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Scabbardfishes fishery at CECAF 34.1.2

A 13 years analysis (2010-2022)



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ABSTRACT

In the CECAF division 34.1.2, the Madeiran drifting longline fishery exploits two sympatric species, *Aphanopus carbo* (Lowe, 1839) and *Aphanopus intermedius* (Parin, 1983), with catch monitoring data from 2010 to 2022 revealing several key population and fishery trends. Total landings showed interannual stability, reaching 2,259 tonnes in 2022, representing a 21.5% increase from 2010 levels. The fleet was dominated by VL1218 vessels (79% of landings), with VL1824 vessels contributing 13%. Based on established species composition ratios (Delgado et al., 2013), the 2022 landings comprised approximately 1,807 tonnes of *A. carbo* and 452 tonnes of *A. intermedius*. In general, the first sale value followed the same trend observed in the annual landings, yielding in 2022 approximately 7.5 M€. The temporal evolution of the mean length by year shows no trend, which supports the stability on the length structure of the exploited population along the whole period. In fact, the analysis of length distribution data indicates neither great changes on the length range between years nor on the mean length (around 114 -118 cm total length). Annual length-frequency and mean length of samples collected from commercial landings and research survey were similar. The annual proportion of adults in the landings was superior to 98%. There was an overall decrease of fishing effort in the available period, reflecting the decline of the number of vessels. In general, catches and CPUE had an overall pattern of increase along the analysed period. All indicators analysed reached a certain level of stability between 2010 and 2016, and even a slight recovery was observed since 2017 to 2022. Overall, it was verified an increase of 399 tonnes in the landings between 2010 and 2022 and an increase of 67 kg/1000 hooks in CPUE for the same period. Total mortality and natural mortality were estimated at 0.96 and 0.24 per year respectively. Fishing mortality was estimated at 0.72 year⁻¹, while the Fishing Mortality at Maximum Sustainable Yield was determined at 0.82 year⁻¹. These findings demonstrate the fishery's remarkable stability in biological parameters despite fluctuating effort levels. The consistent length structure, high adult proportion, and positive CPUE trends indicate sustainable exploitation under current management measures. However, future stock assessments should incorporate these CECAF 34.1.2 data to improve the accuracy of management advice for Northeast Atlantic black scabbardfish populations. The demonstrated resilience of this stock highlights the importance of maintaining current monitoring programs to detect potential changes in these stable population indicators.

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1 STATE OF THE ART

1.1 The fishery

The deep-water fishery operating within Madeira's Exclusive Economic Zone and adjacent international waters (CECAF 34.1.2) represents one of the Northeast Atlantic's oldest continuous fishing traditions, with historical records of scabbardfish exploitation dating to the 17th century (Merrett and Haedrich, 1997). For over three centuries, this remained the sole targeted fishery for scabbardfish in the region (Bordalo-Machado and Figueiredo, 2009), developing into a culturally embedded activity with significant socioeconomic importance for Madeira's coastal communities.

The fishery's ecological dominance is evidenced by the overwhelming predominance of two scabbardfish species *Aphanopus carbo* (Lowe, 1839) and *Aphanopus intermedius* (Parin, 1983). These species collectively constitute approximately 50% of annual landings by weight in Madeira (Delgado et al., 2013, 2018; Hermida and Delgado, 2016), demonstrating their crucial role in both the marine ecosystem and regional fisheries economy.

The sustained importance of these species reflects their unique adaptation to the Macaronesian deep-sea environment and the historical development of specialized fishing techniques to exploit these resources. The deep-sea fishery targeting the scabbardfish species, off the Madeira archipelago, is widely recognized as an artisanal and highly selective activity, targeting predominantly adult individuals and presenting a low rate of bycatch (Severino et al., 2009). The fishing gear used in this fishery is a mid-water horizontal drifting longline, set in the water column usually at depths of between 800 and 1300 m (Figure 1).

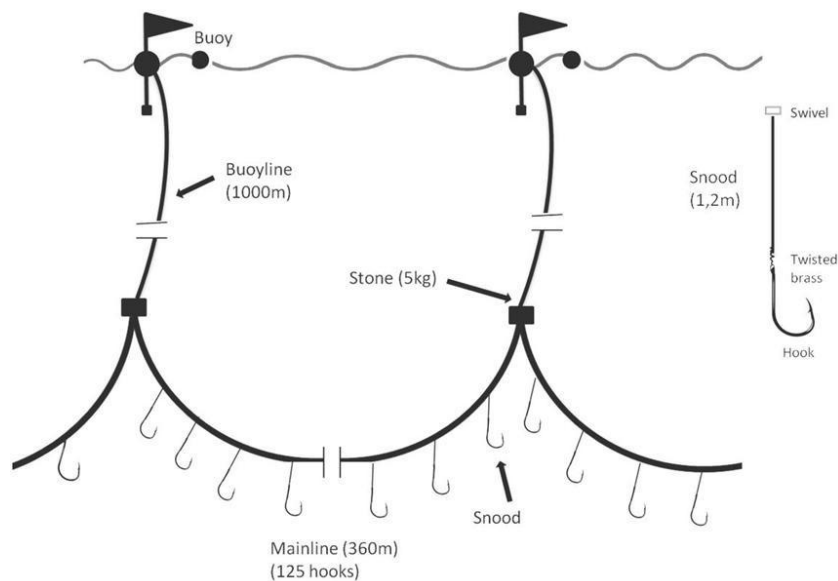


Figure 1 – Mid-water horizontal drifting longline used by the Madeira fishing fleet.

The black and intermediate scabbardfish fishery represents one of the most profitable commercial activities on small-scale fisheries in Madeira archipelago. In 2022, the commercial landings in weight of *Aphanopus* spp. reached annual values of up to 2259 tonnes yielding a total first sale value of approximately 7.5 M€ (Figure 2).

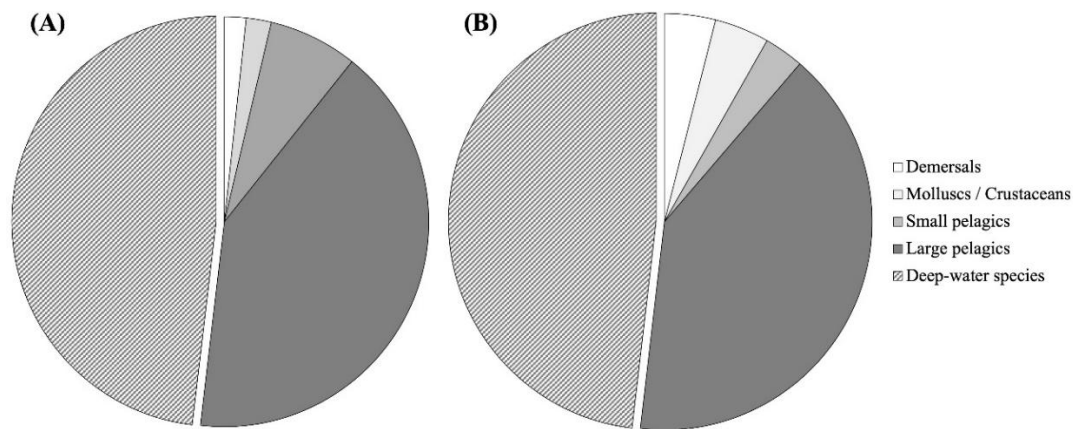


Figure 2 – Landings (A) and economic value (B) by fishery in Madeira archipelago in 2022.

1.2 The fleet

The active fishing fleet targeting scabbardfish species at CECAF area 34.1.2 is artisanal and small-scale.

In 2022, the majority of the vessels targeting scabbardfish species were under 18 m of length (>95%), with an average length of 12 m (Figure 3). This small-scale fishery comprised a fleet of 21 vessels, with an average age of 32 years, an average gross tonnage of 19 and an average engine power of 127 KW.

In the last years, the fishery has achieved a certain stability in the number of active vessels. In 2022, 52% of the active vessels were grouped between 12 and 18 m of overall length, thus hardly having structural and operational conditions to make any significant increase in the present total number of hooks used in each fishing set.

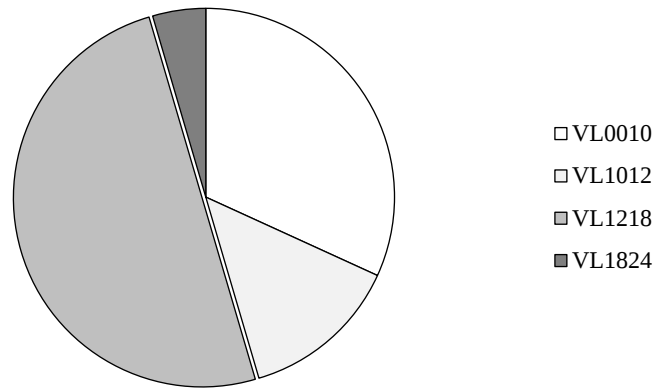


Figure 3 – Proportion of active vessels by length category for scabbardfish species fishery in Madeira archipelago in 2022. VL0010 - vessel size less than 10 m; VL1012 - vessel size between 10 and 11.99 m, VL1218 - vessel size between 12 and 17.99 m and VL1824 - vessel size between 18 and 23.99 m.

1.3 Spatial distribution of the catches

The black and intermediate scabbardfish fishery, carried out by the fishing vessels registered in Madeira, was traditionally performed mostly around the islands of Madeira, Porto Santo and the seamounts inside the Madeira EEZ. However, this fishery has undergone a considerable geographic expansion in recent decades (Figure 4). Progressively, new fishing grounds located in international waters SE of the Azores, off the Canaries and the return to some of the seamounts within the Madeira EEZ became indispensable for this fishery. Therefore, bilateral agreements with the Azores and the Canaries were made to allow the fleet access to those areas.

In 2015, the Scientific, Technical and Economic Committee for Fisheries (STECF) provided an exploratory assessment of the status of the species around Madeira (STECF-14–15). It was mentioned that, for the period 2000-2013, there was a general decline in fishing capacity and fishing effort. In recent years the number of vessels has also declined by 41% (34 to 20 vessels). Furthermore, in the second half of the last decade, some Madeiran vessels targeting the black and intermediate scabbard fish have moved to new fishing grounds, some of them located outside the EEZ of Madeira (SE of the Azores and off the NW of the Canaries) (Figure 4).

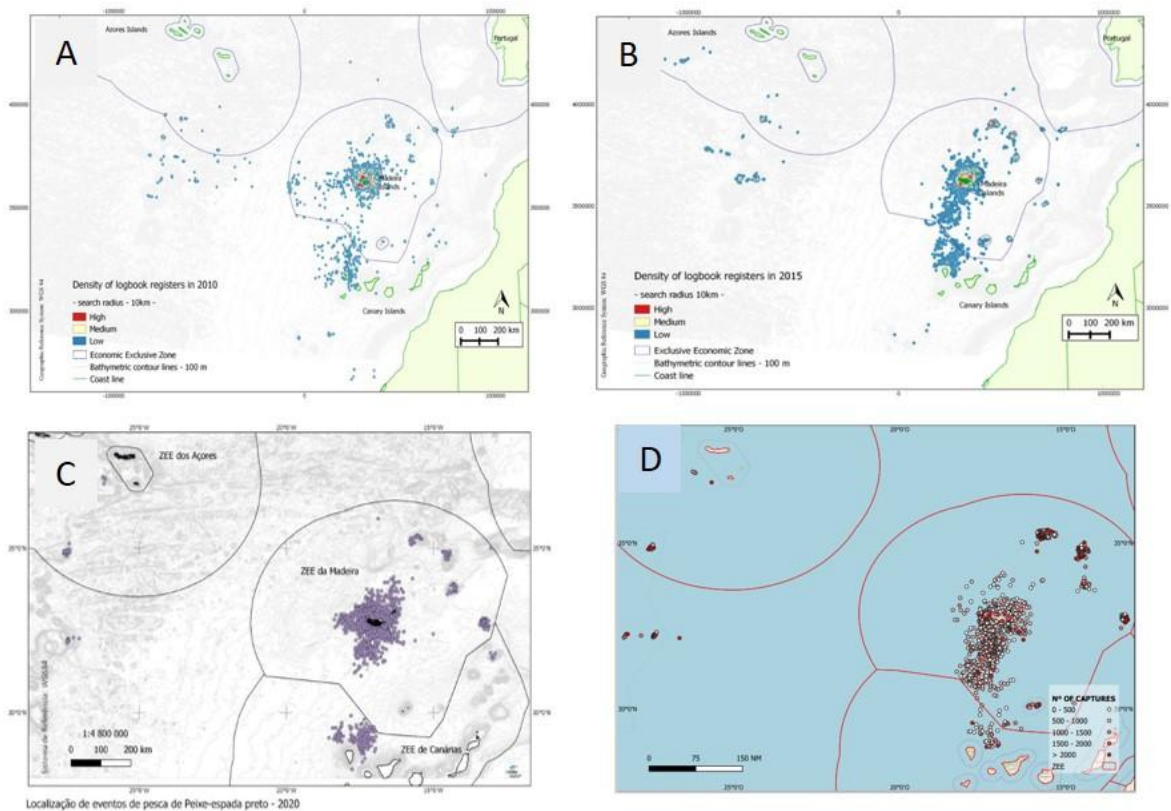


Figure 4 - Density plots illustrating the geographical distribution of the fishing sets with catches in 2010 (A), 2015 (B), 2020 (C) and 2021 (D) with the software Quantum GIS 2.2 (Regional Directorate of the Sea - Madeira).

In 2019 and 2020, most of fishery targeting the black and intermediate scabbardfish have been carried out within the Madeira EEZ. However, the fishing grounds off the Northwest of Canaries continues to be a relevant fishing area for the Madeira fishing fleet, due to the availability of both scabbardfish species and the lack of interest in these species by the Canary fishing fleet, which increases the profitability of the capture of them by the fishing fleet from Madeira. The capture of *Aphanopus* spp. in the Azores fishing grounds, by the fishing fleet from Madeira, has been decreasing since 2015. According to the fishermen the effort is not profitable due to the large distance between Madeira and Azores.

The geographic distribution of the fishery in 2021 showed a similar trend to that observed in 2010, with a considerable quantity of fishing sets being performed off south of the island of Madeira and on the adjacent seamounts. It was also observed that during the spawning season (October to December) most of fishery still remains concentrated off the islands of Madeira and Porto Santo.

2 METHODS

2.1 Fishery dependent data

2.1.1 Landings and mean price

Total landings of *Aphanopus* spp. in CECAF area 34 (in weight, ton, and value, euro) were analysed by year. Fishery dependent data were collected from commercial landings, in the auction houses of the archipelago of Madeira, for the period between 2010 and 2022.

2.1.2 Landings and mean price by vessel length category

Total landings of *Aphanopus* spp. in CECAF area 34 (in weight, tonnes, and value, euro) was analysed by year and by vessel length category. Fishery dependent data were collected from commercial landings for the period between 2010 and 2022. The active fishing fleet at CECAF area is grouped into the following categories: VL0010 (vessel size less than 10 m), VL1012 (vessel size between 10 and 11.99 m), VL1218 (vessel size between 12 and 17.99 m) and VL1824 (vessel size between 18 and 23.99 m).

2.2 Length distribution

Aphanopus spp. length sampling data available for Madeira were analysed considering both species combined by year for the period between 2010 and 2022. The landings were recorded by the Regional Fisheries Department of Madeira and the numbers-at-length were raised to the total landings.

2.3 Capture per unit effort (CPUE)

All landings from the commercial mid-water drifting longline fishery at all the fishing ports of Madeira, in the Northeast Atlantic (32°00'–33°30'N, 15°30'–18°00'W) were considered for this analysis, during the period between 2010 and 2022. From each fishing trip data on total weight landed of the species (in kg), vessel name and corresponding length category, engine power (KW), number of days at sea, number of fishing days and fishing operations, and the total number of hooks were examined. A trip was defined from the moment the vessel leaves the dock to when it gets back to the dock.

2.4 Mortality and Fishing Mortality at Maximum Sustainable Yield

Total mortality (Z) was estimated using the length-converted catch curve method. Natural mortality (M) was calculated using Pauly's empirical equation (Pauly, 1980).

Fishing mortality (F) was derived as $F = Z - M$ and Fishing Mortality at Maximum Sustainable yield (F_{MSY}) was estimated (Beverton-Holt, 1957).

2.5 Research vessel data

In November 2021, a research survey in the aim of the project MACAROFOOD (Sousa et al., 2021) was conducted in CECAF area 34.1.2, to compare catches with those performed by the commercial fleet. This survey also aimed to study the selectivity of fishing gear, hook and bait, to determine the survival rates of the main shark species captured by this fishery and to estimate the catches per unit effort.

3 RESULTS

3.1 Fishery dependent data

3.1.1 Landings and mean price

The annual landings of both scabbardfish species derived from Madeiran mid-water longliners for the period between 2010 and 2022 are presented in Figure 5.

CECAF 34.1.2 area landings varied between 1716 tonnes in 2012 and 2259 tonnes in 2022. A slight increase was observed from 2012 (1716 t) to 2019 (2246 t). From 2020 to 2021 a slight decrease was observed, mainly due to the reduction in fishing days caused by the COVID-19 pandemic. In 2022, a recovery in the landings was observed, achieving similar values to 2018 (2246 t).

In general terms, landings showed a trend of stability for the study period (2010-2022), with a slight increase in 2022 (2259 t).

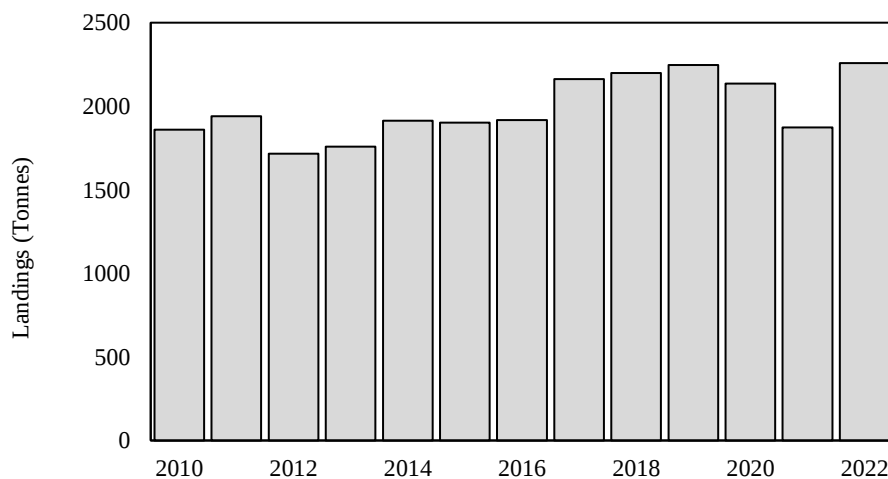


Figure 5 - Time-series of annual landings of *Aphanopus* spp. at CECAF area 34.1.2, between 2010 and 2022.

The EU TAC and total landings for CECAF area 34.1.2 from 2010 to 2022 is presented in Table 1. It was observed a relevant decrease in the EU TAC for the *Aphanopus carbo* fishery in CECAF 34.1.2, from 4285 tonnes in 2010 to 2189 tonnes in 2022.

In 2022, the landings for both *A. carbo* and *A. intermedius* achieved 2259 tonnes in CECAF area 34.1.2. However, according to Delgado et al. (2013) approximately 20% of the total landings of scabbardfish in Madeira archipelago corresponds to the intermediate scabbardfish. As such from the total landings occurred in 2022 (2259 t), approximately 1807 tonnes were estimated to be *A. carbo* and 452 tonnes to be *A. intermedius*.

Table 1 - Black scabbard fish TACs and total landings in CECAF area 34 between 2010 and 2022.

Year	EU TAC CECAF 34.1.2 area	Landings CECAF 34.1.2 area
2010	4 285	1 860
2011	4 071	1 941
2012	3 867	1 716
2013	3 674	1 758
2014	3 490	1 913
2015	3 141	1 902
2016	2 827	1 917
2017	2 488	2 163
2018	2 189	2 199
2019	2 189	2 246
2020	2 189	2 136
2021	2189	1873
2022	2189	2259*

* The value includes the landings of both *Aphanopus carbo* and *Aphanopus intermedius*.

The first sale value of *Aphanopus* spp., in millions of euros, for the period between 2010 and 2022 is presented in Figure 6. This value followed the same trend observed in the annual landings in terms of weight. An increase is observed from 2012 (5.2 M€) to 2022 (7.5 M€). The decrease observed for 2020 to 2021 was related to COVID-19 Pandemic. In 2022, it was observed a

recovery and similar values to 2019 were achieved. The total first sale value yield approximately in 2022 was 7.5 M€.

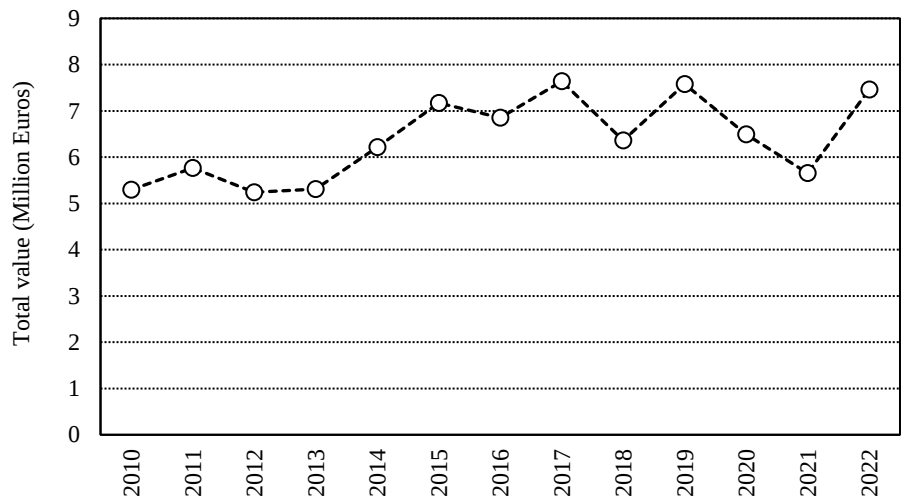


Figure 6 – Economic value of the landings of *Aphanopus* spp., in millions of euros, for CECAF area 34.1.2, between 2010 and 2022.

3.1.2 Landings and mean price by vessel length category

In 2022, the vessel length category VL1218 presented the highest landing values, followed by the vessel segment VL1824. 79% of the landings was performed by vessels in the length size category VL1218 and only 13% by vessels included in the length size category VL1824 (Figure 8).

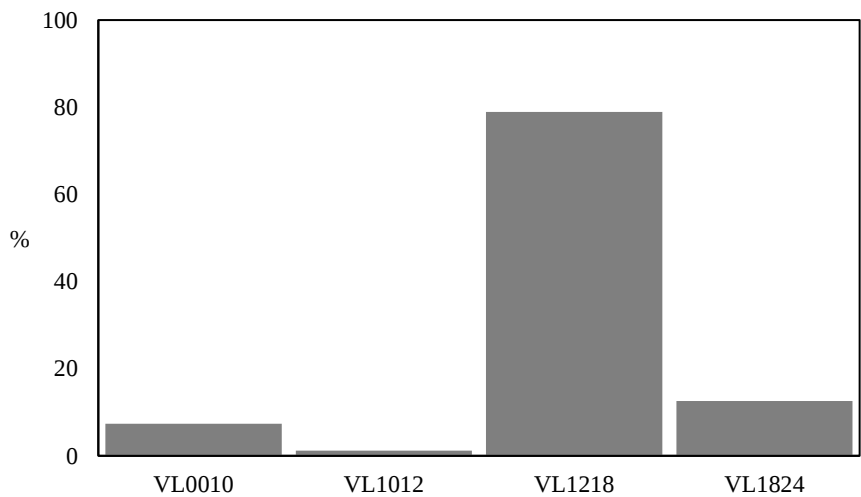


Figure 8 – Proportion of landings by length category of active vessels operating in the scabbardfish fishery at CECAF area 34.1.2 during 2022.

The analyses of landings by vessels length size category, between 2010 and 2022, showed the same trend in each category among the years (Figure 9). The majority of landings was performed by vessels in the length category VL1218 and the minority by vessels in the length category VL1012.

Landings performed by VL1012 vessels varied from 4 tonnes in 2012 to 67 tonnes in 2019, with a mean value of 25 tonnes between 2010 and 2022. Regarding VL1218 vessels the landings varied from 1480 tonnes in 2018 and 1847 tonnes in 2019, with a mean value of 1639 tonnes for the considered time series.

Though the number of vessels in the segment VL1824 represents only 5% of the total active fleet in Madeira, their contribution for the annual landings of this fishery, was higher (*ca.* 12.5%) than both vessel segments VL0010 and VL1012 together (*ca.* 8.5%).

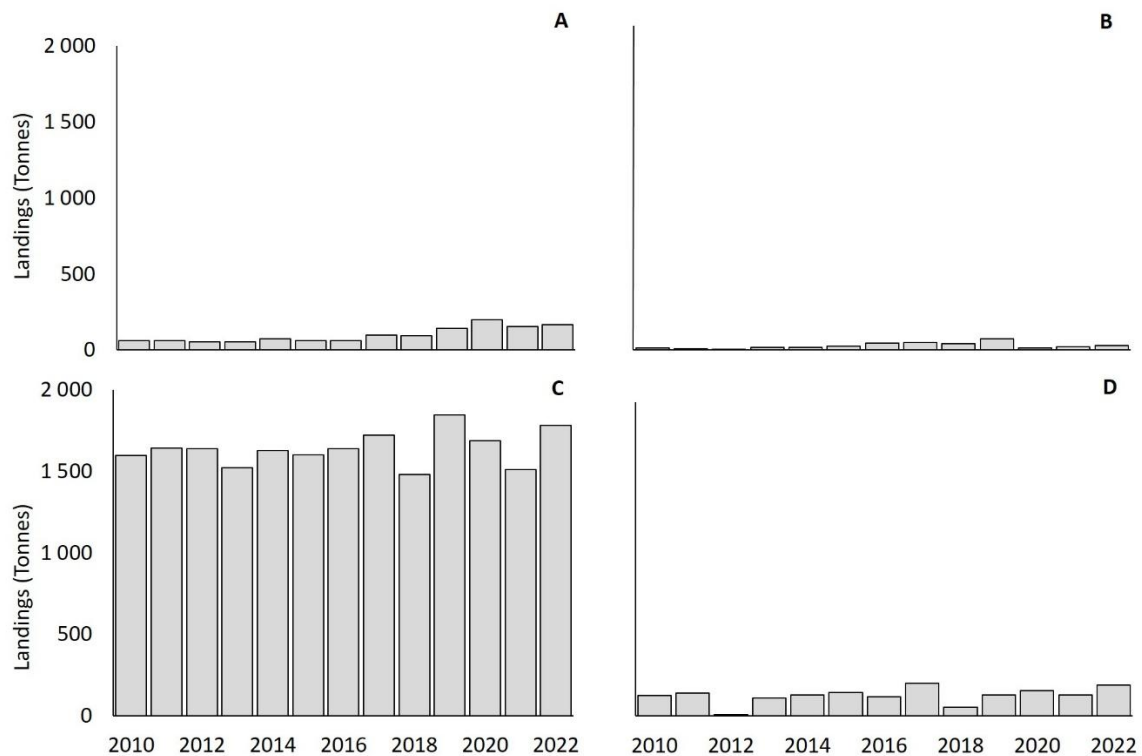


Figure 9 – Landings by length category of active vessels, operating in the scabbardfish fishery at CECAF 34.1.2 area, between 2010 and 2022. A – VL0010, B – VL1012, C – VL1218 and D – VL1824.

In general the total first sale value followed the same trend observed in the landings, for the study period. In 2022, the total economic value (7.5M€) was similar to the highest value obtained in 2019 (7.6M€) (Figure 10). Regarding the economic value by length category, it was verified that VL1218 vessels were the ones that most contributed to the overall value (*ca.* 78.7%). The value

for this category varied from 4.6M€ in 2010 to 6.20M€ in 2019. As observed for the landings, the first sale value for the VL1824 length category (*ca.* 12.6%) was higher than both vessel segments VL0010 and VL1012 together (*ca.* 8.5%).

The decrease observed in the economic value for the vessel segment VL1218 in 2021 is related to the decrease in effort performed by the vessels in this length category due to COVID 19 Pandemic.

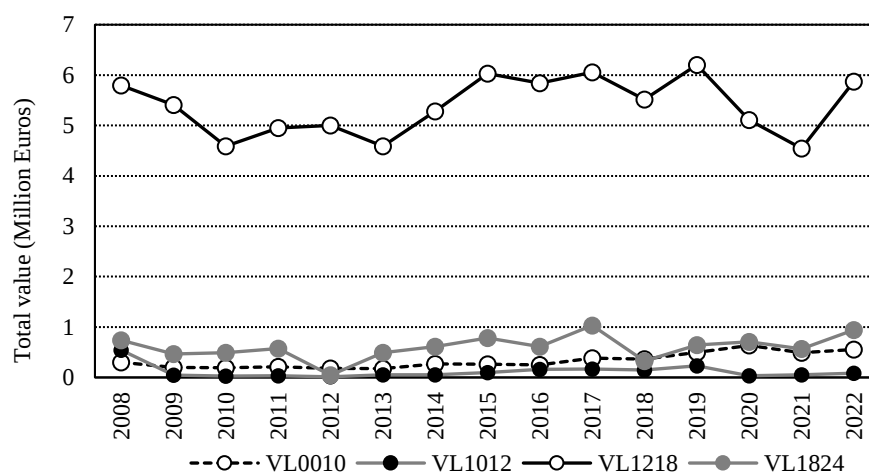


Figure 10 – Economic value of the landings of *Aphanopus* spp., in millions of euros per vessel category between 2010 and 2022.

3.2 Length distribution

The analysis of data indicates neither great changes on the length range between years nor on the mean length (around 114-118 cm total length, TL). From 2010 to 2018 the mean length was between 117 and 118 cm TL, occurring a slight decrease in 2019-2021 (115-116 cm TL). In 2022 it was observed a mean length of 115 cm TL (Figure 11).

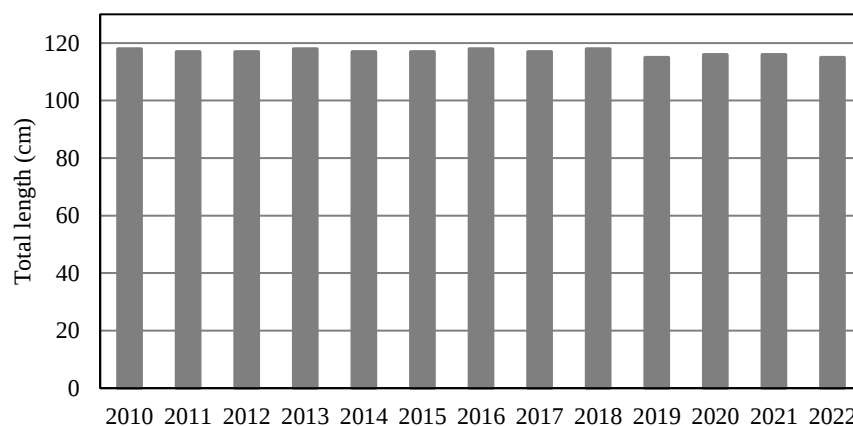


Figure 11 – Mean total length *Aphanopus* spp. landings for the period 2010-2022.

Annual total length–frequency distributions of the exploited population caught by the Madeiran longline fleet in CECAF 34.1.2 area for the period 2010-2022 are presented in Figure 12. The range of scabbardfish total length varied between 87 cm and 155 cm.

Overall, between 2010 and 2022 there was verified a stability in the composition of lengths and average lengths for scabbardfish species caught by the Madeiran fleet.

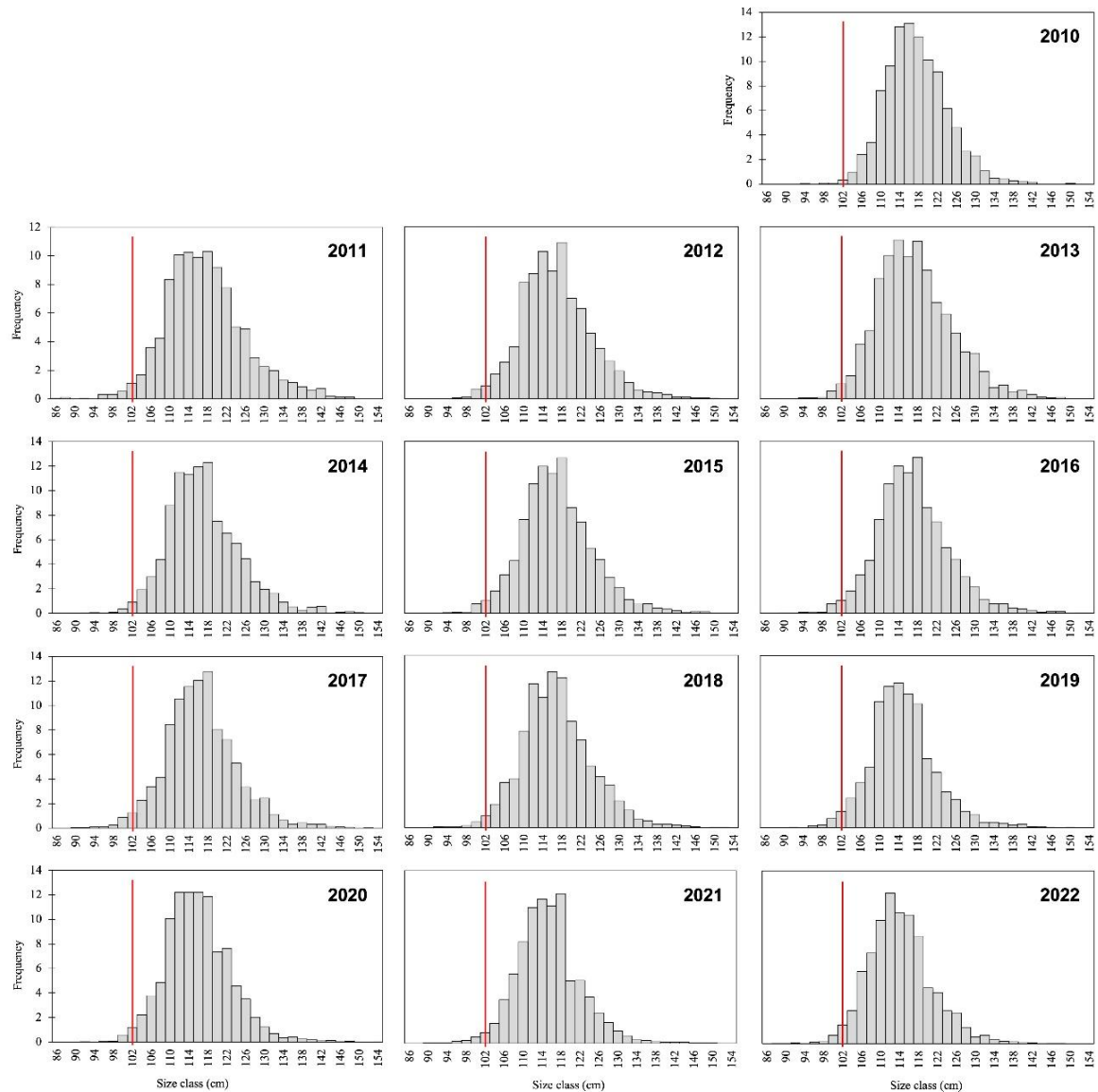


Figure 12 - Annual length–frequency distribution of specimens of *Aphanopus* spp. landed by the Portuguese mid-water longliners operating along CECAF area 34.1.2, from 2010 to 2022. Red line represents the length at first maturity according to Figueiredo et al., 2003.

The proportion of adults, of both scabbardfish species, in the catches performed by the Madeiran vessels showed a dominant pattern from 2010 to 2022 (>98%). This proportion varied between 99.9% in 2010 and 98.6% in 2011 and 2017. In 2022, the proportion of adults was 98.8% (Figure 13).

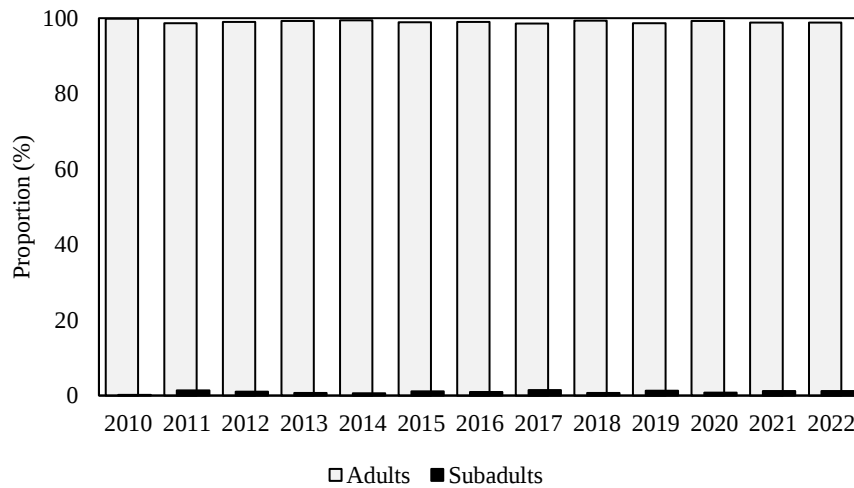


Figure 13 - Proportion of adults and subadults of *Aphanopus* spp. landed by the Portuguese mid-water longliners operating along CECAF area 34.1.2, from 2010 to 2022.

3.3 Catch Per Unit Effort (CPUE)

Fishing effort in total number of hooks and in total number of vessels accumulated per year is represented in Figure 14.

There was an overall decrease of fishing effort in the available period, reflecting the decline of the number of vessels. The year of 2011 stands for the highest total number of hooks (*ca.* 16.8 M) in the period available, since then effort has declined, and it is rather constant in the last years around 14-15 M hooks per year, with the exception of the years 2018 (*ca.* 11.8 M) and 2020 (*ca.* 12.5 M). From 2020 to 2022, it was also observed a decrease of approximately 0.8 M hooks (*ca.* 11.8 M).

The number of vessels operating in the scabbardfish fishery showed a decreasing trend over the study period, from 25 vessels in 2010 to 21 vessels in 2022.

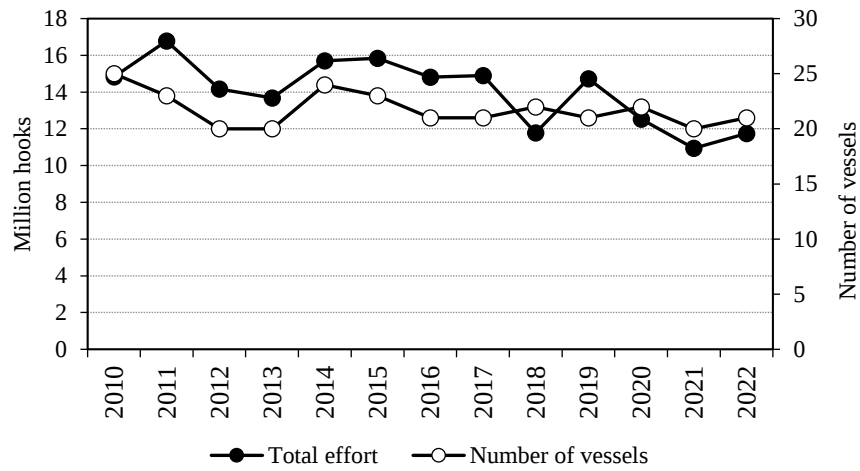


Figure 14 - Time-series of the total annual effort estimated for the CECAF area 34.1.2 (million hooks) for the *Aphanopus* spp. fishery.

In general, catches and CPUE had an overall pattern of increase along the analysed period (Figure 15). All indicators analysed reached a certain level of stability between 2010 and 2016, and even a slight recovery was observed since 2017 to 2022. Overall, it was verified an increase of 399 tonnes in the landings between 2010 and 2022. It was also observed an increase of 67 kg/1000 hooks in CPUE between 2010 and 2022.

A growing trend with an increase of 386 tonnes in the landings and an increase of 21 kg/1000 hooks was observed from 2021 to 2022.

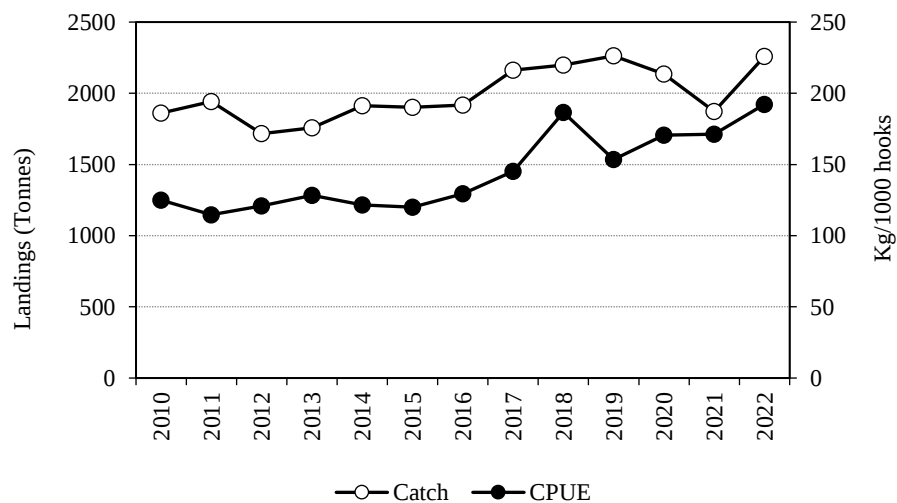


Figure 15- Time-series of catches (t) and catch per unit effort (kg / thousand hooks) of *Aphanopus* spp. in CECAF area 34.1.2, between 2010 and 2022.

In general, total effort and CPUE effort showed different trends for the study period (Figure 16). Total effort decreased from 15 million hooks in 2010 to 12 million hooks in 2022 and CPUE increased from 125 kg/ 1000 hooks in 2010 to 192 kg/ 1000 hooks in 2022. Contrarily to the general trend, the increase in total effort conducted to an increase in CPUE from 2021 to 2022. It was verified that the increase of 0.8 million hooks in 2022 conducted to the increase of 21 kg per 1000 hooks.

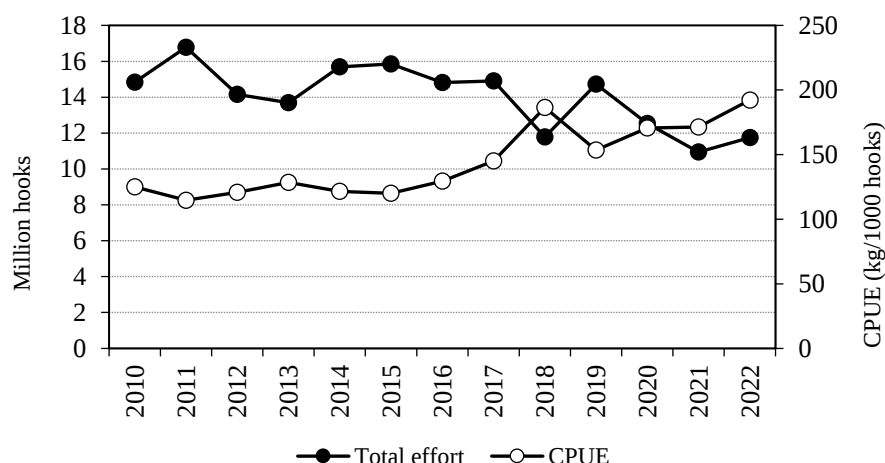


Figure 16 - Time-series of fishing effort (M hooks) and catch per unit effort (kg / thousand hooks) of *Aphanopus* spp. in CECAF area 34.1.2, between 2010 and 2022.

3.4 Mortality and Fishing Mortality at Maximum Sustainable Yield

Total mortality (Z) and natural mortality (M) for females were estimated at 0.96 and 0.24 per year respectively. Fishing mortality (F) was quantified at 0.72 year^{-1} , while the fishing mortality reference point (FMSY), derived from Beverton-Holt yield-per-recruit analysis, was estimated at 0.82 year^{-1} .

3.5 Research vessel data

Aphanopus spp. length composition data from commercial landings and research survey in CECAF area 34.1.2 during 2021, is available in figure 17.

The range of scabbardfish species total length varied between 90 cm and 150 cm for specimens captured by the commercial landings and by the research survey.

Overall, it was verified a similarity in the composition of lengths of *Aphanopus* spp. from the landings and from the research survey performed in 2021.

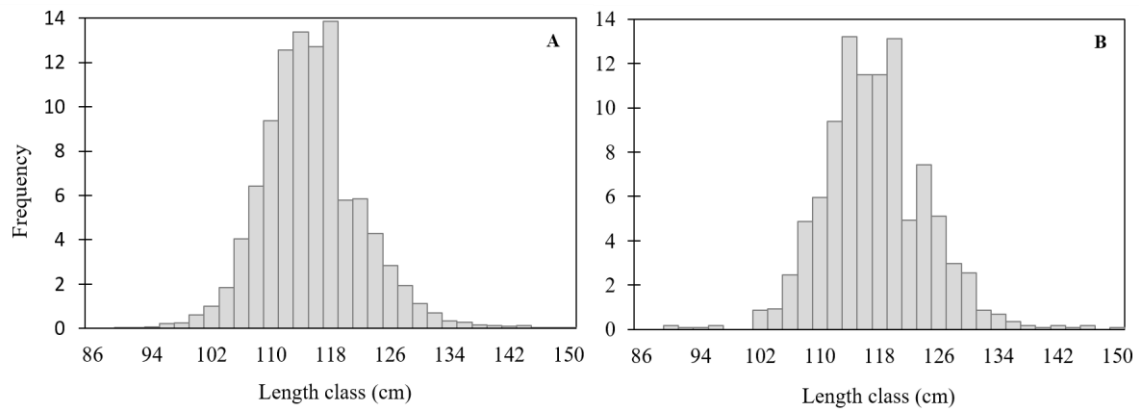


Figure 17 - Annual length–frequency distribution of specimens of *Aphanopus* spp. catches performed by commercial vessels (A) and research survey (B) along CECAF area 34.1.2 during 2021.

The mean length of *Aphanopus* spp. caught by the commercial vessels and research vessel is presented in figure 18. The mean length of the exploited population was around 115 cm for the specimens caught by the commercial fleet, which is about the same mean length registered at the research survey (116 cm).

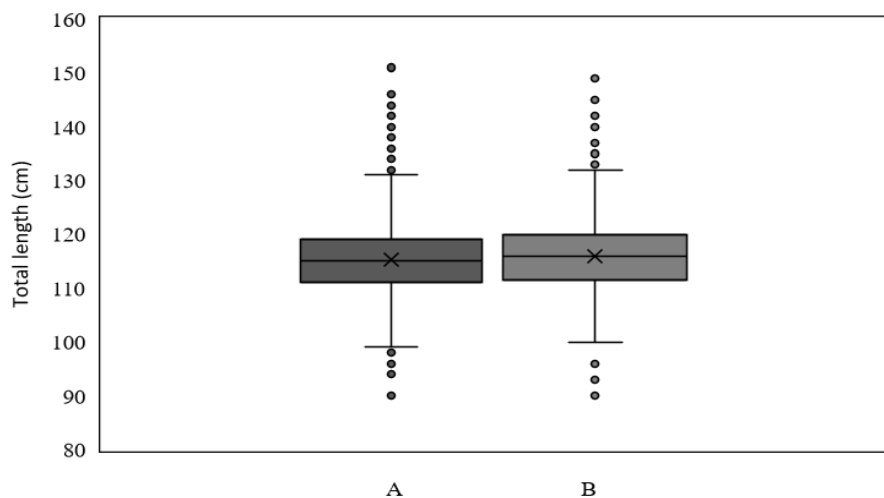


Figure 18 - Mean total length for *Aphanopus* spp. catches performed by commercial vessels (A) and research survey (B) at CECAF area 34.1.2 in 2021. Box plot showing median (black line) and upper and lower quartiles of the data.

4 DISCUSSION

The structure of black scabbardfish stocks in Northeast Atlantic is uncertain. Nevertheless, most of the available information support the assumption of a single stock. This species performs large-scale seasonal migrations to complete their life cycle along the Northeast Atlantic. Spawning

occurs at CECAF areas (Madeira and Canary) and juveniles are recruited at Northern areas (ICES, 2022).

Black and intermediate scabbardfish are two sympatric species that occur at a wide depth range, from 200 m in the northern part of the NE Atlantic (Nakamura and Parin, 1993) to 2300 m off the Canary Islands (Pajuelo et al., 2008). In Madeira both species coexist, and the overall proportion of *A. carbo* in relation to the overall catches of *Aphanopus* spp is about 0.80 (Delgado et al., 2013). Moreover, *A. carbo* is more frequent at 800–1300 m (Morales-Nin and Sena-Carvalho, 1996) and *A. intermedius* at 800-1350 m deep (Delgado et al., 2013). In general, scabbardfish juveniles are mesopelagic and adults are benthopelagic (ICES, 2020).

In Madeira, the fishery target predominantly adults that occur between 800 and 1200 meters deep. The temporal evolution of the mean length by year shows no significative evolution in the trend, which supports the stability on the length structure of the exploited population along the whole period. In fact, catches are constituted almost exclusively by adult specimens over 103 cm total length (Figueiredo et al, 2003) and the catches of subadult individuals are scarce (DRM, 2022). The analysis of length distribution data indicates neither great changes on the length range between years nor on the mean length (around 114 -118 cm total length). The annual proportion of adults in the landings was superior to 98% and subadults scarcely achieve around 1.5% of the total number of individuals captured. This indicate that most of the individuals caught have contributed at least one time to the fitness of the species.

Overall, between 2010 and 2022 there was verified a stability in the composition of lengths and in the average length of scabbardfish species caught by the Madeiran fleet. It was also observed that fishing activity on black and intermediate scabbardfishes has been regular with landings rounding 1700 and 2200 tonnes per year. Inclusive, it was verified an increase of 399 tonnes in the landings between 2010 and 2022 and an increase of 67 kg/1000 hooks in CPUE for the same period. Considering the mean proportion of *A. carbo* (0.80) and *A. intermedius* (0.20) in the landings (Delgado et al., 2013), of the total landings of both scabbardfish species, was estimated that 1807 tonnes corresponded to *A. carbo* and 452 to *A. intermedius* in 2022.

The balance verified in the commercial exploitation of *Aphanopus* spp, is essentially due to the reduction of fishing capacity and fishing effort caused by the reduction of the number of vessels from 34 to 20 between 2000 and 2013. Furthermore, the artisanal and highly selective nature of the fishery in Madeira also contributed to the stability of the exploitation during the last years. In 2022, 79% of the catches were performed by small vessels with length between 12 and 18 m of overall length. Those vessels hardly have structural and operational conditions to make any significant increase in the total number of hooks used in each fishing set and as such fishing effort tends to remain stable.

The F/FMSY ratio of 0.88 suggests the current harvest rate operates at 88% of the maximum sustainable yield threshold.

In the future, the advice for the commercial exploitation of black scabbardfish in North Atlantic should also consider data from CECAF 34.1.2, in order to provide a wider perception of the stock dynamics of these migratory species in the northeast Atlantic (ICES, 2022).

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