

Experimental Final Degree Project

SPATIOTEMPORAL PATTERNS OF DEMERSAL FISH ASSEMBLAGES ON THE DEEPER SHELF ALONG THE CATALAN COAST

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Degree in Biology

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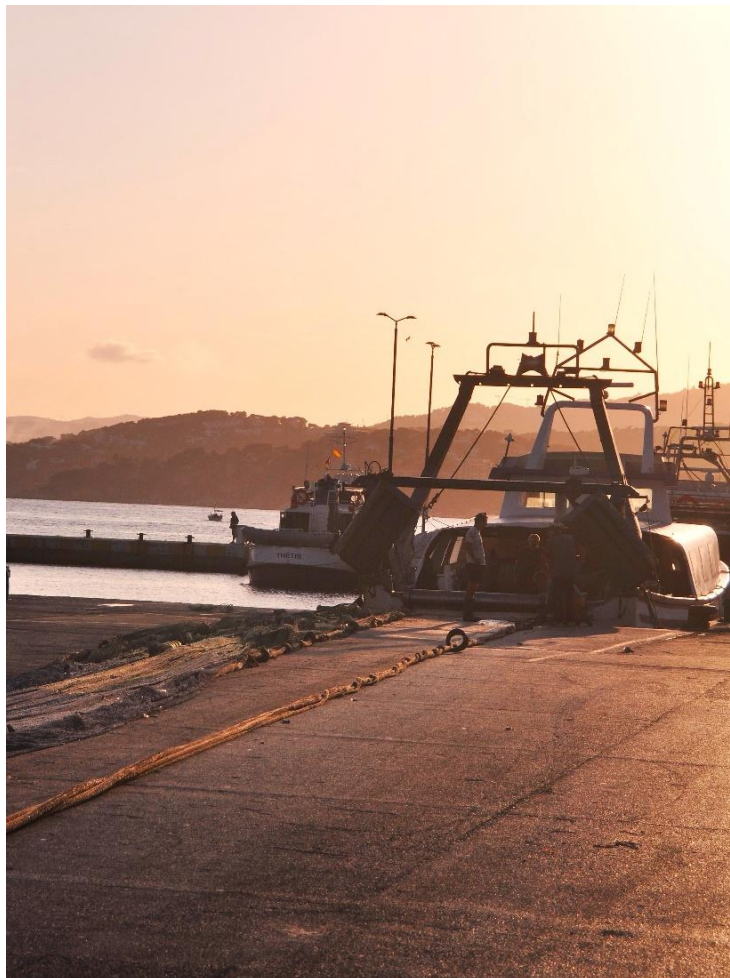


Figure 1. Trawling boat (Palamós). Author's own photograph (2020).

Summary

Title: SPATIOTEMPORAL PATTERNS OF DEMERSAL FISH ASSEMBLAGES ON THE DEEPER SHELF ALONG THE CATALAN COAST

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This study was conducted in the Catalan Coast (NW Mediterranean) in order to characterize the spatiotemporal variability of demersal fish assemblages on the deeper continental shelf (70–200 m) between 2019 and 2024. The analysis relies on data gathered by the Catalan Research Institute for the Governance of the Sea (ICATMAR) through the Catalan bottom trawling monitoring program which was launched in 2019. Using data from 196 commercial bottom trawling hauls, the aim of this study was to investigate spatial differences in fish assemblage among three zones (northern, central and southern) as well as temporal variability across years and seasons, using species richness, species composition, abundance and biomass as descriptors of fish assemblage structure. To assess these patterns, generalized linear models (GLMs) were applied to test differences among factors, while multivariate analyses (nMDS and ANOSIM) were used to explore differences in community structure, and SIMPER analysis was conducted to identify the species contributing most to observed dissimilarities between those communities. A total of 139 species were identified, reflecting high biodiversity on the deeper shelf. Spatial differences were detected between the southern and the other two zones. Seasonal variability was less pronounced, with significant differences mainly observed in abundance between winter and summer. A set of key species, including *Trachurus trachurus*, *Merluccius merluccius*, *Mullus barbatus* and *Engraulis encrasicolus*, among others, were the main contributors to the observed patterns, supporting the spatial differentiation between the different zones and contributing to interannual and intra-annual shifts in demersal fish assemblage composition.

Resum

Títol: PATRONS ESPACIOTEMPORALS DE LES COMUNITATS DE PEIXOS DEMERSALS DE LA PLATAFORMA PROFUNDA AL LLARG DE LA COSTA CATALANA.

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Data: Juny de 2026

Paraules clau: Comunitats de peixos demersals, Pesca d'arrossegament, Nord-oest del mar Mediterrani, Patrons espaiotemporals.

Aquest estudi s'ha dut a terme a la costa catalana (nord-oest del Mar Mediterrani) amb l'objectiu de poder caracteritzar la variabilitat espacio-temporal de les comunitats de peixos demersals a la plataforma continental profunda (70–200 m) entre els anys 2019 i 2024. Aquesta anàlisi s'ha basat en les dades obtingudes per l'Institut Català de Recerca per a la Governança del Mar (ICATMAR) en el marc del programa de monitoratge de la pesca d'arrossegament a Catalunya, iniciat l'any 2019. A partir de dades procedents de 196 pesques comercials d'arrossegament, l'objectiu d'aquest treball ha estat investigar les diferències espacials en les comunitats de peixos entre tres zones (nord, centre i sud), així com la variabilitat temporal al llarg dels anys i les estacions a través de l'estudi de la riquesa d'espècies, la composició d'espècies, l'abundància i la biomassa com a descriptors de l'estructura de les diferents comunitats. Per avaluar aquests patrons, s'han aplicat models lineals generalitzats (GLM) amb l'objectiu d'observar possibles diferències entre factors. S'ha fet servir també anàlisis multivariants (nMDS i ANOSIM) per explorar diferències en l'estructura de la comunitat. A més, per mitjà d'una anàlisi SIMPER s'han identificat les espècies que contribuïen en major mesura a les dissimilaritats observades entre aquestes. En total, s'ha identificat 139 espècies, fet que reflecteix una elevada biodiversitat a la plataforma profunda. S'han detectat diferències espacials entre la zona sud i les altres dues zones. La variabilitat estacional obtinguda va ser menys marcada, amb diferències significatives observades principalment en l'abundància entre l'hivern i l'estiu. Un conjunt d'espècies clau, entre les quals en destaquen *Trachurus trachurus*, *Merluccius merluccius*, *Mullus barbatus* i *Engraulis encrasicolus*, entre d'altres, van ser algunes de les que han contribuït més als patrons observats, reforçant doncs la diferenciació espacial entre zones i contribuint als canvis interanuals i intra-anuals en la composició de les comunitats de peixos demersals.

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1. Introduction

1.1. Mediterranean Sea and demersal fishes

The Mediterranean is considered one of the large marine ecosystems (LME) of the world, owing to its bathymetry, hydrography, productivity and trophic webs (Farriols et al., 2019). The biodiversity in the Mediterranean is therefore primarily shaped by its geographical position and the main connections with surrounding oceans, its geological history and the prevailing oceanographic conditions (Quetglas et al., 2019).

The Mediterranean Sea has been regarded as one of the world's "biodiversity hotspot", with an estimate of about 17.000 marine species (Coll et al., 2010). Most demersal organisms (i.e., organisms that live and feed on or near the seafloor) currently living in the Mediterranean Sea are of Atlantic origin. However, tropical species have been entering the basin for decades, either actively through the Suez Canal, or passively through ship transport (Coll et al. 2010). During the last few decades, both fishing exploitation and changes in environmental conditions, influenced by climate change, have affected the distribution and abundances of Mediterranean demersal species (Quetglas et al., 2019). For example, *Parapenaeus longirostris* underwent a northward latitudinal expansion between 2008 and 2020, a shift that was likely driven by increasing bottom-water temperatures and salinization of the seabed (Mingote et al., 2024).

In the study of marine demersal communities, depth has consistently been identified as one of the main factors influencing species composition, zonation, structure and biodiversity (Farré et al., 2016). The deeper continental shelf, defined in this study as the 70–200m depth range, may act as a key transition zone between shallow and deep environments, where demersal species with both shallow and deep distributions can co-occur, potentially leading to a "mid-domain effect". Owing to these characteristics, the Mediterranean deeper shelf, which largely overlaps with the mesophotic zone supports high levels of habitat complexity and biodiversity (Cerrano et al., 2019).

In NW Mediterranean, demersal fish assemblages inhabiting the deeper continental shelf are characterized by high biodiversity and exhibit clear shifts in species composition, abundance, and functional traits along the depth gradient (Farriols et al., 2019). These communities are typically dominated by commercially and ecologically important species such as the European hake (*Merluccius merluccius*), Red Mullet (*Mullus barbatus*) and Atlantic horse mackerel (*Trachurus trachurus*). From a trophic perspective, these assemblages encompass a wide range of feeding strategies, including lower trophic-level consumers that feed primarily on zooplankton and benthic invertebrates, such as *M. barbatus*, as well as higher-level predators such as *M. merluccius*, one of the main target species of Mediterranean bottom trawl fisheries (Balcells-Surroca, 2016).

The trophic structure of these assemblages is shaped by a wide range of morphological and functional traits associated with feeding behaviour, mobility, and resource use, promoting species coexistence and contributing to community organization (Farré et al., 2016). Despite the high functional diversity observed within this depth range, which provides a degree of functional redundancy among species, these assemblages remain highly susceptible to fishing pressure, which can modify species composition and disrupt trophic interactions (Coll et al., 2010).

1.2. Trawl fisheries in the Catalan Sea

The fishing sector represents an important component of the coastal economy and maritime cultural heritage of Catalonia, playing a significant role in employment generation, seafood supply, and the socioeconomic stability of many coastal communities (Colloca et. al., 2003). Although the Catalan fishing fleet comprises a wide variety of fishing modalities, such as purse seine, trammel nets and bottom or pelagic longlines, among others. Bottom trawl fisheries are one of the most economically important sectors, representing the main contributor to the total economic revenue generated by the Catalan fishing sector (ICATMAR, 22-04). This importance is largely due to the high commercial value of target species such as European hake (*Merluccius merluccius*), deep-water rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*) and red shrimp (*Aristeus antennatus*) (ICATMAR, 25-05).

A bottom trawling system fundamentally consists of a funnel-shaped net, generally towed by a single fishing vessel, in which organisms located along the trajectory of the gear are guided towards the cod-end where they are retained. The vertical opening of the net is maintained by buoyant elements attached to the headline, whereas the footrope incorporates chains or weights to ensure contact with the seabed. Horizontal opening is achieved through otter boards, whose hydrodynamic resistance causes the lateral spread of the gear during towing (Figure 2).

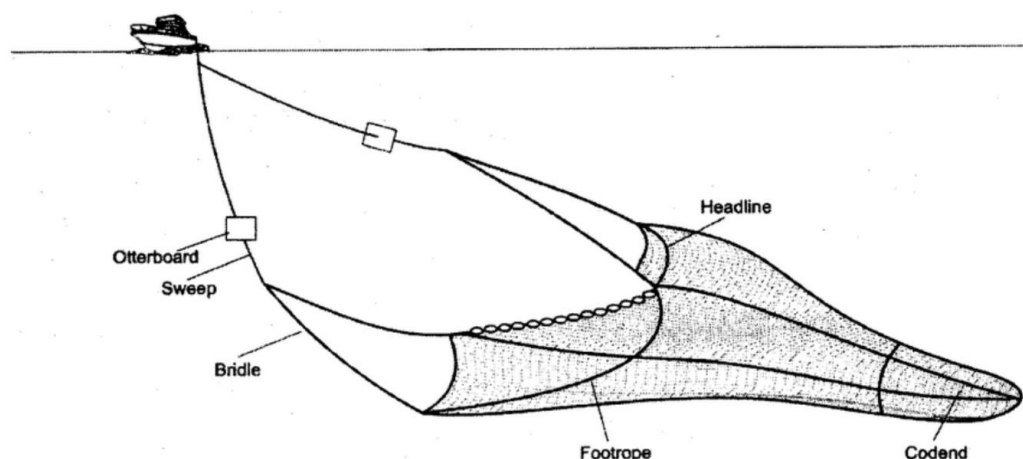


Figure 2. Trawling fishing net and its parts. Extracted from Researchgate.net, Biju Kumar, 2006. Copyright.

Despite its economic importance, bottom trawling is widely recognized as one of the fishing activities with the greatest ecological impact on marine ecosystems (McConnaughey et al., 2020). The interaction between trawl gear and the seabed generates significant physical disturbance, including habitat alteration and degradation, sediment resuspension, increased water turbidity, and modifications to seafloor morphology such as berms and furrows (Tuset et al., 2021). These impacts affect sediment structure, benthic and demersal communities, and associated biological interactions, particularly influencing filter feeders, visually oriented predators, and burrowing organisms, while also altering food-web dynamics and life-history strategies of demersal species (Margalef & J Albaigés, 1989). In addition, the increasing fishing efficiency achieved through technological advancements over recent decades has intensified concerns regarding the overexploitation of demersal resources in the NW Mediterranean (Demirel et al., 2023).

Along the Catalan coast, several technical reports and scientific assessments developed by ICATMAR have highlighted the need to reconcile fishing activities with marine ecosystem conservation, particularly within the framework of the Western Mediterranean Multiannual Plan for demersal fisheries (MAP; Regulation EU 2019/1022), which aims to reduce fishing mortality and promote the sustainable management of marine fishery resources. The need for comprehensive assessments is further reinforced by recent management measures affecting the bottom trawl fishery, including reductions in fishing effort, spatiotemporal closures, gear selectivity regulations, and the incorporation of low-impact technologies designed to reduce seabed disturbance (Bahamon et al., 2024; Carretón et al., 2025; Tuset et al., 2021; Vigo Fernandez et al., 2023). One of the most significant technical measures introduced in Mediterranean trawl fisheries has been the modification of cod-end mesh configuration. Since 2010, the use of 40 mm square meshes has progressively replaced traditional diamond-shaped meshes in order to improve selectivity and facilitate the escape of juvenile individuals. The Catalan trawling fleet has also a daily fishing limit of 12 hours (BOE 1440/1999) and land its catches daily. Fish sales take place at the auctions upon the vessels' arrival. All implemented management measures in bottom trawl fisheries aim to reduce fishing mortality on immature specimens and contribute to the recovery and sustainability of exploited populations.

1.3. Temporal and spatial variability in the Catalan Sea

The Catalan Sea is characterised by a well-defined seasonal variability, with relatively cold winters in the north and long hot summer periods in the south that are almost like those of subtropical regions (Coll et al., 2010). This latitudinal gradient marks the distribution of the species and their exploitation; where in the Catalan coast, the species present are typical of colder waters (Calvo et al., 2011). Nevertheless, fish and benthic species from warmer southern Mediterranean waters are expanding their distribution ranges northward, with more than 30 native warm-water fish species now recorded beyond their original geographic range or showing shifts in their distribution patterns (CIESM, 2008; Calvo et al., 2011).

In the Catalan Sea variability occurs due to an enrichment caused by regional wind conditions, a seasonal thermocline, a slope-shelf current and riverine inputs. These natural characteristics have a significant influence on primary and secondary productivity, and therefore on the fishing productivity of the area (Coll et al., 2008). Temporal trends in the NW Mediterranean highlight changes in the main drivers of biodiversity loss over time. While overexploitation and habitat loss were historically the most important pressures, current impacts are dominated by habitat loss and degradation, alongside fishing, pollution, climate change, eutrophication, and the spread of alien species (Coll et al., 2010).

Analysing seasonality is essential, particularly in multi-species fisheries such as bottom trawling, where species with different life-history strategies and biological processes (e.g. reproduction and recruitment) may occur at different times of the year. For example, the life cycle of red mullet (*Mullus barbatus*) is characterized by a marked spawning peak in spring, whereas recruitment occurs later in the year, mainly during autumn (Gücü & BiNgel, 2022; Lombarte et al., 2000; Tserpes et al., 2002). Consequently, depending on the season, trawling fisheries may affect both spawning adults and recruiting juveniles, influencing their abundance, biomass and population structure (Sala-Coromina et al., 2021). Similarly, the European hake (*Merluccius merluccius*) exhibits marked interannual variability. Although it is a batch-spawning species, reproducing through multiple spawning events throughout the year, recruitment peaks have been observed during spring and summer in some years (ICATMAR, 21-02, 24-05).

Regarding the spatial variability, the Catalan Sea presents a cyclonic circulation with a permanent south-westerly current, the North Current (also known as the Ligurian-Provençal-Catalan Current), which flows from the Ligurian Sea (north-west of Italy) to the Catalan Sea and follows the continental slope. The distribution of living species and communities at the sea is determined by a combination of large-scale biogeographic history, migration patterns and environmental conditions (Calvo et al., 2011). Consequently, demersal communities often exhibit marked spatial variability associated with depth gradients, substrate type, hydrodynamic conditions, productivity patterns, and habitat heterogeneity. Understanding this spatial variability is particularly important in mixed fisheries, as species respond differently to environmental gradients and anthropogenic pressures such as bottom trawling. Therefore, analysing spatial patterns in demersal assemblages is essential to identify ecological structuring processes, assess fishing impacts and improve ecosystem-based fisheries management (Carreton et al., 2025).

To describe the organisation of demersal communities along the Catalan coast, the system can be understood as a continuous environmental gradient mainly driven by variations in continental shelf morphology and sedimentary regimes (Demestre et al., 2000). The coastline is predominantly rocky and highly heterogeneous, with a gradual sediment transition from north to south with sands and gravels associated with rocky outcrops to carbonate-rich sands, muddy sandy sediments, and progressively finer sediments such as muds and clays towards the outer shelf and upper slope. Where the shelf becomes narrower and is deeply incised by submarine canyons, habitat complexity increases, producing a highly heterogeneous seabed dominated by muddy sands interspersed with sandy patches near small coastal

rocky formations, while carbonate sediments are also frequent; this mosaic of substrates supports diverse benthic assemblages, including calcareous algae, molluscs, echinoderms, and seagrass meadows with a rich epiphytic fauna. In areas where the continental shelf widens considerably under the strong influence of large-scale fluvial inputs, most notably from the Ebro River, fine sediments dominate extensive shelf areas, with muds and clays prevailing and low sand content, whereas coarser sediments are mainly restricted to nearshore zones; in estuarine-influenced areas, these deposits may form relatively continuous belts of homogeneous soft substrate extending towards the shelf break and upper slope (Margalef & J Albaigés, 1989).

1.4. Fisheries management

The development of robust scientific assessments has become essential for ensuring the sustainable management of fisheries resources and maintaining the long-term viability of the fishing sector. In the Mediterranean, the ecological complexity of bottom trawl fisheries, which are typically multispecies and spatially and seasonally heterogeneous, highlights the need for the development of long-term scientific monitoring programs (McConnaughey et al., 2020).

In this context, to ensure future provision of marine resources, there's a need to develop science-based management strategies and implement monitoring programs in the NW Mediterranean Sea (ICATMAR, 22-04). For this purpose, the Catalan Research Institute for the Governance of the Sea (ICATMAR) was created in Catalonia (NE Spain) in 2018 as a cooperation body between the General Directorate of Fisheries and Maritime Affairs and the Institute of Marine Sciences (ICM-CSIC). Its aim is to help mitigate overfishing disturbances, being mainly focused on effort limitations and by-catch assessments as well as on ecosystem approaches for maintaining and recovering biodiversity and integrity (Tuset et al., 2021). Nowadays, ICATMAR monitors commercial and recreational marine fishing off the Catalan coast by acquiring biological and fishing data (ICATMAR, 2017).

2.Objectives

This degree thesis aims to characterize the spatiotemporal variability of demersal fish assemblages on the deeper continental shelf (70 to 200 m) across different zones and seasons of the Catalan coast (NW Mediterranean Sea) between 2019 and 2024. This depth strata was chosen because it is the wider depth stratum exploited by bottom trawlers in the study area, and is where most commercially important demersal fish species are extracted (Ribera-Altimir et al., 2023a).

To achieve this main goal, three specific objectives have been defined:

1. Characterize the species composition, abundance and biomass of the fish assemblages analysed.
2. Compare the species composition, abundance and biomass among three zones of the Catalan coast (north, centre and south).
3. Analyse interannual and intra-annual (seasonal) variability in the species compositions, abundance and biomass across the study period.

In this work, the different Sustainable Development Goals (ODS) have been related in terms of their objectives, the type of study carried out, the type of data treatment employed and its function. The main points highlighted were: (a) the goal 3 of Good Health and Well-being, (b) the goal 6 of Clean Water and Sanitation, (c) the goal 8 of Decent Work and Economic Growth, (d) the goal 12 of Responsible Consumption and Production, (e) the goal 14 of Life below Water and (f) the goal 17 of Partnership for the Goals.

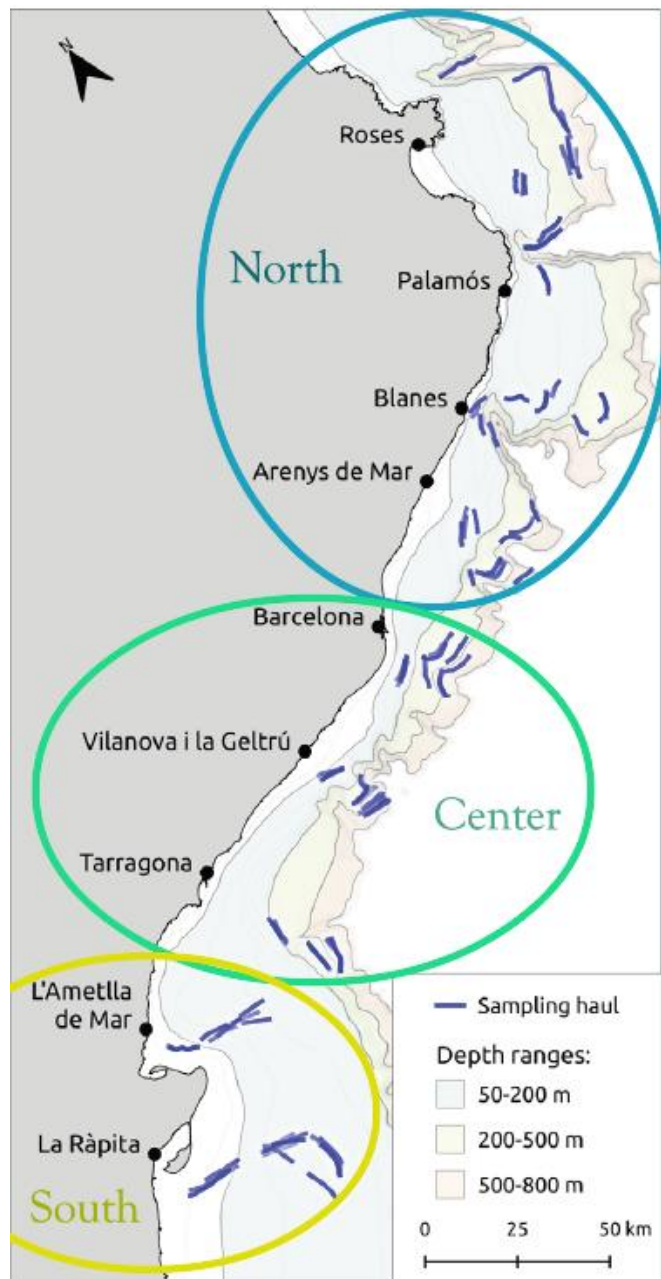
3. Methodology

3.1. Study Area

The Catalan coast was divided in three zones: north, centre and south (Figure 3). The three described zones are defined by the oceanographic characteristics and geomorphological features found in the Catalan Sea (Clavel-Henry et al., 2021).

The north zone is characterized by the presence of large, deeply incised submarine canyons that extend across the continental shelf and the slope. The centre zone also contains submarine canyons, although these are generally narrower and less developed. In contrast, the south zone corresponds to the Ebre delta margin, which is characterized by a broad continental shelf and the absence of submarine canyons. Sampling was conducted at the nine main commercial fishing ports within the three studied zones: a) north, including the ports of Roses, Palamós, Blanes, and Arenys de Mar; b) centre, including the ports of Barcelona, Vilanova i la Geltrú, and Tarragona; and c) south, including the ports of l'Ametlla de Mar and La Ràpita. Sampled ports and the hauls analysed in this study are represented between the depth ranges from 70 to 200m (deeper continental shelf) in the figure 3 (ICATMAR, 24-05).

Figure 3. Bottom trawling hauls conducted by zone along the nine fishing ports from Catalan Sea (NW Mediterranean). Extracted from ICATMAR, 2024. Copyright.



3.2. On-board and laboratory sampling

Data obtained by ICATMAR from the bottom trawl fishery were collected from each port seasonally (winter: January, February and March; spring: April, May and June; summer: July, August, September; Autumn: October, November, December), from January 2019 to December 2024, with a total of 196 hauls (= each time the net is dropped into the sea and pulled back up) conducted in the deeper continental shelf (70 - 200 m).

During onboard sampling (Figure 4), after each haul, fishers sorted the catch into two categories: landed catch (species with commercial interest to be sold in the fish auction) and discarded catch (species with no commercial value and/or undersized or damaged individuals of a commercial species). All individuals in the landed catch were identified onboard, and their total length was measured. Weight was not recorded onboard due to potential measurements errors caused by vessel movement, total length measurements obtained onboard were converted into weight using established length-weight relationships through the database system (Ribera-Altimir et al., 2023b; ICATMAR, 24-05), which were available for all commercially fish species measured onboard. Discarded catch was preserved in coolers and transported to the laboratory. Furthermore, up to 30 discarded individuals belonging to commercial species were retained for biological analysis. Depending on the quantity of discarded material, either the entire sample or a random representative subsample was processed.

In the laboratory (Figure 5), individuals from discarded catch were identified to species level, or to the smallest possible taxonomic level, and the length of each species was recorded. For each haul, geographic position was accurately recorded using GPS, allowing the precise spatial localization of all sampling hauls. The start and end positions of each haul was recorded with a GPS as well as the horizontal opening of the net's mouth, allowing for the calculation of the swept area (area covered by the trawl net) in order to standardize biomass (kg/km²) and abundance (Ind./km²) (Blanco et al., 2023; Ribera-Altimir et al., 2023b; Sala Coromina et al., 2023).



Figure 4. Crew opening the cod end from a trawling catch in l'Ametlla de Mar. Extracted from Balcells, M., 2020. Copyright.



Figure 5. Dissection at the Institute of Marine Sciences (ICM) of *Mullus barbatus* and *Merluccius merluccius*. Author's own photograph (2025).

3.3. Data analysis

3.3.1. Catch composition of fish species

Catch composition of fish species, including Actinopterygii and Elasmobranchii from both landed and discarded fractions was analysed for each haul using three study variables: a) species richness (number of species observed), b) total abundance (ind/km²), and c) total biomass (kg/km²).

The composition of both the commercial and discarded fractions of the catch was recorded for each haul at the lowest possible taxonomic level in the laboratory of Institute of Marine Sciences (ICM), where the different species were identified with the help of ICATMAR researchers and, if it was necessary, through the book of *Marine Ichthyofauna of the Iberian Peninsula and the Balearic Islands* (Lloris, 2015).

Once individuals were identified, species richness was across the different zones, years and seasons to assess potential spatial and temporal variation. As described by Vilas et al. (2020); species richness has been selected because it is the simplest way to describe community and regional diversity.

From the catches obtained in each haul, the swept area was calculated using the recorded start and end coordinates (GPS), the fishing time and the horizontal opening of the gear. For each species, the total weight (kg) and the total number of individuals were recorded. Both values were then standardised to densities per unit area (kg/km² for biomass and nº of individuals/km² for abundance) (ICATMAR, 25-05).

Differences in species richness, biomass (kg/km²) and abundance (ind/km²) were used as response variables in generalised linear models (GLMs) to analyse differences among years, zones and seasons, and were visualized using boxplots and barplots. The fish community was the response variable, while years, zones and seasons were the predictor or explanatory variables, all treated as fixed effects. The choice for the most appropriate link function and error distribution for the GLMs was based on residual analyses. GLM is an extension of linear regression that relates a response variable to predictors using a link function and a specific error distribution, allowing non-normal distributions such as Poisson, Binomial, Gamma, or quasi-Poisson. This approach is particularly suitable for ecological studies because ecological variables rarely follow a normal distribution and often exhibit overdispersion or extreme values.

In this case, the selected family error distribution was “quasi-Poisson” for richness and abundance, and “Gamma (log)” for biomass, as biomass is a continuous and positive variable rather than a count variable. The goodness-of-fit of the fitted model was tested with an ANOVA based on Chi-square tests on the residual deviation and degrees of freedom (significance level $\alpha = 0.05$). The GLM analysis was performed using the mgcv package in R v4.5.2, and the pairwise (post-hoc) comparisons were carried out with the emmeans package. To describe the difference between the levels of the analysed factors, the median was used instead of the mean because the data did not follow a normal distribution.

3.3.2. Fish Assemblage

To study the fish assemblages on the deeper continental shelf, landed and discard fractions were analysed together. Both biomass (kg/km²) and abundance (Individuals/km²) data were used to explore spatial and temporal variability in fish assemblages. Spatial patterns were assessed through differences among geographical zones (north, centre, and south), while temporal variability was evaluated at both interannual (2019–2024) and seasonal (winter, spring, summer, and autumn) scales (Ribera-Altimir et al., 2023), with zone, year, and season included as categorical predictors comprising three, six, and four levels, respectively. To investigate variability in fish assemblages across zones, years and seasons, multivariate analyses were performed using the vegan package in R (R Core Team, 2013). Prior to analysis, data were square root transformed to reduce the influence of highly abundant species. Species-level biomass and abundance data were used to calculate the Bray-Curtis similarity indices between hauls.

Non-metric multidimensional scaling (nMDS) was applied to evaluate differences in fish assemblage composition across zones, years, and seasons to assess potential groupings, gradients, and relationships in community composition. This ordination technique, based on a distance matrix (in this case, Bray-Curtis similarity) among sampling units (hauls), provides a graphical representation of similarities among samples in a reduced ordination space (Kenkel & Orloci, 1986).

Additionally, an analysis of similarity (ANOSIM) was conducted to test for significant differences in fish assemblage composition across the main factors considered. ANOSIM is a non-parametric permutation-based method that assesses whether differences between predefined groups are greater than within-group variation. The test produces an R statistic ranging from -1 to 1, where values closer to 1 indicate a stronger separation between groups. Because ANOSIM is based on categorical predictors, each factor was tested separately to evaluate spatial and temporal differences in fish assemblages using both biomass and abundance (Gao et al., 2023). Based on the initial ANOSIM analysis, the factors showing statistical significance were selected for further analysis of the total catch biomass and abundance of the 80 most representative species.

Finally, a similarity percentages (SIMPER) analysis was performed to identify the species contributing most to the dissimilarities among the different levels of the factors analysed (years, seasons and zones). This method decomposes overall dissimilarity between groups into the contribution of individual species, allowing identification of the taxa driving observed patterns in community structure (Gibert & Escarguel, 2019; Saitoh et al., 2011).

3.4. Artificial intelligence (IA) use Declarations

In accordance with the declaration on the use of artificial intelligence, DeepSeek (version 3) and ChatGPT (GPT-4 version) have been used from February until May of 2026. Throughout this work, it has been used to search for related articles to expedite the search, to understand certain concepts implemented in the work and to summarise them in order to explain them in the most schematic and comprehensible way possible, for the correction and/or writing of the RStudio script within the data processing implemented to obtain the results, and to correct the writing of some paragraphs already written in English; where some of them were also been translated with the help of DeepL Translate.

4. Results

4.1. Catch composition of fish species

4.1.1. Number of fish species (Species Richness)

A total of 139 species were recorded on the deep shelf of the Catalan Coast. Species richness variation among years, zones, and seasons was assessed using GLMs (Table 1):

Table 1. Statistical results of the GLMs for species richness.

a) Model: glm (Species richness ~ years + zones + seasons, family = quasipoisson)					
Deviance Explained: 54.12%					
	Df	Deviance	Resid. Df	Resid. Dev.	p-value
NULL			71	118.921	
Years	5	12.727	66	106.194	0.021
Zones	2	51.208	64	54.986	< 0.01
Seasons	3	0.423	61	54.563	0.923

Results showed that there were a significant effect of years (p -value = 0.02) and zones (p -value < 0.01) on the species richness, but not of seasons (p -value = 0.923) (Table 1).

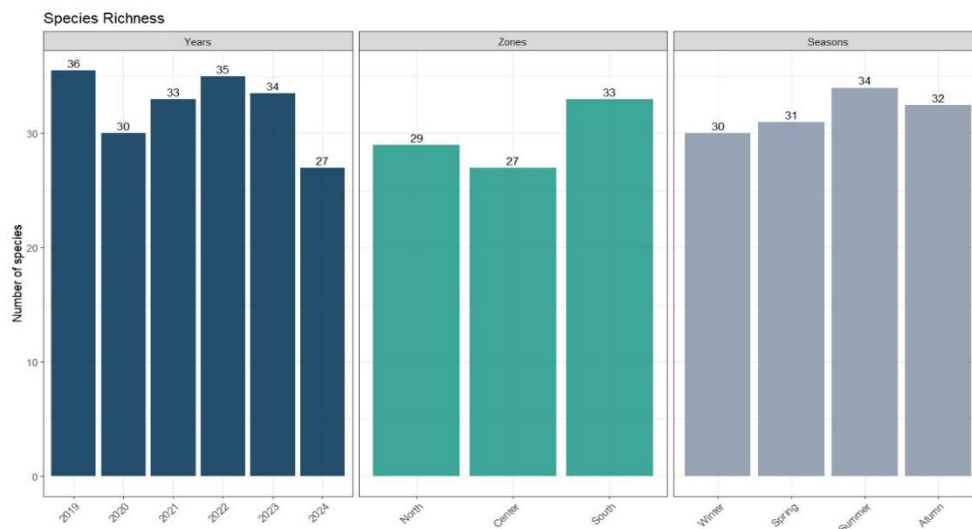


Figure 6. Barplot of mean species richness (nº of species) per haul indicating the temporal variation between the years 2019-2024 (dark-blue), the spatial variation between the zones north, centre and south (blue-green) and the seasonal variation between winter, spring, summer and autumn (grey-blue) in Catalan Sea (NW Mediterranean). Author's own figure.

Overall, species richness across the three factors analysed showed are shown in Figure 6. Significant interannual variation in cumulative species richness was detected, and a clear declining trend emerged across the study period: starting from 36 species in 2019, numbers fell to 30 in 2020, nearly recovered to 35 in 2022, but then dropped again to 27 in 2024. Statistically significant differences were observed among zones, centre recorded the fewest species richness (27), followed by the north (29) and the south was the zone with the highest value observed (33). However, no significant seasonal effect was observed in species richness (Table 1).

4.1.2. Total fish biomass in the catch

Total fish biomass variation among years, zones, and seasons was assessed using GLMs (Table 2), accounting for a mean biomass of 554 ± 48 kg/km² per haul.

Table 2. Statistical results of GLMs for biomass.

a) Model: glm (Biomass ~ years + zones + seasons, family = Gamma (log))					
Deviance Explained:					
	Df	Deviance	Resid. Df	Resid. Dev.	p-value
NULL			71	39.790	
Years	5	3.126	66	36.664	0.098
Zones	2	17.146	64	19.518	< 0.01
Seasons	3	1.346	61	18.172	0.250

Results showed a significant effect of zones on the total fish biomass ($p < 0.01$). In the case of the years and seasons no significant effects were observed (Table 2).

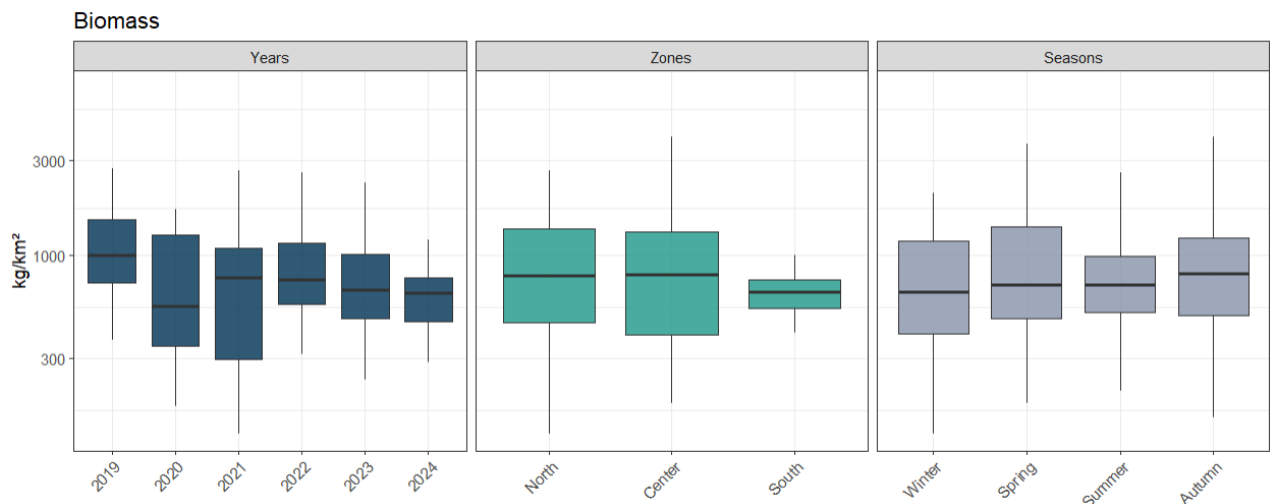


Figure 7. Boxplot of cumulative Biomass (Kg/km²) indicating the temporal variation between the years 2019-2024 (dark-blue), the spatial variation between the zones north, centre and south (blue-green) and the seasonal variation between winter, spring, summer and autumn (grey-blue) in Catalan Sea (NW Mediterranean). Author's own figure.

The interannual effect was not significant, although a gradual decline in biomass over the study period from 995,2 kg/km² in 2019 to 641,6 kg/km² in 2024 was detected (Figure 7). Regarding spatial variation, a significant effect on biomass was observed between zones. The lowest biomass value was recorded in the south zone (651,3 kg/km²), whereas the highest was observed in the centre zone (793,2 kg/km²), closely followed by the north zone (769,4 kg/km²). No significant effect was observed in total fish biomass between seasons (Figure 7).

4.1.3. Total fish abundance in the catch

Total fish abundance variation among years, zones, and seasons was assessed using GLMs (Table 3) accounting for a mean abundance of 13.858 ± 1.586 ind/km² per haul.

Table 3. Statistical results of GLMs for fish abundance.

a) Model: glm (Abundance ~ years + zones + seasons, family = quasipoisson)					
Deviance Explained: 23.71%					
	Df	Deviance	Resid. Df	Resid. Dev.	p-value
NULL			71	1847489	
Years	5	83215	66	1764274	0.767
Zones	2	336392	64	1427883	< 0.01
Seasons	3	18448	61	1409435	0.904

Results showed that only zones had a significant effect on fish abundance ($p < 0.01$). No significant effects were observed between years ($p = 0.767$) and seasons ($p = 0.904$) (Table 3).

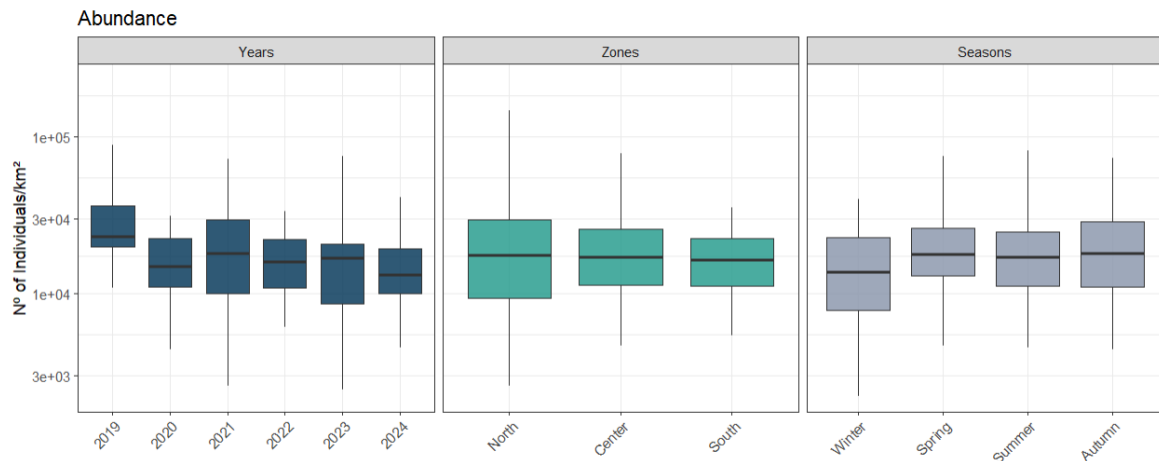


Figure 8. Boxplot of cumulative Abundance (Individuals/Km²) indicating the temporal variation between the years 2019-2024 (dark-blue), the spatial variation between the zones north, centre and south (blue-green) and the seasonal variation between winter, spring, summer and autumn (grey-blue) in Catalan Sea (NW Mediterranean). Author's own figure.

Although there was no significant effect of interannual variation on the fish abundance, a gradual decrease in the cumulative abundance over the years can be identified (Figure 8). Abundance declined from 23.198 ind/km² in 2019 to 13.218 ind/km² in 2024. Interannual variation also showed a marked decrease in 2020, when abundance dropped to 14.980 ind/km²; however, this decline was followed by a recovery in 2021, reaching approximately 18.058 ind/km². Abundance showed significant differences among zones. The lowest value was recorded in the south zone (16.398 ind/km²), while the highest was observed in the north zone (17.491 ind/km²), closely followed by the centre zone with 17.227 ind/km². However, seasons had no significant effect on the total fish abundance.

4.2. Fish assemblage analysis

Table 4. Comparison between the three factors analysed in this study (a) biomass and (b) abundance.

a) Biomass (= kg/km2) data comparison		
Factors analysed	Anosim p-value	Anosim R value
Years	0.0014	0.0358
Seasons	0.0769	0.0118
Zones	1,00E-04	0.1205
b) Abundance (= N° of Individuals/Km2) data comparison		
Factors analysed	Anosim p-value	Anosim R value
Years	0,0026	0,0316
Seasons	0,0230	0,0178
Zones	1,00E-04	0,1808

Since seasons did not affect significantly the biomass, this factor was excluded from the next ANOSIM and SIMPER analyses. In case of abundance, all factors were included as all were significant.

Based on the results of the initial ANOSIM analysis (Table 4), only significant factors were selected for further examination. The total catch biomass and abundance of the 80 most representative species were therefore calculated for these factors, and they are presented in Annexes 8.1–8.5. Biomass results are shown only for zones and years (Annexes 8.1 and 8.2), whereas abundance results are shown for zones, years and stations (Annexes 8.3, 8.4 and 8.5). These annexes are intended to provide additional evidence and context for the ANOSIM and SIMPER results presented in the following sections.

4.2.1. Biomass-based fish assemblage analysis

In order to analyse the fish assemblages based on biomass, two NMDS ordination plots have been produced; one showing the studied zones and stations, grouping all studied years together (Figure 9), and another showing the zones and stations separately for each year to assess interannual variability (Figure 10).

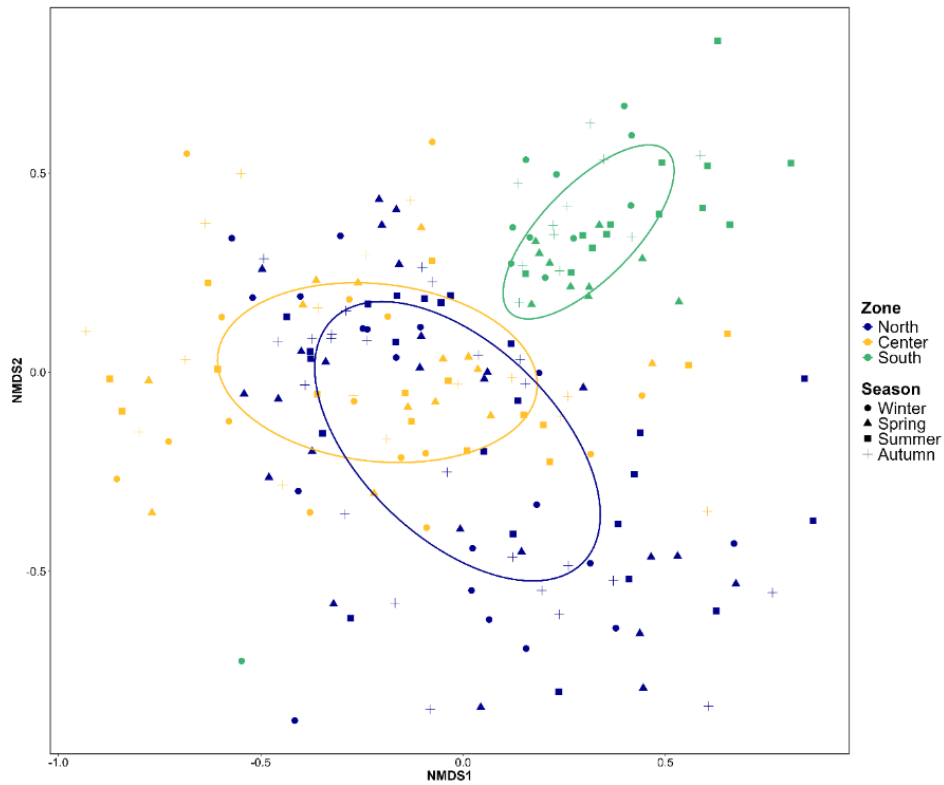


Figure 9. Non-Metric Multidimensional Scalling (nMDS) of the zones and seasons analysed with biomass data. The different zones from Catalan Sea (NW Mediterranean) were represented by colours (blue; north, yellow; centre and green; south). Seasons were indicated by figures (winter; circle, spring; triangle, summer; square and autumn; line). Author's own figure.

Significant differences were found in biomass-based fish assemblage among zones (Table 4) and Figure 9). Being the southern zone significantly different from the other two. Regarding seasons, no significant difference has been found between them (Table 4); either in the different zones as a whole or separately. However, year significantly affect biomass-based assemblage (Table 4 and Figure 10). Figure 10 also showed consistent differences between zones across all years analysed; being the south different from the north and the centre zones.

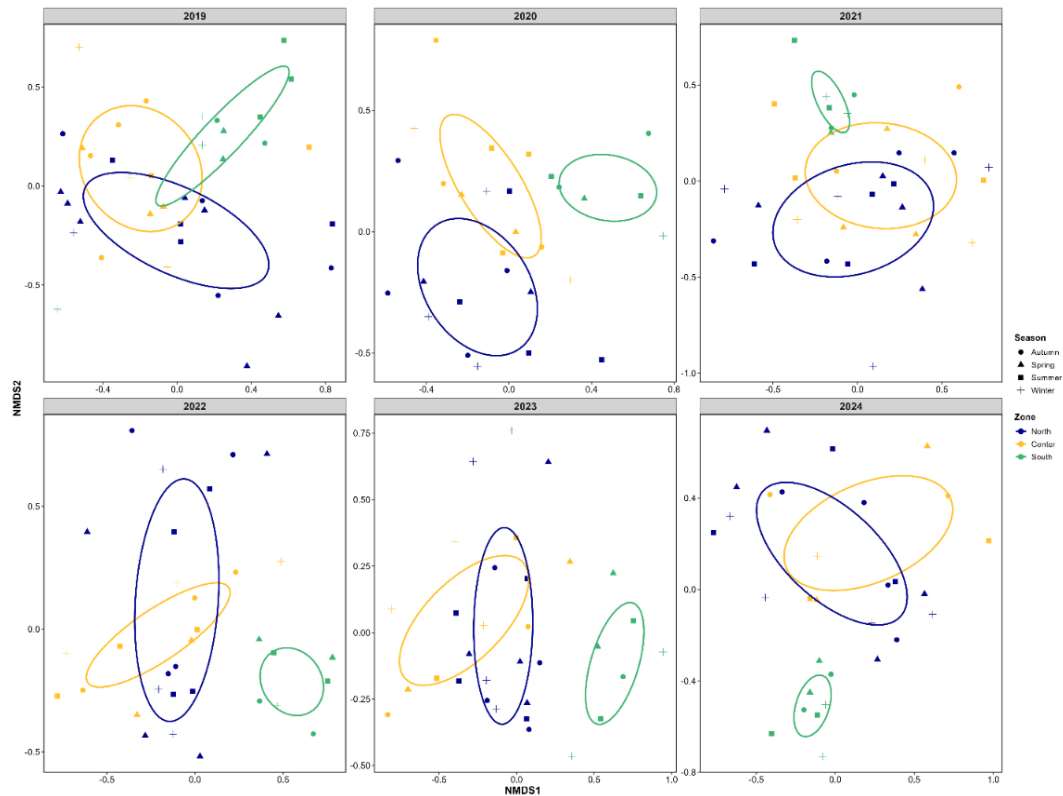


Figure 10. Non-Metric Multidimensional Scalling (nMDS) of the different years analysed (from 2019 to 2024) obtained with biomass data. The different zones from Catalan Sea (NW Mediterranean) were represented by colours (blue; north, yellow; centre and green; south). Seasons were indicated by figures (winter; circle, spring; triangle, summer; square and autumn; line). Author's own figure.

a) Spatial Variability in biomass-based fish assemblages

In order to detect which species contribute most to the dissimilarity between zones in terms of biomass, SIMPER and ANOSIM analysis were performed, revealing significant differences between the studied areas (Table 5).

Table 5. List of fish species contributing to the differences in biomass among zones within the Deeper Shelf. % Difference indicates the contribution of each species to biomass dissimilarity between zones, while Spp1 and Spp2 identify the main contributing species in each zone. ANOSIM R and p-values indicate the strength and significance of zonal differences.

c) Zones compared		Species accounting for differences				
Zone 1	Zone 2	Spp 1	Spp 2	% Difference	Anosim p-value	Anosim R value
North	South	<i>Trachurus trachurus</i>	<i>Lophius budegassa</i>	63,1%	0,0001	0.1998
		<i>Scyllorhinus canicula</i>	<i>Merluccius merluccius</i>			
		<i>Mullus barbatus</i>	<i>Engraulis encrasicolus</i>			
		<i>Boops boops</i>				
		<i>Trachurus trachurus</i>	<i>Lophius budegassa</i>			
Center	South	<i>Merluccius merluccius</i>	<i>Engraulis encrasicolus</i>	70,40%	0,0001	0.1953
		<i>Mullus barbatus</i>	<i>Trisopterus capelanus</i>			
		<i>Scyllorhinus canicula</i>	<i>Trachurus mediterraneus</i>			
		<i>Boops boops</i>				

Within the comparisons between zones (Table 5), the north–south and centre–south comparisons showed significant differences ($p = 0.0001$), whereas no significant differences were detected between the north and centre zones.

SIMPER analyses showed that the south zone was mainly characterised by higher contributions of *Lophius budegassa*, *Engraulis encrasicolus* and *Merluccius merluccius*, whereas the north and centre zones were more associated with *Trachurus trachurus*, *Mullus barbatus*, *Boops boops* and *Scyliorhinus canicula*, but also with *Merluccius merluccius* in the center, having in this case more contribution of *Trisopterus capellanus* and *Trachurus mediterraneus* at the south zone. These species accounted for 63.1–70.4% of the total dissimilarity between zones.

Regarding the total zonal representation of catch biomass (kg/km^2) (Annex 8.1), the species ranked from highest to lowest biomass were: *T. trachurus*, *S. canicula*, *M. merluccius*, *B. boops* and *M. barbatus* in the north; *T. trachurus*, *M. merluccius*, *M. barbatus*, *S. canicula* and *L. budegassa* in the centre; and *L. budegassa*, *M. merluccius*, *M. barbatus*, *E. encrasicolus* and *B. boops* in the south.

b) Interannual Variability in biomass-based fish assemblages

To assess interannual variability in biomass among the different years analysed (from 2019 to 2024), SIMPER and ANOSIM analyses were performed, revealing significant differences between years. However, these differences were not detected in all pairwise comparisons, therefore, species contributing to the differences between years are reported only for significant comparisons (Table 6).

Table 6. List of species contributing to the differences in biomass at the commercial trawling catch among the composition of the different years compared within the Deeper Shelf. % Difference indicates the contribution of each species to biomass dissimilarity between years, while Spp1 and Spp2 identify the main contributing species in each year. ANOSIM R and p-values indicate the strength and significance of annual differences.

d) Years compared		Species accounting for differences				
Year 1	Year 2	Spp 1	Spp 2	% Difference	Anosim p-value	Anosim R value
2019	2021	<i>Trachurus trachurus</i>	<i>Merluccius merluccius</i>	67,90%	0,0289	0,0436
		<i>Scyliorhinus canicula</i>	<i>Mullus barbatus</i>			
		<i>Lophius budegassa</i>	<i>Spicara flexuosa</i>			
		<i>Boops boops</i>				
		<i>Trisopterus capellanus</i>				
2019	2022	<i>Trachurus trachurus</i>	<i>Merluccius merluccius</i>	61,70%	0,0107	0,0628
		<i>Scyliorhinus canicula</i>	<i>Mullus barbatus</i>			
		<i>Lophius budegassa</i>				
		<i>Boops boops</i>				
2019	2023	<i>Scyliorhinus canicula</i>	<i>Trachurus trachurus</i>	66,50%	0,0487	0,0385
		<i>Lophius budegassa</i>	<i>Mullus barbatus</i>			
		<i>Boops boops</i>	<i>Merluccius merluccius</i>			
		<i>Trisopterus capellanus</i>				
2019	2024	<i>Scyliorhinus canicula</i>	<i>Trachurus trachurus</i>	63,20%	0,0310	0,0511
		<i>Lophius budegassa</i>	<i>Boops boops</i>			
			<i>Mullus barbatus</i>			
2020	2022	<i>Trachurus trachurus</i>	<i>Merluccius merluccius</i>	67,30%	0,0035	0,0836
		<i>Boops boops</i>	<i>Lophius budegassa</i>			
		<i>Spicara flexuosa</i>	<i>Scyliorhinus canicula</i>			
		<i>Trisopterus capellanus</i>	<i>Mullus barbatus</i>			
		<i>Lophius budegassa</i>	<i>Trachurus trachurus</i>			
2020	2023	<i>Boops boops</i>	<i>Scyliorhinus canicula</i>	60,90%	0,0496	0,0402
			<i>Mullus barbatus</i>			
			<i>Merluccius merluccius</i>			
		<i>Lophius budegassa</i>	<i>Trachurus trachurus</i>			
2020	2024		<i>Boops boops</i>	61,70%	0,0210	0,0534
			<i>Scyliorhinus canicula</i>			
			<i>Mullus barbatus</i>			
			<i>Merluccius merluccius</i>			
2021	2024	<i>Scyliorhinus canicula</i>	<i>Trachurus trachurus</i>	64,40%	0,0038	0,0768
		<i>Lophius budegassa</i>	<i>Mullus barbatus</i>			
			<i>Merluccius merluccius</i>			
			<i>Boops boops</i>			
2022	2024	<i>Merluccius merluccius</i>	<i>Trachurus trachurus</i>	70,40%	0,0045	0,0770
		<i>Scyliorhinus canicula</i>	<i>Mullus barbatus</i>			
		<i>Lophius budegassa</i>	<i>Boops boops</i>			
			<i>Spicara spp.</i>			

The species contributing most to interannual dissimilarities were *Trachurus trachurus*, *Merluccius merluccius*, *Boops boops* and, to a less extension, *Scyliorhinus canicula*, indicating a relatively stable contribution throughout the study period. Between 2019–2020, differences were associated with *Lophius budegassa* and *Trisopterus capellanus* and *Scyliorhinus canicula*. In contrast, *Mullus barbatus*, *Spicara flexuosa* and *Spicara spp.* contributed more strongly to comparisons involving 2021 onwards.

Although *Merluccius merluccius* remains present over the years, it is particularly notable in 2021 and 2022, as it is the species that contributes most to the percentage difference in the fish community, indicating an increase at its biomass (Annex 8.2).

Regarding the total annual representation of catch biomass (kg/km²) (Annex 8.2), the species ranked from highest to lowest biomass were: *T. trachurus*, *S. canicula*, *L. budegassa*, *M. merluccius* and *B. boops* in 2019; *T. trachurus*, *L. budegassa*, *M. merluccius*, *B. boops* and *S. canicula* in 2020; *M. merluccius*, *T. trachurus*, *S. canicula*, *M. barbatus* and *L. budegassa* in 2021; *M. merluccius*, *T. trachurus*, *L. budegassa*, *S. canicula* and *M. barbatus* in 2022; *T. trachurus*, *M. merluccius*, *M. barbatus*, *S. canicula* and *L. budegassa* in 2023; and *T. trachurus*, *B. boops*, *M. barbatus*, *M. merluccius* and *S. canicula* in 2024.

4.2.2. Abundance-based Fish Assemblage Analysis

To analyse fish assemblages based on abundance, two complementary NMDS ordination plots were generated: one representing the overall distribution of samples according to the studied zones and stations grouping all studied years together (Figure 11), and another displaying the same spatial structure (zones and seasons) separately for each year to assess interannual variability (Figure 12).

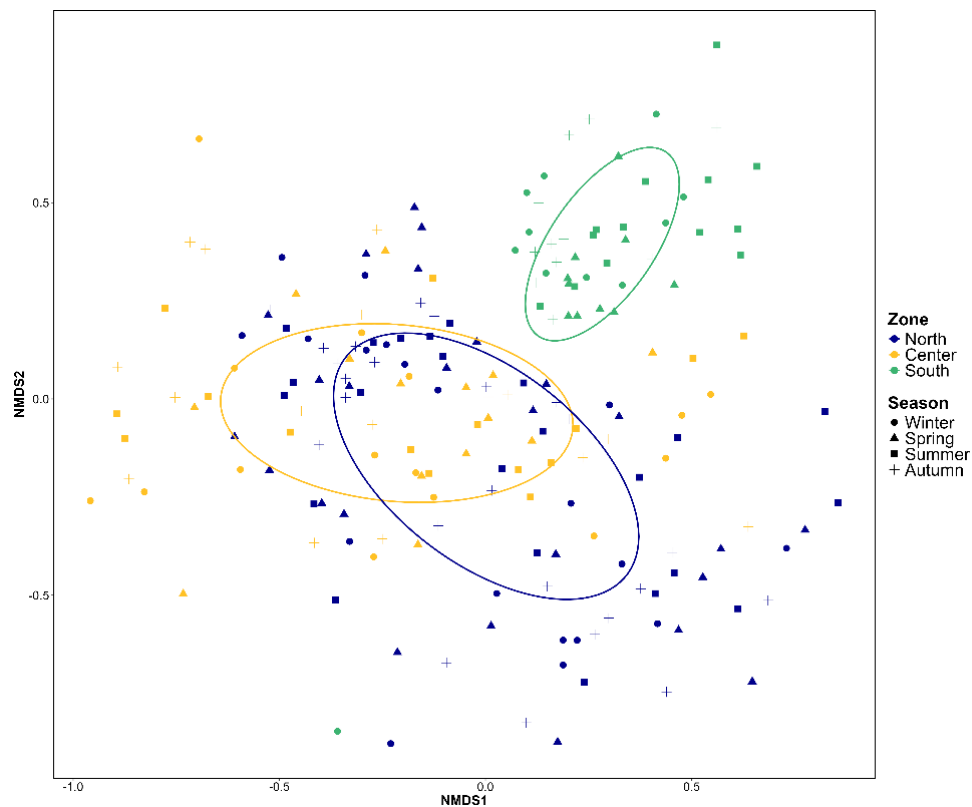


Figure 11. Non-Metric Multidimensional Scalling (nMDS) of the zones and seasons analysed with abundance data. The different zones from Catalan Sea (NW Mediterranean) were represented by colours (blue; north, yellow; centre and green; south). Seasons were indicated by figures (winter; circle, spring; triangle, summer; square and autumn; line). Author's own figure.

As in biomass-based fish assemblage analysis, a consistent spatial pattern was observed, with a clear separation between the north and centre zones and south zone. The latter appeared distinctly differentiated from the other two areas, indicating a marked spatial structuring of fish assemblages along the Catalan coast (Table 4, Figure 11 and Figure 12).

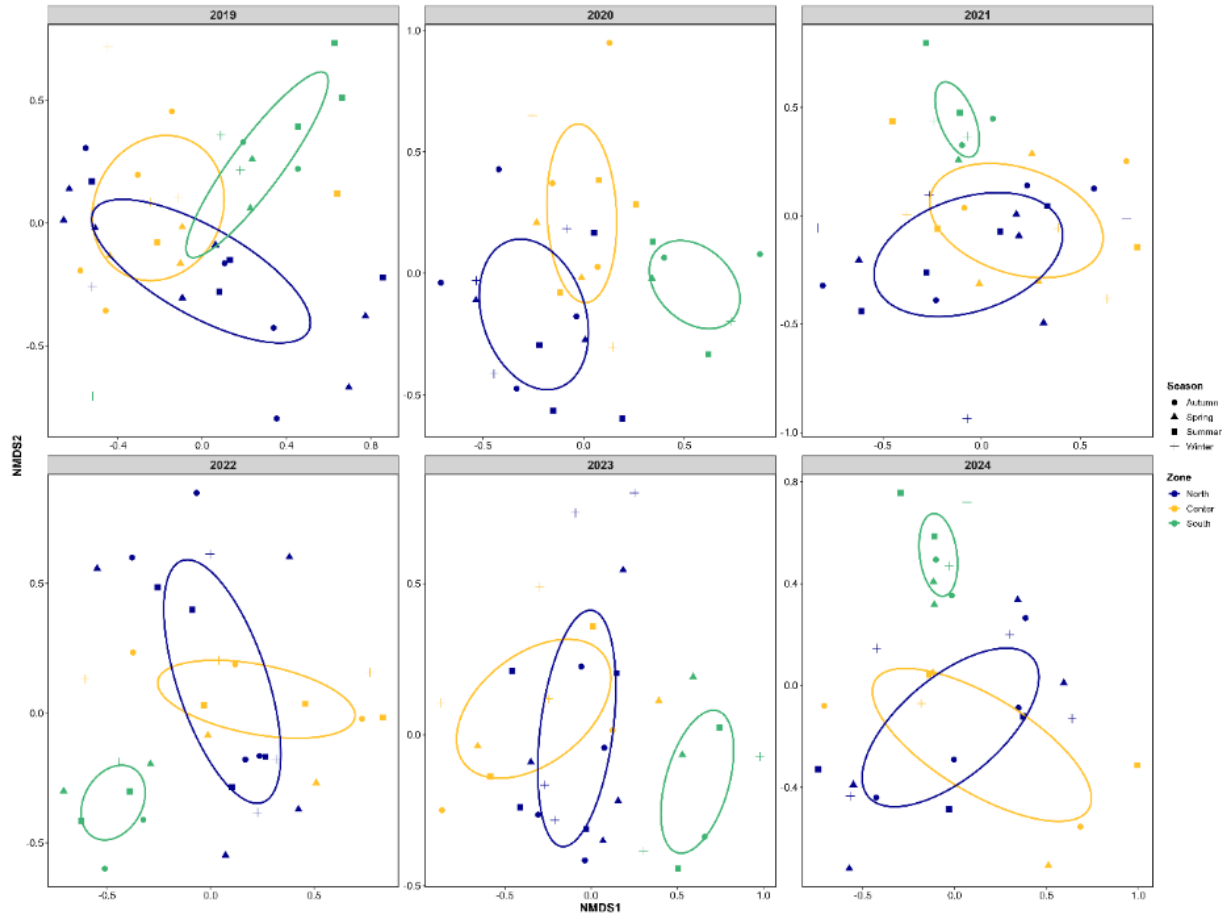


Figure 12. Non-Metric Multidimensional Scalling (nMDS) of the different years analysed (from 2019 to 2024) obtained with abundance data. The different zones from Catalan Sea (NW Mediterranean) were represented by colours (blue; north, yellow; centre and green; south). Seasons were indicated by figures (winter; circle, spring; triangle, summer; square and autumn; line). Author's own figure.

A consistent separation was observed between the south and the north and centre zones (Figure 12). However, from 2020, additional differences between the south and the north and centre zones were detected, reinforcing the persistence of this spatial distinction from 2020 to 2024. In contrast, similar patterns among the three zones were observed in 2019 where no clear separation was detected.

c) Spatial Variability in abundance-based fish assemblage

Comparisons based on ANOSIM analysis showed significant differences between the north and south zones ($p = 0.0001$) and the centre and south zones ($p = 0.0001$), whereas no significant differences were detected between the north and centre zones (Table 7).

Table 7. List of species contributing to the differences in abundance at the commercial trawling catch among the composition of the zones compared within the Deeper Shelf. % Difference indicates the contribution of each species to abundance dissimilarity between zones, while Spp1 and Spp2 identify the main contributing species in each zone. ANOSIM R and p-values indicate the strength and significance of zonal differences.

c) Zones compared		Species accounting for differences				
Zone 1	Zone 2	Spp 1	Spp 2	% Difference	Anosim p-value	Anosim R value
North	South	<i>Trachurus trachurus</i>	<i>Engraulis encrasicolus</i>	65,6%	0,0001	0,2963
		<i>Mullus barbatus</i>	<i>Trisopterus capelanus</i>			
		<i>Merluccius merluccius</i>	<i>Arnoglossus laterna</i>			
		<i>Boops boops</i>	<i>Sardina pilchardus</i>			
		<i>Capros aper</i>				
Center	South	<i>Trachurus trachurus</i>	<i>Engraulis encrasicolus</i>	65,40%	0,0001	0,3190
		<i>Merluccius merluccius</i>	<i>Trisopterus capelanus</i>			
		<i>Capros aper</i>	<i>Sardina pilchardus</i>			
		<i>Mullus barbatus</i>	<i>Arnoglossus laterna</i>			
		<i>Boops boops</i>				

According to SIMPER analyses, the south zone was mainly characterised by higher contributions of *Engraulis encrasicolus*, *Trisopterus capelanus*, *Arnoglossus laterna* and *Sardina pilchardus*, whereas the north and centre zones were more associated with *Trachurus trachurus*, *Mullus barbatus*, *Merluccius merluccius*, *Boops boops* and *Capros aper*. These species explained approximately 65–66% of the total dissimilarity between zones. These results, therefore, have been very different from those obtained with biomass, as for example, the *Lophius budegassa* has been a very prominent species in the southern area in terms of biomass but not in abundance (therefore having a possible strong contribution by this species in terms of weight). This case could also be observed with *Scyliorhinus canicula*, which in terms of biomass has dominated the area in both the north and centre, while showing very low abundance, though still contributing notably to the SIMPER results.

Regarding the total zonal representation of catch abundance (ind/km²) (Annex 8.3), the species ranked from highest to lowest were: *T. trachurus*, *M. merluccius*, *M. barbatus*, *B. boops* and *T. capelanus* in the North; *T. trachurus*, *C. aper*, *M. merluccius*, *M. scolopax* and *M. barbatus* in the Center; and *E. encrasicolus*, *T. capelanus*, *M. merluccius*, *S. pilchardus* and *T. trachurus* in the South.

d) Interannual Variability in abundance-based fish assemblage

Interannual variability in abundance between 2019 and 2024 (table 8) showed significant temporal differences in biomass composition.

Table 8. List of species contributing to the differences in abundance at the commercial trawling catch among the composition of the different years compared within the Deeper Shelf. % Difference indicates the contribution of each species to dissimilarity, while Spp1 and Spp2 identify the main contributing species in each year. ANOSIM R and p-values indicate the strength and significance of annual differences.

f) Years compared		Species accounting for differences				
Year 1	Year 2	Spp 1	Spp 2	% Difference	Anosim p-value	Anosim R value
2019	2022	<i>Trachurus trachurus</i>	<i>Merluccius merluccius</i>	62,9%	0,0128	0,0564
		<i>Engraulis encrasicolus</i>	<i>Mullus barbatus</i>			
		<i>Trisopterus capelanus</i>				
		<i>Capros aper</i>				
		<i>Boops boops</i>				
2020	2022	<i>Scyliorhinus canicula</i>		63,5%	0,0026	0,0864
		<i>Trachurus trachurus</i>	<i>Merluccius merluccius</i>			
		<i>Engraulis encrasicolus</i>	<i>Mullus barbatus</i>			
		<i>Capros aper</i>				
		<i>Boops boops</i>				
2020	2023	<i>Trisopterus capelanus</i>		62,6%	0,0467	0,0416
		<i>Spicara flexuosa</i>				
		<i>Trachurus trachurus</i>	<i>Mullus barbatus</i>			
		<i>Capros aper</i>	<i>Merluccius merluccius</i>			
		<i>Engraulis encrasicolus</i>				
2020	2024	<i>Boops boops</i>		61,2%	0,0149	0,0528
		<i>Trisopterus capelanus</i>	<i>Trachurus trachurus</i>			
		<i>Spicara flexuosa</i>	<i>Boops boops</i>			
		<i>Capros aper</i>	<i>Mullus barbatus</i>			
		<i>Engraulis encrasicolus</i>	<i>Trisopterus capelanus</i>			
2021	2024	<i>Merluccius merluccius</i>		68,1%	0,0037	0,0729
		<i>Engraulis encrasicolus</i>	<i>Trachurus trachurus</i>			
		<i>Capros aper</i>	<i>Mullus barbatus</i>			
		<i>Spicara flexuosa</i>	<i>Boops boops</i>			
			<i>Trisopterus capelanus</i>			
2022	2024		<i>Spicara spp.</i>	65,1%	0,0042	0,0739
		<i>Merluccius merluccius</i>	<i>Trachurus trachurus</i>			
		<i>Engraulis encrasicolus</i>	<i>Mullus barbatus</i>			
		<i>Capros aper</i>	<i>Spicara spp.</i>			
			<i>Boops boops</i>			
			<i>Trisopterus capelanus</i>			

Table 8 showed only the significant pairwise comparison between years obtained in the SIMPER analysis. Significant interannual variability was observed, particularly between 2022 and the other years analysed, as well as 2024 (Table 8). Regarding the top species accounting to abundance dissimilarities *Merluccius merluccius* played an important role, showing higher abundances in 2021 and 2022 (Annex 8.4), indicating an increase during that period. In contrast, differences involving 2024 were more strongly associated with other species, such as *Trachurus trachurus* and *Mullus barbatus*. Notably, *Mullus barbatus* became more prominent in the later years (2023–2024), suggesting an increased contribution towards the end of the study period (Annex 8.4). Species such as *Trachurus trachurus*, *Boops boops*, and *Trisopterus capelanus* remain relatively constant across all years, indicating a stable baseline component of the assemblage.

For the total annual representation of catch abundance (ind/Km²) (Annex 8.4), the species ranked from highest to lowest abundance were: *T. trachurus*, *E. encrasicolus*, *T. capelanus*, *C. aper* and *M. barbatus* in 2019; *C. aper*, *T. trachurus*, *M. scolopax*, *B. boops* and *T. capelanus* in 2020; *M. merluccius*, *T. trachurus*, *M. barbatus*, *E. encrasicolus* and *C. aper* in 2021; *M. merluccius*, *T. trachurus*, *M. barbatus*, *T. capelanus* and *E. encrasicolus* in 2022; *T. trachurus*, *M. merluccius*, *T. capelanus*, *E. encrasicolus* and *L. budegassa* in 2023; and *T. trachurus*, *B. boops*, *M. barbatus*, *Spicara spp.* and *M. merluccius* in 2024.

e) Seasonal variability in abundance-based fish assemblage

According to the ANOSIM results, the comparisons between Winter–Spring, Winter–Autumn, Spring–Summer, Spring–Autumn, and Summer–Autumn were not statistically significant. Only the Winter–Summer comparison showed significant differences in species composition ($p = 0.0245$), and was therefore, considered for SIMPER analysis. This analysis revealed that a relatively small set of species accounted for most of the dissimilarity (69.5%; Table 9).

Table 9. List of species contributing to the differences in abundance at the commercial trawling catch among the composition of the different years compared within the Deeper Shelf. % Difference indicates the contribution of each species to abundance dissimilarity between zones, while Spp1 and Spp2 identify the main contributing species in each zone. ANOSIM R and p-values indicate the strength and significance of zonal differences.

g) Seasons compared		Species accounting for differences				
Season 1	Season 2	Spp 1	Spp 2	% Difference	Anosim p-value	Anosim R value
Winter	Summer	<i>Capros aper</i>	<i>Trachurus trachurus</i>	69,5%	0,0245	0,0354
		<i>Mullus barbatus</i>	<i>Engraulis encrasicolus</i>			
		<i>Boops boops</i>	<i>Merluccius merluccius</i>			
		<i>Spicara spp.</i>	<i>Trisopterus capelanus</i>			
		<i>Scyliorhinus canicula</i>	<i>Spicara flexuosa</i>			
		<i>Macroramphosus scolopax</i>				

Regarding the top species in seasonal variability, winter assemblages was mainly associated with *Capros aper*, *Mullus barbatus*, *Boops boops*, *Spicara spp.* and *Scyliorhinus canicula*, whereas summer assemblages were characterised by higher contributions of *Trachurus trachurus*, *Engraulis encrasicolus*, *Merluccius merluccius*, *Trisopterus capelanus*, *Spicara flexuosa* and *Macroramphosus scolopax*. The seasonal differences are partly associated with changes in the contribution of key species such as *Merluccius merluccius*, which increased in summer.

For the total seasonal catch abundance (ind/Km²) (Annex 8.5), the species ranked from highest to lowest abundance were: *C. aper*, *T. trachurus*, *M. scolopax*, *M. barbatus* and *M. merluccius* in winter; *T. trachurus*, *M. merluccius*, *M. barbatus*, *C. aper* and *T. capelanus* in spring; *T. trachurus*, *E. encrasicolus*, *M. merluccius*, *T. capelanus* and *S. pilchardus* in summer; and *T. trachurus*, *B. boops*, *T. capelanus*, *M. barbatus* and *E. encrasicolus* in autumn.

5. Discussion

The catch composition of demersal fish species inhabiting the deeper continental shelf of the Catalan Sea showed a highly diverse assemblage comprising a total of 139 species, accounting for a mean abundance of 13.858 ± 1.586 ind/km² and a mean biomass of 554 ± 48 kg/km² per haul. These findings are consistent with previous studies conducted in the area (Blanco et al., 2023; Sánchez et al., 2007; Teresa Farriols et al., 2019; Vilas et al., 2020), which reported high species richness, abundance and biomass that were associated with the environmental complexity and habitat heterogeneity of the deeper continental shelf of the northwestern Mediterranean. Depth is a major driver of demersal fish distribution, with fish densities generally decreasing with increasing depth. However, the deeper continental shelf supports the highest densities of many demersal fish species and constitutes one of the most important fishing grounds for these resources. In contrast, decapod crustaceans become increasingly dominant on the continental shelf (0 - 200m), where they tend to reach their maximum abundance (Massutí & Reñones, 2005). The ecological productivity and resource diversity of this depth range have supported multispecies trawl fisheries throughout the Mediterranean for centuries, with historical records documenting their existence since at least the fourteenth century (De Nicolò, 2018).

Several environmental factors influence fish communities in the Catalan Sea, including temperature, water mixing and seasonal stratification, wind-driven deep convection, ocean currents and fronts, and nutrient availability. These communities are further shaped by riverine inputs such as those from the Ebre River, phytoplankton and zooplankton blooms, and anthropogenic pressures (Estrada et al., 2022; Papiol et al., 2012). Some of these environmental factors may explain the consistent pattern of spatial variability observed in the present study along the Catalan coast, where the south zone differed from the north and center zones in terms of fish abundance and biomass. In this sense, the south zone in the Catalan Sea, which is mainly dominated by muddy sediments associated with inputs from the Ebre River, has also shown a distinct fish assemblage structure in previous studies (Demestre et al., 2000). This pattern of spatial variability could be consistent with identifying the Ebre Delta environment as a hotspot for demersal fish communities (Coll et al., 2010). The higher contribution of species such as European anchovy (*Engraulis encrasicolus*) in this area, both in abundance and biomass can be related with higher recruitment in the area influenced by Ebre delta (Lloret et al., 2004). However, other species such as blackbellied angler (*Lophius budegassa*), European hake (*Merluccius merluccius*) and Mediterranean horse mackerel (*Trachurus mediterraneus*) were also well represented in this zone, particularly in terms of biomass rather than abundance. This pattern may reflect that relatively high biomass coupled with low abundance could indicate the presence of larger and mature individuals. Species typically associated with the southern sector, such as Mediterranean sculdfish (*Arnoglossus laterna*) and sardine (*Sardina pilchardus*), contributed substantially to total abundance, likely owing to their relatively small body size and high population densities. The high productivity of the south area is likely driven by the combined influence of persistent local upwelling associated with the intrusion of northern water masses and the nutrient inputs provided by the Ebre River, which enhance primary production and sustain productive trophic webs (Vilas et al., 2020). The strong influence of the Ebre River has made this region, together with the Gulf of Lion (French NW Mediterranean), one of the main spawning areas for both European anchovy (*Engraulis encrasicolus*) and European sardine (*Sardina pilchardus*) in the northwestern Mediterranean (Costalago, 2015).

Significant interannual differences in fish assemblage abundance and biomass observed in the present study indicates that demersal fish communities on the deeper continental shelf are dynamic rather than temporally stable, responding to fluctuations in environmental conditions (Carreton et al., 2025). In particular, the marked increase in both abundance and biomass of European hake (*Merluccius merluccius*) between 2021 and 2022 is indicative of a strong recruitment event. This interpretation is supported by information reported in the annual *State of Fisheries in Catalonia* (ICATMAR) reports. During 2021, relatively high abundances of hake were already recorded, partly associated with the capture of individuals below the Minimum Conservation Reference Size (MCRS) (ICATMAR, 22-05). In contrast, 2022 was characterized by a substantial increase in biomass together with a high incidence of juvenile individuals in commercial catches (ICATMAR, 23-07; 23-08). Collectively, these observations suggest the successful incorporation of an exceptionally abundant year class into the exploitable fraction of the population. This interpretation is further supported by the seasonal analyses, which revealed significantly higher abundances during summer. Such a pattern is consistent with the recruitment dynamics of *M. merluccius*, as juveniles are known to colonize shelf habitats following spawning periods, leading to seasonal increases in local abundance (Sala-Coromina et al., 2021; ICATMAR, 23-08). Recruitment variability is widely recognized as one of the main drivers of interannual fluctuations in Mediterranean hake populations, influencing both population structure and the composition of demersal assemblages (Balcells-Surroca, 2016; Lloret & Leonart, 2002).

On the other hand, abundance data analysis highlighted the role of European anchovy (*Engraulis encrasicolus*) and boarfish (*Capros aper*) in species composition between 2019 and 2022. *E. encrasicolus* showed highly variable abundance and was notably present during this period. This pattern can be partially explained by the species behavioural ecology, as juveniles tend to form dense aggregations to feed at similar depths to those exploited by trawl fisheries during daylight hours, making them particularly susceptible to capture (Tudela & Palomera, 1997). However, despite its notable presence in the catches, a marked decline in the species has been reported in recent years, possibly linked—among other factors—to the combined effects of fishing pressure and increasing water temperatures associated with climate change (Ramirez-Llodra et al., 2010). In contrast, boarfish (*Capros aper*), and simultaneously Picarel (*Spicara flexuosa*) and picarels (*Spicara* spp.), those two dominated in both abundance and biomass from 2021 onwards, are species with short-lived cycles and relatively low or even negligible commercial value (Blanchard & Vandermeirsch, 2005; Karachle & Stergiou, 2014). Therefore, their dominance may reflect an ecosystem that, under fishing pressure and other stressors, tends to favour species with high colonisation capacity; a pattern that has also been observed under warming conditions in other warm-affinity fish species (Poulard & Blanchard, 2005).

During the 2019–2024 period, horse mackerel (*Trachurus trachurus*) remains relatively constant in terms of both abundance and biomass. Bogue (*Boops boops*), in contrast, does not reach a high or stable contribution within the dominant species group in all years, but it appears persistently in most of them, thus constituting a recurrent component of community variability. A particularly notable trend was observed for red mullet (*Mullus barbatus*), which showed a progressive increase in its contribution to both abundance and biomass from 2021 onwards. This pattern is consistent with recent observations from Catalan fishing grounds, where increases in the abundance of this species have been reported (ICATMAR, 25-04). The expansion of *M. barbatus* may be linked to favourable environmental conditions and its ecological plasticity, which allow the species to respond rapidly to changes in habitat conditions and resource availability.

More broadly, these temporal shifts in species dominance suggest ongoing changes in community composition, potentially reflecting the combined effects of environmental variability, climate-driven changes, and fishing pressure, which selectively favour species with particular life-history and ecological traits (Tserpes et al., 2002). Regarding dogfish (*Scyliorhinus canicula*), its dominance in biomass but not in abundance suggests that the species contributes substantially to community biomass through relatively small number of large-bodied individuals, rather than through high population densities.

Although seasonal variability explained less of the observed variation in fish assemblage than spatial or interannual factors, results in the present study indicated that demersal fish assemblages along the Catalan coast are nevertheless influenced by seasonal processes. The absence of significant seasonal differences in biomass, contrasted with significant changes in abundance, suggests that seasonal fluctuations are primarily driven by variations in the number of individuals rather than by changes in their overall weight. Similar patterns have been reported for demersal communities in the northwestern Mediterranean, where seasonal differences are largely associated with recruitment dynamics and shifts in species composition (Vilas et al., 2020). Most of the seasonal variation observed in the present study occurred between summer and winter, in agreement with previous findings from the southern zone of Catalan Coast (NW Mediterranean) (Vilas et al., 2020). The lower abundance during winter, may reflect seasonal changes in species distribution and habitat use, resulting in a more diverse but less densely populated assemblage. Such patterns are consistent with the seasonal movements described for several Mediterranean demersal species, which undertake migrations between the continental shelf (50-200m) and the upper slope (200-350m) in relation to reproductive and feeding cycles (Sala-Coromina et al., 2021; Vilas et al., 2020).

Recruitment pulses are known to strongly influence the abundance patterns of Mediterranean demersal communities and may account for a substantial proportion of the seasonal variability observed in this study (Vilas et al., 2020). Overall, these findings suggest that recruitment and seasonal habitat shifts are key drivers of temporal changes in the structure of demersal fish assemblages on the Catalan continental shelf.

During winter, fish assemblage is dominated by species such as *Capros aper*, *Mullus barbatus*, and longspine snipefish (*Macroramphosus scolopax*), although also with contributions from *Boops boops*, *Spicara spp.* and *Scyliorhinus canicula*. This composition indicates a community clearly associated with benthic and demersal species typical of the Mediterranean (Demestre et al., 2000; Massutí & Reñones, 2005). The differences observed in winter, although it has no significant differences with species richness in the GLM analysis, the lower total abundance observed in the boxplot could indicate a community with fewer individuals and suggests a less aggregated but more diverse structure. This pattern is consistent with post-spawning processes described by Sala-Coromina (2021), in which adults disperse after spawning, as well as with studies reporting lower densities and greater dispersion of communities during this period (Vilas et al., 2020).

In spring, unless no clear differences have been observed, the assemblage remains partially similar to winter but with a greater presence of species in the early stages of recruitment, such as *Merluccius merluccius*, *Trachurus trachurus* and Mediterranean poor cod (*Trisopterus capellanus*), together with the persistence of *Mullus barbatus* and *Capros aper*. This period is characterized by the progressive incorporation of juveniles into the community, anticipating the peak of recruitment during summer (Lloret & Lleonart, 2002; Massutí & Reñones, 2005).

During summer, assemblage clearly differs from the rest of the seasons and is dominated by species such as *Trachurus trachurus*, *Engraulis encrasicolus*, *Merluccius merluccius*, *Trisopterus capellanus*, *Spicara flexuosa* and *Sardina pilchardus*. This composition reflects a community strongly structured by recruitment processes, with a high presence of juvenile individuals, particularly in species such as the already mentioned *M. merluccius*, which reaches peak abundance during this period (Balcells-Surroca, 2016; Lloret & Lleonart, 2002; Sala-Coromina et al., 2021). On the other hand, the presence of species such as *E. encrasicolus* and *S. pilchardus*, as previously mentioned, is associated with areas influenced by upwelling processes and riverine inputs (Costalago, 2015; Vilas et al., 2020).

Although no clear differences have been observed, the higher abundance and biomass observed in boxplots during autumn, may be linked to the incorporation of recruits into the demersal assemblage and to the seasonal aggregation of commercially important species. In autumn, the assemblage reaches its maximum development, with high abundance and a clear dominance of *Boops boops*, *Trisopterus capellanus*, *Mullus barbatus*, *Engraulis encrasicolus* and *Trachurus trachurus* (thus showing an important and consistent role throughout the annual cycle). This configuration reflects a more mature community, in which individuals recruited during spring and summer have grown and contribute more significantly to the population structure before their subsequent dispersion (Lloret & Lleonart, 2002; Vilas et al., 2020).

The results of this study contribute to the achievement of several Sustainable Development Goals, particularly the goal 3 (Good Health and Well-being) and the goal 6 (Clean Water and Sanitation), by highlighting the importance of fish community structure as an indicator of coastal ecosystem health, for example in areas influenced by riverine inputs such as the Ebre River. They also provide relevant knowledge to support the sustainable management of bottom trawl fisheries (goal 8; Decent Work and Economic Growth) and promote informed and responsible consumption of marine resources based on the understanding of species status (goal 12; Responsible Consumption and Production). Additionally, this study contributes to the goal 14 (Life Below Water) by improving the understanding of demersal fish assemblages. Finally, the collaboration with the members from ICATMAR reflects the goal 17 (Partnerships for the Goals), emphasizing its role of cooperation between university students and scientific institutions.

6. Conclusions

By integrating the observed temporal trends (2019-2024) with the spatial (north, center and south zones) and seasonal variability in community structure, this study provides a fish communities on the deeper continental shelf, offering a valuable framework for future monitoring and management efforts:

- The fish composition of bottom trawl catches on the deeper continental shelf of the Catalan Sea exhibited high species richness (139 species), highlighting the multispecific nature of these fishing grounds.
- No interannual or seasonal effect was detected on total fish biomass and abundance caught by bottom trawling in the deeper shelf fishing grounds during the study period, suggesting the absence of a consistent temporal pattern.
- Spatial differences were observed across the Catalan fishing grounds in terms of species richness, total fish biomass and abundance, with the southern zone differing from the other two defined zones. This overall pattern is consistent with the spatial differences found in biomass and abundance-based fish assemblages on the deeper shelf, where the southern zone—under the influence of the Ebre River—showed a higher contribution of several commercially valuable species, both pelagic and demersal, such as European anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), scadfish (*Arnoglossus laterna*) and blackbellied angler (*Lophius budegassa*).
- Significant interannual differences were observed in fish assemblage structure, particularly between 2021 and 2022. These were mainly driven by a strong recruitment event of European hake (*Merluccius merluccius*), reflected in increased abundance in 2021 and a marked rise in biomass and juvenile presence in 2022. Additionally, from 2021 onwards, red mullet (*Mullus barbatus*) showed a progressive increase in its contribution to both abundance and biomass, indicating a sustained positive trend in recent years. More broadly, these temporal shifts suggest a directional shift in community composition, potentially reflecting the combined effects of environmental variability, climate-driven changes, and fishing pressure.
- Regarding intra-annual (seasonal) variability, results indicate that this factor is primarily driven by abundance rather than biomass, although significant differences were only detected between winter and summer. This suggests that seasonal changes are more closely related to fluctuations in number of individuals than to their size and/or weight, likely due to recruitment processes in certain species such as European hake (*Merluccius merluccius*) and possibly others. The recruitment events appear to be concentrated in summer, while winter communities tend to be more dispersed. This pattern may support a seasonal migration from the upper slope during winter to the continental shelf in summer, associated with reproductive and recruitment processes in various species.

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8. ANNEXES

8.1. Zonal representation of catch biomass (kg/km2) among 2019 to 2024 at the deeper shelf in Catalonia (NE Spain). SE: standard error

2019-2024 Catch Biomass (Kg/Km2) at the Deeper Shelf		Zone					
		North		Center		South	
Class	Species	Mean	SE	Mean	SE	Mean	SE
Actinopterygii	<i>Trachurus trachurus</i>	174,09	479,70	246,35	623,91	20,63	35,78
	<i>Merluccius merluccius</i>	58,89	53,31	82,83	94,00	56,02	56,63
	<i>Boops boops</i>	50,94	201,06	29,51	74,53	21,52	69,93
	<i>Mullus barbatus</i>	49,67	57,29	48,26	45,42	28,43	32,23
	<i>Lophius budegassa</i>	32,14	44,19	38,40	32,82	72,59	64,87
	<i>Trisopterus capelanus</i>	22,58	27,53	19,35	17,48	20,22	17,46
	<i>Pagellus erythrinus</i>	11,56	20,32	1,61	5,47	1,42	2,63
	<i>Mullus surmuletus</i>	11,00	24,70	1,57	3,02	1,94	3,78
	<i>Spicara spp.</i>	10,76	37,70	9,65	28,02	1,84	4,03
	<i>Spicara flexuosa</i>	9,34	18,89	15,80	29,78	1,41	3,88
	<i>Phycis blennoides</i>	8,83	14,41	8,06	13,50	1,04	2,22
	<i>Capros aper</i>	6,21	22,45	6,56	28,11	1,37	7,15
	<i>Lepidorhombus boscii</i>	6,02	8,25	3,93	4,82	0,13	0,59
	<i>Pagellus bogaraveo</i>	5,30	15,75	0,52	1,98	0,34	1,64
	<i>Helicolenus dactylopterus</i>	5,28	12,20	4,73	11,94	0,07	0,46
	<i>Scorpaena elongata</i>	4,61	15,22	0,99	1,58	0,09	0,60
	<i>Eutrigla gurnardus</i>	3,70	6,87	0,56	0,96	7,66	8,85
	<i>Trachinus draco</i>	3,58	7,84	2,40	4,73	3,09	3,58
	<i>Lophius piscatorius</i>	2,96	15,15	2,53	6,16	2,98	11,70
	<i>Zeus faber</i>	2,88	11,34	1,01	2,52	0,61	2,05
	<i>Chelidonichthys cuculus</i>	2,68	7,50	0,57	1,67	0,50	1,60
	<i>Citharus linguatula</i>	2,65	3,79	1,88	2,62	8,71	7,55
	<i>Trigla lyra</i>	2,26	4,46	3,14	4,86	0,18	1,19
	<i>Serranus hepatus</i>	1,79	4,01	1,63	7,47	2,26	2,99
	<i>Lepidotrigla dieuzeidei</i>	1,63	4,84	0,31	1,06	0,23	0,83
	<i>Lepidotrigla cavillone</i>	1,55	2,20	0,70	3,49	4,02	4,50
	<i>Spicara maena</i>	1,49	4,22	3,84	18,78	0,35	1,00
	<i>Serranus cabrilla</i>	1,49	4,75	0,09	0,54	0,01	0,05
	<i>Macroramphosus scolopax</i>	1,41	4,69	8,07	56,72	0,62	4,14
	<i>Chelidonichthys obscurus</i>	1,40	5,50	0,17	0,98	1,26	3,82
	<i>Engraulis encrasicolus</i>	1,38	6,75	2,79	8,16	22,63	40,36
	<i>Argentina sphyraena</i>	1,34	3,78	2,68	8,58	0,06	0,19
	<i>Micromesistius pontassou</i>	1,27	6,00	0,00	0,00	0,83	5,44
	<i>Trachurus mediterraneus</i>	1,10	7,79	0,00	0,00	11,23	49,96
	<i>Scomber scombrus</i>	0,97	2,55	5,39	17,63	8,58	16,17
	<i>Conger conger</i>	0,94	2,00	0,66	2,86	0,52	1,12
	<i>Trachurus picturatus</i>	0,77	3,12	14,17	59,94	0,02	0,14
	<i>Chelidonichthys lastoviza</i>	0,74	4,83	0,14	0,78	0,06	0,26
	<i>Scorpaena scrofa</i>	0,74	2,69	0,08	0,47	0,02	0,10
	<i>Spicara smaris</i>	0,74	6,35	0,19	1,20	0,06	0,27
	<i>Pagellus acarne</i>	0,71	3,34	0,15	0,52	0,40	1,24
	<i>Uranoscopus scaber</i>	0,67	1,45	0,60	1,36	0,81	2,15
	<i>Blennius ocellaris</i>	0,57	1,27	0,83	1,76	0,41	1,06
	<i>Pagrus pagrus</i>	0,57	4,36	0,07	0,47	0,08	0,52
	<i>Chelidonichthys lucerna</i>	0,54	1,08	1,28	2,07	2,14	3,15
	<i>Arnoglossus laterna</i>	0,48	0,75	0,56	0,77	4,22	3,53
	<i>Scorpaena loppei</i>	0,34	2,18	0,02	0,09	0,01	0,06
	<i>Sardina pilchardus</i>	0,24	0,84	1,21	4,13	6,04	10,55
	<i>Cepola macrophthalma</i>	0,24	0,72	0,24	0,74	2,66	6,17
	<i>Spondyliosa cantharus</i>	0,22	0,65	0,00	0,00	0,17	0,54
	<i>Arnoglossus rueppelii</i>	0,22	1,37	0,32	0,98	0,08	0,50
	<i>Xiphias gladius</i>	0,21	2,01	0,00	0,00	0,00	0,00
	<i>Mola mola</i>	0,17	1,62	3,07	20,77	0,00	0,00
	<i>Phycis phycis</i>	0,17	1,53	0,02	0,16	0,00	0,00
	<i>Scomber colias</i>	0,16	1,39	0,16	1,00	2,33	8,72
	<i>Sardinella aurita</i>	0,13	1,22	0,39	2,55	0,12	0,42
	<i>Gadiculus argenteus</i>	0,13	0,76	0,34	0,95	0,00	0,00
	<i>Molva macrophthalma</i>	0,12	0,49	0,42	2,51	0,01	0,06
	<i>Muraena helena</i>	0,12	1,15	0,00	0,00	0,00	0,00
	<i>Dentex dentex</i>	0,08	0,74	0,00	0,00	0,20	1,35
	<i>Gobius niger</i>	0,06	0,43	0,51	2,43	0,99	2,20
	<i>Arnoglossus imperialis</i>	0,03	0,21	0,19	0,84	0,19	0,68
	<i>Lepidorhombus whiffiagonis</i>	0,02	0,17	1,23	7,55	0,00	0,00
	<i>Alosa fallax</i>	0,02	0,18	0,05	0,41	3,95	11,53
	<i>Scorpaena porcus</i>	0,02	0,18	0,00	0,00	0,00	0,00
	<i>Scorpaena notata</i>	0,00	0,00	0,52	3,22	0,36	1,65
	<i>Lepidopus caudatus</i>	0,00	0,01	0,42	2,70	0,02	0,13
	<i>Pteroplatytrigon violacea</i>	0,00	0,00	0,00	0,00	0,55	3,69
	<i>Chelon auratus</i>	0,00	0,00	0,00	0,00	0,36	2,44
	<i>Solea solea</i>	0,00	0,00	0,00	0,00	0,31	0,76
	<i>Scophthalmus maximus</i>	0,00	0,00	0,00	0,00	0,23	1,52
	<i>Dicentrarchus labrax</i>	0,00	0,00	0,00	0,00	0,22	0,96
	<i>Chelon saliens</i>	0,00	0,00	0,00	0,00	0,20	1,35
	<i>Thunnus thynnus</i>	0,00	0,00	0,26	1,99	0,00	0,00
Elasmobranchii	<i>Scyliorhinus canicula</i>	68,28	108,63	42,43	74,76	14,15	28,89
	<i>Raja clavata</i>	6,36	34,24	0,00	0,00	1,30	5,97
	<i>Raja spp.</i>	1,31	9,84	0,67	2,53	2,41	7,13
	<i>Torpedo marmorata</i>	0,64	2,30	0,97	2,68	0,00	0,00
	<i>Oxynotus centrina</i>	0,51	4,86	0,00	0,00	0,00	0,00
	<i>Raja polystigma</i>	0,22	1,30	0,81	3,83	0,07	0,46

#It has been defined the 80th first species

8.2. Annual representation of catch biomass (kg/km2) among 2019 to 2024 at the deeper shelf in Catalonia (NE Spain). SE: standard error

Catch Biomass (Kg/Km2) at the Deeper Shelf			Year											
		2019		2020		2021		2022		2023		2024		
Class	Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Actinopterygii	Trachurus trachurus	131,44	228,22	96,91	155,02	67,94	153,04	65,67	116,26	241,88	607,39	384,31	971,64	
	Merluccius merluccius	49,60	38,35	44,33	29,07	77,98	80,94	113,32	120,78	53,50	31,63	52,55	36,72	
	Boops boops	39,39	90,52	43,65	88,30	28,33	49,14	15,22	33,42	10,98	37,00	93,17	342,28	
	Mullus barbatus	36,91	36,47	34,06	36,21	44,51	68,06	44,25	53,18	43,68	42,30	64,44	51,08	
	Lophius budegassa	56,30	55,87	45,71	36,14	40,73	45,19	45,92	63,32	39,93	51,56	28,40	33,01	
	Trisopterus capellanus	31,02	33,40	20,59	22,26	11,77	13,51	17,79	17,08	22,09	20,11	21,85	18,49	
	Pagellus erythrinus	1,95	3,95	8,43	18,89	4,73	12,35	7,12	14,59	4,30	9,76	12,03	24,00	
	Mullus surmuletus	5,53	12,46	9,56	27,05	7,35	21,05	5,75	18,05	2,37	4,05	6,00	16,20	
	Spicara spp.	0,00	0,00	0,32	1,46	0,65	2,45	4,26	9,29	13,82	34,57	34,23	61,38	
	Spicara flexuosa	7,89	15,69	15,05	27,38	20,42	33,32	10,13	19,96	1,96	5,44	1,13	6,00	
	Phycis blennoides	8,44	13,57	4,10	9,61	6,60	13,87	7,59	15,37	7,69	10,25	5,76	12,69	
	Capros aper	3,62	9,10	10,12	39,98	8,64	35,11	2,96	5,58	4,74	10,52	1,53	3,79	
	Lepidorhombus boscii	4,79	10,02	3,74	5,03	2,95	5,85	3,67	5,44	4,64	5,06	4,29	6,40	
	Pagellus bogaraveo	1,48	3,52	5,12	18,48	3,85	12,98	3,44	14,38	1,35	4,68	1,21	4,23	
	Helicolenus dactylopterus	3,84	11,29	0,15	0,36	3,43	13,39	7,30	14,53	4,88	9,52	3,45	7,59	
	Scorpaena elongata	3,17	9,32	1,26	2,82	5,33	21,44	2,44	8,74	1,28	2,05	0,78	2,37	
	Eutrigla gurnardus	4,28	8,00	3,26	6,14	1,98	3,62	3,54	7,81	3,42	6,55	5,47	7,63	
	Trachinus draco	2,48	3,86	4,15	7,37	3,27	5,93	3,18	6,20	1,87	3,46	3,94	9,32	
	Lophius piscatorius	2,89	10,08	5,77	24,41	0,96	3,38	2,52	6,85	4,48	13,77	0,63	2,12	
	Zeus faber	2,22	5,97	0,33	1,09	0,67	3,70	3,22	16,80	2,09	5,37	2,00	3,87	
	Chelidonichthys cuculus	3,07	10,78	1,30	3,14	1,18	3,08	1,59	2,85	0,57	1,27	1,18	2,86	
	Citharus linguatula	5,35	7,32	4,75	4,98	4,36	5,37	2,48	2,87	2,54	4,42	3,12	5,52	
	Trigla lyra	2,45	5,34	0,93	2,46	1,17	2,34	3,35	5,40	2,83	4,86	1,37	2,92	
	Serranus hepatus	2,33	5,92	3,72	10,65	1,49	1,99	1,00	1,50	1,41	2,88	1,25	1,41	
	Lepidotrigla dieuzeidei	2,36	6,06	0,48	1,53	0,09	0,18	0,84	4,12	1,14	2,35	0,21	0,93	
	Lepidotrigla cavillone	1,70	3,12	2,69	5,63	2,09	3,57	1,68	2,63	1,18	2,31	1,89	2,95	
	Spicara maena	1,81	4,24	6,84	26,27	2,83	7,14	0,18	1,03	0,11	0,46	0,32	0,77	
	Serranus cabrilla	0,31	0,92	0,63	2,02	0,93	2,82	1,59	6,98	0,19	0,67	0,71	2,09	
	Macroramphosus scolopax	1,22	4,59	15,53	81,64	2,06	6,92	0,94	2,64	0,50	1,10	0,89	2,40	
	Chelidonichthys obscurus	1,29	4,66	1,52	6,87	0,80	2,41	0,47	1,12	1,58	5,78	0,27	1,14	
	Engraulis encrasicolus	14,85	38,88	8,53	29,43	5,49	10,99	4,78	10,58	2,94	8,40	2,03	5,13	
	Argentina sphyraena	1,14	3,42	3,12	11,29	1,70	4,97	0,61	1,28	1,36	4,59	0,98	2,43	
	Micromesistius poussou	3,44	10,40	0,29	0,98	0,40	1,17	5,21	25,58	3,66	17,53	4,27	20,38	
	Trachurus mediterraneus	18,99	60,49	0,45	1,89	7,26	38,58	1,47	4,53	0,15	0,40	0,32	1,57	
	Scomber scombrus	1,08	1,66	6,27	23,38	4,55	8,79	0,91	1,73	6,47	15,22	6,11	14,33	
	Conger conger	0,91	2,06	0,91	1,91	0,40	0,88	1,26	3,90	0,56	1,43	0,47	1,33	
	Trachurus picturatus	20,66	74,65	1,55	6,42	0,91	3,63	0,00	0,00	1,38	4,81	0,54	1,87	
	Chelidonichthys lastoviza	0,15	0,95	1,52	7,95	0,16	0,71	0,00	0,00	0,04	0,20	0,75	3,11	
	Scorpaena scrofa	0,21	1,17	0,41	1,31	0,35	1,22	0,60	3,42	0,04	0,22	0,68	2,30	
	Spicara smarini	0,35	1,52	0,09	0,30	0,00	0,00	0,10	0,54	0,00	0,00	2,02	11,06	
	Pagellus acarne	0,45	1,39	0,10	0,38	0,32	1,60	0,44	1,96	0,13	0,48	1,38	5,17	
	Uranoscopus scaber	0,60	1,33	1,29	2,27	0,39	0,98	0,40	0,87	0,81	2,34	0,70	1,33	
	Blennius ocellaris	0,41	0,79	1,11	2,20	0,70	1,28	0,48	1,58	0,68	1,48	0,37	0,58	
	Pagrus pagrus	0,11	0,65	0,00	0,00	1,32	7,08	0,24	0,91	0,00	0,00	0,00	0,00	
	Chelidonichthys lucerna	0,77	1,51	1,06	1,53	0,94	1,73	1,53	3,23	1,76	2,60	0,79	1,37	
	Mola mola	0,00	0,00	6,03	29,63	0,00	0,00	0,75	4,33	0,00	0,00	0,00	0,00	
	Lepidorhombus whiffiagonis	0,00	0,00	0,06	0,31	0,05	0,28	0,00	0,00	1,79	10,05	0,50	2,73	
	Sardina pilchardus	1,81	6,52	0,41	1,04	2,65	5,97	3,00	9,49	1,80	5,71	1,28	2,66	
	Scorpaena notata	0,65	2,36	0,37	1,30	0,00	0,00	0,92	4,32	0,48	1,96	0,00	0,00	
	Arnoglossus laterna	1,77	3,01	1,53	2,94	1,31	1,75	1,44	2,62	1,09	1,84	0,96	1,82	
	Gobius niger	0,66	2,15	0,56	1,61	0,01	0,08	0,00	0,00	0,47	1,18	0,80	3,21	
	Molva macrophthalma	0,09	0,51	0,04	0,17	0,05	0,28	0,68	3,34	0,07	0,38	0,19	0,71	
	Lepidopus caudatus	0,09	0,36	0,00	0,00	0,01	0,04	0,63	3,63	0,05	0,25	0,00	0,00	
	Sardinella aurita	0,00	0,00	0,00	0,00	0,72	3,39	0,02	0,09	0,01	0,05	0,43	2,13	
	Alosa fallax	0,72	3,02	0,34	1,84	0,60	3,48	0,44	1,35	1,04	5,58	2,59	12,37	
	Cepola macrophthalma	1,68	6,05	1,41	3,71	0,46	1,13	0,20	0,40	0,17	0,30	0,90	1,78	
	Scomber colias	2,56	9,49	0,00	0,00	0,00	0,00	0,16	0,51	0,47	2,35	0,39	1,18	
	Pteroplatytrigon violacea	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,77	4,38	0,00	0,00	
	Chelon auratus	0,00	0,00	0,56	3,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Solea solea	0,16	0,57	0,00	0,00	0,07	0,42	0,07	0,39	0,04	0,20	0,07	0,40	
	Scophthalmus maximus	0,27	1,65	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Dicentrarchus labrax	0,03	0,14	0,19	1,03	0,00	0,00	0,00	0,00	0,11	0,61	0,00	0,00	
	Chelon saliens	0,00	0,00	0,00	0,00	0,27	1,55	0,00	0,00	0,00	0,00	0,00	0,00	
	Scorpaena lopei	0,66	3,35	0,00	0,00	0,05	0,16	0,07	0,29	0,03	0,11	0,04	0,24	
	Xiphias gladius	0,00	0,00	0,66	3,56	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Spondyliosoma cantharus	0,20	0,55	0,09	0,39	0,56	2,29	0,07	0,22	0,22	0,66	0,10	0,54	
	Arnoglossus rueppellii	0,14	0,57	0,07	0,28	0,53	2,20	0,19	0,64	0,26	1,11	0,09	0,48	
	Phycis phycis	0,00	0,00	0,04	0,23	0,43	2,49	0,00	0,00	0,00	0,00	0,04	0,24	
	Arnoglossus imperialis	0,00	0,00	0,02	0,12	0,42	0,87	0,03	0,08	0,22	1,09	0,00	0,00	
	Dentex dentex	0,00	0,00	0,00	0,00	0,00	0,00	0,49	1,97	0,00	0,00	0,00	0,00	
	Thunnus thynnus	0,00	0,00	0,00	0,00	0,00	0,00	0,47	2,69	0,00	0,00	0,00	0,00	
	Gadiculus argenteus	0,02	0,09	0,00	0,00	0,16	0,68	0,17	0,66	0,34	1,25	0,25	0,92	
	Muraena helena	0,29	1,78	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	
	Scorpaena porcus	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,32	
Elasmobranchii	Scyliorhinus canicula	69,75	124,58	37,91	49,73	44,72	110,77	45,17	50,68	41,73	94,08	43,33	55,96	
	Raja clavata	1,84	7,86	1,91	10,31	7,66	44,68	1,88	6,97	0,00	0,00	6,31	34,56	
	Raja spp.	0,00	0,00	3,19	17,08	1,56	6,61	0,95	3,87	1,21	3,44	1,71	5,17	
	Torpedo marmorata	0,84	2,00	0,89	3,46	0,28	0,99	0,29	0,82	0,86	3,12	0,41	1,54	
	Oxymotus centrina	0,13	0,78	0,00	0,00	1,36	7,94	0,00	0,00	0,00	0,00	0,00	0,00	
	Raja polystigma	0,31	0,92	0,56	2,16	0,00	0,00	0,00	0,00	0,00	0,00	1,25	5,21	
#It has been defined the SD0s first species														

#It has been defined the 80th first species

8.3. Zonal representation of catch abundance (kg/km2) among 2019 to 2024 at the deeper shelf in Catalonia (NE Spain). SE: standard error

2019-2024 Catch Abundance (N° of Individuals/Km2) at the Deeper Shelf		Zone					
		North		Center		South	
Class	Species	Mean	SE	Mean	SE	Mean	SE
Actinopterygii	<i>Trachurus trachurus</i>	5019,52	13590,63	4857,33	10797,22	612,50	893,68
	<i>Merluccius merluccius</i>	1073,87	2615,15	1739,08	3707,03	814,71	1032,03
	<i>Mullus barbatus</i>	903,52	1066,91	839,44	845,42	588,18	684,22
	<i>Boops boops</i>	896,86	3666,22	488,14	1253,97	358,34	921,38
	<i>Trisopterus capellanus</i>	739,07	811,04	707,70	889,04	846,10	1019,82
	<i>Capros aper</i>	648,80	1146,73	2427,79	13910,19	274,62	1224,28
	<i>Spicara flexuosa</i>	288,67	625,20	367,80	718,17	44,92	154,06
	<i>Spicara spp.</i>	260,07	871,10	216,52	565,83	43,65	100,11
	<i>Helicolenus dactylopterus</i>	216,01	533,33	318,38	748,68	1,15	5,34
	<i>Macroramphosus scolopax</i>	168,63	585,70	1365,41	9699,02	86,80	567,20
	<i>Phycis blennoides</i>	148,27	248,88	206,18	644,49	14,36	30,43
	<i>Pagellus erythrinus</i>	145,04	259,73	21,65	90,42	15,63	25,66
	<i>Lophius budegassa</i>	133,21	175,85	236,66	360,80	435,45	517,92
	<i>Eutrigla gurnardus</i>	128,05	230,87	10,65	24,70	332,04	436,45
	<i>Micromesistius poutassou</i>	126,35	912,71	590,36	2639,43	24,63	147,21
	<i>Lepidorhombus bosci</i>	126,21	167,85	132,34	196,05	1,03	4,54
	<i>Mullus surmuletus</i>	125,76	319,99	13,16	26,14	18,04	31,33
	<i>Argentina sphyraena</i>	121,93	339,34	420,65	1662,50	5,80	21,33
	<i>Pagellus bogaraveo</i>	120,41	327,88	10,78	35,46	4,59	16,85
	<i>Chelidonichthys cuculus</i>	113,27	251,68	15,31	39,04	21,38	61,50
	<i>Lepidotrigla dieuzeidei</i>	109,22	275,25	28,95	94,65	23,84	85,99
	<i>Lepidotrigla cavillone</i>	107,42	152,49	45,39	223,32	309,62	344,83
	<i>Engraulis encrasicolus</i>	105,42	532,09	291,19	854,28	3240,87	7986,91
	<i>Trigla lyra</i>	94,08	216,91	160,02	275,87	3,73	25,03
	<i>Serranus hepatus</i>	85,32	141,50	118,46	588,46	145,65	194,55
	<i>Arnoglossus laterna</i>	77,86	122,96	78,57	110,68	632,14	539,75
	<i>Citharus linguatula</i>	75,27	139,30	71,30	119,77	316,25	295,14
	<i>Spicara maena</i>	46,24	129,25	85,73	377,51	13,30	48,60
	<i>Trachinus draco</i>	43,11	91,00	26,71	51,28	47,62	47,19
	<i>Serranus cabrilla</i>	35,92	119,93	8,34	59,79	0,40	1,50
	<i>Chelidonichthys obscurus</i>	29,26	115,93	3,68	18,00	29,96	110,31
	<i>Scorpaena elongata</i>	26,76	97,50	13,91	22,47	1,88	11,70
	<i>Trachurus mediterraneus</i>	26,01	155,52	177,83	848,83	339,90	1124,16
	<i>Arnoglossus rueppelii</i>	24,09	155,30	56,39	180,99	11,95	73,64
	<i>Callionymus maculatus</i>	23,74	79,90	25,50	100,75	6,04	16,44
	<i>Spicara smaris</i>	22,06	185,45	8,53	51,77	3,86	18,15
	<i>Arnoglossus thori</i>	20,10	68,01	1,98	9,20	0,00	0,00
	<i>Scorpaena loppei</i>	19,71	125,61	1,20	4,67	0,50	3,34
	<i>Gadiculus argenteus</i>	18,26	74,19	74,31	231,20	0,00	0,00
	<i>Blennius ocellaris</i>	18,25	40,16	21,61	44,35	11,88	26,17
	<i>Scorpaena notata</i>	14,25	58,16	4,46	17,47	6,20	23,11
	<i>Trachurus picturatus</i>	13,26	52,26	123,13	507,33	0,24	1,62
	<i>Scomber scombrus</i>	12,23	52,28	68,75	279,26	87,85	144,67
	<i>Pagellus acarne</i>	11,47	59,58	2,16	10,09	7,13	19,48
	<i>Chelidonichthys lastoviza</i>	9,92	72,38	0,85	3,88	0,58	2,24
	<i>Cepola macrophthalma</i>	8,26	22,52	9,52	22,85	119,97	319,24
	<i>Carapus acus</i>	8,07	52,07	1,20	5,36	2,97	10,15
	<i>Sardina pilchardus</i>	7,50	23,13	103,47	533,09	654,55	1443,23
	<i>Microchirus variegatus</i>	6,86	15,91	3,79	22,95	0,55	2,94
	<i>Lesueurigobius friesii</i>	6,48	23,86	8,95	40,57	30,45	42,90
	<i>Zeus faber</i>	5,21	11,41	6,35	13,58	8,09	27,23
	<i>Scorpaena scrofa</i>	4,78	16,29	0,92	4,44	0,25	1,67
	<i>Arnoglossus imperialis</i>	4,60	29,02	20,60	95,23	19,22	68,50
	<i>Sarpa salpa</i>	4,56	43,50	0,00	0,00	0,00	0,00
	<i>Uranoscopus scaber</i>	3,95	8,09	2,45	6,22	4,57	12,46
	<i>Conger conger</i>	3,83	7,61	2,01	5,59	2,55	5,63
	<i>Scomber colias</i>	3,67	33,36	1,55	9,32	25,78	87,07
	<i>Lophius piscatorius</i>	3,50	9,02	6,40	20,63	29,07	137,48
	<i>Trachyrincus scabrus</i>	2,96	27,31	0,00	0,00	0,00	0,00
	<i>Chelidonichthys lucerna</i>	2,74	6,61	7,41	12,42	18,53	23,62
	<i>Callionymus risso</i>	2,39	22,83	0,45	3,52	0,00	0,00
	<i>Deltentosteus quadrimaculatus</i>	2,29	11,70	0,00	0,00	0,26	1,75
	<i>Coelorhynchus caelorhynchus</i>	2,02	11,10	2,93	22,67	0,00	0,00
	<i>Spondylosoma cantharus</i>	1,94	6,44	0,63	3,15	1,46	4,03
	<i>Anthias anthias</i>	1,86	13,96	0,00	0,00	0,00	0,00
	<i>Sardinella aurita</i>	1,71	15,28	8,17	53,32	2,19	7,01
	<i>Alosa fallax</i>	1,67	15,15	0,16	1,21	5,52	12,18
	<i>Callionymus lyra</i>	1,38	12,38	0,00	0,00	0,00	0,00
	<i>Symphurus nigrescens</i>	1,36	5,52	3,21	16,96	1,94	7,76
	<i>Monochirus hispidus</i>	1,27	8,54	0,00	0,00	0,09	0,63
	<i>Molva macrophthalma</i>	1,25	4,79	25,56	175,69	0,12	0,83
	<i>Ophidion barbatum</i>	1,12	5,73	0,50	3,02	0,00	0,00
	<i>Gaidropsarus macrophthalmus</i>	1,01	8,79	0,00	0,00	0,41	2,05
	<i>Galeus melastomus</i>	0,97	6,65	9,16	27,89	0,00	0,00
Elasmobranchii	<i>Scyliorhinus canicula</i>	516,07	989,94	327,95	516,38	76,25	159,91
	<i>Raja clavata</i>	7,43	52,12	0,00	0,00	1,16	4,58
	<i>Raja spp.</i>	4,69	33,78	0,78	2,70	5,04	15,40
	<i>Torpedo marmorata</i>	2,06	6,34	5,85	17,89	0,00	0,00
	<i>Oxymotus centrina</i>	0,10	1,00	0,00	0,00	0,07	0,47
	<i>Raja polystigma</i>	0,53	2,77	0,50	1,87	0,12	0,83

#It has been defined the 80th first species

8.4. Annual representation of catch abundance (kg/km2) among 2019 to 2024 at the deeper shelf in Catalonia (NE Spain). SE: standard error

Catch Abundance (N° of Individuals/Km2) at the Deeper Shelf		Year											
		2019		2020		2021		2022		2023		2024	
Class	Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Actinopterygii	<i>Trachurus trachurus</i>	4159,23	10613,36	2731,04	3938,80	1703,31	2987,93	1587,76	2751,31	5329,97	13404,31	8588,67	20657,81
	<i>Merluccius merluccius</i>	589,33	403,88	782,25	957,00	2212,80	4815,66	2126,26	4243,50	786,62	640,10	769,19	817,01
	<i>Mullus barbatus</i>	620,38	604,46	732,24	834,97	836,60	1330,52	783,21	926,02	808,28	805,31	1136,37	918,90
	<i>Boops boops</i>	526,52	1029,93	835,68	1748,87	520,01	921,88	261,56	552,37	218,83	799,32	1649,02	6229,10
	<i>Trisopterus capellanus</i>	1041,27	1234,15	814,73	1169,07	548,64	618,05	625,00	618,09	757,94	685,70	702,10	664,08
	<i>Capros aper</i>	754,12	1643,57	4318,33	19973,70	603,75	1264,04	433,60	713,02	605,31	1156,83	299,07	816,97
	<i>Spicara flexuosa</i>	170,16	336,14	467,55	834,92	545,56	912,58	269,17	548,92	61,91	153,77	30,69	164,64
	<i>Spicara spp.</i>	0,00	0,00	6,29	28,96	14,88	58,41	119,83	279,30	311,60	701,41	800,28	1389,51
	<i>Helicolenus dactylopterus</i>	114,16	325,41	5,24	12,05	180,95	658,31	394,62	800,51	304,93	678,92	179,64	427,09
	<i>Macroramphosus scolopax</i>	159,32	619,82	2681,17	13953,01	287,89	923,88	81,18	203,59	79,91	189,95	78,13	195,15
	<i>Phycis blennoides</i>	141,24	241,57	71,57	190,14	129,32	233,51	238,36	848,91	117,72	165,58	101,25	242,09
	<i>Pagellus erythrinus</i>	19,98	41,39	100,67	214,50	60,34	155,38	82,08	162,33	52,89	115,89	168,98	348,74
	<i>Lophius budegassa</i>	200,38	197,56	139,49	139,77	313,43	495,67	271,97	425,64	339,29	490,89	125,60	114,44
	<i>Eutrigla gurnardus</i>	133,01	246,84	97,33	215,00	150,54	325,92	124,27	352,29	136,83	277,37	191,96	283,61
	<i>Micromesistius pontassou</i>	342,00	1414,59	4,23	13,09	16,47	58,08	236,37	1144,53	217,67	828,44	652,79	3480,98
	<i>Lepidorhombus boscii</i>	99,38	170,40	84,75	108,99	63,82	122,57	85,44	186,89	148,92	192,95	116,11	190,56
	<i>Mullus surmuletus</i>	47,92	113,65	115,49	360,85	100,59	314,70	64,25	222,44	22,44	41,68	53,91	152,68
	<i>Argentina sphyraena</i>	141,14	358,42	544,86	2299,68	145,00	380,09	43,43	93,42	209,82	690,04	78,47	190,08
	<i>Pagellus bogaraveo</i>	25,32	64,38	152,43	472,65	75,62	228,17	49,47	165,21	37,83	145,82	33,80	113,99
	<i>Chelidonichthys cuculus</i>	95,59	288,37	87,61	241,06	60,83	155,24	55,66	111,20	24,81	55,33	43,88	100,74
	<i>Lepidotrigla dieuzeidei</i>	141,26	323,38	44,97	135,82	10,34	24,24	57,15	239,32	103,14	192,34	17,96	76,77
	<i>Lepidotrigla cavillone</i>	124,41	227,08	180,33	375,24	161,67	288,79	116,02	187,61	87,08	171,31	145,42	217,73
	<i>Engraulis encrasicolus</i>	2391,55	8717,74	640,02	1665,38	734,25	1663,84	592,60	1312,04	379,24	1161,65	226,94	612,88
	<i>Trigla lyra</i>	101,61	239,28	36,47	122,04	62,33	146,68	131,49	262,82	144,38	287,84	77,76	193,73
	<i>Serranus hepatus</i>	85,87	182,95	259,60	839,25	96,18	132,93	55,88	78,30	96,25	196,56	81,35	97,09
	<i>Arnoglossus laterna</i>	268,31	473,49	232,17	460,09	203,17	271,88	207,52	378,53	173,62	274,17	133,50	235,35
	<i>Citharus linguatula</i>	178,10	300,23	182,86	192,15	164,95	229,74	70,48	100,20	85,02	165,24	87,80	159,94
	<i>Spicara maena</i>	48,23	116,20	171,11	527,76	73,42	176,95	6,01	34,52	1,65	6,77	13,58	74,39
	<i>Trachinus draco</i>	34,80	54,40	52,51	94,47	42,73	85,66	36,88	68,41	26,69	47,73	43,31	78,44
	<i>Serranus cabrilla</i>	16,83	75,86	18,12	60,63	34,96	150,32	27,37	115,77	4,25	14,30	13,12	36,18
	<i>Chelidonichthys obscurus</i>	23,86	92,70	30,55	140,84	18,24	52,05	11,98	28,13	42,16	157,68	2,49	9,27
	<i>Scorpaena elongata</i>	24,13	52,40	10,86	20,30	34,98	146,96	15,03	39,63	9,16	18,13	4,81	11,92
	<i>Trachurus mediterraneus</i>	540,07	1407,40	10,32	49,54	163,22	804,63	35,17	125,48	12,75	53,76	13,05	55,60
	<i>Arnoglossus rupepelli</i>	20,65	85,21	8,92	34,24	57,76	250,83	34,29	121,34	50,61	211,19	11,82	59,82
	<i>Callionymus maculatus</i>	24,83	60,79	30,29	135,82	10,24	23,17	14,53	34,23	28,02	119,09	13,88	36,08
	<i>Spicara smaris</i>	15,27	65,75	7,74	26,92	0,84	4,91	2,65	11,36	0,00	0,00	59,09	322,51
	<i>Arnoglossus thori</i>	11,85	60,29	4,59	14,16	23,83	84,14	10,79	36,82	4,71	18,00	1,59	6,51
	<i>Scorpaena loppei</i>	37,90	192,91	3,58	13,19	3,35	12,25	3,46	16,38	1,36	5,79	2,40	13,14
	<i>Gadiculus argenteus</i>	6,84	31,73	6,05	28,16	52,69	245,09	30,75	112,50	33,90	100,49	59,80	183,68
	<i>Blennius ocellaris</i>	10,81	21,27	33,27	62,27	21,22	40,42	12,13	35,64	20,22	41,33	11,60	17,99
	<i>Scorpaena notata</i>	11,96	36,18	7,28	31,30	19,27	83,43	8,16	21,54	7,63	27,37	0,31	1,71
	<i>Trachurus picturatus</i>	179,13	632,13	14,35	50,19	7,85	26,85	0,00	0,00	24,90	78,64	10,59	35,09
	<i>Scomber scombrus</i>	27,65	83,34	101,65	390,93	40,37	79,84	10,02	27,48	65,18	135,46	46,81	129,19
	<i>Pagellus acarne</i>	8,37	23,75	2,13	7,09	3,13	12,22	4,51	17,49	1,03	3,04	27,56	100,48
	<i>Chelidonichthys lastoviza</i>	0,72	4,42	23,94	125,38	1,27	5,85	0,00	0,00	0,55	2,17	6,58	27,16
	<i>Cepola macrophthalmia</i>	84,36	330,19	52,38	147,89	15,82	37,04	7,23	13,27	6,92	11,21	33,30	65,38
	<i>Carapus acus</i>	0,00	0,00	4,54	15,80	18,57	83,68	1,01	4,86	1,85	7,29	2,80	10,94
	<i>Sardina pilchardus</i>	183,57	777,20	20,80	57,83	219,81	629,75	171,18	547,38	426,13	1531,36	66,94	158,33
	<i>Microchirus variegatus</i>	1,64	7,12	3,58	10,02	4,40	14,94	3,12	8,91	8,64	32,67	6,03	15,27
	<i>Lesueurigobius friesii</i>	7,02	16,85	16,05	57,38	13,54	31,68	18,45	38,53	12,05	32,51	10,32	31,58
	<i>Zeus faber</i>	6,76	11,22	1,87	5,65	1,49	3,88	8,66	20,73	6,82	9,40	11,78	32,41
	<i>Scorpaena scrofa</i>	1,14	5,45	5,99	20,63	2,59	11,22	1,68	9,64	0,30	1,70	4,37	13,22
	<i>Arnoglossus imperialis</i>	0,00	0,00	1,90	10,24	45,07	91,80	3,30	9,27	25,71	125,32	0,00	0,00
	<i>Sarpa salpa</i>	0,00	0,00	0,00	0,00	0,00	0,00	12,57	72,23	0,00	0,00	0,00	0,00
	<i>Uranoscopus scaber</i>	3,25	8,32	7,33	12,39	1,97	5,21	2,08	4,10	4,03	12,68	3,73	6,61
	<i>Conger conger</i>	3,78	7,68	4,36	7,45	2,46	5,49	3,33	8,00	2,50	6,26	1,34	3,74
	<i>Scomber colias</i>	22,77	88,29	0,00	0,00	0,00	0,00	2,90	11,98	11,40	56,58	8,72	42,12
	<i>Lophius piscatorius</i>	4,87	12,71	2,19	5,18	6,78	23,02	3,89	8,10	40,71	162,65	3,35	9,82
	<i>Trachyrincus scabrus</i>	0,22	1,37	0,00	0,00	0,00	0,00	0,00	0,00	0,95	5,37	8,68	47,55
	<i>Chelidonichthys lucerna</i>	6,56	14,14	6,05	8,63	7,41	17,89	9,75	17,26	11,48	19,67	5,40	9,55
	<i>Callionymus risso</i>	6,45	35,48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	<i>Delentosteus quadrimaculatus</i>	0,23	1,43	4,93	18,53	0,25	1,45	0,36	2,05	1,50	8,51	0,00	0,00
	<i>Coelorhynchus caelorhynchus</i>	0,00	0,00	0,00	0,00	0,00	0,00	5,58	18,06	5,49	31,05	0,00	0,00
	<i>Spondyliosoma cantharus</i>	1,99	7,21	0,51	1,96	2,26	6,15	0,73	2,40	2,00	5,44	0,84	4,61
	<i>Anthias anthias</i>	0,14	0,84	0,00	0,00	3,86	22,51	0,98	4,20	0,00	0,00	0,00	0,00
	<i>Sardinella aurita</i>	1,37	5,89	0,00	0,00	14,00	70,60	0,69	2,77	0,38	2,18	6,04	27,14
	<i>Alosa fallax</i>	1,46	5,21	0,43	2,33	0,96	5,59	1,20	3,68	5,97	26,57	2,62	9,99
	<i>Callionymus lyra</i>	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,94	20,84	0,00	0,00
	<i>Symphurus nigrescens</i>	1,49	5,06	3,67	9,73	1,23	5,88	4,25	22,40	1,13	5,32	0,74	4,05
	<i>Monochirus hispidus</i>	0,11	0,68	2,15	11,60	1,56	9,09	0,00	0,00	0,00	0,00	0,00	0,00
	<i>Molva macrophthalmia</i>	0,38	1,68	1,26	5,29	0,19	1,13	42,76	236,47	4,59	18,12	1,26	5,56
	<i>Ophidion barbatum</i>	0,21	1,30	1,04	4,31	0,90	4,04	1,93	8,50	0,00	0,00	0,00	0,00
	<i>Gaidropsarus macrophthalmus</i>	0,00	0,00	0,00	0,00	0,60	2,51	0,00	0,00	2,61	14,76	0,21	1,12
	<i>Galeus melastomus</i>	0,60	3,69	0,00	0,00	5,29	23,34	1,08	6,19	12,50	30,73	0,00	0,00
Elasmobranchii	<i>Scyliorhinus canicula</i>	512,54	924,03	246,93	319,02	430,78	1170,71	325,30	432,86	304,19	806,10	277,25	341,25
	<i>Raja clavata</i>	2,35	9,19	0,54	2,90	14,29	83,35	1,10	3,88	0,00	0,00	3,36	18,40
	<i>Raja spp.</i>	0,00	0,00	12,17	58,95	1,74	7,86	1,94	8,98	2,29	5,63	5,03	

8.5. Seasonal representation of catch abundance (kg/km2) among 2019 to 2024 at the deeper shelf in Catalonia (NE Spain). SE: standard error

2019-2024 Catch Abundance (N° of Individuals/Km2) at the Deeper Shelf		Seasons							
		Winter		Spring		Summer		Autumn	
Class	Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Actinopterygii	<i>Trachurus trachurus</i>	2400,58	577,26	3378,74	1119,05	2666,73	1244,13	7180,22	2497,00
	<i>Merluccius merluccius</i>	688,24	114,32	1324,23	491,87	2022,03	570,14	779,36	86,01
	<i>Mullus barbatus</i>	970,50	182,65	930,41	124,13	564,63	93,12	803,87	123,55
	<i>Boops boops</i>	624,75	210,65	497,07	183,08	278,28	91,91	1183,62	668,56
	<i>Trisopterus capelanus</i>	647,49	139,05	730,32	98,39	789,18	112,10	835,71	150,93
	<i>Capros aper</i>	2993,47	2397,72	799,58	182,35	515,23	144,48	331,44	103,84
	<i>Spicara flexuosa</i>	205,71	82,18	258,91	71,70	353,92	105,99	203,24	75,81
	<i>Spicara spp.</i>	216,86	90,83	163,99	99,08	180,39	78,08	228,00	115,41
	<i>Helicolenus dactylopterus</i>	136,60	72,81	293,61	97,99	261,85	96,75	96,54	34,40
	<i>Macroramphosus scolopax</i>	1853,63	1670,30	190,70	103,23	97,07	31,98	68,00	21,94
	<i>Phycis blennoides</i>	124,57	29,71	124,21	29,58	168,44	97,35	122,12	34,58
	<i>Pagellus erythrinus</i>	94,51	32,35	76,86	27,47	79,87	29,78	60,95	21,89
	<i>Lophius budegassa</i>	141,40	30,45	306,37	65,50	287,12	58,69	194,09	36,73
	<i>Eutrigla gurnardus</i>	105,98	32,38	109,34	29,58	118,92	26,77	216,50	61,07
	<i>Micromesistius poutassou</i>	35,20	22,37	668,32	425,48	138,70	128,90	129,86	80,22
	<i>Lepidorhombus boscii</i>	70,51	18,22	101,42	21,92	128,81	31,62	93,34	19,30
	<i>Mullus surmuletus</i>	95,22	54,93	65,90	28,37	58,30	21,32	50,17	17,88
	<i>Argentina sphyraena</i>	303,83	271,10	171,36	86,44	86,55	39,79	198,29	63,59
	<i>Pagellus bogaraveo</i>	55,06	28,01	41,67	24,32	49,13	19,72	93,84	49,94
	<i>Chelidonichthys cuculus</i>	85,69	39,67	51,11	20,54	51,26	15,44	63,01	25,42
	<i>Lepidotrigla dieuzeidei</i>	82,74	35,19	62,05	24,39	59,32	28,88	58,04	28,06
	<i>Lepidotrigla cavillone</i>	161,87	49,88	145,32	39,59	99,44	23,41	136,39	28,54
	<i>Engraulis encrasicolus</i>	274,51	124,68	496,04	152,38	2265,26	1073,33	406,21	133,44
	<i>Trigla lyra</i>	60,88	21,10	71,32	22,33	107,37	38,25	129,81	36,76
	<i>Serranus hepatus</i>	170,57	100,97	106,75	21,38	70,28	13,13	96,77	28,42
	<i>Arnoglossus laterna</i>	125,19	31,66	275,24	59,52	204,60	56,48	209,62	50,73
	<i>Citharus linguatula</i>	129,46	28,44	142,87	28,97	159,99	38,45	85,74	19,46
	<i>Spicara maena</i>	93,29	62,98	49,47	17,72	28,06	15,95	37,19	17,66
	<i>Trachinus draco</i>	26,19	6,51	30,07	6,32	55,04	13,77	43,32	11,30
	<i>Serranus cabrilla</i>	31,44	20,06	9,92	3,82	13,75	9,41	23,23	13,77
	<i>Chelidonichthys obscurus</i>	29,38	16,90	17,32	11,24	35,84	18,68	4,57	2,08
	<i>Scorpaena elongata</i>	18,60	6,86	35,08	18,06	7,56	2,55	8,10	1,91
	<i>Trachurus mediterraneus</i>	338,13	174,02	38,21	27,44	43,45	19,88	177,01	121,75
	<i>Arnoglossus rueppelii</i>	68,13	40,20	21,68	13,52	17,63	12,34	21,29	10,89
	<i>Callionymus maculatus</i>	24,83	16,24	14,89	5,65	24,66	13,90	16,83	6,36
	<i>Spicara smaris</i>	0,64	0,64	39,87	36,05	13,41	8,20	0,54	0,54
	<i>Arnoglossus thori</i>	4,34	2,05	4,66	2,40	21,84	11,61	8,06	4,97
	<i>Scorpaena loppei</i>	32,01	26,19	4,47	4,14	0,83	0,62	3,65	1,96
	<i>Gadiculus argenteus</i>	35,34	18,11	10,41	8,52	32,04	28,10	46,78	19,31
	<i>Blennius ocellaris</i>	15,96	4,58	10,07	2,98	23,83	6,69	20,89	6,62
	<i>Scorpaena notata</i>	8,57	4,55	19,50	10,75	6,78	3,16	3,07	1,31
	<i>Trachurus picturatus</i>	41,34	32,73	22,71	8,61	55,04	51,62	55,39	51,84
	<i>Scomber scombrus</i>	14,70	7,15	29,24	14,18	74,70	19,93	64,46	40,95
	<i>Pagellus acarne</i>	10,40	7,25	3,36	1,64	3,57	2,28	13,35	9,25
	<i>Chelidonichthys lastoviza</i>	0,96	0,76	14,52	13,78	4,08	2,96	0,33	0,23
	<i>Cepola macrophthalmia</i>	21,46	13,02	43,82	16,99	22,64	7,85	48,11	38,55
	<i>Carapus acus</i>	4,49	2,02	11,27	9,94	0,91	0,67	2,72	1,74
	<i>Sardina pilchardus</i>	18,15	8,83	259,65	177,26	353,57	126,21	93,60	37,44
	<i>Microchirus variegatus</i>	6,40	3,99	2,13	0,86	3,55	1,83	5,95	2,26
	<i>Lesueurigobius friesii</i>	11,12	4,60	6,60	2,32	18,32	7,56	14,49	4,15
	<i>Zeus faber</i>	3,53	1,25	5,39	1,14	7,31	3,62	8,30	2,44
	<i>Scorpaena scrofa</i>	1,60	0,81	4,03	2,43	1,58	1,08	2,96	1,74
	<i>Arnoglossus imperialis</i>	19,78	15,79	12,99	8,62	13,53	7,34	5,94	2,69
	<i>Sarpa salpa</i>	0,00	0,00	0,00	0,00	0,00	0,00	8,14	8,14
	<i>Uranoscopus scaber</i>	3,79	1,69	3,87	1,17	4,08	1,30	2,83	0,86
	<i>Conger conger</i>	2,71	0,95	3,31	0,99	3,73	1,11	2,14	0,71
	<i>Scomber colias</i>	7,62	7,08	16,84	11,12	7,98	4,85	0,23	0,23
	<i>Lophius piscatorius</i>	1,13	0,61	4,13	1,61	27,08	18,01	7,38	3,46
	<i>Trachyrincus scabrus</i>	6,46	5,81	0,17	0,17	0,00	0,00	0,00	0,00
	<i>Chelidonichthys lucerna</i>	5,38	1,49	7,87	1,84	12,46	3,02	5,19	1,75
	<i>Callionymus risso</i>	0,00	0,00	4,44	4,44	0,53	0,53	0,00	0,00
	<i>Delentosteus quadrimaculatus</i>	0,26	0,26	2,28	1,61	0,00	0,00	1,89	1,56
	<i>Coelorhynchus caelorhynchus</i>	5,24	4,10	1,45	1,45	1,04	1,04	0,00	0,00
	<i>Spondyliosoma cantharus</i>	1,06	0,55	4,55	1,26	0,20	0,20	0,00	0,00
	<i>Anthias anthias</i>	2,92	2,92	0,32	0,23	0,00	0,00	0,43	0,43
	<i>Sardinella aurita</i>	12,62	9,60	0,46	0,33	0,74	0,55	2,27	1,34
	<i>Alosa fallax</i>	1,15	1,15	4,88	3,13	1,97	0,80	0,36	0,27
	<i>Callionymus lyra</i>	0,00	0,00	2,41	2,41	0,00	0,00	0,16	0,16
	<i>Symphurus nigrescens</i>	3,77	2,92	2,25	1,23	1,42	0,73	1,00	0,45
	<i>Monochirus hispidus</i>	1,39	1,39	0,00	0,00	0,08	0,08	1,04	1,04
	<i>Molva macrophthalmia</i>	0,86	0,38	2,53	1,71	27,46	26,65	1,76	1,37
	<i>Ophidion barbatum</i>	0,70	0,53	0,00	0,00	0,56	0,45	1,42	0,97
	<i>Guidropsarus macrophthalmus</i>	0,14	0,14	0,00	0,00	1,88	1,65	0,16	0,16
	<i>Galeus melastomus</i>	4,31	2,37	2,33	1,74	1,64	1,40	4,84	3,39
Elasmobranchii	<i>Scyliorhinus canicula</i>	286,84	77,76	577,66	170,02	264,93	82,23	300,90	64,32
	<i>Raja clavata</i>	1,21	0,69	10,95	9,95	0,33	0,24	2,35	2,00
	<i>Raja spp.</i>	0,58	0,36	2,37	1,45	4,25	1,96	6,70	6,21
	<i>Torpedo marmorata</i>	2,34	1,09	1,70	0,76	4,06	2,54	2,80	1,12
	<i>Oxynotus centrina</i>	0,28	0,22	0,00	0,00	0,00	0,00	0,00	0,00
	<i>Raja polystigma</i>	0,62	0,30	0,97	0,53	0,00	0,00	0,16	0,16

#It has been defined the 80th first species