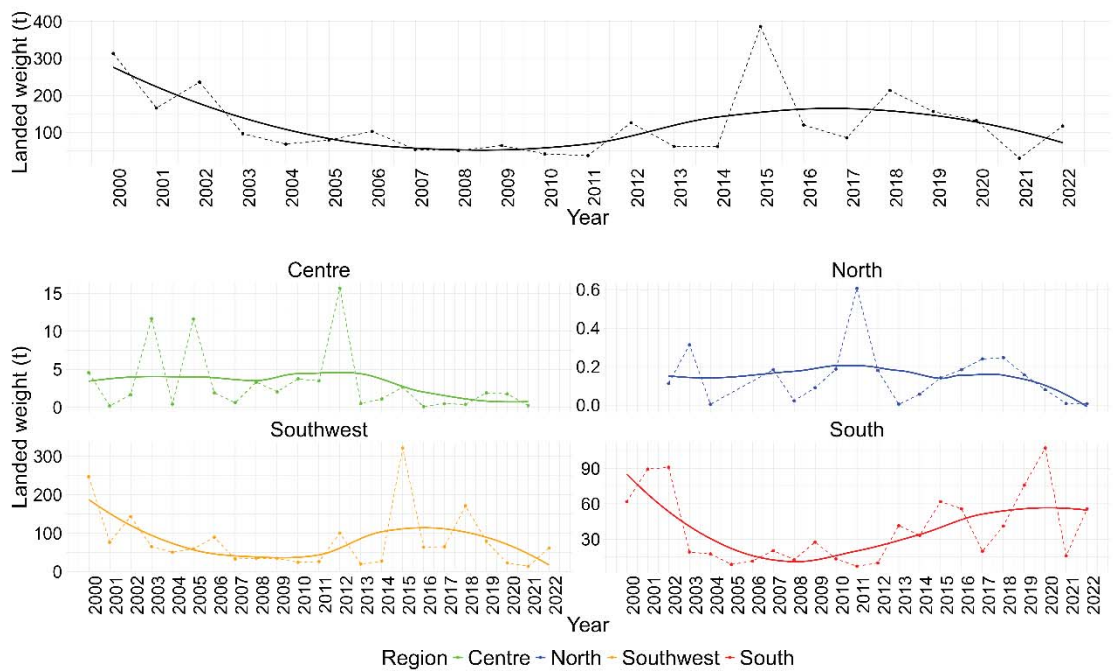


Figure 3.19 - Locally estimated scatterplot smoothing trend for axillary seabream between 2000 and 2022, showing the total weight sold in tonnes per year.

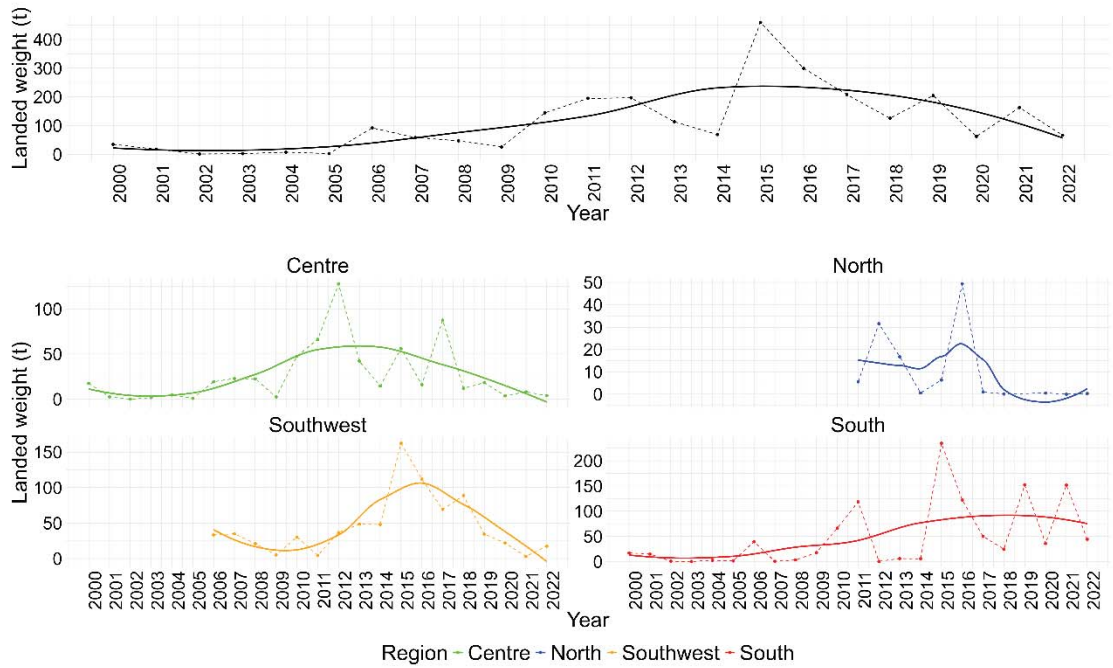


Figure 3.20 - Locally estimated scatterplot smoothing trend for Atlantic bonito between 2000 and 2022, showing the total weight sold in tonnes per year.

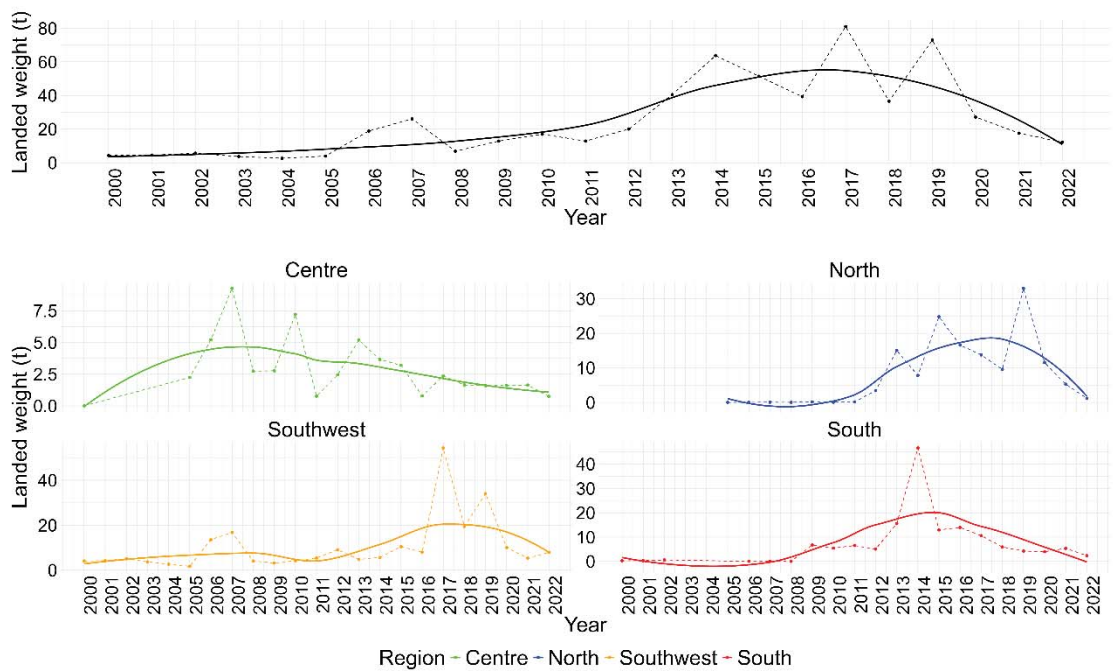


Figure 3.21 - Locally estimated scatterplot smoothing trend for white seabream between 2000 and 2022, showing the total weight sold in tonnes per year.

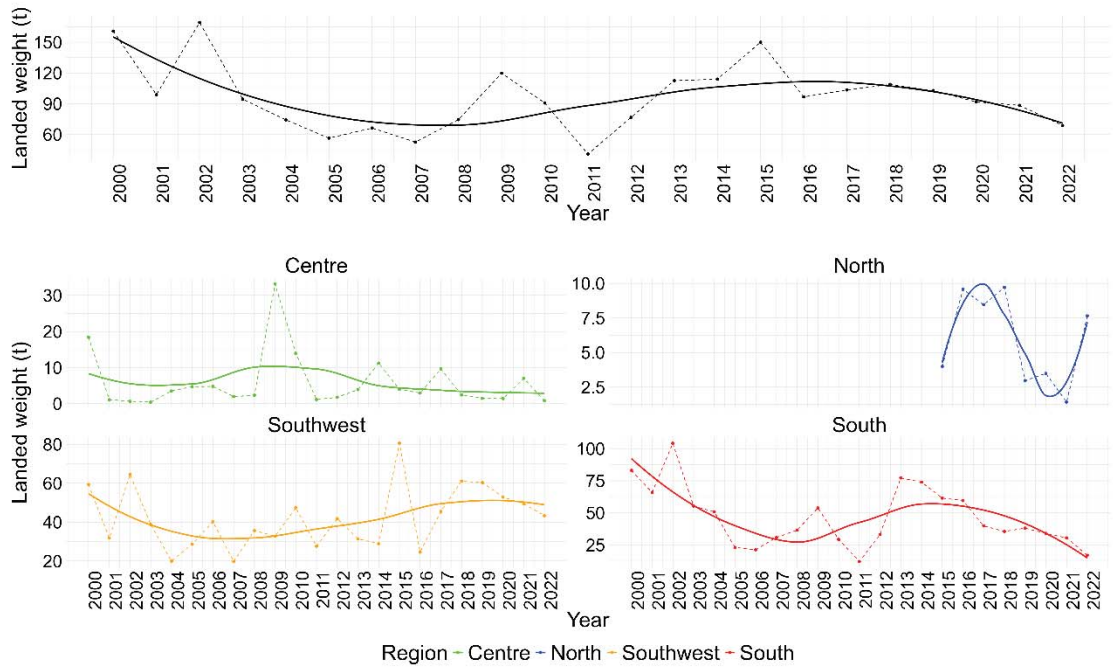


Figure 3.22 - Locally estimated scatterplot smoothing trend for common two-banded seabream between 2000 and 2022, showing the total weight sold in tonnes per year.

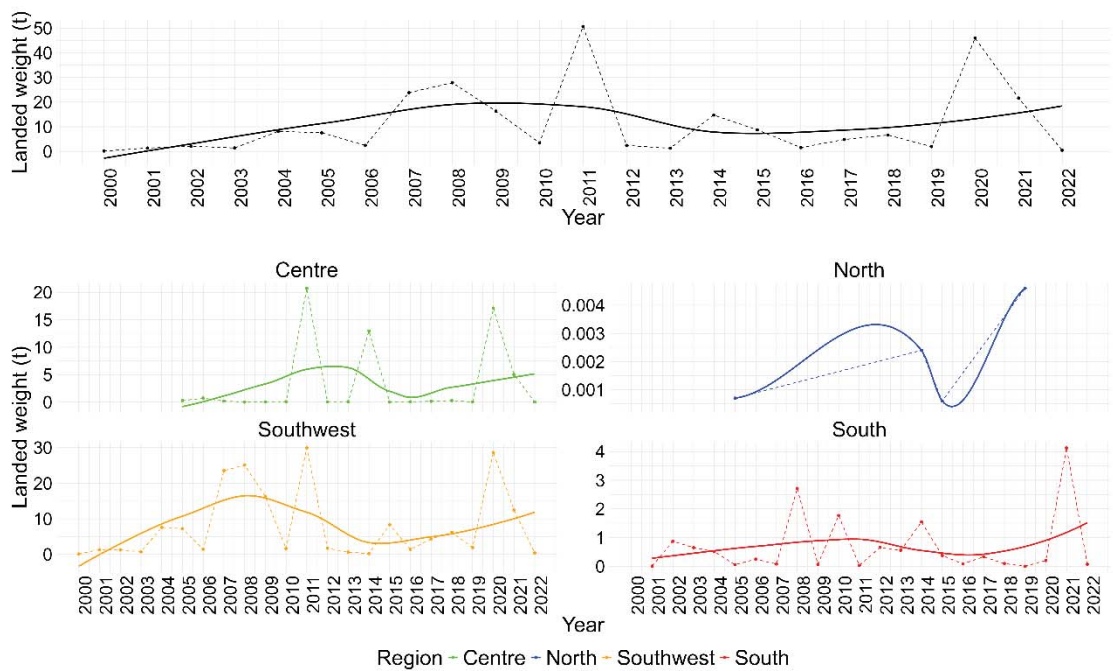


Figure 3.23 - Locally estimated scatterplot smoothing trend for meagre between 2000 and 2022, showing the total weight sold in tonnes per year.

Table 3.7 – Recent trend in terms of landed weight (t) for the selected species

Species	Mean recent years (t)	Mean prior years (t)	Recent trend
Sardine	0.65	0.35	1.88
Others	0.22	0.12	1.76
Atlantic horse mackerel	0.36	0.21	1.7
Atlantic bonito	0.16	0.1	1.59
Common octopus	0.03	0.02	1.43
Common two-banded seabream	0.02	0.02	1.17
Atlantic bluefin tuna	0.22	0.22	1.03
European anchovy	1.3	1.29	1.01
Chub Mackerel	1.55	1.73	0.9
Axillary seabream	0.04	0.05	0.8
Meagre	0.15	0.26	0.58
White seabream	0.01	0.02	0.45

3.6 Relationships between species landings over time

The dynamics between species in terms of value sold can facilitate comprehension of market fluctuations, which may be attributed to variations in species availability, whether due to physical factors or quota limitations.

In the northern region, European anchovy and sardine landings were significantly negatively correlated at time lags 0, +1 and -1 (Fig. 3.24), indicating that years with higher European anchovy landings were associated with years of lower sardine landings both in the same year, previous and next years.

Furthermore, the centre region comparison between the sardine and the Atlantic horse mackerel landings also presented a significant negative correlation between the two species (Fig. 3.25). However, this correlation, only shows a statistically significant correlation between the variables with a three-year delay at a time lag of -3. This means years with higher sardine landings were associated with lower Atlantic horse mackerel landings three years prior. In view of the negligible correlation observed in the remaining years of the study, this information should be handled carefully.

The remaining pairs were found to be either significantly positively correlated or not significantly correlated at all. In the Southwest, two pairs were selected: the Atlantic horse mackerel and the chub mackerel (Fig. 3.26) and the chub mackerel and axillary seabream (Fig. 3.27). In the south three pairs were selected: common two-banded seabream and the Atlantic horse mackerel (Fig. 3.28), the axillary seabream and mullets nei. (Fig. 3.29) and the common two-banded seabream and Atlantic bonito (Fig. 3.30).

The Atlantic horse mackerel and the chub mackerel pair, and in the South the common two-banded seabream and the Atlantic horse mackerel, and the axillary seabream and mullets nei. pairs demonstrated a significant positive correlation. Years with higher Atlantic horse mackerel landings were associated with higher chub mackerel landings in the same year and throughout the next four years since they were statistically correlated at time lags ranging from 0 to +4. Years with higher common two-banded seabream landings were associated with higher Atlantic horse mackerel landings in the same year and the year prior to that, as evidenced by a statistically significant correlation at time lags 0 and -1, while

higher axillary landings were associated with higher mullets nei. landings in the next year as they were significantly correlated at the time lag +1.

The final two pairs analysed in this study, chub mackerel and axillary seabream in the Southwest and common two-banded seabream and Atlantic bonito in the South did not demonstrate any statistically significant correlation.

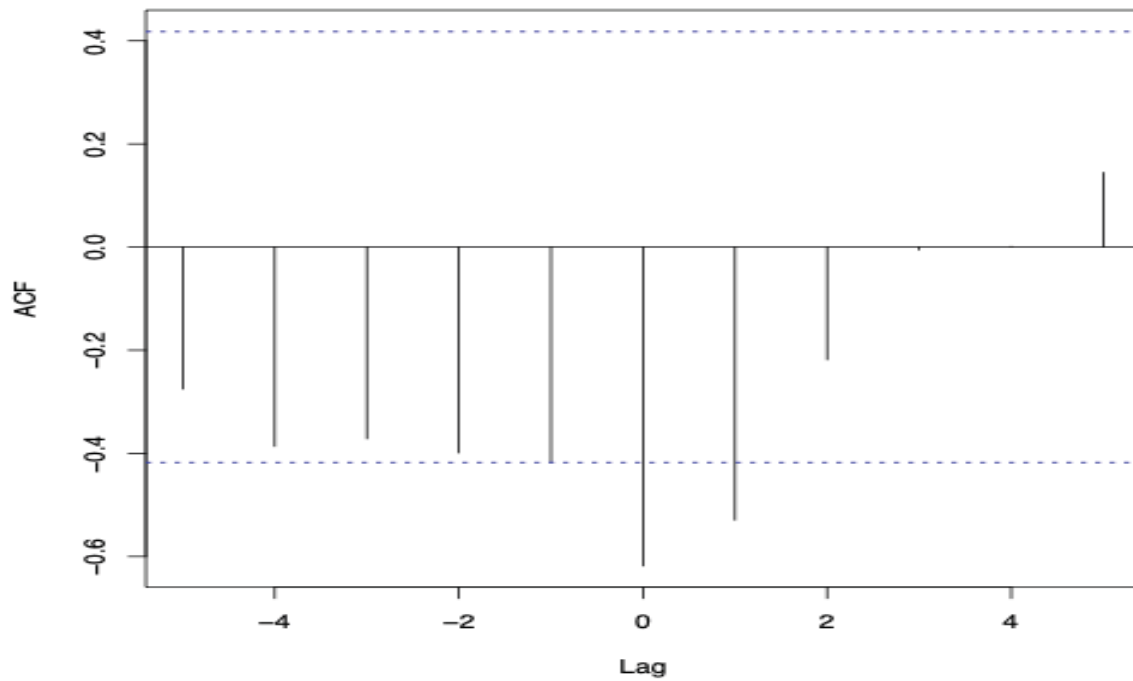


Figure 3.24 - Cross-correlation function between the European anchovy and the sardine in the North region with a maximum lag of 5.

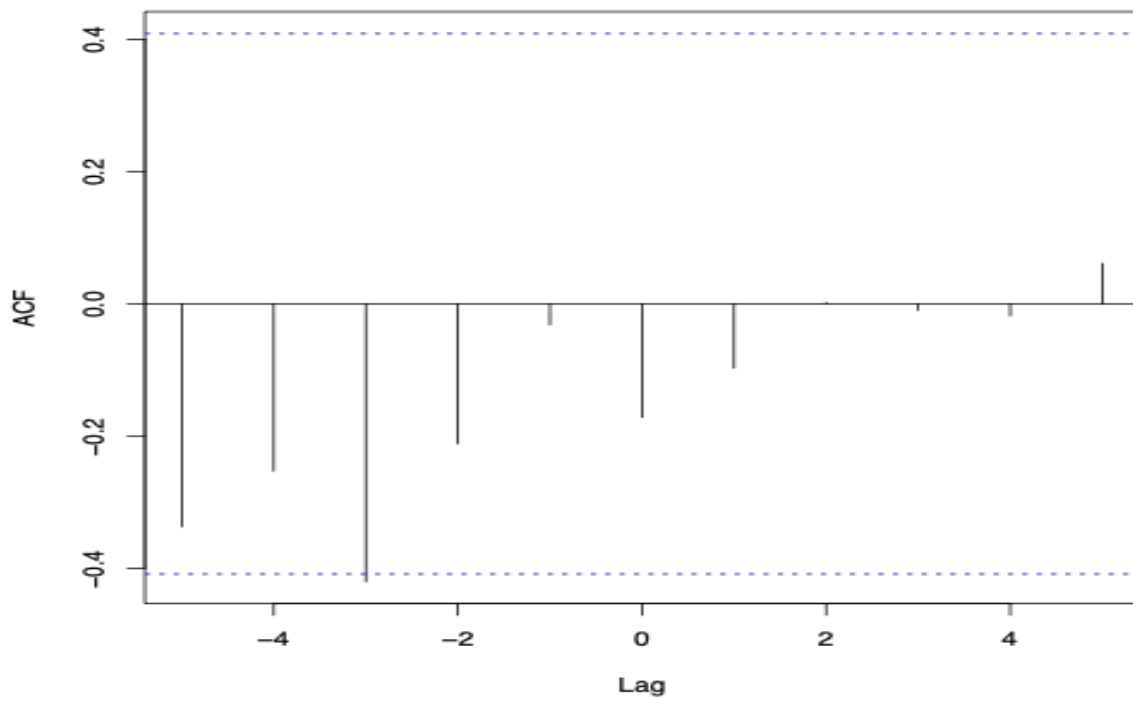


Figure 3.25 - Cross-correlation function between the sardine and the Atlantic horse mackerel in the Centre region with a maximum lag of 5.

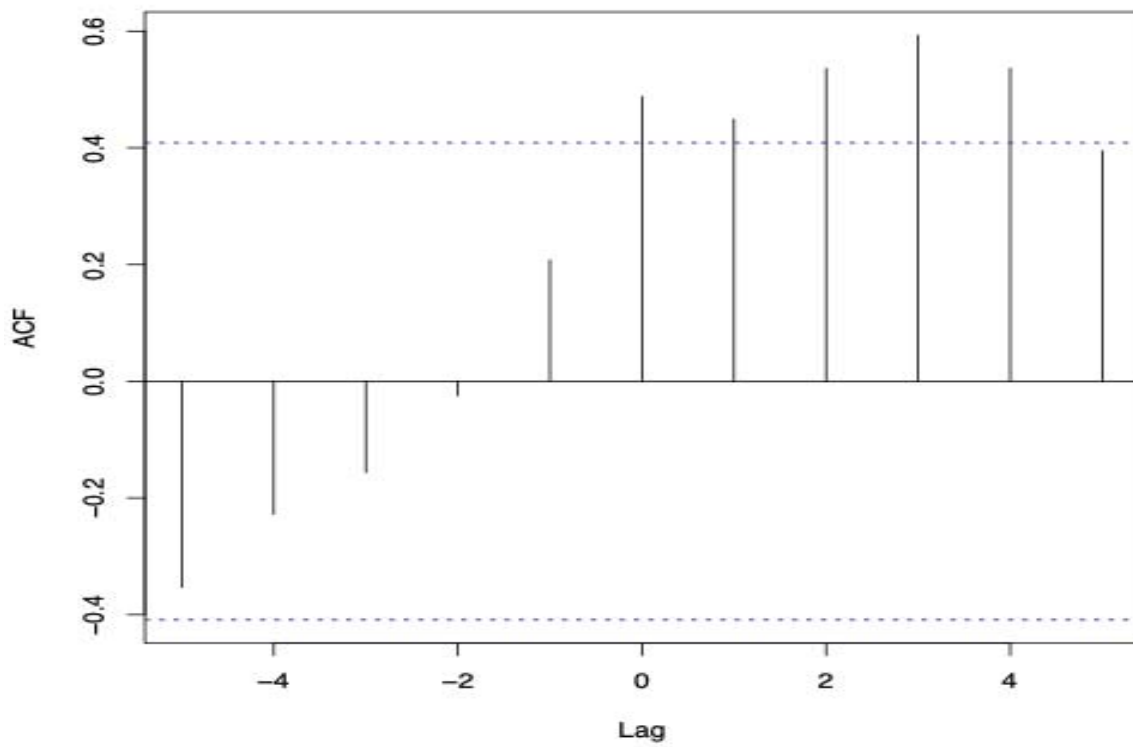


Figure 3.26 - Cross-correlation function between the Atlantic horse mackerel and the chub mackerel in the Southwest region with a maximum lag of 5.

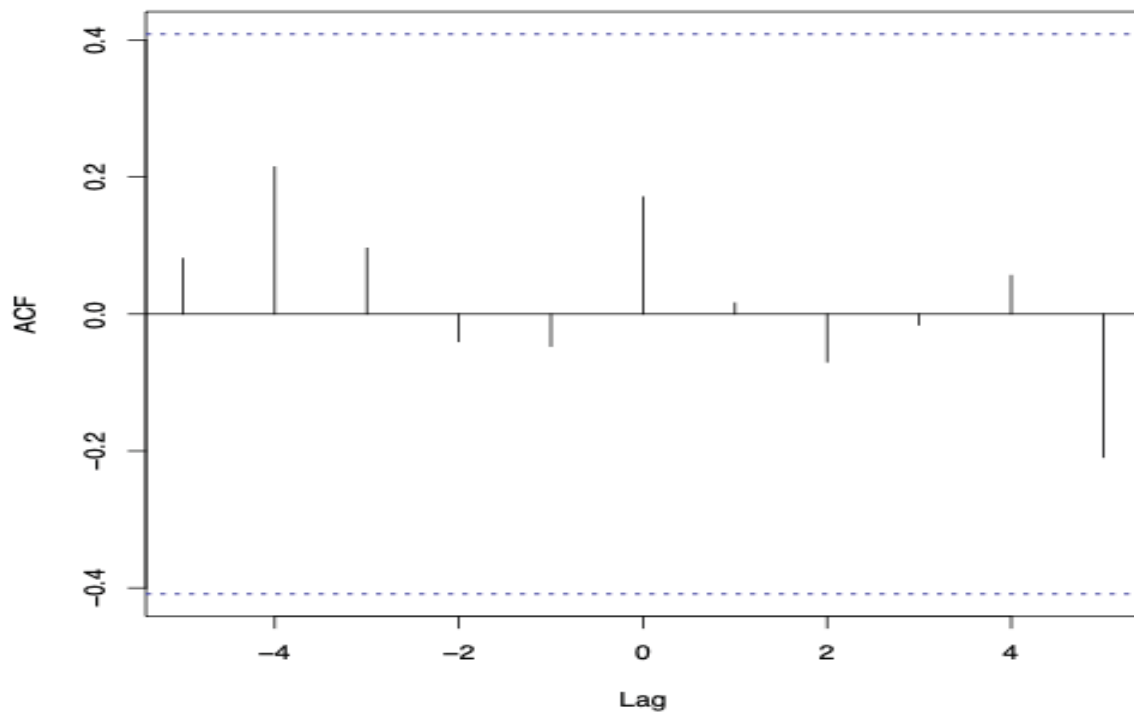


Figure 3.27 - Cross-correlation function between the chub mackerel and the axillary seabream in the Southwest region with a maximum lag of 5.

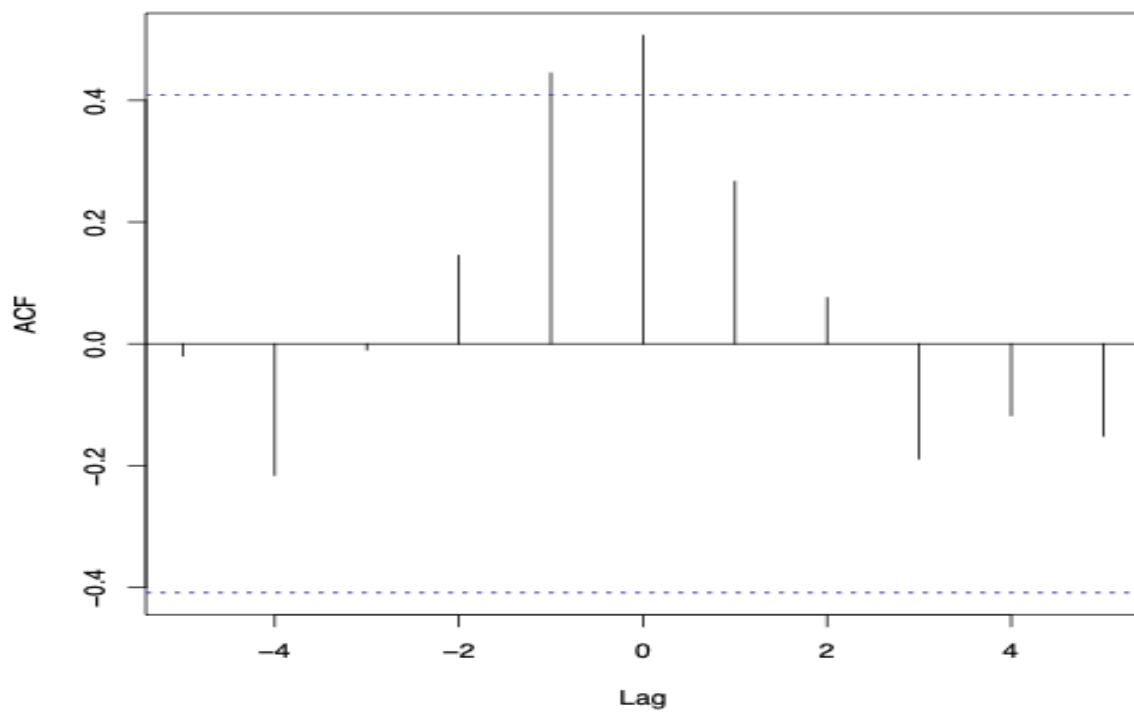


Figure 3.28 - Cross-correlation function between the common two-banded seabream and the Atlantic horse mackerel in the South region with a maximum lag of 5.

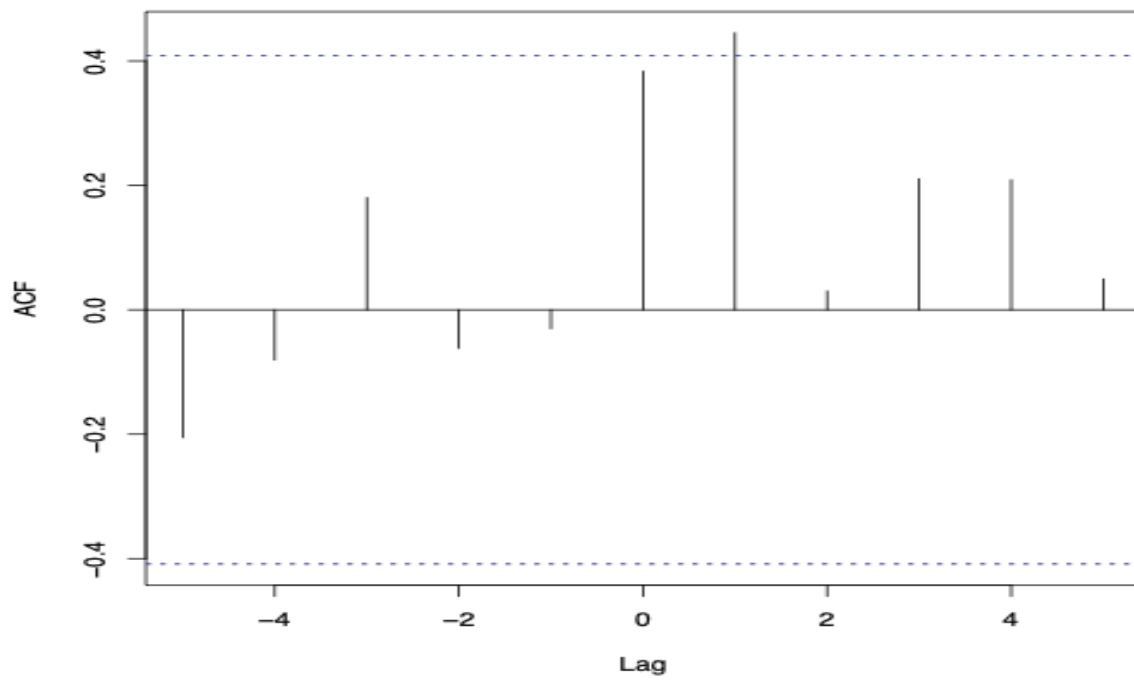


Figure 3.29 - Cross-correlation function between the axillary seabream and the mullets nei in the South region with a maximum lag of 5.

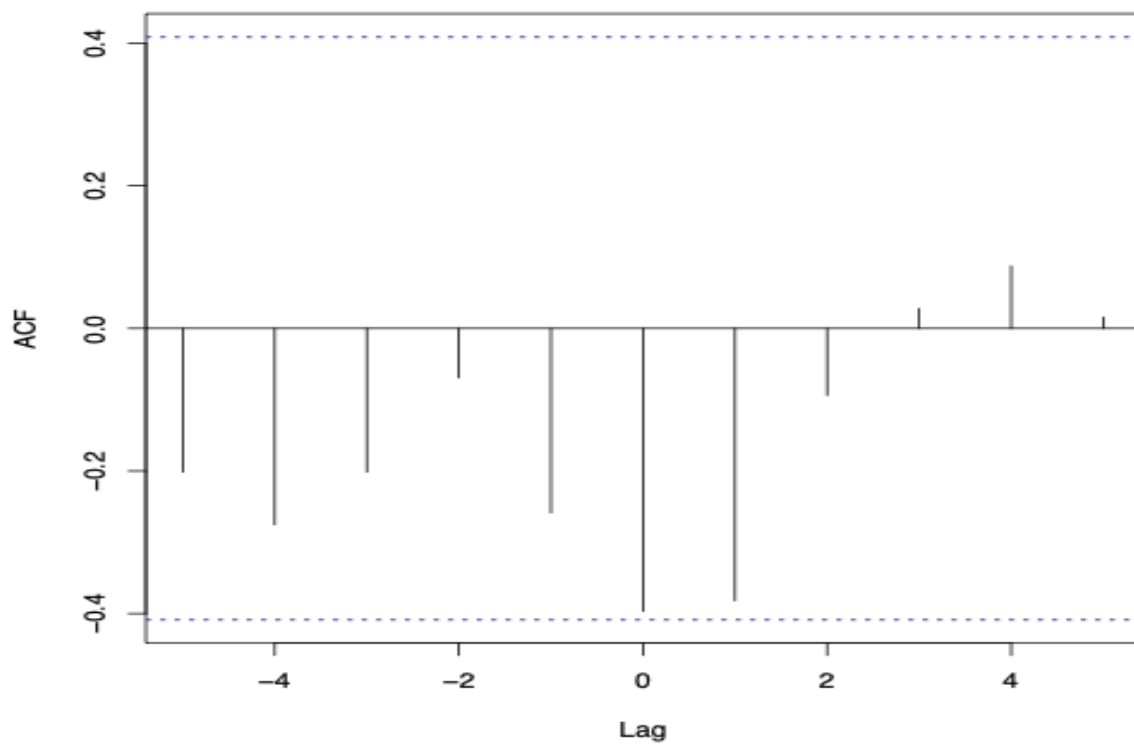


Figure 3.30 - Cross-correlation function between the common two-banded seabream and the Atlantic bonito in the South region with a maximum lag of 5.

4. Discussion

Purse seine fishing accounted for 51.7% of landings by weight in Portugal in 2024 while only 8.1% of the vessels having a purse seine fishing license, making it one of the country's most important fisheries (Instituto Nacional de Estatística, I.P., 2025). As such, it strongly impacts the fishing sector and the status of the species caught, making it important to adapt the regulation to maintain the sustainability of the fisheries. In the case of the purse seine fishery (Portaria n.º 218/2023), this may imply amending the allowed target and bycatch species to better reflect their regional and temporal variability in the landings.

This study aimed to ascertain the alignment of current policies with scientific knowledge by examining the most prevalent species in purse seine fisheries across Portugal. The timeframe covered in this analysis spanned from 2000 to 2022, except for the species selection, which was limited to a ten-year period from 2013 to 2022 to provide a more accurate representation of recent trends in landings. As anticipated, the results revealed the sardine to be the dominant species, and a key component of Portuguese fisheries (Cardoso *et al.*, 2019). The findings consistently demonstrated the sardine's prominence, with its presence at the forefront of charts depicting total quantity and sales value. Despite the implementation of catch and effort controls for purse seine fishing to protect against the decline of sardines (Silva *et al.*, 2015), sardines remained one of the most widely fished species and a key target for purse seine fishing. According to the current regulation, the other small pelagic species targeted by purse seine fishing are Mediterranean horse mackerel, blue jack mackerel and Atlantic horse mackerel, European anchovy, bogue, and chub mackerel, which somewhat aligns with the present data. Overall, the most dominant species in the purse seine fisheries demonstrate a significantly higher prevalence when compared to the subsequent species in the analysis. Despite this, these species must not be disregarded, as the absolute values remain elevated and they represent the best alternatives as accessory species. The species present as non-pelagic target species are mostly incongruent with those deemed most important in this study. Although mullets, Atlantic bonito and garfish might be considered important enough to be considered targeted species in the northern region, according to ICES (2020) there is a need to establish the threshold at which a species is considered as such. Species such as the Atlantic bluefin tuna and the common octopus are, in fact, rarely caught but retained due to their high economic value, other species in the study, which are not present as target species, show higher favouritism than those that are present. Species such as seerfishes, skipjack tuna, triggerfishes, and bluefish do not appear in sufficient quantities in the data to be considered targeted species. Instead, they appear alongside a large number of other species that are considered accessory, including European hake, pouting and red pandora to name a few, and as such, can only make up to 20% of a vessel's total catch in the trip.

Due to its heterogeneity as a transition zone between temperate and subtropical waters, the Portuguese coast is divided into four different regions, where the northern or southern distribution limits of many species overlap (Cardoso *et al.*, 2019). The presence of different species, variations in their abundance, and regional economic and cultural differences result in distinct species being caught and valued across regions. The clear contrasts observed between regions for certain species confirm that this division turned out to be a good decision, and it is evident from the data that regional preferences for different species vary, which may be attributed to factors such as availability or cultural preferences leading to higher demand. In light of these findings, it is advisable to revise and present the law with regionalisms, and to review the species currently in place, with a focus on introducing others that are deemed preferable by fishermen. Regarding the findings in this study, species like the seerfishes, triggerfishes, skipjack tuna and bluefish should be dropped as targeted non-small pelagic species giving room to seabreams, more specifically the axillary seabream, the white seabream and the common two-banded

seabream. This approach may be considered a preliminary measure leading to the implementation of a region-based regulation in the future.

Purse seine fishing in continental Portugal peaks in the summer with a peak landed weight in September, possibly due to better climatic conditions that facilitate the fishing process and increase sardine catches, as this period falls outside their usual spawning period (November to February in northern Portugal and October to April in central and southern Portugal) (Stratoudakis *et al.*, 2007), and a peak in landed value in August with high values for June, July and September, being the hottest months in the year this leads to a higher demand for seafood as the population's consumption tends to increase. Cultural events such as the *Santos Populares*, which occur throughout June, also lead to high demand for sardines, as they are one of the main attractions of the event.

The size of the fish caught has varied over the years, with a smaller proportion of larger fish (T2) being replaced by smaller ones (T3 and T4). This could be explained by the declining health of the exploited fisheries, with smaller fish being caught more frequently. The sardine fishery was an example of this decline. In 2021, ICES advised limiting the total allowable catch (TAC) in Portugal and Spain because catches had surpassed the maximum sustainable yield (MSY) (ICES 2021). However, since then it seems the sardine is recovering and the stock is above the reference point for the maximum sustainable yield since 2020 (Szalaj *et al.*, 2024).

To our knowledge, this is the first large-scale study in Portugal specifically examining bycatch within the purse seine fishery. As such, it establishes a foundation for future research on the evolution and management of this sector. Ultimately, this knowledge can support the development of more tailored management measures that align with fishermen's interests while ensuring species conservation and sustainable fisheries practices.

A particularly relevant topic for further research is the interaction between species in purse seine fisheries, i.e. the effect of one species on another. While the present study did not allow for an in-depth exploration of this interaction, the analysis of the structure of fish landed by purse seiners, in terms of weight and value, provided an opportunity to select some species and compare their evolution in more detail. While sardine remains a central and well-recognised species in Portugal, other commercially relevant species have received comparatively less attention. By identifying and characterising the most important species within the purse seine fishery, this study contributes to a more balanced understanding of the fishery's composition. This improved perspective enhances the overall assessment of species status, helping to address existing knowledge gaps and supporting more informed monitoring and protection measures where necessary.

In conclusion, bycatch is substantially high for certain species along continental Portugal. However, as expected, sardine and chub mackerel were generally the most landed species both in weight and value during the study period. The current regulation should be reviewed in light of the species targeted by purse seine fishing. Region-based regulations seem to be a good alternative to the current countrywide policies, as these do not account for regional differences, which can result in suboptimal species health and fisheries sustainability.

5. Collaboration in IPMA fisheries monitoring activities

Alongside the tasks developed in the present study, other activities were carried out within the scope of IPMA's responsibilities during the curricular internship.

The intern participated in the Demersal campaign, an annual scientific survey conducted by IPMA along the Portuguese continental coast to assess the status of demersal species populations. Although the campaign lasted one month, the intern only participated for approximately half of this period, supporting the scientific team operating in the North and Centre regions of Portugal.

To carry out the survey, the Portuguese coast was divided latitudinally into several sectors. Within each sector, four random sampling points were selected at different distances from the shore and depths where the trawl net was lowered for a standardised period for fishing. Once the time has finished the trawl net is pulled in and the fish are brought onto the sorting tables. Here is where the technical team proceeds with the sorting, with the intern helping by separating the fish by species for subsequent sampling in the laboratory.

All species were sampled by measuring and weighing them at least once. The weight of all the fish caught for each species was measured, but values for each metric at the individual level were only obtained for a maximum of 100 specimens, which were randomly collected from the pool of caught fish for that species. In an attempt to save any individuals that were still alive, the remaining fish were thrown back into the sea as quickly as possible.

After taking the initial measurements, each team went to their station to work on the species that had been assigned to them for the journey. The intern worked with a colleague on the hake and the four-spotted megrim. They also had the opportunity to spend a day assisting with the identification and sampling of the less abundant and common species caught.

Once the total weight had been recorded, the intern and his partner proceeded to measure the total length of the hake and four-spot megrim to separate them into length classes. To make sure they sampled a maximum of five individuals per length class (1 cm per class), the team used one box for every centimetre interval. Once the measuring was finished, the sampling began, with one person working on the fish and another writing the information onto the data sheet. The sampling for each individual specimen consisted of recording the following:

- Total length (to the millimetre).
- Total weight (to the centigram).
- Sex.
- Maturity state (according to the ICES scale of 2007 (ICES, 2007, WKMAT2007)).
- Stomach contents (according to the 2022 scale (Annex 21)).
- Eviscerated weight (to the centigram).

Moreover, after dissecting the fish, the otoliths and gonads were removed and stored according to the following protocol:

- Two otoliths were collected from individuals over 20 cm for each length class, sex, and region. For individuals under 20 cm, four otoliths were collected for each length class and region.
- Gonads were collected from two males and two females in each length class and region (North, Southwest, and South), along with the otoliths of all the individuals from which gonads were removed.

In addition to the samples collected for monitoring purposes, various tissue samples were collected for specific studies. These included fish eyeballs and muscle for population studies, and stomachs for trophic studies. Some of these were taken from randomly selected individuals until the required number was reached.

In order to gather data on the composition of catches (both landings and discards), trips were conducted on the purse seine vessels *Princesa de Sesimbra* and *Luis Adrião*, in the port of Sesimbra. Random samples were examined on board, and information regarding the size and weight of each species was collected. With the assistance of crewmembers, should it be required, the same information was collected on fish that were discarded, both on board the vessel and on land after triage. The data collected was processed in accordance with the protocol designed by PNAB (Annex 22). On land, the intern was able to assist with the biological sampling of sardines and hake, which involved measuring and weighing the specimens, as well as dissecting them to retrieve otoliths and gonads.

The activities developed enabled the intern to significantly broaden their skill set and gain valuable hands-on experience in a professional environment. By actively participating in a variety of tasks and responsibilities, the intern strengthened their analytical thinking, communication, teamwork and organisational skills. Furthermore, this experience offered an in-depth insight into the inner workings of a prestigious institution like IPMA, providing a comprehensive understanding of its strategic and operational processes. Through observing its internal processes and external engagements, the intern gained insight into how the institution manages resources effectively, coordinates stakeholders, and contributes to advancing best practice in project management globally.

6. References

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Legislation

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Annexes

Annex 1 - All existing unique entries present in the data.

Common name						
Atlantic horse mackerel	Angular roughshark	Wedge sole	Pollack	Large-eye dentex	Black angler	Neon flying squid
Atlantic Mackerel	Atlantic bonito	European hake	Murex	Common dolphinfish	Atlantic saury	African striped grunt
Chub Mackerel	Lusitanian toadfish	Picarels nei	Allis shad	Knobbed triton	Trumpetfish	Tonguesole nei
European squid	Thickback soles nei	Spinous spider crab	Rock cook	Wolffishes nei	Striped venus	Mediterranean moray
Sardine	Common cuttlefish	Pargo Aémea	Sea lamprey	Gulper shark	Dogfishes nei	Grey triggerfish
Soles nei	Roncadores nep	Surmullet	Forkbeard	Escolar	Purple dye murex	Flyingfishes nei
Sand sole	Marine fishes nei	Gray weakfish	Angler	Kitefin shark	Donax clams nei	Greater amberjack
Seabreams nei	Meagres nei	Piper gurnard	Combers nei	European lobster	Spotted ray	West African goatfish
Black seabream	European anchovy	Common eagle ray	European flounder	Bean solen	Common octopus	Scup
Bogue	Spotted seabass	Torpedo rays	Monkfishes nei	Saithe	Butterfly rays nei	Roundnose grenadier
Sand steenbras	Hammerhead sharks nei	Marlins nei	Twaite shad	Pargo Semea	Red gurnard	Monrovia doctorfish
Raja rays nei	Blue shark	Bullet tuna	Brill	Dentex nei	Blonde ray	Bigeye tuna
Seabasses nei	White seabream	Leerfish	Poor cod	Sompat grunt	Velvet swimcrab	Dusky grouper
Mulletts nei	Annular seabream	True tunas nei	Megrim	Splendid alfonsino	Smooth callista	Thickback sole
Salema	Plain bonito	Stingrays nei	Atlantic bluefin tuna	Bigeye grunt	Smooth-hound	Eels nei
Garfish	European seabass	Bluemouth rockfish	Blackbelly rosefish	Rubberlip grunt	Pata roxa denisa	Black cardinal fish
Blue jack mackerel	Red porgy	Smooth-hounds nei	Thresher	Greater forkbeard	Greater weever	Orange roughy
Common two-banded seabream	Zebra seabream	Spiny butterfly ray	Swordfish	Picked dogfish	Starry smooth-hound	Atlantic herring
Gilthead seabream	Meagre	Thornback ray	Sand smelt	European barracuda	Horned octopus	Saddled seabream
Sharpsnout seabream	Pouting	Silvery John dory	Angels sharks nei	Boe drum	Banded carpet shell	Undulate ray
Jacks nei	Triggerfishes nei	Red pandora	Tub gurnard	Stargazers nei	Grenadiers nei	Rainha Senegal
Octopuses nei	John dory	Common dentex	Silver scabbardfish	Barnacle	Four-spot megrim	Red mullet
Morays nei	False scad	Skipjack tuna	Shortfin squids nei	Hakes nei	Redbanded seabream	Longnosed skate
European conger	Bluefish	Seerfishes nei	Portuguese dogfish	Atlantic salmon	Albacore	Red scorpionfish
Porgies nei	Swallowtail seaperch	Linguado Ferrugento	Shortfin mako	Greenland shark	Cantarihos do Norte nep	Thicklip grey mullet
Common pandora	Common sole	Lefteye flounders nei	Alfonsinos nei	Groupers nei	Crevalle jack	Small-eyed ray
Surmullets nei	Marine molluscs nei	Forkbeards nei	White hake	Sandy ray	Rainbow wrasse	Sword razor shell
Axillary seabream	Blacksport seabream	nursehounds nei	Scorpionfishes	Yellowtail amberjack	Mediterranean horse mackerel	West African croakers nei
Blue butterflyfish	Weevers nei	rockfishes nei	Blackmouth catshark	Black scabbardfish	Fish roe	Stony sea urchin
Blue whiting	Turbot	Wreckfish	Yellowfin tuna	Sturgeon	Alfonsino	Golden redfish
Mediterranean slimehead	Large-scaled gurnard	Pandalid shrimps nei	Leafscale gulper shark	Longfin yellowtail	Birdbeak dogfish	Bluespotted seabream
Atlantic cod	Plesionika shrimps nei	Amberjacks nei	Senegalese hake	Green crab	Henslow's swimming crab	Common spiny lobster
Spiny lobsters nei	Atlantic white marlin	Cuckoo ray	Atlantic sailfish	Morocco dentex	Senegalese sole	White grouper
Mediterranean scaldfish	Longnose velvet dogfish					

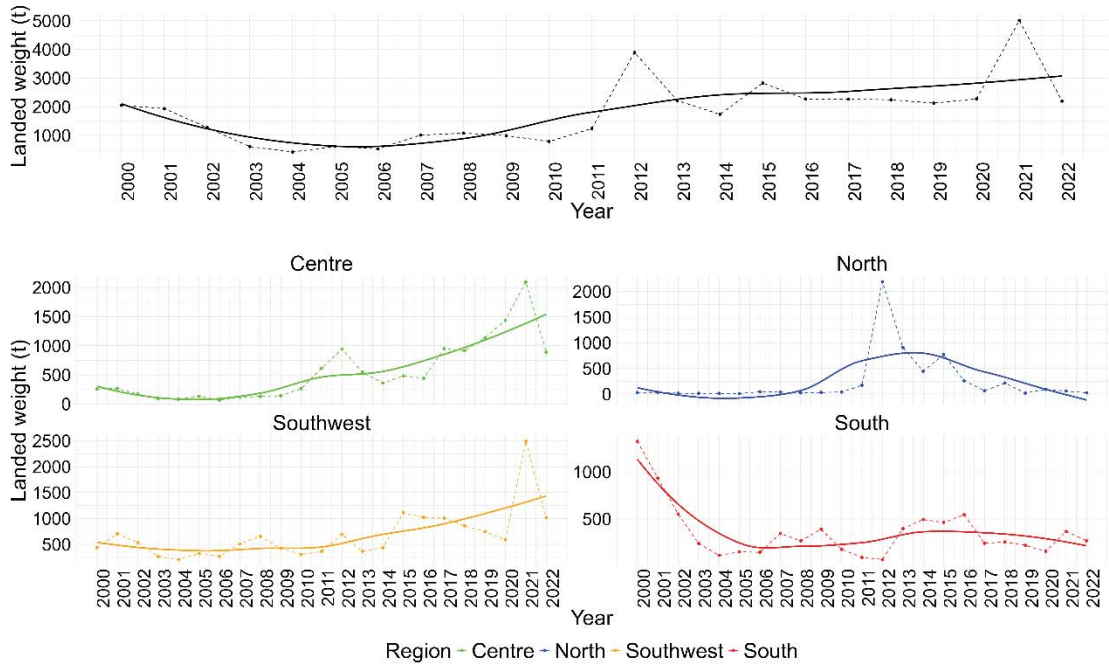
Annex 2 - Extended table for total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) for the main species caught on purse-seiners in Continental Portugal between 2013 and 2022.

Species	Mean % of sale	Total value of sales (€)	SD	Cumulative mean % of sale
Sardine	49.94	257479.68	6433.11	49.94
European anchovy	17.98	94193.27	5346.43	67.91
Chub Mackerel	14.87	77361.95	2561.01	82.79
Atlantic horse mackerel	11.12	59574.74	2774.15	93.91
Blue jack mackerel	1.33	7177.03	506.12	95.24
Axillary seabream	1.03	5229.23	301.77	96.27
Atlantic bonito	0.67	3471.01	164	96.94
White seabream	0.48	2391.46	136.29	97.42
Common two-banded seabream	0.40	1989.78	58.98	97.82
Gilthead seabream	0.33	1703.38	64.87	98.15
Mullets nei	0.23	1168.87	94.79	98.37
Mediterranean horse mackerel	0.16	815.55	32.41	98.53
Common octopus	0.15	800.44	49.5	98.68
Atlantic Mackerel	0.14	764.48	56.53	98.82
Bogue	0.14	705.01	31.32	98.96
Meagre	0.13	665.8	66.28	99.09
Black seabream	0.11	531.65	27.89	99.20
European seabass	0.10	472.64	30.22	99.29
Common pandora	0.08	409.65	11.76	99.37
Sand steenbras	0.05	280.57	27.98	99.43

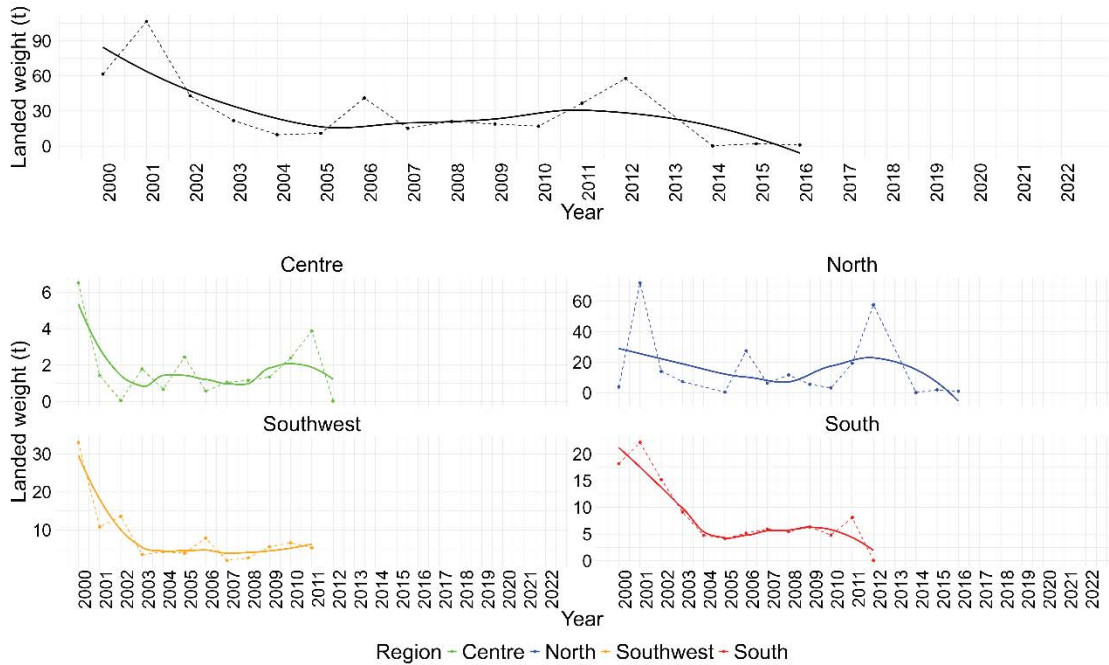
Annex 3 - Extended table for total landings in value, mean and standard deviation (SD) of the percentage and cumulative percentage of landings in value (€) for the main species caught on purse-seiners in Continental Portugal between 2000 and 2022.

Species	Mean % of sale	Total value of sales (€)	SD	Cumulative mean % of sale
Sardine	65.46	670491263.38	6095835.29	65.46
Chub Mackerel	10.24	114466510.97	3338688.37	75.70
Atlantic horse mackerel	9.44	104541751.49	2437340.79	85.14
European anchovy	9.13	107547471.14	5503665.2	94.27
Axillary seabream	1.04	10848928.82	272295.11	95.30
Blue jack mackerel	0.80	9384564.33	443044.03	96.11
Common two-banded seabream	0.51	5203650.01	93361.36	96.62
Atlantic bonito	0.43	4748735.66	176891.12	97.05
Gilthead seabream	0.34	3515031.65	61886.08	97.39
White seabream	0.32	3407430.66	125113.73	97.71
Mulletts nei	0.19	2321016.96	206551.54	97.90
Sand steenbras	0.18	1896260.45	108949.03	98.08
Black seabream	0.17	1735044.69	41633.23	98.26
Marine fishes nei	0.16	831685.16	176203.14	98.41
Meagre	0.15	1518817.14	68090.27	98.56
Atlantic Mackerel	0.15	1630907.95	59199.28	98.71
Mediterranean horse mackerel	0.12	967868.91	41834.42	98.83
Seabasses nei	0.12	507572.98	46341.91	98.95
Bogue	0.11	1215736.39	40696.01	99.06
Seabreams nei	0.10	659213.95	42450.8	99.16

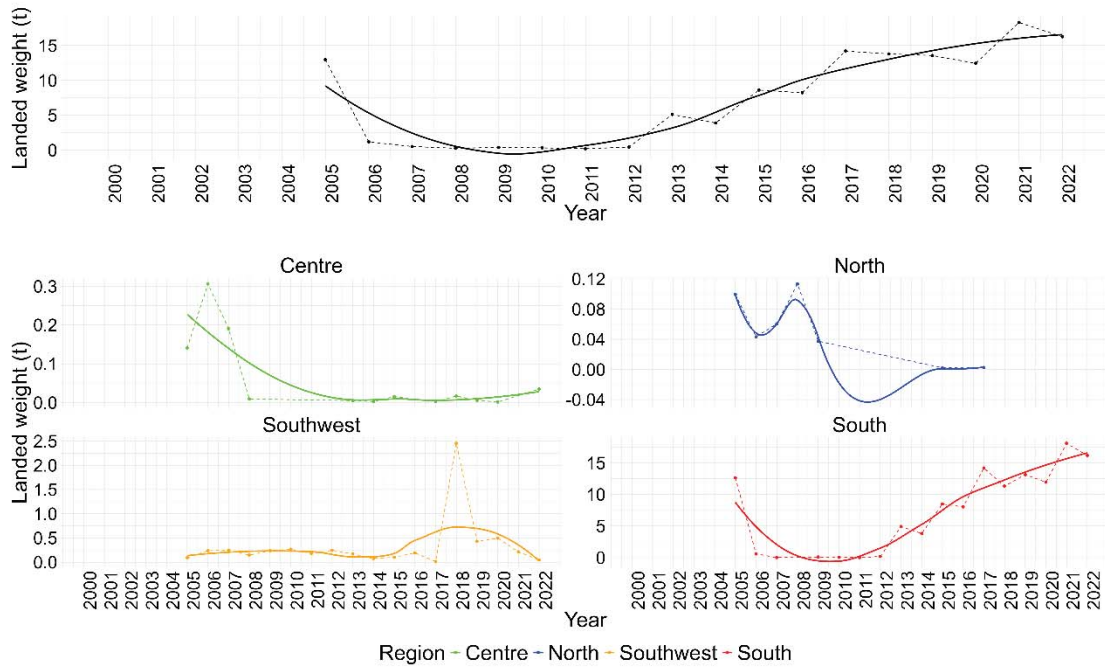
Annex 4 - Locally estimated scatterplot smoothing trend for Others between 2000 and 2022, showing the total weight sold in tonnes per year.



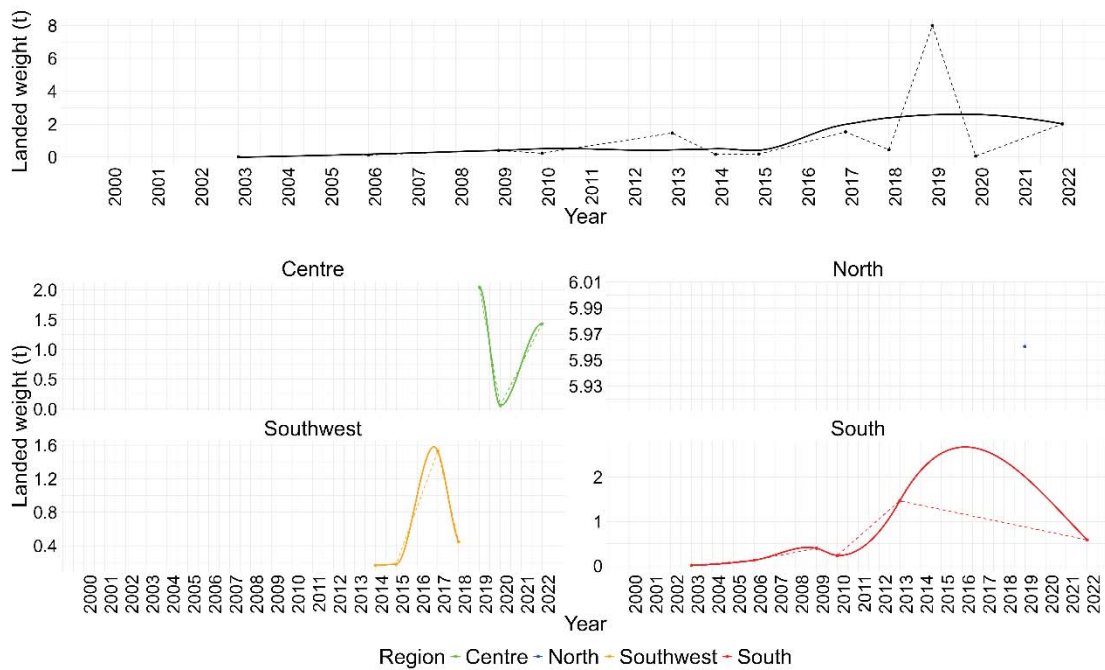
Annex 5 - Locally estimated scatterplot smoothing trend for mullets nei, between 2000 and 2022, showing the total weight sold in tonnes per year.



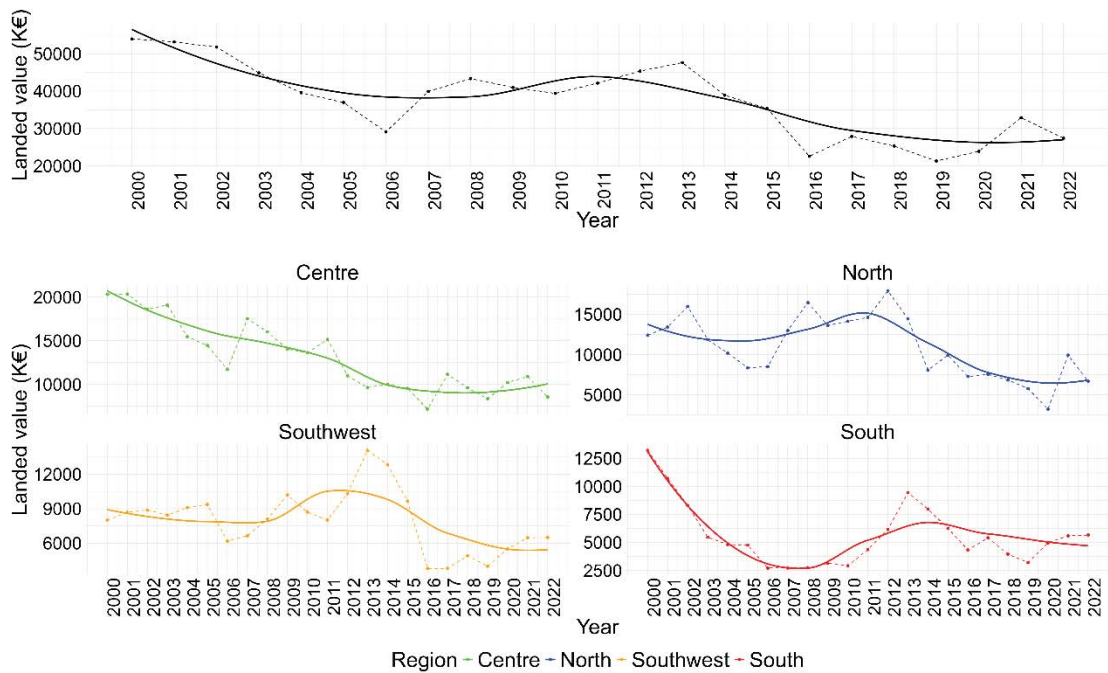
Annex 6 - Locally estimated scatterplot smoothing trend for common octopus between 2000 and 2022, showing the total weight sold in tonnes per year.



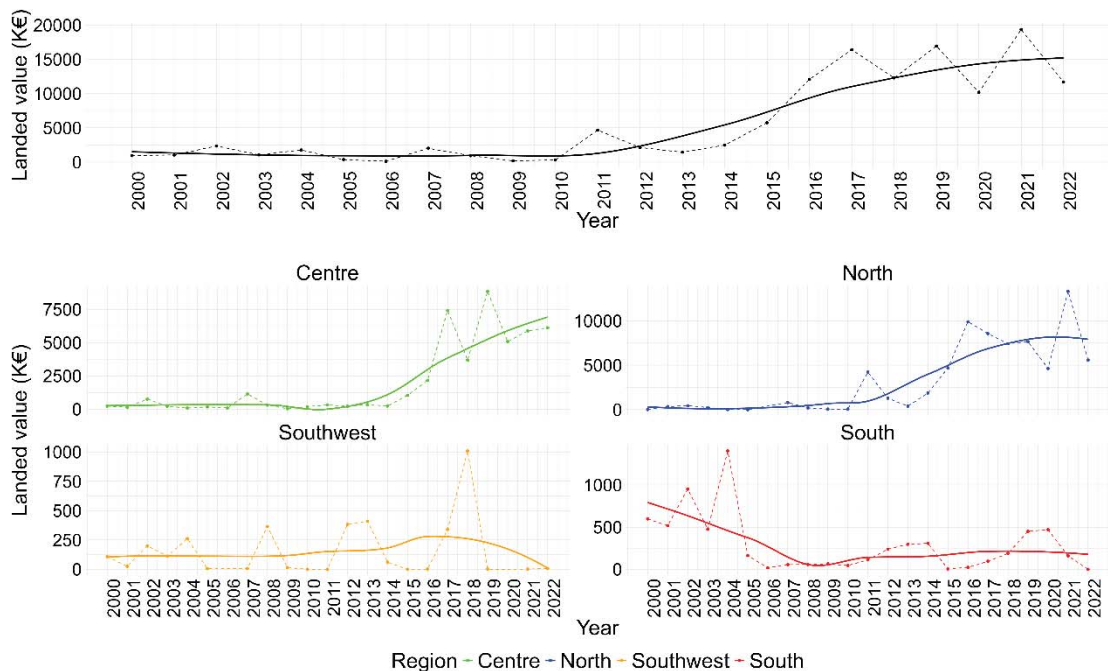
Annex 7 - Locally estimated scatterplot smoothing trend for Atlantic bluefin tuna between 2000 and 2022, showing the total weight sold in tonnes per year.



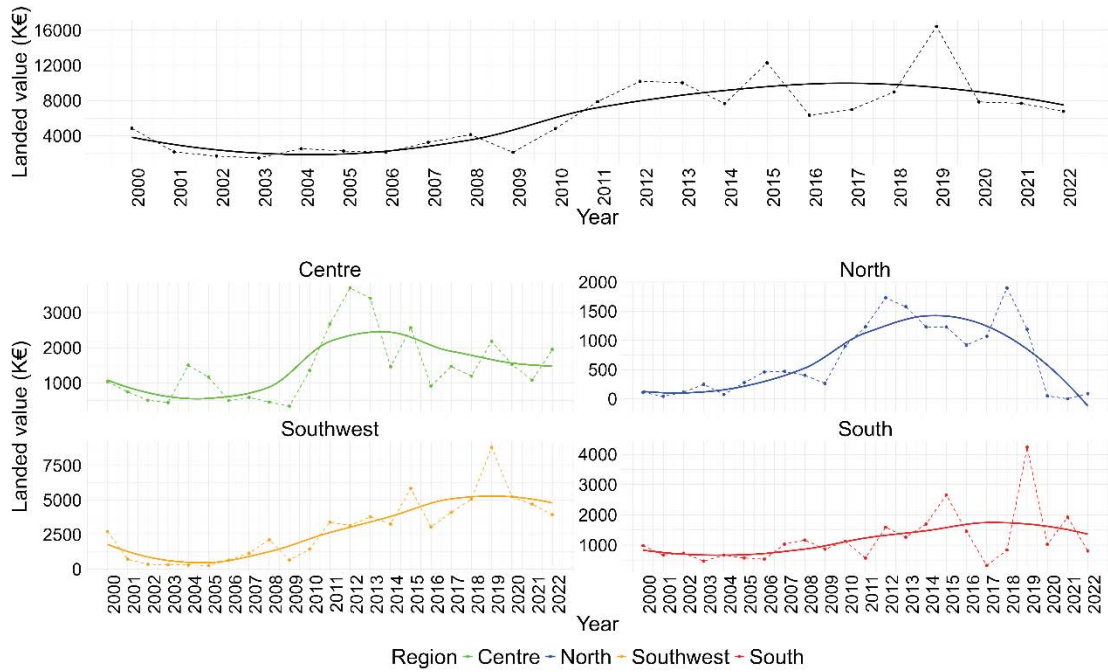
Annex 8 - Locally estimated scatterplot smoothing trend for sardines between 2000 and 2022, showing the total first sale value in thousands of euros per year.



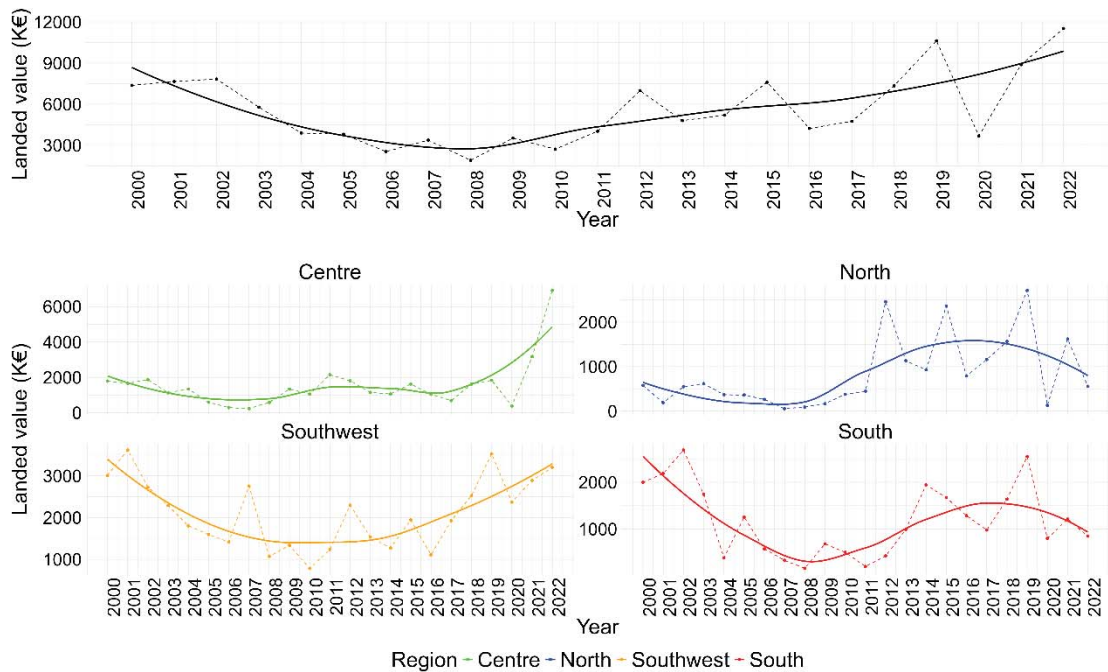
Annex 9 - Locally estimated scatterplot smoothing trend for European anchovy between 2000 and 2022, showing the total first sale value in thousands of euros per year.



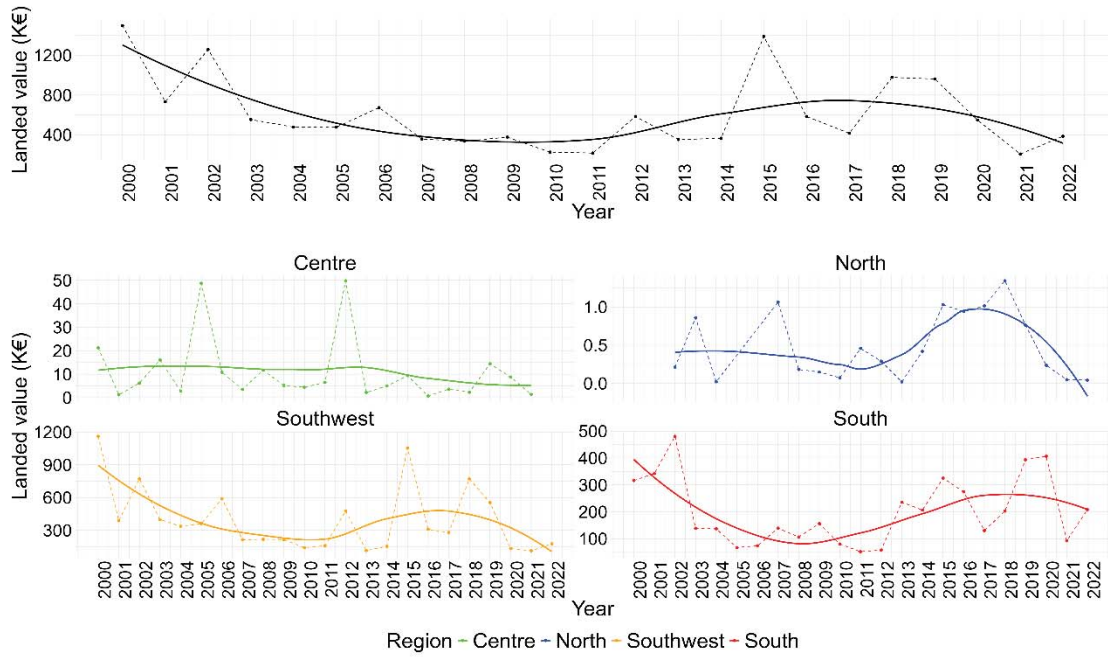
Annex 10 - Locally estimated scatterplot smoothing trend for chub mackerel between 2000 and 2022, showing the total first sale value in thousands of euros per year.



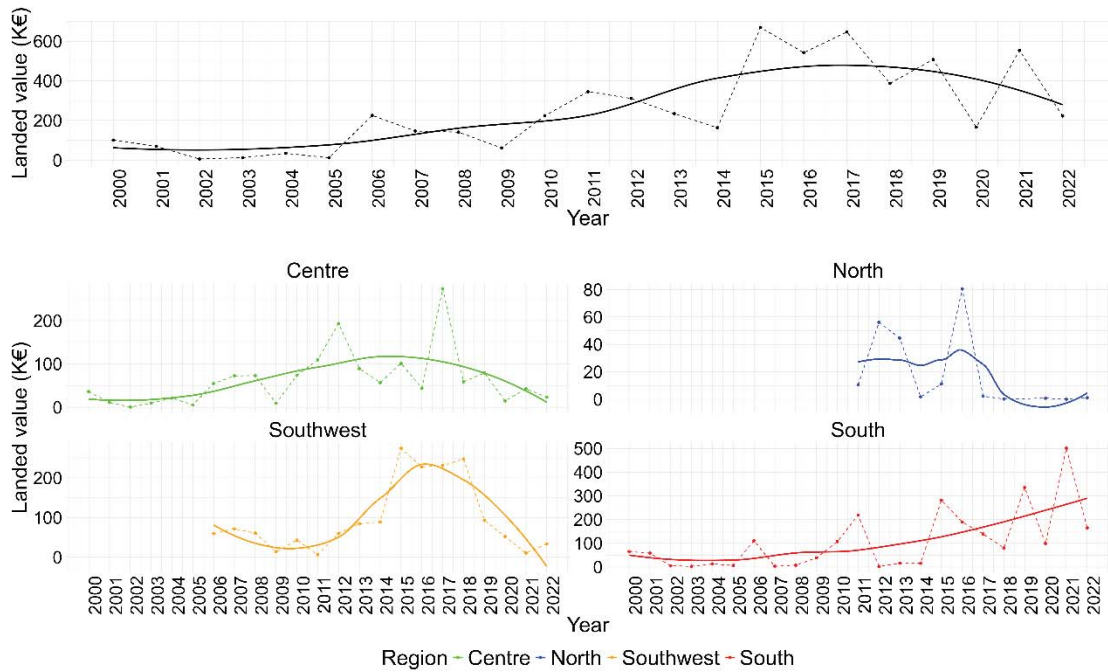
Annex 11 - Locally estimated scatterplot smoothing trend for Atlantic horse mackerel between 2000 and 2022, showing the total first sale value in thousands of euros per year.



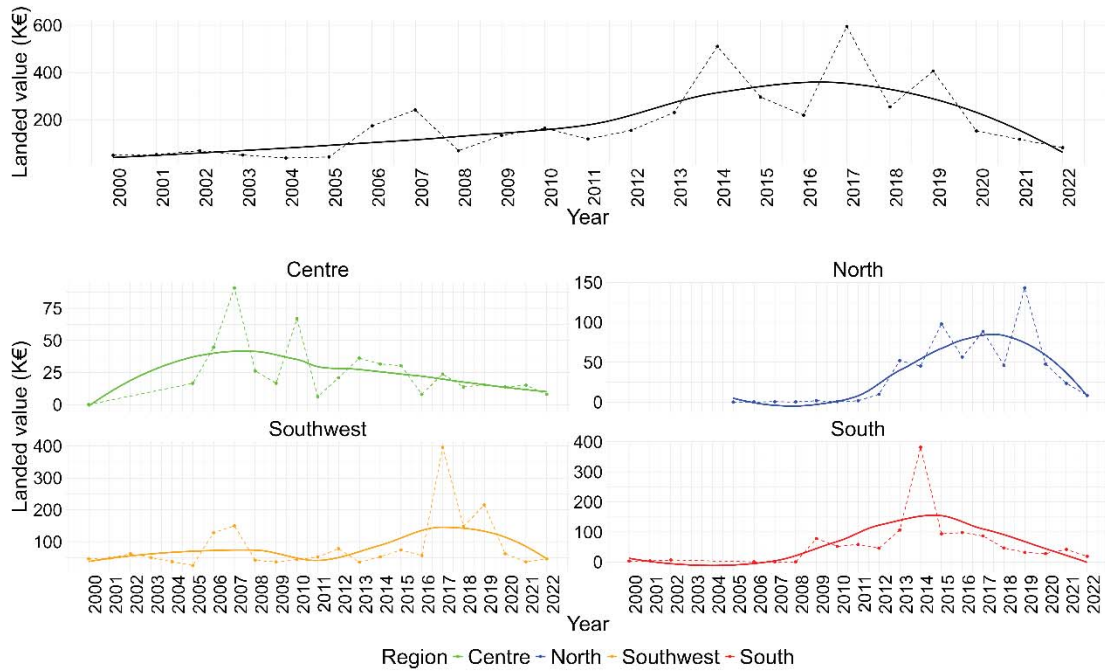
Annex 12 - Locally estimated scatterplot smoothing trend for axillary seabream between 2000 and 2022, showing the total first sale value in thousands of euros per year.



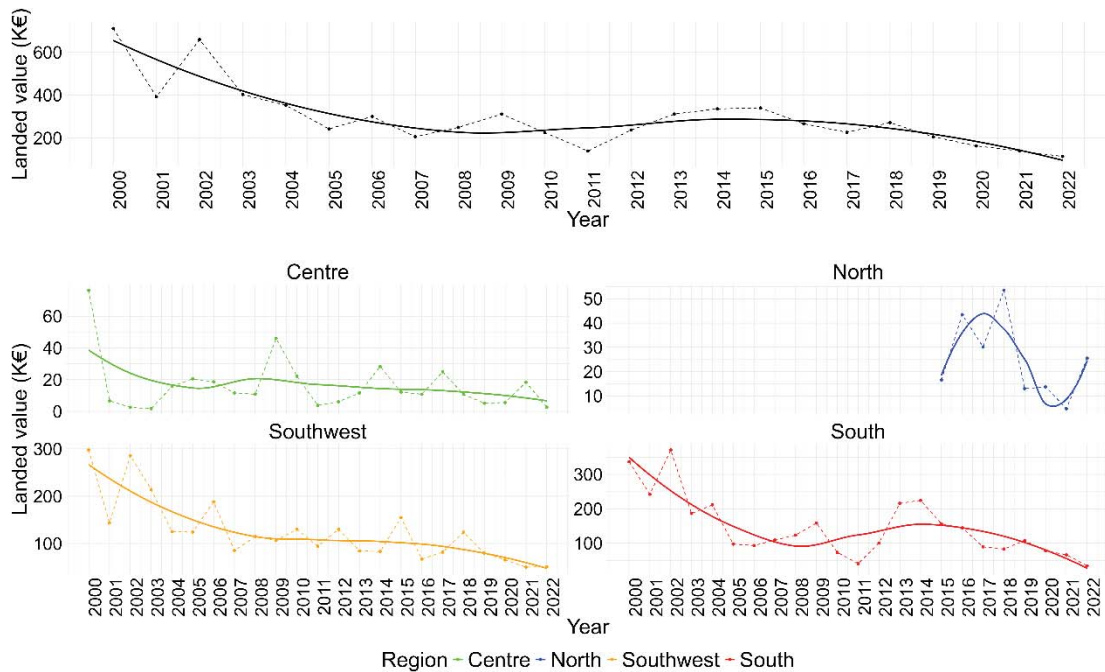
Annex 13 - Locally estimated scatterplot smoothing trend for Atlantic bonito between 2000 and 2022, showing the total first sale value in thousands of euros per year.



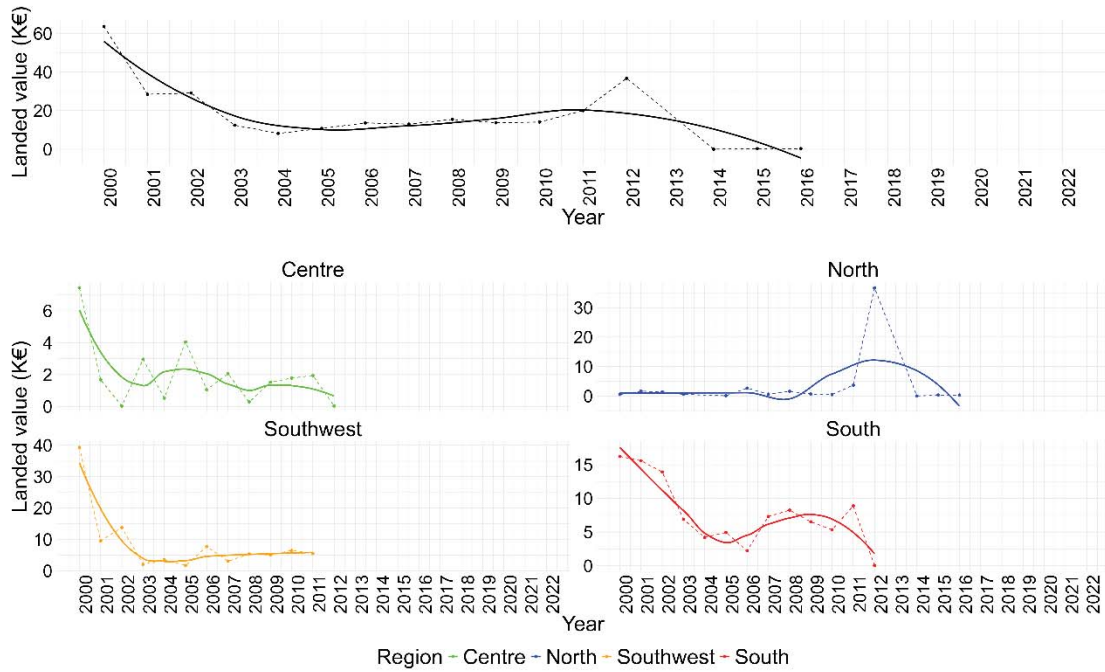
Annex 14 - Locally estimated scatterplot smoothing trend for white seabream between 2000 and 2022, showing the total first sale value in thousands of euros per year.



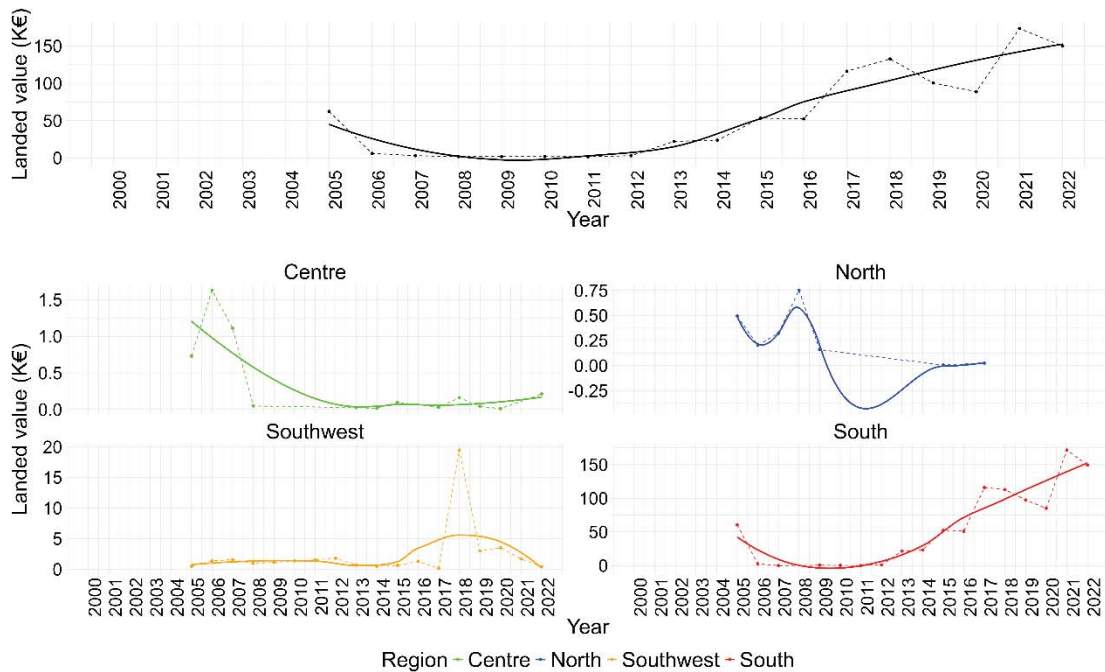
Annex 15 - Locally estimated scatterplot smoothing trend for Common two-banded seabream between 2000 and 2022, showing the total first sale value in thousands of euros per year.



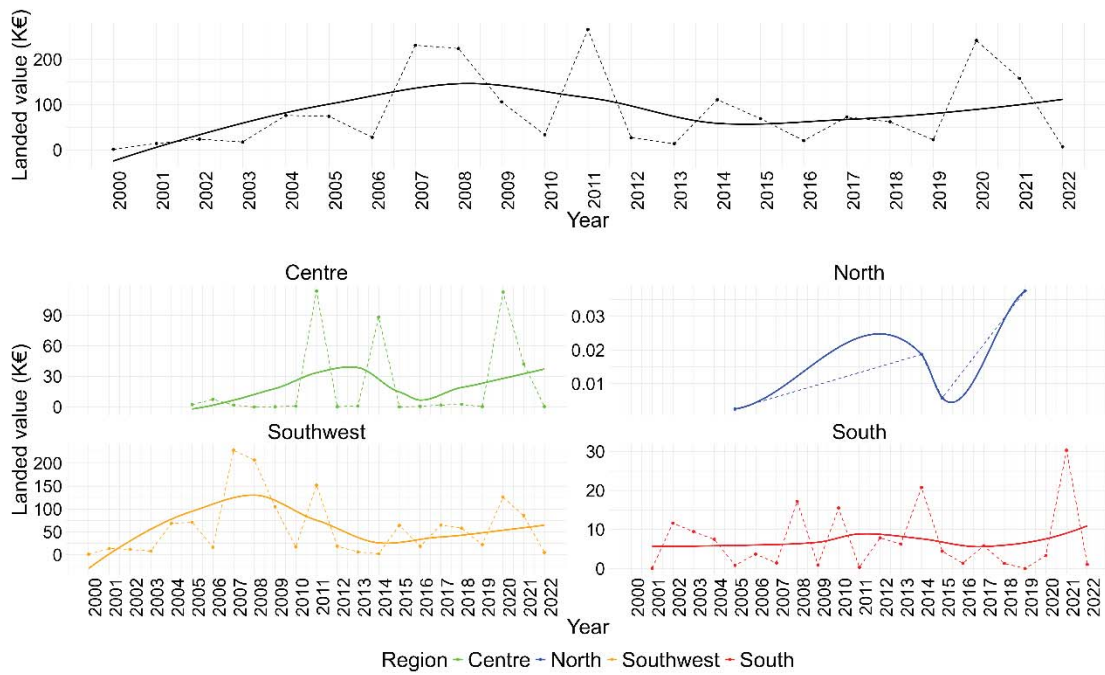
Annex 16 - Locally estimated scatterplot smoothing trend for mullets nei. between 2000 and 2022, showing the total first sale value in thousands of euros per year.



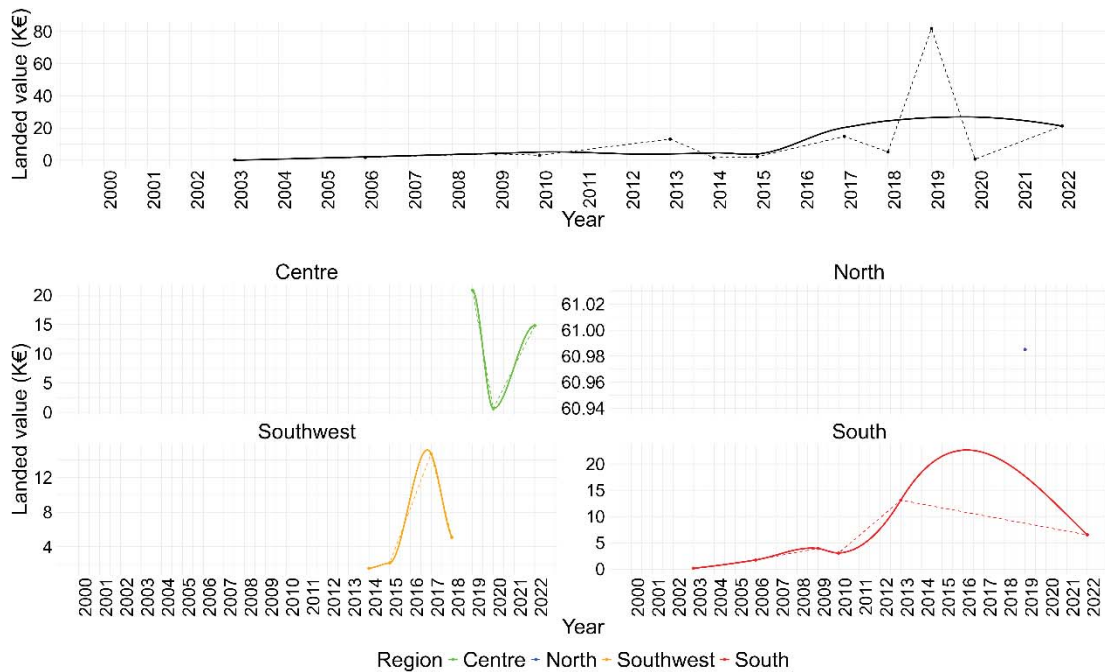
Annex 17 - Locally estimated scatterplot smoothing trend for common octopus between 2000 and 2022, showing the total first sale value in thousands of euros per year.



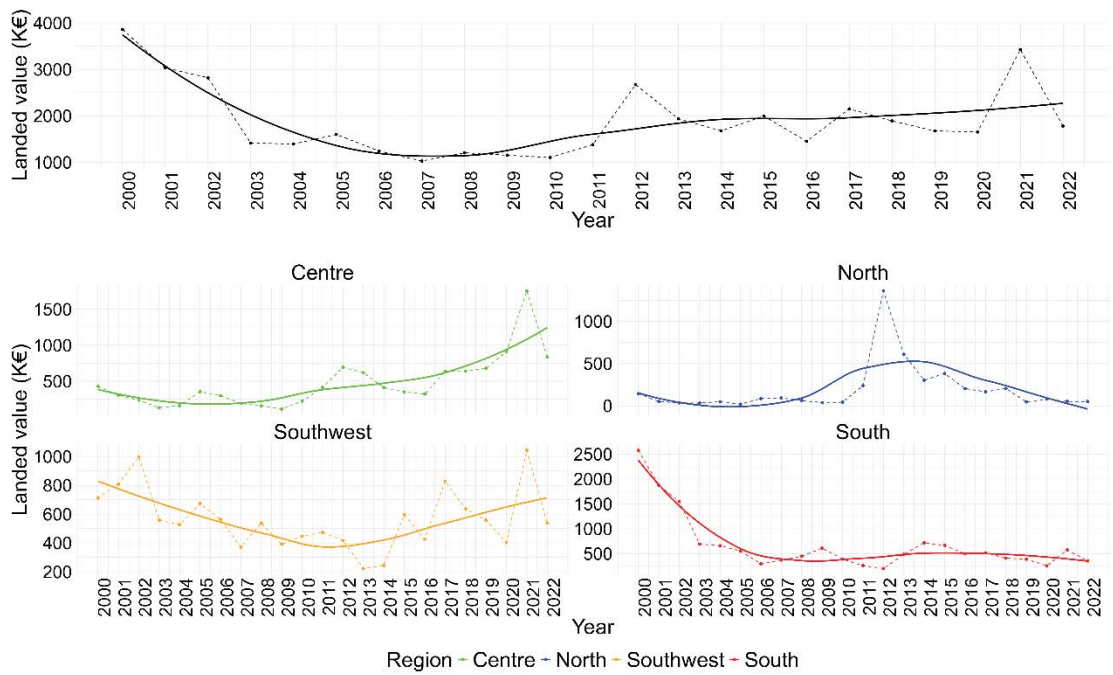
Annex 18 - Locally estimated scatterplot smoothing trend for meagre between 2000 and 2022, showing the total first sale value in thousands of euros per year.



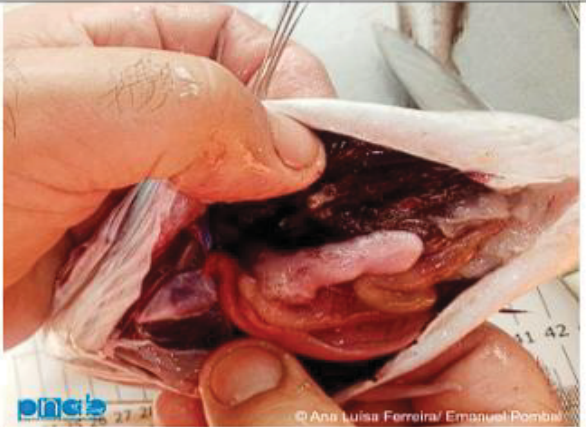

Annex 19 - Locally estimated scatterplot smoothing trend for Atlantic bluefin tuna between 2000 and 2022, showing the total first sale value in thousands of euros per year.






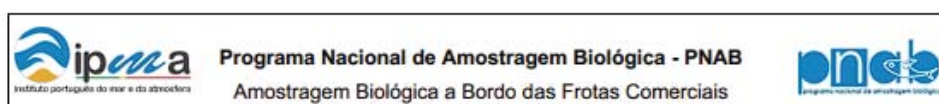
Annex 20 - Locally estimated scatterplot smoothing trend for Others between 2000 and 2022, showing the total first sale value in thousands of euros per year.



Escala de enchimento do estômago

Estado do Estômago		Descrição	Imagem
1	Vazio	Estômago sem conteúdo	
2	Meio cheio	Estômago com conteúdo ocupando até cerca de metade (<50%) da sua capacidade.	
3	Cheio	Estômago com conteúdo ocupando mais de metade (>50%) da sua capacidade. Se for possível, registar a espécie e comprimento da espécie. Caso não seja registar RP – restos de peixe; RC – Restos de crustáceos.	
4	A rebentar	Estômago com mais de metade da sua capacidade ocupada. Se for possível, registar a espécie e comprimento da espécie. Caso não seja registar RP – restos de peixe; RC – Restos de crustáceos.	

			
5	Evaginado	Estômago sai pela boca do peixe.	
6	Ingerido na operação de pesca	Peixe ou outro organismo marinho que se encontra no estômago em estado fresco, sem sinais de digestão prévia.	

**Folha de Cerco****Resumo da viagem:**

Nome da embarcação: _____ Nome do Mestre: _____
 Matrícula: _____ Potência do motor: _____ (kW/cv)
 Porto de Embarque: _____ Porto de desembarque: _____
 Data do início da viagem: ___/___/___ Data do fim da viagem: ___/___/___
 Hora do início da viagem: _____ Hora do fim da viagem: _____
 Rede de pesca: Malhagem da rede (mm): _____ Comprimento x altura (m): _____
 Captura total: _____ (kg) Valor (€): _____
 Desembarque: _____ (kg/caixa) Caldeirada: _____ (kg)
 Rejeições: _____ (kg/caixa) Rejeição (bordo) Rejeição (cais)
 Slipping: _____ (kg/caixa) 1 caixa = _____ (kg)
 Amostra c/ destino laboratório: sim não Nome do Observador: _____

Resumo do Lance de Pesca:

Data: ___/___/___ Lance nº: ___ de ___ Local de pesca: _____
 Início **largada**: Posição Geográfica: Lat. _____ N Long. _____ W Prof.: _____ m/br
 Fim **transbordo**: Posição Geográfica: Lat. _____ N Long. _____ W Prof.: _____ m/br
 Tipo de Fundo: Rochoso Arenoso Escala Beaufort: _____
 Transferência p/outras embarcações: Sim Não Nome: _____ kg/cx
 Marcação na sonda: Pouca Moderada Intensa Espécie Prevista: _____

Operações:	Hora início	Hora fim	Observações
Navegação 1			Ex: Razões Paragem da Pesquisa? N ^o de outras embarcações no mesmo pesqueiro, etc
Pesquisa (sonar ligado)			
Largada da rede			
Viragem da retenida			
Alagem da rede			
Enxugar a rede			
Transbordo do Pescado			
Paragem para descanso			
Navegação 2			Temp. Água (°C):

Comprimentos (cm)



Informação da viagem: Matrícula: ___ - ___ - ___ Nome Navio: _____
Data Partida: ___/___/___ Data Chegada: ___/___/___

Informação sobre o lance:

Lance nº: ___ Data: ___/___/___/___/___/___

Espécie: _____ Cod. FAO: _____	
Captura <input type="checkbox"/> Slipping <input type="checkbox"/> Desemb. <input type="checkbox"/> Caldeirada <input type="checkbox"/>	
Rejeição (bordo) <input type="checkbox"/> Rejeição (cais) <input type="checkbox"/>	
cm	Nº de indivíduos
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	nº ind.: _____ peso: _____ kg
Peso Fracção (kg):	

Espécie: _____ Cod. FAO: _____	
Captura <input type="checkbox"/> Slipping <input type="checkbox"/> Desemb. <input type="checkbox"/> Caldeirada <input type="checkbox"/>	
Rejeição (bordo) <input type="checkbox"/> Rejeição (cais) <input type="checkbox"/>	
cm	Nº de indivíduos
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	nº ind.: _____ peso: _____ kg
Peso Fracção (kg):	

Comprimentos (0,5 cm)



Informação da viagem:

Matrícula: ___ - ___ - ___ Nome Navio: _____

Data Partida: ___ / ___ / ___ Data Chegada: ___ / ___ / ___

Informações sobre o lance:

Lance nº: ___ Data: ___ / ___ / ___ / ___ / ___

Espécie: _____ Cod. FAO: _____	
Captura <input type="checkbox"/> Slipping <input type="checkbox"/> Desemb. <input type="checkbox"/> Caldeirada <input type="checkbox"/>	
Rejeição (bordo) <input type="checkbox"/> Rejeição (cais) <input type="checkbox"/>	
cm	Nº de indivíduos
0	
0,5	
1	
1,5	
2	
2,5	
3	
3,5	
4	
4,5	
5	
5,5	
6	
6,5	
7	
7,5	
8	
8,5	
9	
9,5	
Total	nº ind.: _____ peso: _____ kg
Peso Fracção (kg):	

Espécie: _____ Cod. FAO: _____	
Captura <input type="checkbox"/> Slipping <input type="checkbox"/> Desemb. <input type="checkbox"/> Caldeirada <input type="checkbox"/>	
Rejeição (bordo) <input type="checkbox"/> Rejeição (cais) <input type="checkbox"/>	
cm	Nº de indivíduos
0	
0,5	
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1,5	
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2,5	
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4,5	
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6,5	
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7,5	
8	
8,5	
9	
9,5	
Total	nº ind.: _____ peso: _____ kg
Peso Fracção (kg):	