



SPECIES-SPECIFIC EVIDENCE OF STRUCTURAL CHANGE IN PORTUGUESE FISHERIES: A 30-YEAR ANALYSIS OF CFP REFORM INFLUENCE

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ABSTRACT

This study provides the first national, species disaggregated quantitative assessment of structural changes in Portuguese marine fisheries over three decades (1995 – 2024), coinciding with major reforms of the European Union’s Common Fisheries Policy (CFP). Using annual landings data for 47 species, Spearman rank correlation was applied to detect long term monotonic trends between year and landing volume, a non parametric approach robust to non normality, zeros, and outliers. Results reveal a pervasive decline: 26 species (55.3%) exhibited significant negative trends (ρ as low as -0.953 , $P < 0.001$), including commercially important demersals such as European hake and gurnards. Conversely, 9 species (19.1%) showed significant positive trends (e.g. Atlantic mackerel, European sea bass; ρ up to $+0.778$, $P < 0.001$), while 12 species (25.5%) remained statistically non significant. These patterns are directionally consistent with CFP objectives to reduce fishing mortality and promote selective exploitation, while acknowledging alternative drivers such as climate variability and reporting changes. The findings indicate systemic restructuring of Portuguese fisheries, with widespread reductions in demersal landings and selective increases among pelagic species, reflecting adaptive responses to regulatory and ecological pressures. This work contributes novel species level evidence of long term structural transformation, offering a baseline for future causal analyses using interrupted time series or multivariate approaches. By quantifying monotonic trends across 47 species, the study enhances understanding of policy aligned shifts in fleet behavior and ecosystem exploitation, informing adaptive governance and sustainability strategies under evolving EU fisheries frameworks.

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INTRODUCTION

The Common Fisheries Policy (CFP) is the European Union's principal framework for managing marine fisheries, aiming to balance the exploitation of marine resources with ecological sustainability and socioeconomic resilience (European Commission, 2020). Over the past three decades, major CFP reforms — most notably in 1992, 2002, and 2013 — introduced instruments such as Total Allowable Catches (TACs), technical conservation measures, and structural adjustment policies to curb overfishing, rebuild stocks, and promote selective fishing practices. These reforms increasingly align with ecosystem based management principles and broader sustainability objectives articulated under the European Green Deal and the EU Biodiversity Strategy for 2030 (Froese et al., 2014; EEA, 2020).

Portugal's accession to the European Economic Community (EEC) occurred on 1 January 1986, following the Treaty of Accession signed on 12 June 1985. Since then, successive CFP reforms have shaped national fisheries through conservation and management measures, quota based allocation under the principle of relative stability, and periodic structural adjustments. Portugal's fleets are characterized by multispecies fisheries with an important small scale coastal segment operating across ecologically diverse areas (Borges et al., 2008; Pita and Gaspar, 2020). This inherent complexity renders the reconciliation of ecological objectives with economic viability particularly challenging and underscores the importance of rigorous, policy relevant evaluation.

Existing work on CFP impacts includes qualitative assessments, governance analyses, and localized socioeconomic case studies (Simmonds et al., 2011; Pita and Gaspar, 2020). While these approaches provide valuable insights, there remains a notable scarcity of national, species disaggregated quantitative analyses tracking long horizon landings for Portugal. This analytical gap constrains the ability to relate sectoral outcomes to discrete policy milestones and to characterize structural transformations within the fisheries sector. Addressing this gap requires species level, long term indicators that are robust to the distributional features of fishery data.

The present study undertakes a national, species level assessment of long term monotonic trends in mainland Portuguese landings over 1995–2024, a period that coincides with the implementation of key CFP reforms. Annual landings for 47 species are analysed using Spearman rank correlation between year and landing volume, a non parametric method suitable for non normality, zero inflation, and outliers typical of fisheries time series. Preliminary evidence from the compiled results (Table 1) indicates significant negative monotonic trends for many demersal species — e.g. European hake *Merluccius* spp. and gurnards *Triglidae* — and significant positive trends for selected pelagic or coastal species such as Atlantic mackerel *Scomber scombrus* and European sea

bass *Dicentrarchus labrax*. These contrasting patterns suggest pervasive, species specific directional changes in landings over the study period.

Consistent with best practice, causal attribution to specific policy instruments is not asserted in this section; the emphasis is on documenting monotonic trends that are directionally consistent with CFP objectives while acknowledging potential roles for external drivers (e.g. climate variability, market dynamics, or reporting practices) elaborated elsewhere in the manuscript.

Accordingly, the central research question is: How have long term, species specific monotonic trends in Portuguese fish landings correlated with the implementation periods of CFP reforms? By quantifying national, species disaggregated trends over three decades, this study contributes empirical evidence on structural change relevant to EU fisheries governance and provides a foundation for subsequent causal analyses using designs such as interrupted time series or multivariate models.

Theoretical framework and literature review

Fisheries management requires balancing ecological sustainability with socioeconomic objectives. The Common Fisheries Policy (CFP) is the European Union's principal mechanism for regulating fishing activities across Member States through conservation, control, structural, and market measures. Core instruments include Total Allowable Catches (TACs) and national quotas allocated under relative stability, technical measures to protect juveniles and habitats, and structural policies addressing capacity and effort (European Commission, 2020). The scientific basis increasingly emphasizes Maximum Sustainable Yield (MSY) and ecosystem based management (EBM) — frameworks that seek sustainable exploitation while accounting for multispecies interactions, habitats, and human uses (Pikitch et al., 2004; Garcia & Cochrane, 2005; ICES, 2022). In parallel, recent EU strategies (e.g. the European Green Deal and the EU Biodiversity Strategy for 2030) further articulate ecological and climate objectives that frame contemporary fisheries governance (Cardinale et al., 2017; EEA, 2020).

Evolution of the CFP

The institutional development of the CFP traces back to the 1958 Treaty of Rome, with distinct fisheries provisions emerging by 1970 in the form of a common market organization and structural measures. The principle of equal access to waters was subsequently modified by derogations allowing coastal states to reserve inshore waters (generally up to 12 nautical miles) for local fleets. The 1977 declaration of 200 nautical mile Exclusive Economic Zones expanded the spatial scope of EU fisheries, necessitating stronger conservation and allocation rules (Symes & Hoefnagel, 2010).

A foundational step occurred in 1983 with Regulation (EEC) No 170/83, introducing TACs and national quotas under relative stability to ensure predictability across Member States (Daw & Gray, 2005). The inshore access derogation has been consistently renewed in successive frameworks (e.g. Council Regulation (EEC) No 3760/92, Art. 6; Council Regulation (EC) No 2371/2002, Art. 17(2); Regulation (EU) No 1380/2013, Art. 5(2)).

Key CFP reforms and their implications

- 1992 Reform (Council Regulation (EEC) No 3760/92): Introduced effort regulation and multiannual guidance programs to address overcapacity; formalized licensing systems to control access.
- 2002 Reform (Council Regulation (EC) No 2371/2002): Strengthened long term planning via recovery and management plans; created Regional Advisory Councils to enhance stakeholder input; curtailed aid for new vessels; aimed to align capacity with resources, although overcapacity and discarding persisted, and stock recovery remained limited (Froese et al., 2012).
- 2013 Reform (Regulation (EU) No 1380/2013): Set explicit MSY targets, elevated multiannual plans, introduced the Landing Obligation (discard ban) to improve selectivity and accountability, and advanced regionalization and capacity management.
- Strategic updates (post 2013): Subsequent implementation has aligned with the European Green Deal and the EU Biodiversity Strategy for 2030, emphasizing low impact, climate resilient fisheries and biodiversity protection (Cardinale et al., 2017; EEA, 2020).

Impacts of CFP reforms

Prior studies document mixed biological and economic outcomes across EU regions (Froese et al., 2012), but national, species disaggregated assessments over long horizons remain scarce for Portugal. The Portuguese fleet structure — dominated by small scale, multigear operations targeting diverse assemblages across ecologically heterogeneous areas — complicates evaluation and heightens the relevance of species level indicators (Borges et al., 2008; Pita & Gaspar, 2020). Qualitative governance assessments and localized socioeconomic studies provide valuable context (Simmonds et al., 2011; Pita & Gaspar, 2020), yet they are not designed to track national scale, species specific landing trajectories across decades. This gap constrains the ability to appraise whether sectoral outcomes are directionally consistent with major policy milestones and to characterize structural transformations in catch composition.

In this study, patterns summarized in Table 1 show widespread significant negative monotonic trends for demersal and coastal species — e.g. gurnards (*Triglidae*;

$\rho = -0.916$) and European pilchard/sardine (*Sardina pilchardus*; $\rho = -0.872$) — alongside significant positive trends for selected pelagic or coastal species — e.g. Atlantic mackerel (*Scomber scombrus*; $\rho = +0.778$) and European sea bass (*Dicentrarchus labrax*; $\rho = +0.762$). Across all 47 species, 26 (55.3%) exhibited significant negative trends, 9 (19.1%) significant positive trends, and 12 (25.5%) were non significant. These contrasting trends are compatible with policy objectives that emphasize reducing fishing mortality on vulnerable components of the ecosystem and increasing selectivity; however, causal attribution is beyond the scope of correlational trend analysis and may be influenced by external drivers such as environmental variability or reporting practices (EEA, 2020; European Commission, 2020).

Statistical rationale and operationalization of Spearman correlation

Spearman rank correlation coefficient (ρ) measures the strength and direction of monotonic association between an ordinal predictor and a continuous response without assuming linearity or normality (Zar, 2005). This property is valuable for fisheries landings data, which often exhibit skewness, zero inflation, outliers, and heteroscedasticity. In contrast to parametric trend estimators, Spearman ρ detects directional change (increasing, decreasing, or stable) regardless of magnitude and is robust to distributional irregularities (Lehmann & D'Abrera, 2006; Legendre & Legendre, 2012).

While interrupted time series (ITS) or breakpoint analyses are well-suited to examine discrete policy shocks at known intervention dates, they rely on structural assumptions about level and slope changes and typically require model specification and controls for confounders to support causal inference (Linden, 2015). Given the exploratory, species disaggregated scope across 47 series and the absence of standardized covariates, Spearman correlation provides a transparent, reproducible first step for identifying long term monotonic patterns that can inform subsequent ITS or multivariate modeling.

Annual landings (tonnes) for 47 species in mainland Portugal (1995–2024) are analyzed as species specific time series of 30 observations. For each species, year is treated as an ordinal predictor and landings as the response. Spearman ρ is computed using standard implementations (e.g. `scipy.stats.spearmanr`), with exact or approximate p values depending on ties (Virtanen et al., 2020; McKinney, 2010). The null hypothesis $H_0: \rho = 0$ is tested at $\alpha = 0.05$. Results are classified as significantly positive ($\rho > 0, P < 0.05$), significantly negative ($\rho < 0, P < 0.05$), or non significant ($P \geq 0.05$). This non parametric approach retains zeros and potential outliers to preserve rank information. As a correlational method, Spearman ρ cannot detect non monotonic dynamics (e.g. dome shaped responses) nor attribute causality; these limitations are addressed in the Discussion, and directions for future ITS or econometric analyses are outlined.

Conceptual lenses: Adaptive governance and resilience

Adaptive governance emphasizes iterative learning, stakeholder participation, and responsiveness to ecological and socioeconomic feedbacks (Folke et al., 2005; Chaffin et al., 2014). Resilience theory focuses on the capacity of coupled social ecological systems — such as fisheries — to absorb disturbances while maintaining core functions and structures (Gunderson & Holling, 2003). Within these lenses, CFP reforms can be viewed as institutional responses to regime level stressors. The species level patterns documented in Table 1 — pervasive declines for many demersals (e.g. *Triglidae*; *Sardina pilchardus*) alongside selective increases for pelagics (e.g. *Scomber scombrus*; *Dicentrarchus labrax*) — are directionally consistent with governance mechanisms that seek to curtail fishing mortality and enhance selectivity through TACs, multi annual plans, and the landing obligation. Nevertheless, observed trends may also reflect climate variability, distributional shifts, markets, or reporting changes; hence, the interpretation remains correlational (EEA, 2020; European Commission, 2020).

Synthesis and link to the research question

The literature establishes (i) the policy architecture and objectives of the CFP, (ii) the relevance of MSY and EBM as guiding paradigms, and (iii) the need for national, species disaggregated, long horizon evidence for complex, mixed fisheries such as Portugal's (Pikitch et al., 2004; Garcia & Cochrane, 2005; Borges et al., 2008; Pita & Gaspar, 2020; Simmonds et al., 2011; Froese et al., 2012; ICES, 2022). Building on these foundations, the present study deploys a robust non parametric trend metric (Spearman ρ) to quantify species specific monotonic changes across 1995–2024 and to evaluate their directional consistency with major CFP reform periods. The empirical patterns summarized in Table 1 motivate the central research question: How have long term, species specific monotonic trends in Portuguese fish landings correlated with the implementation periods of CFP reforms? This question frames the Results and Discussion, and provides a platform for future causal analyses (e.g. ITS) to isolate policy effects from confounding environmental and economic drivers (Linden, 2015).

MATERIALS AND METHODS

Data source

The primary dataset comprises annual fish landings (quantity in tonnes) for mainland Portugal, disaggregated by species, spanning the period 1995–2024. The dataset includes 47 species, representing a wide range of ecological guilds and commercial categories. Data were obtained from two authoritative national sources: the Instituto Nacional de Estatística (INE) and the Direção-Geral de Recursos Naturais, Segurança e Serviços

Marítimos (DGRM), which are the official repositories of Portuguese fisheries statistics. These sources ensure the reliability and representativeness of the time series.

Prior to analysis, raw data underwent quality checks to preserve zeros and outliers, avoiding bias in rank-based statistics. A duplicated terminal row for 2024 (with zero values) was removed to maintain the intended 30-year horizon. No imputation or smoothing was applied, as the chosen method is robust to sparse values and distributional irregularities.

Statistical approach: Spearman rank correlation

The objective was to detect long-term monotonic trends in species-specific landings over three decades. For each species, Spearman rank correlation coefficient (ρ) was computed between year (treated as an ordinal predictor) and annual landing volume (in tonnes). This non-parametric method was selected because fisheries data typically violate parametric assumptions due to non-normality, zero inflation, and outliers (Zar, 2005; Lehmann & D'Abbrera, 2006). Spearman correlation evaluates whether landings tend to increase or decrease consistently over time, without assuming linearity.

The null hypothesis ($H_0: \rho = 0$) was tested for each species using exact or approximate p-values depending on the presence of tied ranks, with a significance threshold of $\alpha = 0.05$. Results were classified as:

- Significantly negative trend ($\rho < 0, P < 0.05$),
- Significantly positive trend ($\rho > 0, P < 0.05$),
- Non-significant trend ($P \geq 0.05$).

This approach was implemented in Python using `scipy.stats.spearmanr` (Virtanen et al., 2020) and `pandas` for data handling (McKinney, 2010). Missing or zero landing values were retained, as Spearman's method is robust to sparse data and outliers.

Rationale for method selection

Interrupted time-series (ITS) or breakpoint analyses are commonly used to evaluate discrete policy shocks; however, these methods require predefined intervention points, parametric assumptions about level and slope changes, and control variables to isolate causal effects (Linden, 2015). Given the exploratory nature of this study, the absence of standardized covariates, and the goal of detecting directional trends across 47 heterogeneous species, Spearman correlation provides a transparent, reproducible first step. ITS and econometric models are recommended for future research to quantify causal impacts of CFP reforms.

Limitations

This analysis does not control external drivers such as climate variability, oceanographic shifts, illegal, unreported, and unregulated (IUU) fishing, or changes in reporting protocols, all of which may influence landing trajectories independently of policy reforms.

Consequently, results are interpreted as correlational descriptors of monotonic change, not as causal estimates. These limitations are acknowledged in the Discussion, and directions for future work include integrating biological reference points, environmental indicators, and socioeconomic variables into multivariate models.

RESULTS

Species-specific monotonic trends

Spearman rank correlation analysis was applied to annual landings for 47 species in mainland Portugal over the period 1995 – 2024. The results indicate pervasive directional changes in species-level landings, summarized in Table 1. Statistical significance was assessed at $\alpha = 0.05$. Among the 47 species analyzed:

- Twenty-six species (55.3%) exhibited significant negative monotonic trends ($\rho < 0$, $P < 0.05$), indicating sustained declines in landings over time. The most pronounced decreases were observed for miscellaneous species ($\rho = -0.953$), gurnards (*Triglidae*; $\rho = -0.916$), alfonsino (*Beryx splendens*; $\rho = -0.903$), and European pilchard/sardine (*Sardina pilchardus*; $\rho = -0.872$). Other demersal species such as European hake *Merluccius* spp. also showed strong negative correlations ($\rho = -0.794$, $P < 0.001$).
- Nine species (19.1%) displayed significant positive monotonic trends ($\rho > 0$, $P < 0.05$), suggesting

sustained increases in landings. These include Atlantic mackerel (*Scomber scombrus*; $\rho = +0.778$), European sea bass (*Dicentrarchus labrax*; $\rho = +0.762$), blue jack mackerel (*Trachurus picturatus*; $\rho = +0.681$), and gilt-head bream (*Sparus aurata*; $\rho = +0.661$). Additional positive trends were observed for meagre *Argyrosomus regius*, turbot *Psetta maxima*, and European anchovy *Engraulis encrasicolus*.

- Twelve species (25.5%) showed non-significant or weak trends ($P \geq 0.05$), indicating relative stability or high variability without clear directional change. Examples include horse mackerel (*Trachurus trachurus*; $\rho = 0.289$, $P = 0.121$) and cuttlefish (*Sepia officinalis*; $\rho = -0.253$, $P = 0.177$).

The range of Spearman coefficients across all species was substantial, from -0.953 to $+0.778$, reflecting heterogeneous responses among taxonomic groups and ecological guilds. These patterns suggest a systemic restructuring of Portuguese fisheries, characterized by widespread declines in demersal and benthic species and selective increases among pelagic and coastal species. Table 1 provides full species-specific estimates of Spearman ρ , P -values, and trend classification (negative, positive, or non-significant). Significant correlations are highlighted for clarity. This table enables independent verification of the reported counts and supports interpretation of species-level responses in the context of CFP reform periods.

Table 1. Species-specific monotonic trends in Portuguese landings (1995 – 2024)

Common Name	Scientific Name	Spearman ρ	P -value	Trend Classification
Miscellaneous	<i>Various species</i>	-0.953	<0.001	Negative
Gurnard	<i>Various Triglidae species</i>	-0.916	<0.001	Negative
Alfonsino	<i>Beryx splendens</i>	-0.903	<0.001	Negative
Groupers	<i>Various Epinephelus species</i>	-0.889	<0.001	Negative
European Conger	<i>Conger conger</i>	-0.881	<0.001	Negative
Picarel	<i>Spicara smaris</i>	-0.880	<0.001	Negative
European Pilchard / Sardine	<i>Sardina pilchardus</i>	-0.872	<0.001	Negative
Sea Bream	<i>Various Diplodus species</i>	-0.830	<0.001	Negative
Atlantic Bonito	<i>Sarda sarda</i>	-0.820	<0.001	Negative
Common Sole and Wedge Sole	<i>Solea solea and Dicologlossa cuneata</i>	-0.810	<0.001	Negative
Red Sea Bream	<i>Pagellus bogaraveo</i>	-0.795	<0.001	Negative
Black Scabbardfish	<i>Aphanopus carbo</i>	-0.794	<0.001	Negative

Continued. Table 1

Common Name	Scientific Name	Spearman ρ	P-value	Trend Classification
Hake	<i>Various Merluccius species</i>	-0.794	<0.001	Negative
Sole	<i>Solea species</i>	-0.779	<0.001	Negative
Wreckfish	<i>Polyprion americanus</i>	-0.767	<0.001	Negative
Pout Whiting	<i>Trisopterus luscus</i>	-0.754	<0.001	Negative
Red Sea Breams	<i>Various Pagrus species</i>	-0.745	<0.001	Negative
Forkbeard	<i>Phycis phycis</i>	-0.703	<0.001	Negative
Rays	<i>Rajidae family</i>	-0.654	<0.001	Negative
Atlantic Pomfret	<i>Brama brama</i>	-0.641	<0.001	Negative
Greater Forkbeard	<i>Phycis blennoides</i>	-0.575	<0.001	Negative
Sargo Bream	<i>Diplodus sargus</i>	-0.533	0.002	Negative
Stone Bass	<i>Polyprion americanus</i>	-0.524	0.003	Negative
Octopuses	<i>Octopus vulgaris</i>	-0.501	0.005	Negative
Megrim	<i>Lepidorhombus whiffiagonis</i>	-0.382	0.037	Negative
Redfish	<i>Various Sebastes species</i>	-0.370	0.044	Negative
Atlantic Mackerel	<i>Scomber scombrus</i>	0.778	<0.001	Positive
European Sea Bass	<i>Dicentrarchus labrax</i>	0.762	<0.001	Positive
Blue Jack Mackerel	<i>Trachurus picturatus</i>	0.681	<0.001	Positive
Gilt-head Bream	<i>Sparus aurata</i>	0.661	<0.001	Positive
Meagre	<i>Argyrosomus regius</i>	0.607	<0.001	Positive
Black John Dory	<i>Allocyttus niger</i>	0.591	<0.001	Positive
Turbot	<i>Psetta maxima</i>	0.549	0.002	Positive
European Anchovy	<i>Engraulis encrasicolus</i>	0.544	0.002	Positive
Brill	<i>Scophthalmus rhombus</i>	0.447	0.013	Positive
Horse Mackerel	<i>Trachurus trachurus</i>	0.289	0.121	Non-significant
Cuttlefish	<i>Sepia officinalis</i>	-0.253	0.177	Non-significant
Monkfish	<i>Lophius species</i>	-0.241	0.200	Non-significant
Squids	<i>Various Loligo or Todarodes species</i>	-0.231	0.219	Non-significant
Scabbardfish	<i>Lepidopus caudatus</i>	-0.199	0.291	Non-significant
Mulletts	<i>Mugilidae family</i>	0.194	0.305	Non-significant
Tunas and Scombrids	<i>Scombridae family</i>	0.134	0.480	Non-significant
Bogue	<i>Boops boops</i>	0.131	0.492	Non-significant
Salema Porgy	<i>Sarpa salpa</i>	-0.079	0.680	Non-significant

Continued. Table 1

Common Name	Scientific Name	Spearman ρ	P-value	Trend Classification
Red Mullet	<i>Various Mullus species</i>	0.057	0.766	Non-significant
Tope Shark	<i>Galeorhinus galeus</i>	-0.027	0.889	Non-significant
Shortfin Squids	<i>Todarodes species</i>	0.015	0.939	Non-significant

Note: ρ = Spearman rank correlation coefficient; α = 0.05 significance level.

Source: Instituto Nacional de Estatística (INE) and Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos (DGRM), annual fish landings by species for mainland Portugal (1995–2024), as compiled in Annex I.

DISCUSSION

Ecological implications

The species-level Spearman analysis reveals pervasive monotonic changes in Portuguese landings over 1995 – 2024, with 26 of 47 species (55.3%) showing significant negative correlations ($\rho < 0$, $P < 0.05$) and nine species (19.1%) showing significant positive correlations ($\rho > 0$, $P < 0.05$). Twelve species (25.5%) exhibited non-significant or weak trends ($P \geq 0.05$). Coefficients span -0.953 to $+0.778$, indicating heterogeneous responses across taxonomic and ecological groups. Pronounced negative trends include gurnards (*Triglidae*; $\rho = -0.916$), *Sardina pilchardus* ($\rho = -0.872$), *Beryx splendens* ($\rho = -0.903$), and *Conger conger* ($\rho = -0.881$). Strong positive trends include *Scomber scombrus* ($\rho = +0.778$), *Dicentrarchus labrax* ($\rho = +0.762$), and *Trachurus picturatus* ($\rho = +0.681$). By contrast, species such as horse mackerel *Trachurus trachurus* and cuttlefish *Sepia officinalis* exhibit non-significant trends.

These patterns are directionally consistent with long-term management aims to reduce fishing mortality on vulnerable components of the ecosystem and to incentivize selective exploitation (e.g. through TACs, multiannual plans, and the landing obligation) under successive CFP reforms (Council Regulation (EEC) No 3760/92; Council Regulation (EC) No 2371/2002; Regulation (EU) No 1380/2013). At the same time, declines in demersal/benthic species and selective increases in certain pelagics can also arise from non-policy drivers, including climate variability, distributional shifts, and reporting changes (EEA, 2020; Froese et al., 2012). Accordingly, the results are interpreted as correlational descriptors of monotonic change, not causal effects. The overall picture, however, is of structural transformation at species level — consistent with a rebalancing of exploitation patterns and potential reductions in aggregate pressure on some demersal guilds.

Socioeconomic considerations and regional heterogeneity

Species-specific directional changes imply uneven exposure across fleet segments and regions. Widespread declines among demersals (e.g. *Triglidae*; *S. pilchardus*),

together with a subset of increasing pelagics (e.g. *S. scombrus*, *D. labrax*), are consistent with differentiated impacts on small-scale multigear coastal fleets versus purse-seine or mobile-gear segments (Borges et al., 2008; Pita and Gaspar, 2020). In particular, fleets and communities specializing in demersal targets may face persistent adjustment pressures as landings trend downward, whereas segments with access to growing pelagic opportunities may experience relative gains. These inferences do not derive from causal estimates in this paper; they are contextualized by prior socioeconomic literature and Commission state-of-play assessments (European Commission, 2020; Pita and Gaspar, 2020; Borges et al., 2008). The heterogeneity observed underscores the importance of regionally differentiated support and transition measures in any future policy refinements.

Policy implications in relation to CFP objectives

The prevalence of significantly negative ρ values — together with selective positive trends — aligns with CFP objectives intended to:

- Reduce fishing mortality and rebuild overexploited stocks;
- Improve selectivity and accountability via the landing obligation and multiannual plans;
- Stabilize exploitation rates around MSY proxies (Regulation (EU) No 1380/2013; Cardinale et al., 2013; ICES, 2022).

However, several objectives cannot be inferred from monotonic trends in landings alone, including biological status relative to MSY for individual stocks, distributive equity, profitability, and broader ecosystem outcomes. These require integrated biological, environmental, and economic indicators not estimated here (European Commission, 2020; EEA, 2020). Thus, findings should be read as consistent with selected CFP aims (mortality reduction, selectivity, accounting) while agnostic regarding comprehensive attainment of all policy targets.

Comparison with previous evidence

The documented pattern of widespread declines alongside selective increases complements multi-region syntheses that report mixed progress under the CFP and emphasize the interaction of governance and ecological variability (Froese et al., 2012; Cardinale et al., 2013). The Portuguese case — characterized by multispecies, small-scale coastal operations — illustrates how structural policy instruments can be associated with species-level reconfiguration of landings over extended horizons, while remaining sensitive to external environmental and market drivers (Borges et al., 2008; Pita and Gaspar, 2020; European Commission, 2020). The results comport with ecosystem-based perspectives that expect differential responses across guilds and trophic levels under selective pressure and changing conditions (Pikitch et al., 2004; Smith et al., 2011; Garcia & Cochrane, 2005).

Methodological considerations

The choice of Spearman rank correlation provided a robust, distribution-free indicator of directional change at species level across three decades, suitable for data characterized by skewness, zeros, and outliers (Zar, 2005; Lehmann and D'Abbrera, 2006; Legendre and Legendre, 2012). The method does not assume linearity and is insensitive to the magnitude scale of landings, which is advantageous for multispecies comparisons. At the same time, Spearman ρ cannot detect non-monotonic or stepwise dynamics, and it does not support causal attribution. These features position the present analysis as a transparent first step, to be complemented by causal designs such as interrupted time-series or structural break tests that explicitly model the 1992, 2002, and 2013 reform periods (Linden, 2015). Future work can also incorporate covariates (e.g. environmental indices, effort, market factors) to improve identification.

Limitations and directions for future research

Several limitations warrant emphasis. First, landings are an aggregate outcome shaped by regulations, stock dynamics, effort allocation, market demand, and reporting practices; they are not a direct measure of stock status. Second, the analysis does not control for climate and oceanographic variability, nor for potential IUU signals, which may influence observed trajectories (EEA, 2020; Froese et al., 2012). Third, species-level series may embed compositional shifts within broader groupings (e.g. “miscellaneous”), which complicates biological interpretation.

Future research should therefore:

- Implement interrupted time-series and related quasi-experimental models to quantify level and slope changes at reform junctures (1992, 2002, 2013) and test robustness across specifications (Linden, 2015);

- Integrate biological reference points (stock status relative to MSY), environmental covariates (e.g. temperature anomalies), and effort/gear data to disentangle policy from environmental and market drivers (ICES, 2022; EEA, 2020);
- Evaluate distributional impacts across regions and fleet segments using socioeconomic indicators (European Commission, 2020; Pita and Gaspar, 2020);
- Refine species groupings to separate mixed categories where feasible.

Synthesis

In summary, Portuguese fisheries exhibit systematic, species-level directional change over 1995 – 2024: widespread declines for many demersal and coastal species, and selective increases among pelagics and certain coastal taxa. These outcomes are consistent with CFP objectives to reduce mortality and enhance selectivity, while remaining compatible with alternative explanations involving environmental variability and reporting. The findings substantiate a structural transformation of landings composition at national scale, motivate targeted socioeconomic support where exposure is greatest, and delineate a clear pathway for causal evaluation of specific reform instruments in future work (Cardinale et al., 2013; European Commission, 2020; ICES, 2022; EEA, 2020; Linden, 2015).

CONCLUSIONS

This study provides the first national, species disaggregated quantitative evidence of structural transformation in Portuguese marine fisheries over three decades (1995 – 2024), coinciding with major Common Fisheries Policy (CFP) reform milestones. Using Spearman rank correlation analysis across 47 species, the research documents systematic changes in landing patterns that are directionally consistent with policy objectives aimed at reducing fishing mortality and promoting selective exploitation.

Key findings include:

- Widespread declines: 26 species (55.3%) exhibited significant negative monotonic trends (ρ as low as -0.953 , $P < 0.001$), notably demersal and benthic taxa such as gurnards *Triglidae*, European pilchard *Sardina pilchardus*, and European hake *Merluccius* spp.
- Selective increases: Nine species (19.1%) showed significant positive trends (ρ up to $+0.778$), including Atlantic mackerel *Scomber scombrus*, European sea bass *Dicentrarchus labrax*, and gilt head bream *Sparus aurata*.

- Relative stability: Twelve species (25.5%) displayed non significant or weak trends, indicating heterogeneous responses across ecological guilds.

These patterns underscore a systemic reconfiguration of Portuguese fisheries, characterized by reductions in demersal landings and selective growth among pelagic species. While consistent with CFP objectives to curb fishing pressure and enhance selectivity, the analysis does not establish causality; observed trends may also reflect climate variability, market dynamics, and reporting changes.

The study's novelty lies in its species level resolution and long term scope, providing a robust empirical baseline for evaluating governance outcomes. Future research should employ interrupted time series or multivariate models to isolate policy effects from confounding drivers and integrate biological, environmental, and socioeconomic indicators to strengthen causal inference. Policy design should continue to prioritize ecological targets while addressing regional disparities and socioeconomic vulnerabilities to ensure a just and sustainable transition for all fleet segments.

SPECIFIČNI DOKAZI STRUKTURNIH PROMJENA U PORTUGALSKOM RIBARSTVU: 30-GODIŠNJA ANALIZA UTJECAJA REFORME ZAJEDNIČKE RIBARSTVENE POLITIKE (ZRP)

SAŽETAK

Ova studija pruža prvu nacionalnu, po vrstama razvrstanu kvantitativnu procjenu strukturnih promjena u portugalskom morskom ribarstvu tijekom tri desetljeća (1995. – 2024.), što se podudara s velikim reformama Zajedničke ribarstvene politike (ZRP) Europske unije. Koristeći godišnje podatke o iskrcaju za 47 vrsta, primijenjena je Spearmanova korelacija rangova za otkrivanje dugoročnih monotonih trendova između godine i volumena iskrcaja. Rezultati otkrivaju sveprisutni pad: 26 vrsta (55,3%) pokazalo je značajne negativne trendove (ρ i do $-0,953$, $P < 0,001$), uključujući komercijalno važne pridnene vrste poput oslića i kokota. Suprotno tome, 9 vrsta (19,1%) pokazalo je značajne pozitivne trendove (npr. atlantska skuša, brancin; ρ do $+0,778$, $P < 0,001$), dok je 12 vrsta (25,5%) ostalo statistički neznačajno. Ovi obrasci su usmjereno u skladu s ciljevima ZRP-a za smanjenje smrtnosti ribolova i promicanje selektivnog iskorištavanja, uz istovremeno priznavanje alternativnih pokretača poput klimatske varijabilnosti i promjena u izvještavanju. Nalazi ukazuju na sustavno restrukturiranje portugalskog ribarstva, s raširenim smanjenjem pridnenog iskrcavanja i selektivnim povećanjem među pelagičnim vrstama, što odražava adaptivne odgovore na regulatorne i ekološke pritiske. Ovaj rad doprinosi novim dokazima

na razini vrste o dugoročnoj strukturnoj transformaciji, nudeći osnovu za buduće kauzalne analize korištenjem prekinutih vremenskih serija ili multivarijantnih pristupa. Kvantificiranjem monotonih trendova kod 47 vrsta, studija poboljšava razumijevanje promjena usklađenih s politikom u ponašanju flote i iskorištavanju ekosustava, informirajući adaptivno upravljanje i strategije održivosti u okviru razvojnih okvira EU u ribarstvu.

Ključne riječi: strukturna transformacija, trendovi na razini vrsta, spearmanova korelacija rangova, upravljanje morskim resursima, evaluacija ribarske politike

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CONFLICT OF INTEREST

The author has declared no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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ANNEX I

Annual Fish Landings (t) by Species for Mainland Portugal (1995 – 2024)

(Part 1 of 4)

Year	Forkbeard (<i>Phycis phycis</i>)	Megrim (<i>Lepidorhombus whiffiagonis</i>)	Tunas and Scombrids (<i>Scombridae</i> family)	Wreckfish (<i>Polyprion americanus</i>)	Red Sea Bream (<i>Pagellus bogaraveo</i>)	Sargo Bream (<i>Diplodus sargus</i>)	European Anchovy (<i>Engraulis encrasicolus</i>)	Horse Mackerel (<i>Trachurus trachurus</i>)	Blue Jack Mackerel (<i>Trachurus picturatus</i>)	Atlantic Mackerel (<i>Scomber scombrus</i>)	Stone Bass (<i>Polyprion americanus</i>)	European Conger (<i>Conger conger</i>)	Meagre (<i>Argyrosomus regius</i>)	Gilthead Bream (<i>Sparus aurata</i>)
1995	333	151	954	169	1 014	88	2 251	17 165	729	2 870	405	2 814	69	200
1996	309	165	1 039	184	1 129	111	2 747	13 595	1 009	3 872	291	2 553	80	209
1997	321	150	1 062	139	887	157	632	18 331	834	4 819	218	2 254	113	189
1998	317	179	1 175	115	851	133	1 625	20 487	526	6 476	202	2 171	105	172
1999	311	120	1 173	76	873	105	1 403	14 181	315	13 545	141	1 735	116	151
2000	280	152	1 481	77	1 266	141	309	14 092	424	10 455	72	1 130	100	183
2001	338	129	1 009	38	1 177	125	854	13 693	409	4 220	77	1 339	158	213
2002	302	132	966	42	1 099	142	915	14 189	622	5 131	88	1 046	353	185
2003	349	186	1 016	44	1 033	102	478	11 147	773	7 633	209	1 129	200	93
2004	328	182	1 597	75	780	92	648	12 971	568	13 425	110	1 207	231	136
2005	294	215	1 391	77	675	97	124	13 228	1 019	13 777	174	1 202	389	134
2006	259	236	1 794	107	957	121	108	14 342	1 144	12 501	322	1 282	315	143
2007	284	232	1 996	107	843	140	870	10 322	2 801	19 804	493	1 366	328	205
2008	298	190	1 195	97	772	126	335	9 250	3 039	22 808	300	1 151	408	186
2009	513	222	1 752	111	962	85	72	10 723	3 099	13 798	224	1 394	515	194
2010	515	207	2 702	112	1 023	105	130	11 652	1 688	22 026	104	1 314	438	218

Year	Forkbeard (<i>Phycis phycis</i>)	Megrim (<i>Lepidorhombus whiffiagonis</i>)	Tunas and Scombrids (<i>Scombridae</i> family)	Wreckfish (<i>Polyprion americanus</i>)	Red Sea Bream (<i>Pagellus bogaraveo</i>)	Sargo Bream (<i>Diplodus sargus</i>)	European Anchovy (<i>Engraulis encrasicolus</i>)	Horse Mackerel (<i>Trachurus trachurus</i>)	Blue Jack Mackerel (<i>Trachurus picturatus</i>)	Atlantic Mackerel (<i>Scomber scombrus</i>)	Stone Bass (<i>Polyprion americanus</i>)	European Conger (<i>Conger conger</i>)	Meagre (<i>Argyrosomus regius</i>)	Gilthead Bream (<i>Sparus aurata</i>)
2011	487	215	2 121	102	857	95	3 280	10 024	2 806	30 457	152	1 441	366	283
2012	478	143	1 421	103	781	108	777	14 893	3 556	36 571	157	1 114	407	230
2013	297	121	1 319	86	734	94	390	15 337	2 353	36 863	161	989	497	294
2014	248	172	856	56	684	75	817	14 920	1 947	29 034	95	1 089	464	299
2015	221	160	1 654	33	1 044	88	2 531	19 955	2 364	45 728	84	1 015	491	241
2016	201	120	1 361	18	673	86	6 925	20 014	3 453	27 398	62	961	586	224
2017	193	160	1 032	17	559	104	9 021	19 054	3 709	19 089	86	982	348	261
2018	179	137	1 210	14	636	118	8 198	15 944	2 689	33 139	84	800	509	274
2019	185	124	1 445	16	519	126	9 115	17 167	2 376	45 865	76	800	429	271
2020	191	151	1 007	18	464	108	5 475	14 609	2 479	23 280	90	836	314	315
2021	175	143	1 325	15	293	81	9 630	16 634	5 034	22 484	92	790	369	289
2022	173	109	832	6	366	73	3 533	17 702	2 106	20 640	83	681	297	219
2023	161	96	1 567	5	392	84	4 566	15 958	1 642	31 736	119	723	264	191
2024	145	100	1 236	5	337	85	5 882	14 228	2 209	17 879	74	711	400	231

(Part 2 of 4)

Year	Scabbardfish (<i>Lepidopus caudatus</i>)	Black Scabbardfish (<i>Aphanopus carbo</i>)	Hake (various <i>Merluccius</i> species)	Rays (<i>Rajidae</i> family)	European Sea Bass (<i>Dicentrarchus labrax</i>)	Red Mullet (various <i>Mullus</i> species)	Atlantic Bonito (<i>Sarda sarda</i>)	European Pilchard / Sardine (<i>Sardina pilchardus</i>)	Sea Bream (various <i>Diplodus</i> species)	Sole (<i>Solea</i> species)	Monkfish (<i>Lophius</i> species)	Greater Forkbeard (<i>Phycis blennoides</i>)	Atlantic Pomfret (<i>Brama brama</i>)	Tope Shark (<i>Galeorhinus galeus</i>)	Pout Whiting (<i>Trisopterus luscus</i>)
1995	8 222	4 272	3 602	1 444	360	199	2 934	81 992	1 029	148	576	2 154	26	149	3 006
1996	7 547	3 683	3 608	1 548	432	141	2 950	83 006	1 032	137	836	3 346	63	145	2 380
1997	6 402	3 552	2 770	1 539	274	191	2 049	76 399	1 016	90	1 089	2 305	99	85	2 026
1998	4 306	3 147	2 684	1 505	317	148	2 830	80 148	982	114	1 058	1 666	11	95	2 228
1999	3 173	2 741	3 083	1 409	374	172	1 921	69 337	868	95	995	2 451	19	79	2 750
2000	15	2 790	2 978	1 520	454	147	2 186	62 556	917	124	821	2 069	5	41	3 199
2001	22	2 744	2 968	1 579	409	184	3 085	64 946	756	140	576	1 649	7	43	4 445
2002	66	2 692	2 544	1 510	398	155	2 908	63 577	867	190	485	1 596	76	46	3 031
2003	22	2 630	1 940	1 598	360	115	2 673	63 937	906	228	625	2 575	4	56	3 304
2004	68	2 463	1 948	1 614	390	108	2 367	57 170	826	178	397	4 193	4	44	3 381
2005	19	2 746	1 965	1 666	488	109	2 397	50 481	717	146	306	5 126	664	44	2 597
2006	6	2 674	2 219	1 554	650	169	2 615	48 022	805	113	251	2 430	384	57	2 139
2007	8	3 456	1 985	1 504	596	227	2 604	58 134	851	104	381	3 870	89	57	2 672
2008	12	3 601	2 037	1 525	485	178	2 378	65 279	782	98	296	4 210	360	42	3 101
2009	79	3 493	2 161	1 498	455	202	1 752	55 105	858	110	306	2 039	5	45	3 266
2010	16	3 453	2 361	1 496	523	275	2 362	58 083	866	123	275	1 476	39	39	2 690
2011	101	3 475	2 198	1 444	465	242	959	55 179	857	126	320	693	27	44	2 229
2012	28	2 668	2 575	1 131	401	230	766	31 326	724	71	694	1 947	413	42	2 160
2013	61	2 130	2 730	1 096	562	189	250	27 658	743	88	526	1 996	2	41	1 764

Year	Scabbardfish (<i>Lepidopus caudatus</i>)	Black Scabbardfish (<i>Aphanopus carbo</i>)	Hake (various <i>Merluccius</i> species)	Rays (Rajidae family)	European Sea Bass (<i>Dicentrarchus labrax</i>)	Red Mullet (various <i>Mullus</i> species)	Atlantic Bonito (<i>Sarda sarda</i>)	European Pilchard / Sardine (<i>Sardina pilchardus</i>)	Sea Bream (various <i>Diplodus</i> species)	Sole (<i>Solea</i> species)	Monkfish (<i>Lophius</i> species)	Greater Forkbeard (<i>Phycis blennoides</i>)	Atlantic Pomfret (<i>Brama brama</i>)	Tope Shark (<i>Galeorhinus galeus</i>)	Pout Whiting (<i>Trisopterus luscus</i>)
2014	143	2 109	2 374	1 016	710	218	588	15 808	848	95	551	1 244	3	341	2 032
2015	82	2 527	2 001	1 014	489	276	1 413	13 690	818	95	583	1 415	6	215	2 161
2016	51	2 456	1 972	1 027	611	206	619	13 488	776	87	504	1 526	0	106	1 785
2017	52	2 117	1 483	1 144	641	161	633	14 516	850	65	538	1 603	0	55	2 026
2018	25	1 728	1 488	1 106	542	166	855	9 662	729	73	338	1 483	1	57	1 797
2019	39	2 302	1 906	1 134	602	166	705	9 677	718	76	305	1 429	5	58	1 786
2020	83	2 369	1 893	1 229	689	146	575	14 503	640	94	602	1 789	1	70	1 678
2021	54	2 245	1 955	1 360	672	117	952	26 672	699	71	524	1 210	4	60	1 694
2022	56	1 993	1 581	1 315	529	132	828	24 272	607	53	418	1 956	0	52	1 317
2023	53	2 092	1 400	1 445	546	166	685	25 069	624	53	609	1 983	1	53	908
2024	60	1 723	896	1 386	556	182	562	31 909	525	32	924	1 224	0	57	845

(Part 3 of 4)

Year	Common Sole and Wedge Sole (<i>Solea solea</i> and <i>Dicologlossa cuneata</i>)	Gurnard (various <i>Triglidae</i> species)	Bogue (<i>Boops boops</i>)	Picarel (<i>Spicara smaris</i>)	Salema Porgy (<i>Sarpa salpa</i>)	Groupers (various <i>Epinephelus</i> species)	Turbot (<i>Psetta maxima</i>)	Brill (<i>Scophthalmus rhombus</i>)	Mulletts (<i>Mugilidae</i> family)	Redfish (various <i>Sebastes</i> species)	Alfonsino (<i>Beryx splendens</i>)	Black John Dory (<i>Alloctytus niger</i>)	Miscellaneous (various species)	Cuttlefish (<i>Sepia officinalis</i>)	Squids (various <i>Loligo</i> or <i>Todarodes</i> species)
1995	1 702	596	393	230	384	72	54	57	380	291	272	155	14 547	988	904
1996	1 240	630	322	336	281	62	38	48	286	251	190	155	9 196	1 636	463
1997	1 060	608	343	330	335	30	29	39	287	294	171	175	8 883	1 423	844
1998	971	499	299	357	187	36	27	33	306	311	147	304	10 201	1 734	1 013
1999	1 004	490	327	265	265	13	34	39	307	243	143	322	8 250	1 162	327
2000	1 297	645	636	83	238	4	63	46	324	124	40	382	5 794	1 357	614
2001	1 156	603	892	97	302	3	83	57	310	146	43	396	5 110	1 348	863
2002	927	632	753	111	225	8	69	47	274	151	59	385	4 946	1 368	679
2003	958	598	658	141	224	14	62	40	227	191	45	357	4 760	1 298	289
2004	1 109	543	369	183	205	15	67	51	209	180	53	273	4 026	1 665	1 009
2005	1 074	513	335	129	233	11	71	50	215	154	45	234	4 102	1 802	482
2006	811	493	303	140	258	5	53	34	300	181	27	249	4 388	1 787	89
2007	563	371	225	185	315	13	30	18	239	284	50	256	4 219	1 517	128
2008	626	397	153	158	268	4	29	27	268	181	42	195	3 812	1 453	360
2009	838	412	173	124	221	2	44	33	221	179	34	259	3 538	1 259	269
2010	917	358	182	105	169	2	72	50	242	137	27	344	3 715	2 010	273
2011	1 021	399	261	96	190	1	51	42	305	158	21	376	4 121	1 522	324
2012	798	385	270	143	247	3	49	40	2 457	216	11	403	3 805	1 180	359
2013	855	376	205	90	136	3	42	44	1 249	218	17	462	3 088	1 317	180

Year	Common Sole and Wedge Sole (<i>Solea solea</i> and <i>Dicologlossa cuneata</i>)	Gurnard (various <i>Triglidae</i> species)	Bogue (<i>Boops boops</i>)	Picarel (<i>Spicara smaris</i>)	Salema Porgy (<i>Sarpa salpa</i>)	Groupers (various <i>Epinephelus</i> species)	Turbot (<i>Psetta maxima</i>)	Brill (<i>Scophthalmus rhombus</i>)	Mulletts (<i>Mugilidae</i> family)	Redfish (various <i>Sebastes</i> species)	Alfonsino (<i>Beryx splendens</i>)	Black John Dory (<i>Alloctytus niger</i>)	Miscellaneous (various species)	Cuttlefish (<i>Sepia officinalis</i>)	Squids (various <i>Loligo</i> or <i>Todarodes</i> species)
2014	842	430	222	59	224	1	37	38	664	160	18	470	1 863	1 256	171
2015	832	388	466	66	189	3	62	35	392	172	31	396	1 885	1 274	414
2016	773	362	779	70	221	1	48	40	492	174	24	309	1 991	1 290	301
2017	767	345	540	69	257	1	53	55	252	223	20	332	2 362	1 023	254
2018	671	321	522	58	246	2	71	54	501	189	22	318	2 309	1 018	448
2019	719	334	351	36	168	2	88	58	326	158	10	380	2 415	1 105	443
2020	809	341	328	43	296	2	125	87	276	167	18	355	2 332	1 268	516
2021	717	279	473	29	303	1	149	84	464	172	14	387	2 005	1 436	504
2022	636	284	523	33	308	1	137	75	414	180	17	405	1 714	1 102	765
2023	624	277	582	38	254	0	147	68	244	162	13	417	1 561	1 550	535
2024	495	226	650	32	304	0	126	59	244	135	13	424	1 518	1 412	482

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Year	Octopuses (<i>Octopus vulgaris</i>)	Shortfin Squids (<i>Todarodes species</i>)	Year	Octopuses (<i>Octopus vulgaris</i>)	Shortfin Squids (<i>Todarodes species</i>)
1995	9 736	102	2010	10 665	40
1996	11 552	122	2011	7 266	76
1997	9 056	364	2012	9 653	97
1998	6 407	388	2013	12 910	75
1999	9 181	314	2014	10 661	78
2000	9 658	323	2015	7 675	99
2001	8 106	233	2016	10 567	144
2002	8 158	205	2017	5 850	26
2003	9 699	147	2018	6 763	130
2004	8 211	241	2019	5 896	172
2005	10 826	187	2020	5 223	62
2006	7 071	42	2021	7 196	2 517
2007	8 501	21	2022	7 896	1 205
2008	13 381	18	2023	6 244	1 050
2009	7 940	18	2024	4 956	1 679

Note: Abbreviations: spp. = multiple species; family = family-level aggregate; various = composite grouping; t = tonnes. Latin names in parentheses are italicized.

Source: Instituto Nacional de Estatística (INE) and Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos (DGRM).