WGDEEP 2021, WD 01

CPUE Standardization of Silver smelt in 5b and 6a

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Abstract

At the WKGSS 2020 benchmark of Greater silver smelt in 5b and 6a, a combined and standardized CPUE series for the Faroe and EU fleets has been introduced (Quirijns and Pastoors 2020). On checking the data in preparation for WGDEEP 2020, a small error was detected in the way CPUE was calculated. This report provides a summary of the issue and proposed a method to repair the situation. The overall trend in CPUE is still similar although there are some differences in the most recent year.

1 Introduction

At the WKGSS 2020 benchmark of Greater silver smelt in 5b and 6a, a combined and standardized CPUE series for the Faroe and EU fleets has been introduced (Quirijns and Pastoors 2020). During WGDEEP 2020 two small errors were detected in the way CPUE was calculated and solutions to these errors were provided (Pastoors and Quirijns 2020). This report provides a an update of the CPUE calculation for Greater silver smelt, with the time series update to 2020 according to the method agreed in WGDEEP 2020.

2 Results

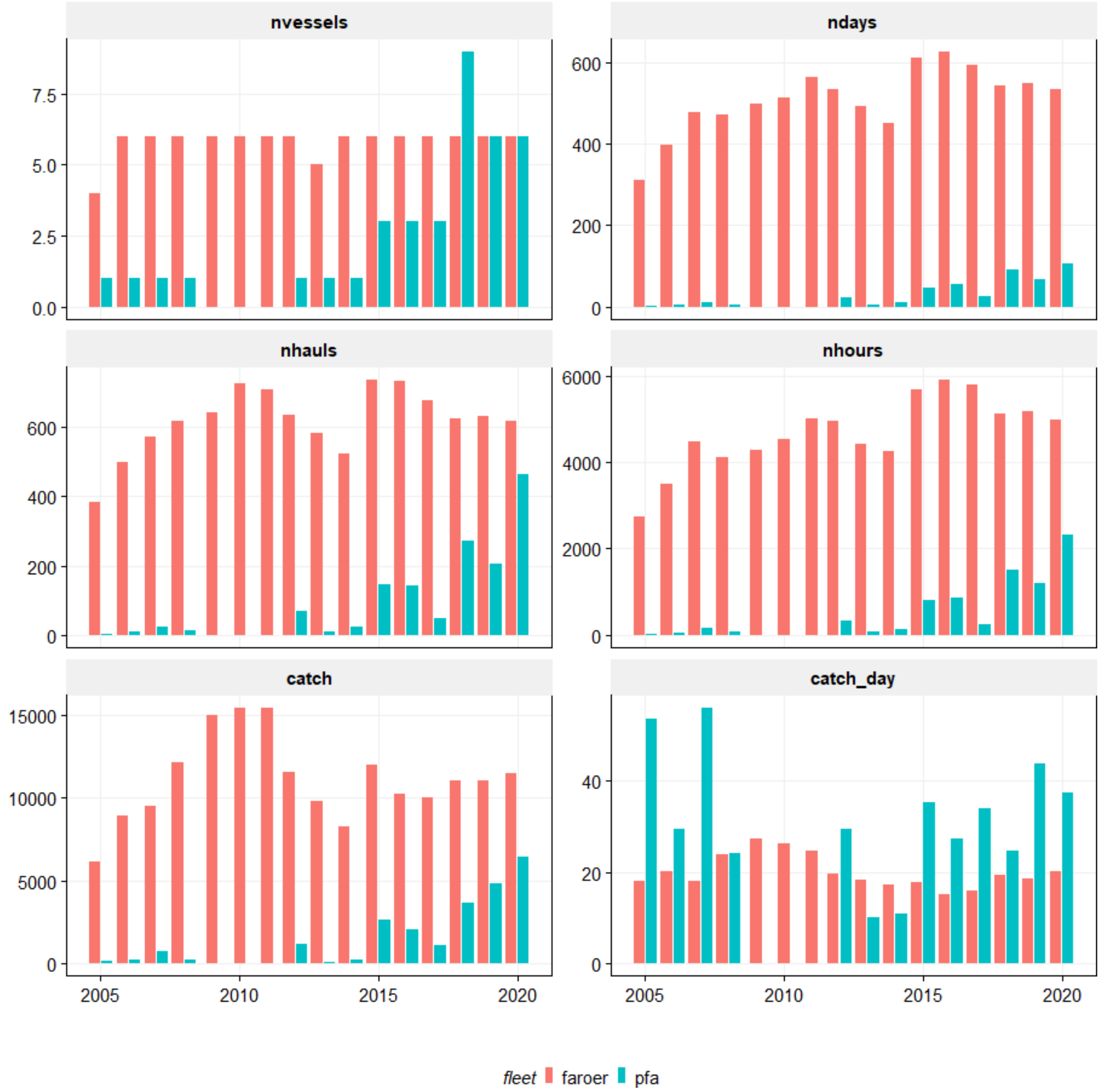


Figure 1: ARU.27.5b6a metrics describing the fisheries

The ‘raw’ (unstandardized) CPUE is based on the catch per day and per rectangle.

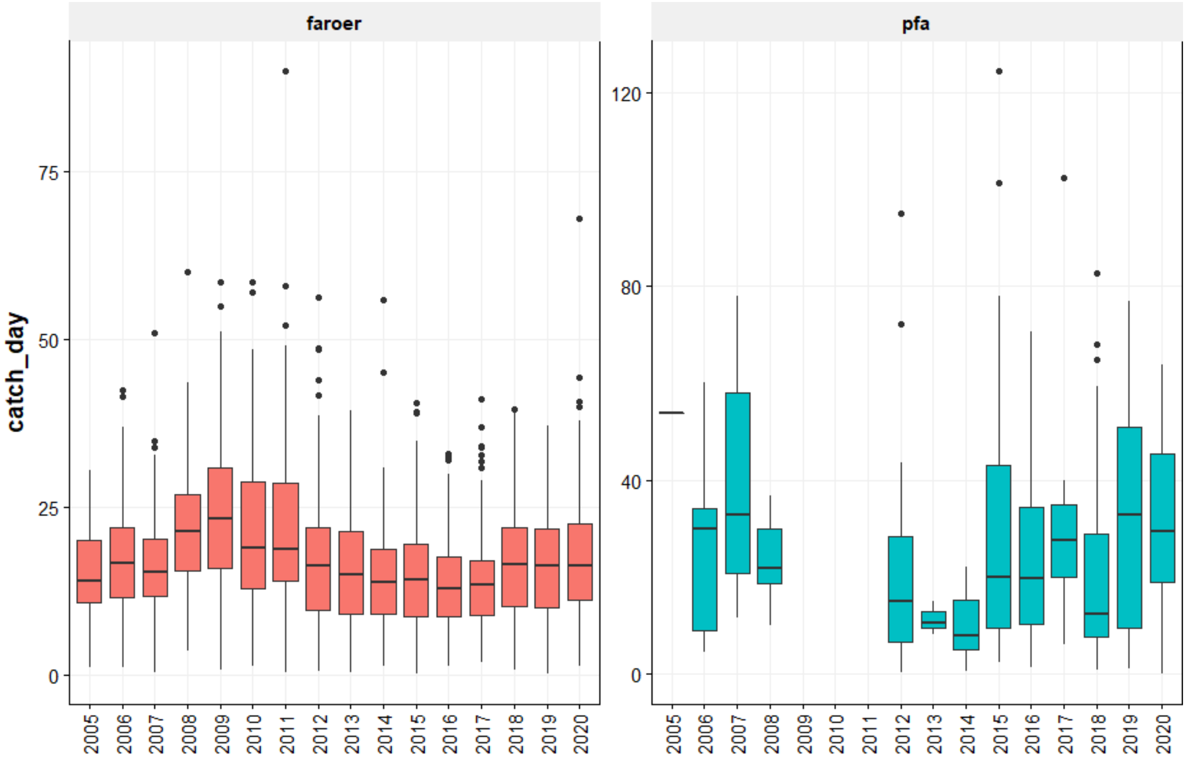


Figure 2: ARU.27.5b6a Catch per unit effort.

For the years 2015-2020, below are the spatial distributions of the used number of hauls by fleet.

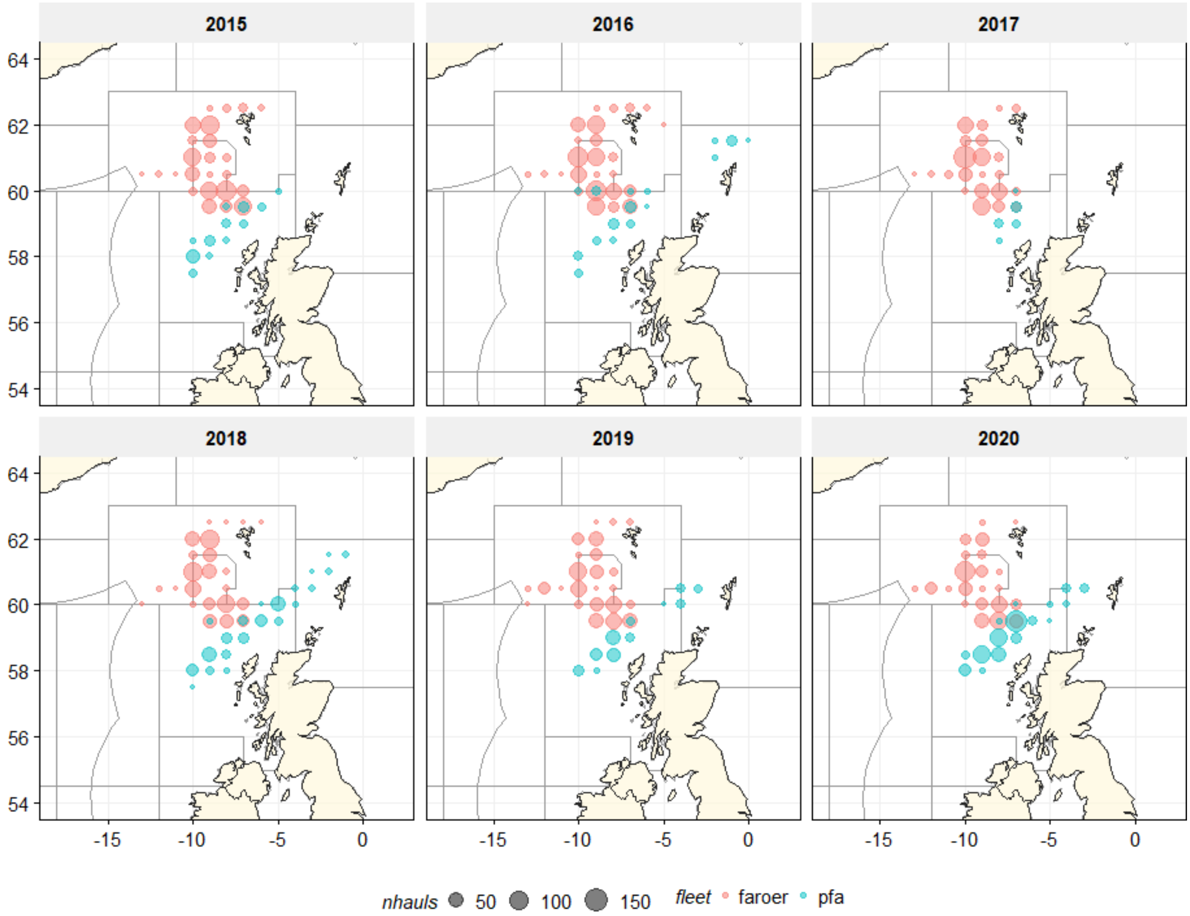


Figure 3: ARU.27.5b6a plot of the number of hauls by rectangle and day

Standardized CPUE index

We applied the same model for standardization of of CPUE: CPUE ~ year + week + depth, where CPUE is expressed as catch per day and per rectangle. Catches have first been summed by vessel, year, week and rectangle and the number of hauls and fishing days have been calculated. Then the catches and effort (fishing days) have been summed over all vessels by year and week and the average depth has been calculated. CPUE was then calculated as the average catch per rectangle and per day.

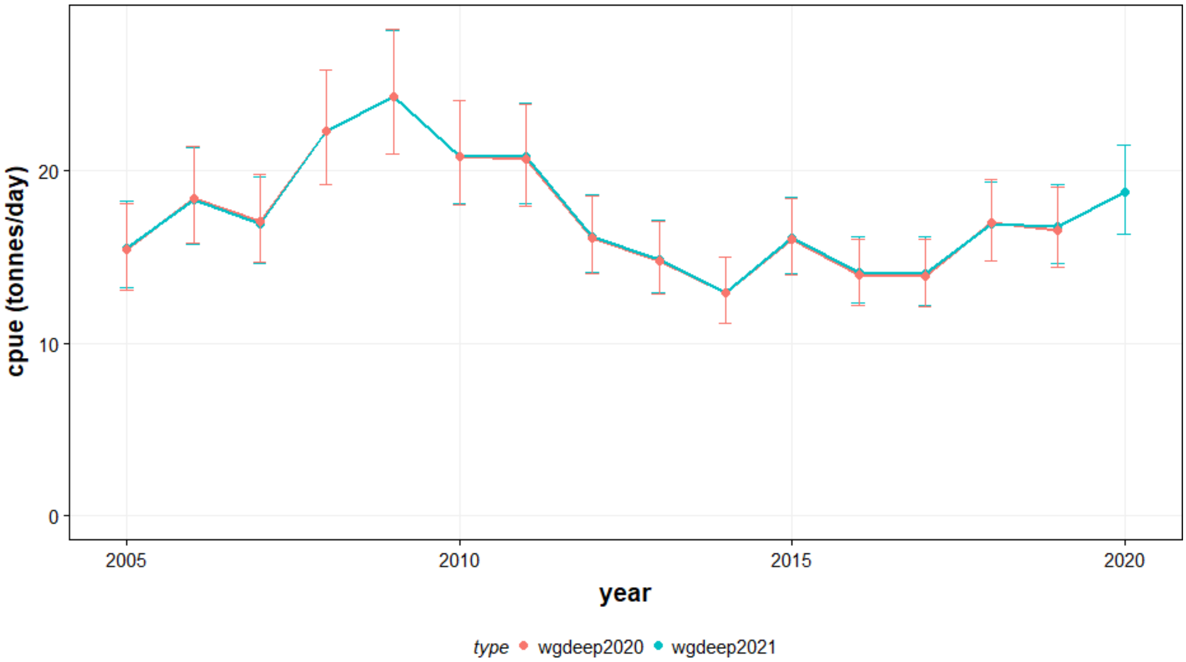
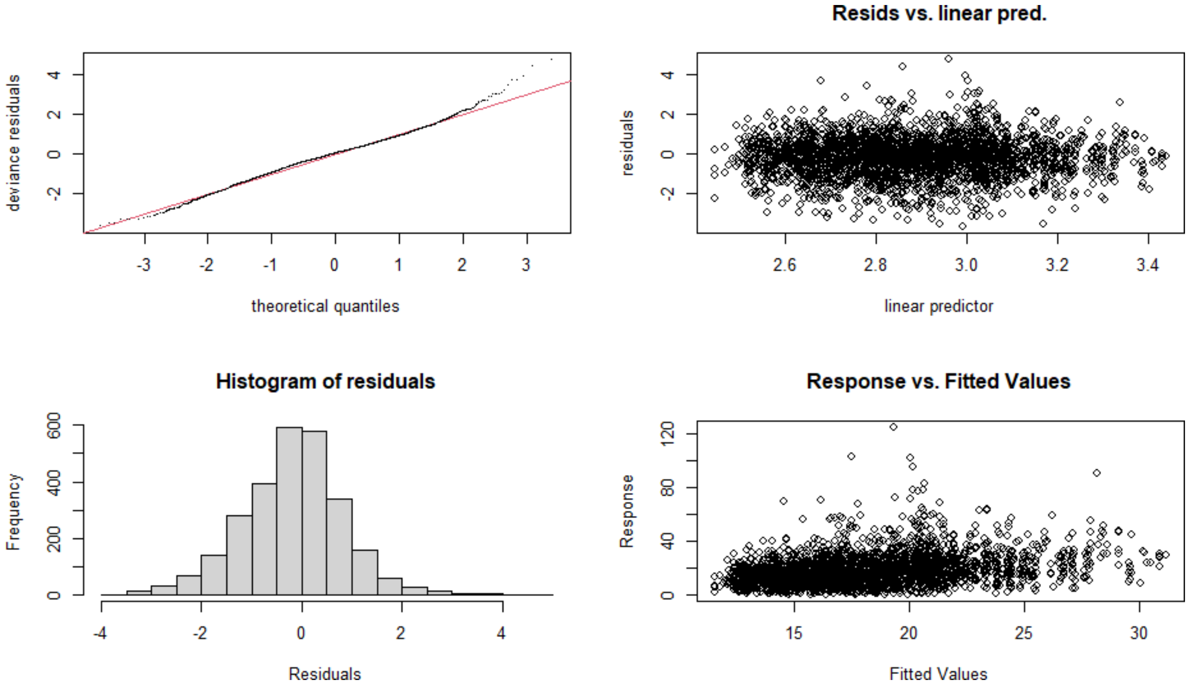


Figure 4: ARU.27.5b6a standardized CPUE (catch per rectangle and day), in comparison with WKGSS series

Model diagnostics




```
Method: UBRE   Optimizer: outer newton
Model required no smoothing parameter selectionModel rank =  41 / 41
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Figure 5: ARU.27.5b6a standardized CPUE model diagnostics

Evaluation of explanatory variables

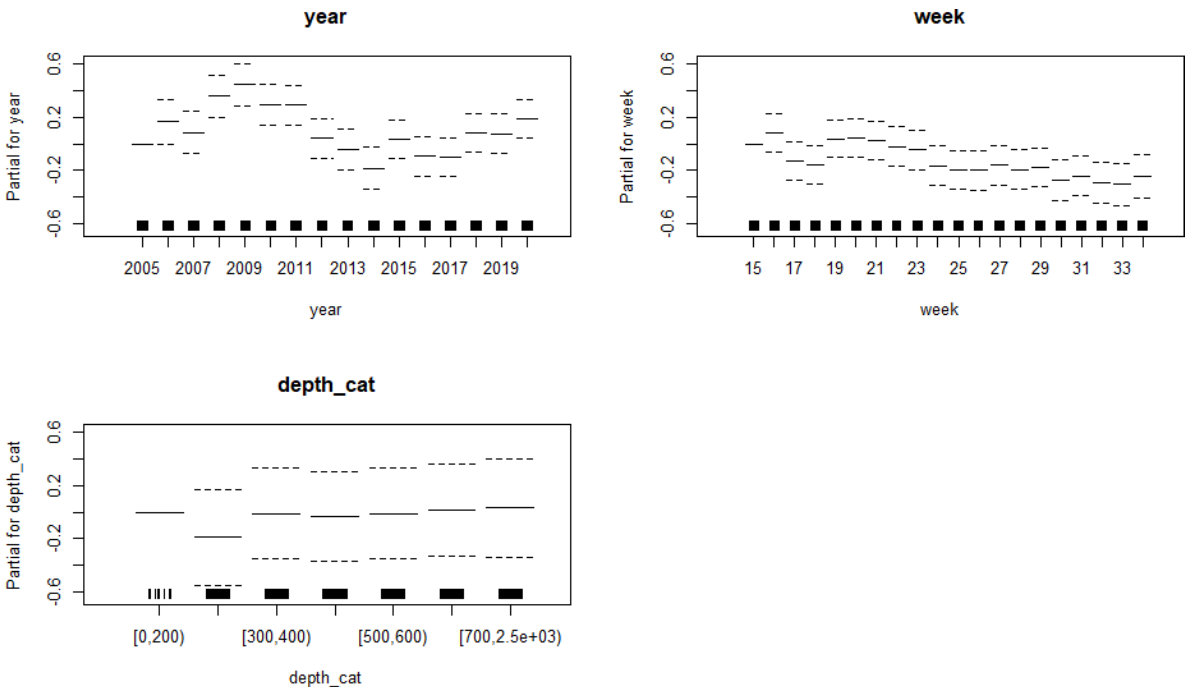

Figure 6: ARU.27.5b6a standardized CPUE explanatory variables

year	cpue	lwr	upr
2005	15.55	13.22	18.29
2006	18.34	15.75	21.36
2007	16.95	14.63	19.64
2008	22.29	19.23	25.84
2009	24.3	20.99	28.13
2010	20.87	18.09	24.09
2011	20.83	18.11	23.96
2012	16.2	14.09	18.61
2013	14.89	12.92	17.16
2014	12.94	11.19	14.98
2015	16.13	14.07	18.49
2016	14.13	12.34	16.18
2017	14.05	12.21	16.16
2018	16.91	14.77	19.37
2019	16.77	14.63	19.24
2020	18.74	16.33	21.5

Table 1: ARU.27.5b6a standardized commercial CPUE (tonnes/day) for greater silversmelt, with lower and upper values based on the standard error.

Single fleet analysis

A single fleet analysis was carried out by using the combined raw CPUE datasets and extracting the separate parts for the Faroese and PFA fleets. These data were then processed in a similar fashion as in the combined analysis. It is clear that the Faroese data is substantially more precise that the data from PFA as evident from the confidence intervals. This is likely due to the number of observations, where the dataset from Faroe Islands over all years is based on 10 times the number of hauls compared to the PFA data.

Figure 7: ARU.27.5b6a standardized single fleet CPUE (catch per rectangle and day)

3 Discussion

CPUE standardization using GLM procedures is a common way of dealing with CPUE information. Here we used aggregated data (catch per day) as the main response variable and year, week and depth category as explanatory variables. by area and period, which cannot use attributes that are related to the hauls. The standardized CPUE for WGDEEP 2021 is highly consistent with the CPUE that was calculated during WGDEEP 2020.

Both data sources (Faroese data and PFA data) indicate an increase in CPUE in the last 5-6 years although it does not reach the level seen in the late 2000s. The data from the Faroese fisheries are generated from a targetted fishery on silver smelt, while the data from the PFA is from a mixed fishery with blue whiting (blue whiting in the daytime, silver smelt in the nighttime). This probably leads to the higher uncertainties in the CPUE estimates for the PFA compared to the Faroese fleet. It is also noted that the number of observations in the PFA fisheries prior to 2015 is much lower than after 2015, because the self-sampling program only started in 2015.

4 References

Pastoors, M. A. and F. J. Quirijns (2020). Correcting an error in the CPUE Standardizing of Greater silversmelt for WGDEEP 2020, WD05.

Quirijns, F. J. and M. A. Pastoors (2020). CPUE standardization for greater silversmelt in 5b6a. WKGSS 2020, WD03.

REPORT

PFA self-sampling report for WGDEEP 2021 (WD02)

M.A. Pastoors

PFA report 2021/04

20/04/2020

Pelagic Freezer-trawler Association (PFA)

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Please cite as:

M.A. Pastoors (2021) **PFA self-sampling report WGDEEP 2021**. WGDEEP 2021, WD 02 / PFA report 2021/04

Summary

This report summarizes the self-sampling data collected by the Pelagic Freezer-trawler Association (PFA) with a focus on Argentines or Silversmelts. The self-sampling data consists of two main sources: (1) the historical catch per haul data derived from a limited number private logbooks of skippers, and (2) the self-sampling program that has been initiated from 2015 onwards on an increasing number of freezer-trawlers.

The PFA fishery for argentines takes place in the months April and May, and sometimes into June. The predominant fishing area is ICES division 27.6.a with also some catches being taken in 2.a, 4.a and 5.b. The fishery is combined with the fishery for blue whiting, whereby the catches of blue whiting take place during the day and catch of argentines mostly in the night.

Overall, the self-sampling activities for the argentines fisheries during the years 2000 – 2020 covered 48 fishing trips with 1248 hauls, a total catch of 30253 tonnes and 18635 individual length measurements.

The length compositions of argentines are relatively stable over the years, varying between 34 and 36 cm. A standardized CPUE series of the PFA fisheries is presented based on a GLM on CPUE (catch/rectangle/day) with year, week and depth as explanatory variables. Catch rates in 2019 and 2020 have been estimated higher than the preceding years, in line with reports from the skippers in the fleet.

1 Introduction

The Pelagic Freezer-trawler Association (PFA) is an association that has nine member companies that together operate 17 (in 2019) freezer trawlers in six European countries (www.pelagicfish.eu).

In 2015, the PFA has initiated a self-sampling programme that expands the ongoing monitoring programmes on board of pelagic freezer-trawlers by the specialized crew of the vessels. The primary objective of that monitoring programme is to assess the quality of fish. The expansion in the self-sampling programme consists of recording of haul information, recording the species compositions by haul and regularly taking random length-samples from the catch. The self-sampling is carried out by the vessel quality managers on board of the vessels, who have a long experience in assessing the quality of fish, and by the skippers/officers with respect to the haul information. The scientific coordination of the self-sampling programme is carried out by Martin Pastoors (PFA chief science officer) with support of Floor Quirijns (contractor).

2 Overview of self-sampling methodology

The PFA self-sampling programme has been implemented incrementally on many vessels that belong to the members of the PFA. The self-sampling programme is designed in such a way that it follows as closely as possible the working practices on board of the different vessels and that it delivers relevant information for documenting the performance of the fishery and to assist stock assessments of the stocks involved. The following main elements can be distinguished in the self-sampling protocol:

- haul information (date, time, position, weather conditions, environmental conditions, gear attributed, estimated catch, optionally: species composition)
- batch information (total catch per batch=production unit, including variables like species, average size, average weight, fat content, gonads y/n and stomach fill)
- linking batch and haul information (essentially a key of how much of a batch is caught in which of the hauls)
- length information (length frequency measurements, either by batch or by haul)

The self-sampling information is collected using standardized Excel worksheets. Each participating vessel will send in the information collected during a trip by the end of the trip. The data will be checked and added to the database by Floor Quirijns and/or Martin Pastoors, who will also generate standardized trip reports (using RMarkdown) which will be sent back to the vessel within one or two days. The compiled data for all vessels is being used for specific purposes, e.g. reporting to expert groups, addressing specific fishery or biological questions and supporting detailed biological studies. The PFA publishes an annual report on the self-sampling programme.

A major feature of the PFA self-sampling programme is that it is tuned to the capacity of the vessel-crew to collect certain kinds of data. Depending on the number of crew and the space available on the vessel, certain types of measurements can or cannot be carried out. That is why the programme is essentially tuned to each vessel separately. And that is also the reason that the totals presented in this report can be somewhat different dependent on which variable is used. For example the estimate of total catch is different from the sum of the catch by species because not all vessels have supplied data on the species composition of the catch.

The historical data retrieval program has been based on skippers' private logbooks that have been kept for fisheries practice recording. This data delivers information on the catch composition by haul and species. As part of a generic effort to retrieve the historical information, excel based versions of the logbooks have been converted into a standardized database. A major effort has been spent in making the information from the skippers' logbooks consistent and useable, so that the units are consistent between vessels and years. In addition, the species composition has been approximated from the logbooks using automated techniques. For example, skippers may have described the catch of a certain haul as "her 10% hom" which would then be converted to 90% herring and 10% horse mackerel. All conversion have been fully documented in R code. For this report, skippers' logbooks of 4 vessels have been used covering the period 2000-2015.

The freezer-trawler fishery is mostly focussed on the key target species herring, mackerel, horse mackerel and blue whiting. However, during the months april to june there is also a more limited directed fishery for greater argentine (Argentina silus) and lesser argentine (Argentina sphyraena), mostly in ICES division 27.6.a and 27.4.a.

For this report, the PFA self-sampling data has been filtered using the following criteria:

- hauls in divisions 27.2.a, 27.4.a, 27.5.b, 27.6.a
- catch of arg, aru, ary by trip and week at least 5% of the total catch of that trip and week.
- catch of arg, aru, ary by trip and week at least 50 tonnes.

3 Results

3.1 General summary of self-sampling for Silver smelts**

An overview of all the self-sampled trips for arg, aru, ary in 27.2.a, 27.4.a, 27.5.b, 27.6.a

year	nvessels	ntrips	ndays	nhauls	catch	nlength
2001	1	1	10	32	1,635	0
2003	1	1	18	43	2,132	0
2004	1	2	38	96	4,925	0
2005	1	1	7	14	1,340	0
2006	1	1	12	25	1,495	0
2007	1	1	13	29	1,505	0
2008	1	1	7	16	680	0
2012	1	2	27	74	3,044	0
2013	1	1	12	27	1,260	0
2014	1	1	14	30	1,885	0
2015	3	4	51	123	9,712	15,672
2016	3	3	73	158	11,025	10,166
2017	4	4	43	118	10,345	11,178
2018	9	9	103	273	17,215	17,783
2019	6	8	80	197	18,938	8,821
2020	6	8	117	319	22,536	18,781
(all)		48	625	1,574	109,672	82,401

Table 3.1.1: PFA fisheries for argentines (and blue whiting). Self-sampling Summary of number of vessels, trips, days, hauls, catch (tonnes) and number of fish measured.

The majority of hauls have been recorded in division 27.6.a (81%).

division	2001	2003	2004	2005	2006	2007	2008	2012	2013	2014	2015	2016	2017	2018	2019	2020	all	perc
27.6.a	32	4	65	3	2	17	16	70	27	25	116	97	109	239	175	281	1,278	81.2%
27.5.b	0	36	12	11	8	12	0	4	0	2	7	42	9	5	0	4	152	9.7%
27.4.a	0	0	0	0	13	0	0	0	0	3	0	19	0	26	22	34	117	7.4%
27.2.a	0	3	19	0	2	0	0	0	0	0	0	0	0	3	0	0	27	1.7%
(all)	32	43	96	14	25	29	16	74	27	30	123	158	118	273	197	319	1,574	100.0%

Table 3.1.2: PFA fisheries for argentines (and blue whiting). Self-sampling Summary of number of hauls per year and division.

Catch by species in the selected fisheries

species	english_name	scientific_name	2015	2016	2017	2018	2019	2020	all	perc
whb	blue whiting	Micromesistius poutassou	6,781	7,735	7,688	13,110	13,602	13,115	62,030	69.1%
arg	argentines	Argentina spp	2,841	2,551	2,438	3,682	4,824	7,561	23,897	26.6%
her	herring	Clupea harengus	0	0	0	0	0	1,438	1,438	1.6%
mac	mackerel	Scomber scombrus	29	27	124	264	446	312	1,203	1.3%
hke	hake	Merluccius merluccius	51	642	89	126	59	50	1,017	1.1%
hom	horse mackerel	Trachurus trachurus	0	50	0	1	2	0	52	0.1%
squ	various squids nei	Loliginidae, Ommastrephidae	10	0	3	3	3	14	33	0.0%
mcd	NA	Ceratoscopelus maderensis	0	0	0	0	0	23	23	0.0%
sqr	squid	Loligo vulgaris	0	0	0	4	1	16	21	0.0%
mzz	other fish	Osteichthyes	0	0	0	20	0	0	20	0.0%
oth	NA	NA	1	21	3	6	2	8	41	0.0%
(all)	(all)	(all)	9,713	11,026	10,346	17,215	18,938	22,537	89,774	100.0%

Table 3.1.3: PFA fisheries for argentines (and blue whiting). Self-sampling Summary of total catch (tonnes) by species.

Haul positions

An overview of all self-sampled hauls in the PFA fisheries for argentines (and blue whiting)..

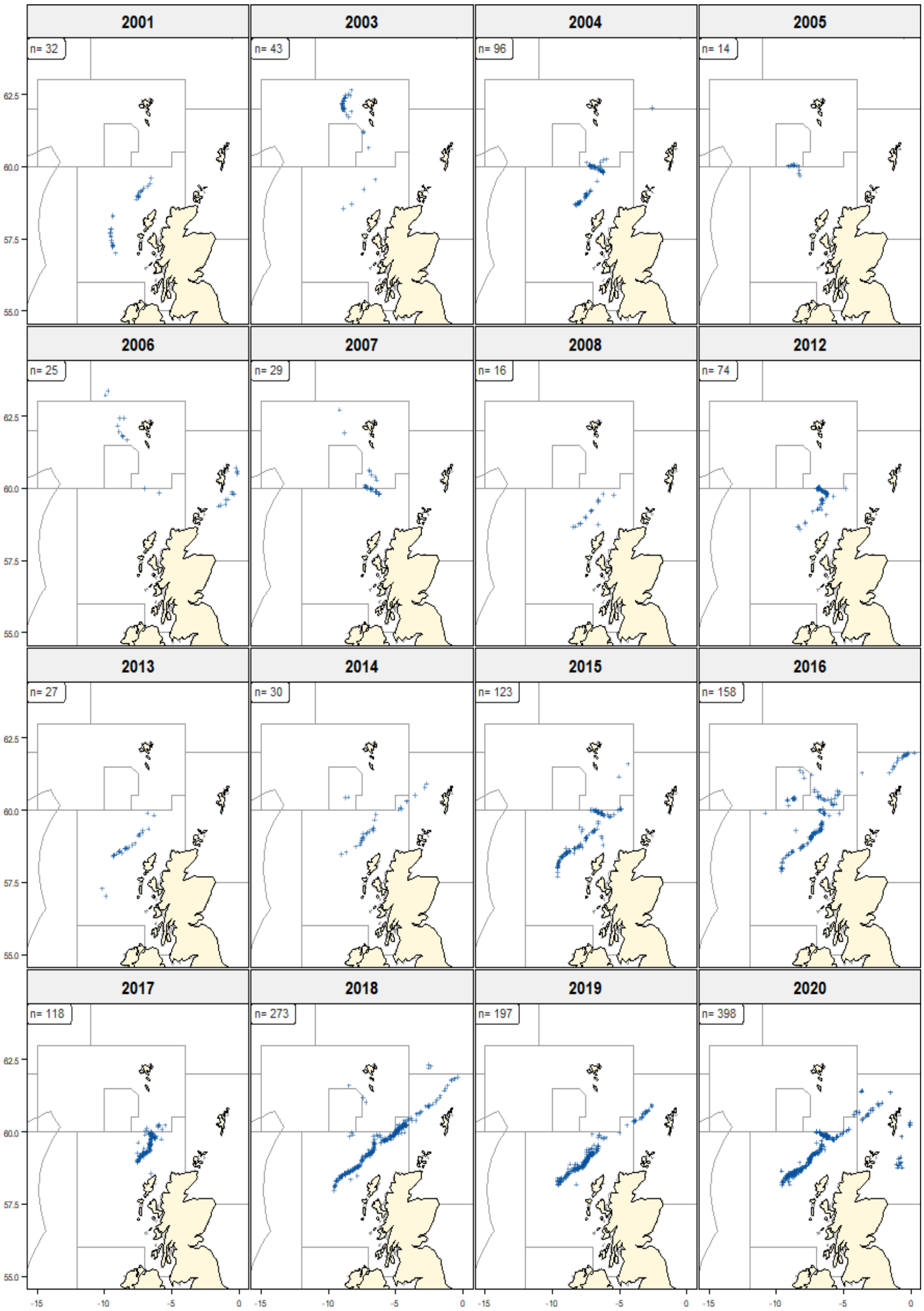


Figure 3.1.1: PFA fisheries for argentines (and blue whiting). Self-sampling haul positions. N indicates the number of hauls.

Total catch per rectangle for the main target species

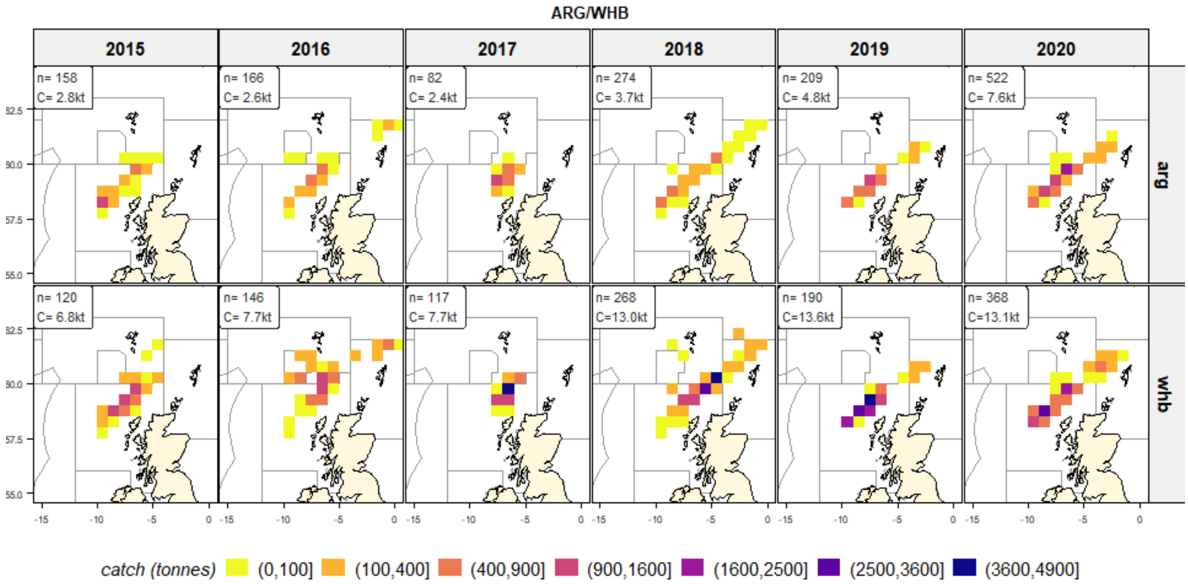


Figure 3.1.2: PFA fisheries for argentines (and blue whiting). Self-sampling catch per species and per rectangle. N indicates the number of hauls. Catch refers to the total catch per year.

Average fishing depth by rectangle

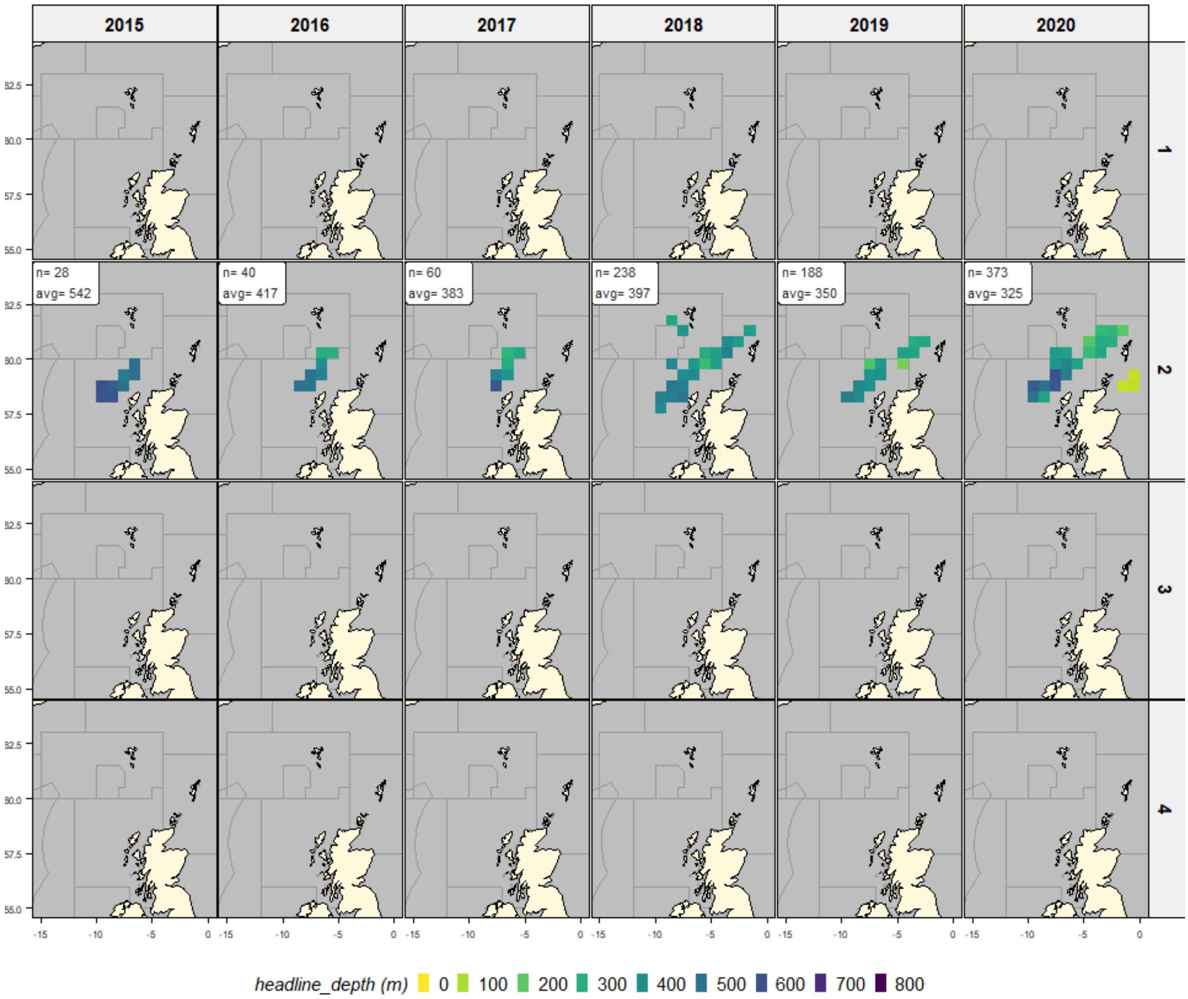


Figure 3.1.3: PFA fisheries for argentines (and blue whiting). Average fishing depth (m) by year and quarter. N indicates the number of hauls. Avg refers to the average fishing depth.

Average temperature at fishing depth by rectangle

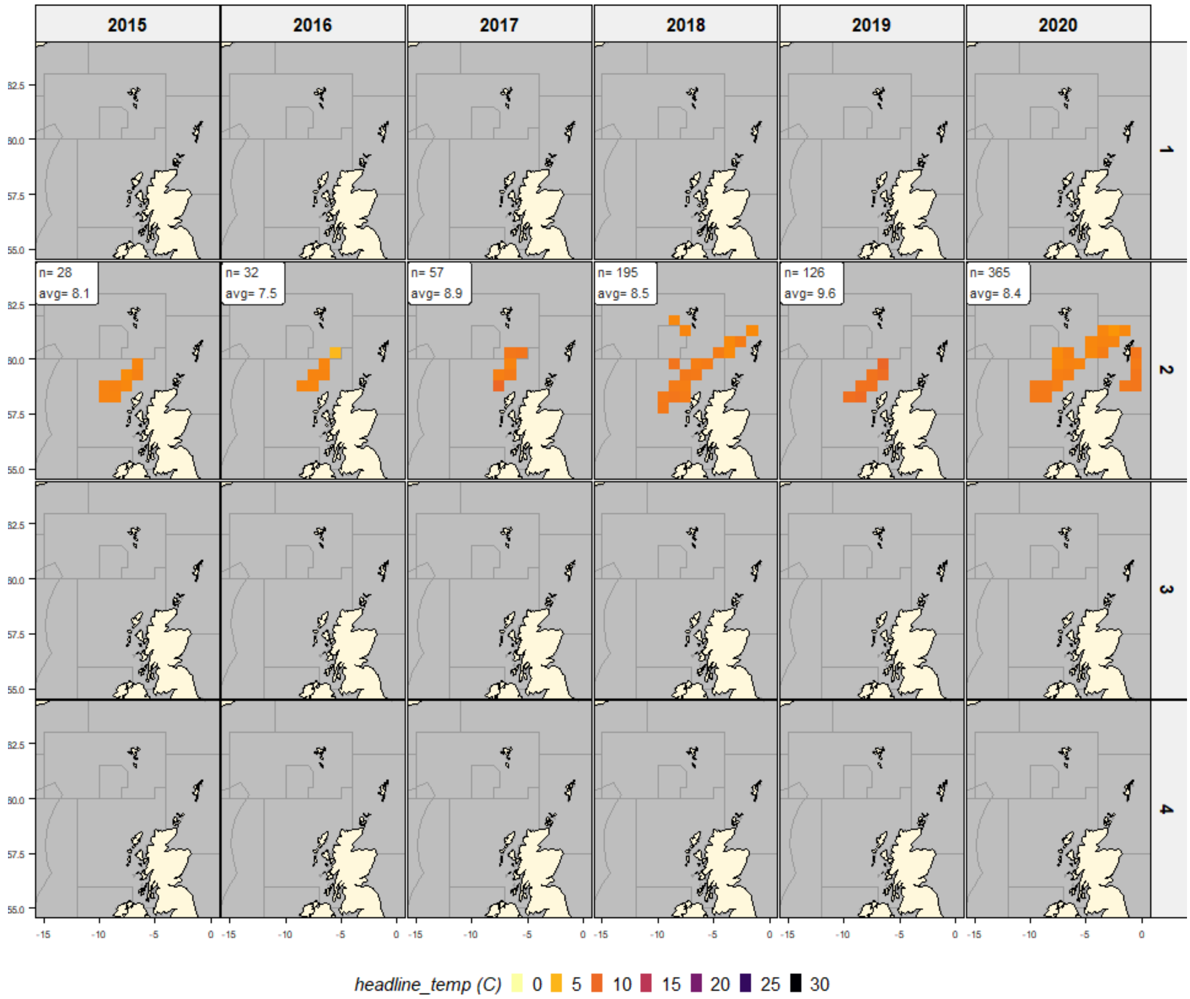


Figure 3.1.4: PFA fisheries for argentines (and blue whiting). Average temperature at fishing depth (C) by year and quarter. N indicates the number of hauls. Avg refers to the average temperature.

Average windspeed by rectangle

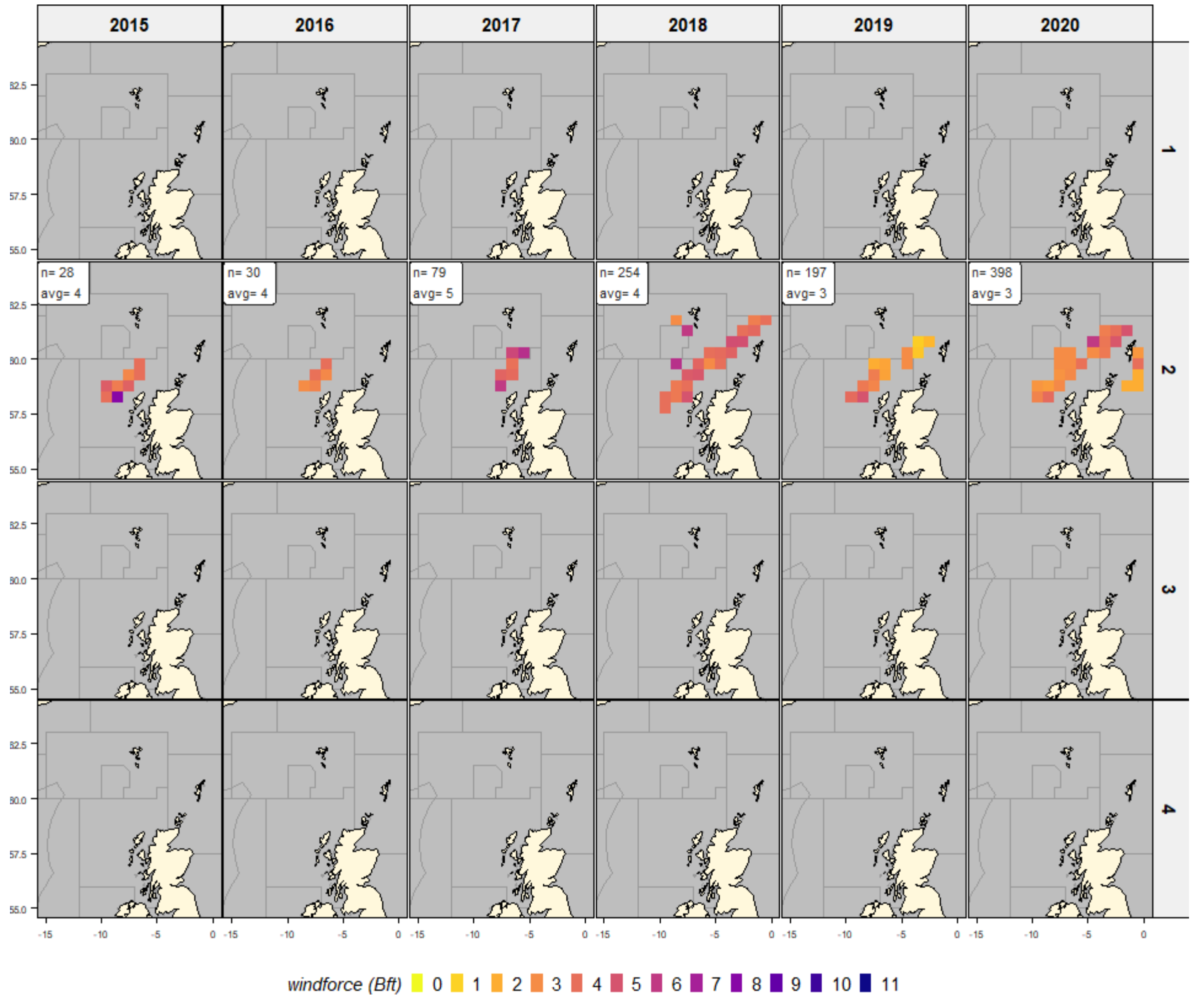


Figure 3.1.5: PFA fisheries for argentines (and blue whiting). Average wind speed (Bft) by year and quarter. N indicates the number of hauls. Avg refers to the average wind speed.

3.2 Argentines (ARG, Argentina spp.)

The Argentines fishery takes place as a summer fishery from June to September and a winter fishery in December. Overall, the self-sampling activities for the Argentines fisheries during the years 2000 – 2020 covered 48 fishing trips with 1685 hauls, a total catch of 30253 tonnes and 18635 individual length measurements. The main fishing areas are ICES divisions 27.4.a, 27.4.b and 27.7.d.

species	division	year	nvessels	ntrips	ndays	nhauls	catch	catchperc	nlength
arg	27.2.a	2004	1	1	1	1	80	3	0
arg	27.4.a	2014	1	1	1	3	9	5	0
arg	27.4.a	2016	2	2	8	18	150	6	362
arg	27.4.a	2018	5	5	13	25	181	5	239
arg	27.4.a	2019	1	1	9	21	329	7	628
arg	27.4.a	2020	3	3	9	17	490	6	377
arg	27.5.b	2003	1	1	12	28	821	100	0
arg	27.5.b	2004	1	2	6	8	182	7	0
arg	27.5.b	2005	1	1	2	3	108	100	0
arg	27.5.b	2006	1	1	4	6	222	94	0
arg	27.5.b	2007	1	1	4	6	130	18	0
arg	27.5.b	2012	1	1	4	4	25	2	0
arg	27.5.b	2015	2	3	4	5	155	5	637
arg	27.5.b	2016	2	2	8	14	139	5	119
arg	27.5.b	2017	1	1	1	1	6	0	2
arg	27.5.b	2018	1	1	1	1	4	0	6
arg	27.5.b	2020	1	1	2	2	87	1	48
arg	27.6.a	2001	1	1	6	9	121	100	0
arg	27.6.a	2003	1	1	3	4	0	0	0
arg	27.6.a	2004	1	2	23	61	2,272	90	0
arg	27.6.a	2006	1	1	1	2	14	6	0
arg	27.6.a	2007	1	1	8	17	599	82	0
arg	27.6.a	2008	1	1	5	12	216	100	0
arg	27.6.a	2012	1	2	25	67	1,246	98	0
arg	27.6.a	2013	1	1	11	23	127	100	0
arg	27.6.a	2014	1	1	10	19	186	95	0
arg	27.6.a	2015	3	4	47	105	2,686	95	5,178
arg	27.6.a	2016	3	3	45	86	2,262	89	1,063
arg	27.6.a	2017	4	4	38	81	2,432	100	980
arg	27.6.a	2018	9	9	83	204	3,498	95	1,396
arg	27.6.a	2019	6	8	59	129	4,495	93	3,038
arg	27.6.a	2020	6	8	97	266	6,984	92	4,557
arg	(all)	2001		1	6	9	121	100	0
arg	(all)	2003		2	15	32	821	100	0
arg	(all)	2004		5	30	70	2,534	100	0
arg	(all)	2005		1	2	3	108	100	0
arg	(all)	2006		2	5	8	236	100	0
arg	(all)	2007		2	12	23	729	100	0
arg	(all)	2008		1	5	12	216	100	0
arg	(all)	2012		3	29	71	1,271	100	0
arg	(all)	2013		1	11	23	127	100	0
arg	(all)	2014		2	11	22	195	100	0
arg	(all)	2015		7	51	110	2,841	100	5,815
arg	(all)	2016		7	61	118	2,551	100	1,544

arg	(all)	2017	5	39	82	2,438	100	982
arg	(all)	2018	15	97	230	3,683	100	1,641
arg	(all)	2019	9	68	150	4,824	100	3,666
arg	(all)	2020	12	108	285	7,561	99	4,982
arg	(all)	(all)	75	550	1,248	30,256		18,630

Table 3.2.1: Argentines. Self-sampling summary with the number of days, hauls, trips, vessels, catch (tonnes), number of fish measured, catch rates (ton/effort).

Argentines (ARG). Catch by month

species	month	2001	2003	2004	2005	2006	2007	2008	2012	2013	2014	2015	2016	2017	2018	2019	2020	all	perc
arg	Apr	63	0	485	107	0	0	0	675	127	20	569	433	43	921	981	3,397	7,821	25.9%
arg	May	57	821	1,969	0	235	728	216	521	0	174	1,928	1,869	2,394	2,760	3,842	3,128	20,642	68.3%
arg	Jun	0	0	80	0	0	0	0	75	0	0	0	247	0	0	0	1,034	1,436	4.7%
arg	Jul	0	0	0	0	0	0	0	0	0	0	343	0	0	0	0	0	343	1.1%
arg	(all)	120	821	2,534	107	235	728	216	1,271	127	194	2,840	2,549	2,437	3,681	4,823	7,559	30,242	100.0%

Table 3.2.2: Argentines. Self-sampling summary with the catch (tonnes) by year and month.

Argentines (ARG). Catch by rectangle

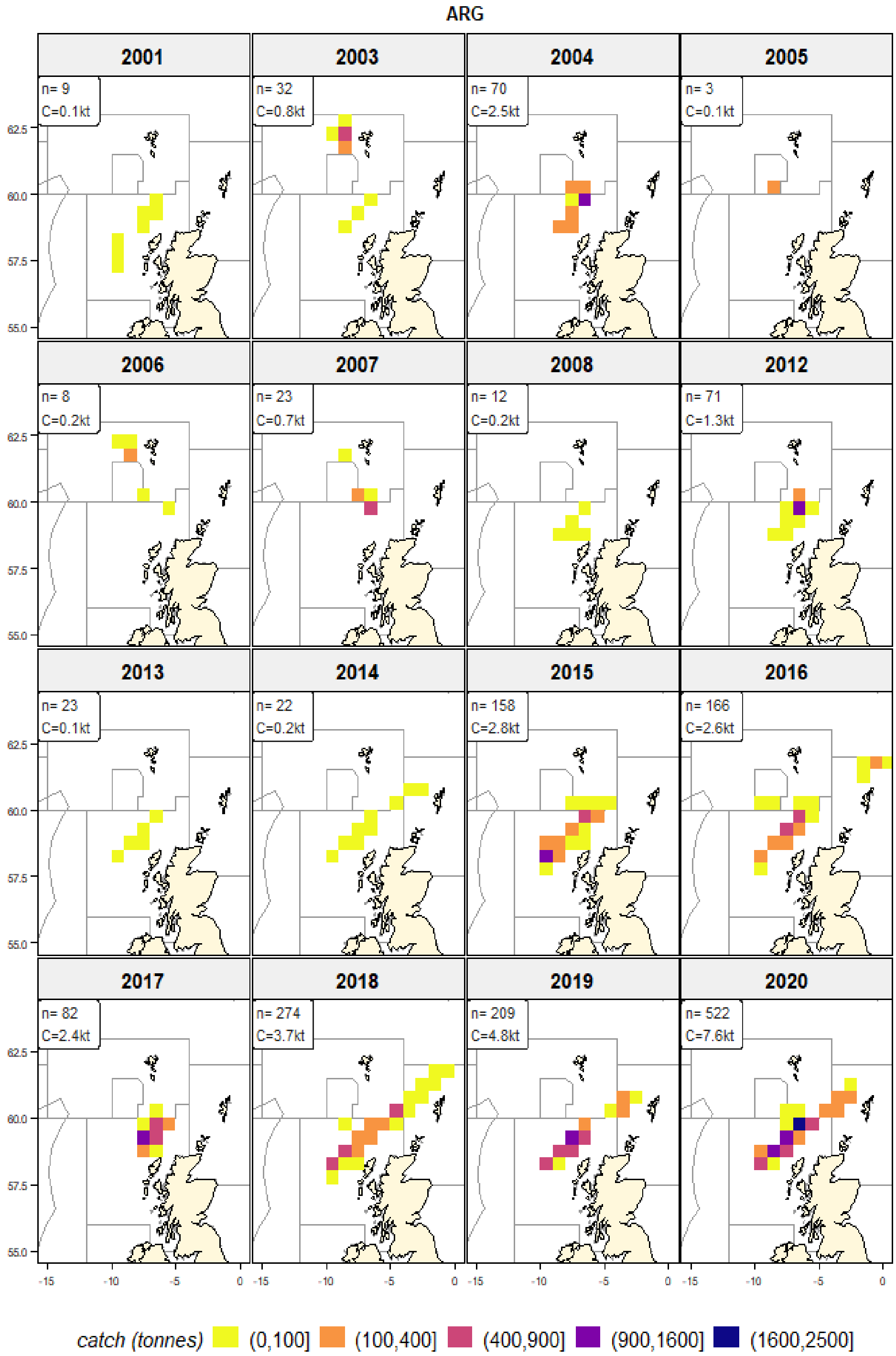


Figure 3.2.1: Argentines. Catch per per rectangle. N indicates the number of hauls; Catch refers to the total catch per year.

Argentines (ARG). Spatial-temporal evolution of the fishery

Spatial-temporal evolution of the fishery by year and month from the haul-by-haul catch information. THe fishing season is from June until September and a winter fishery in December. The midpoint of the distribution is indicated by the blue triangle. The catch has been used as weighting factor in the calculation of the midpoint.

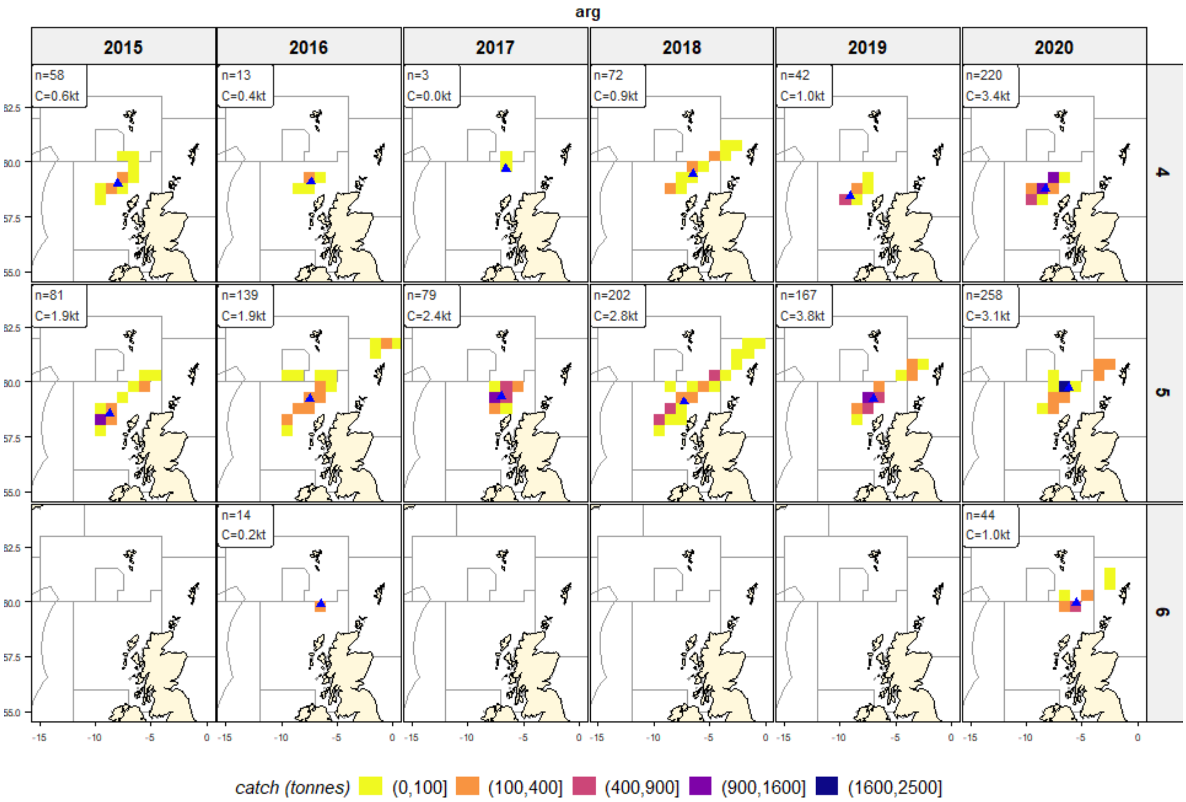


Figure 3.2.2: Argentines. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day.

Argentines (ARG). Length distributions of the catch

The length distribution of argentines in the catches is relatively stable between 34 and 36 cm.

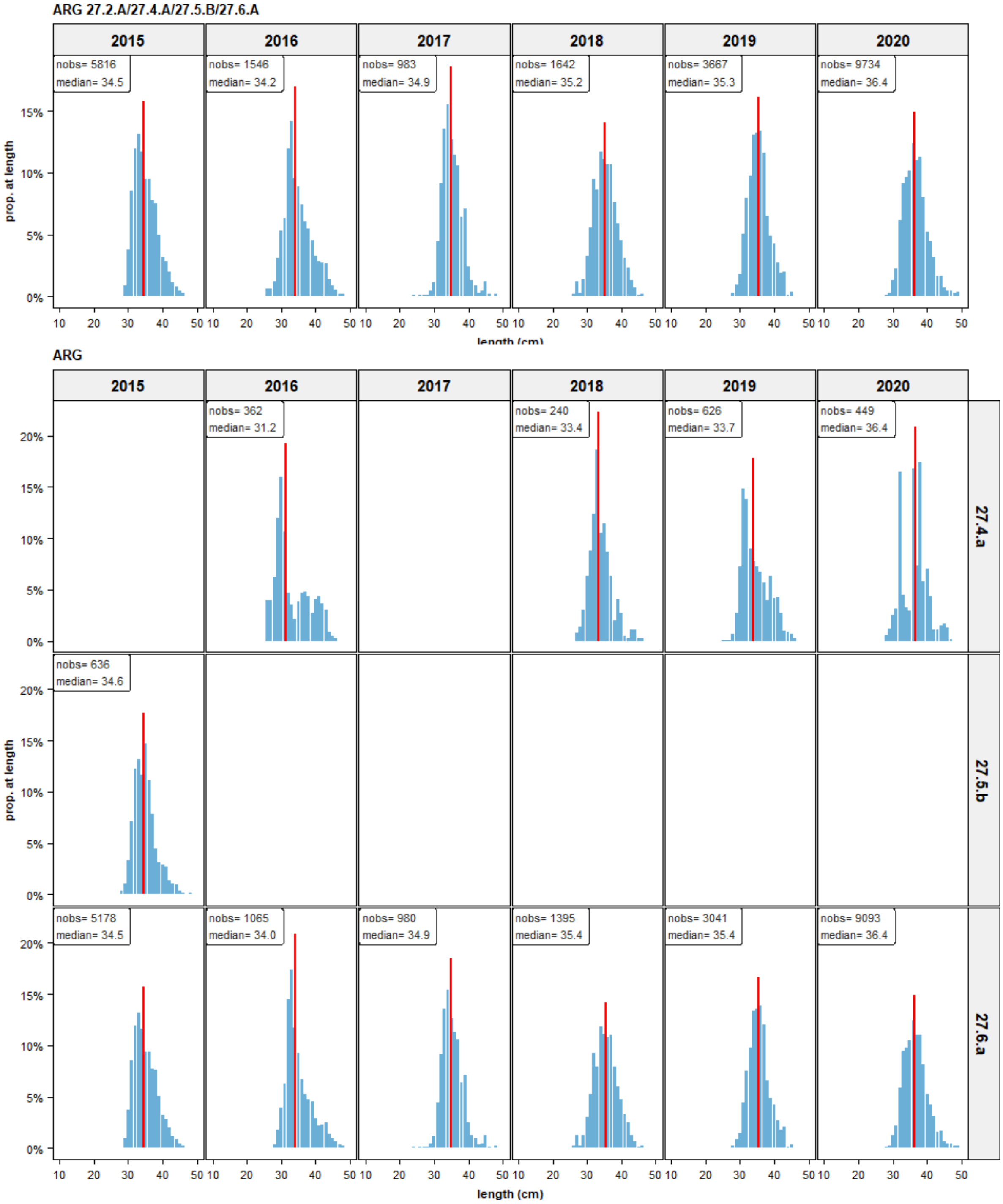


Figure 3.2.3: Argentines. Length distributions by year (top) and by year and division (bottom). Nobs refers to the number of observations; median denotes the median length.

Catch at depth

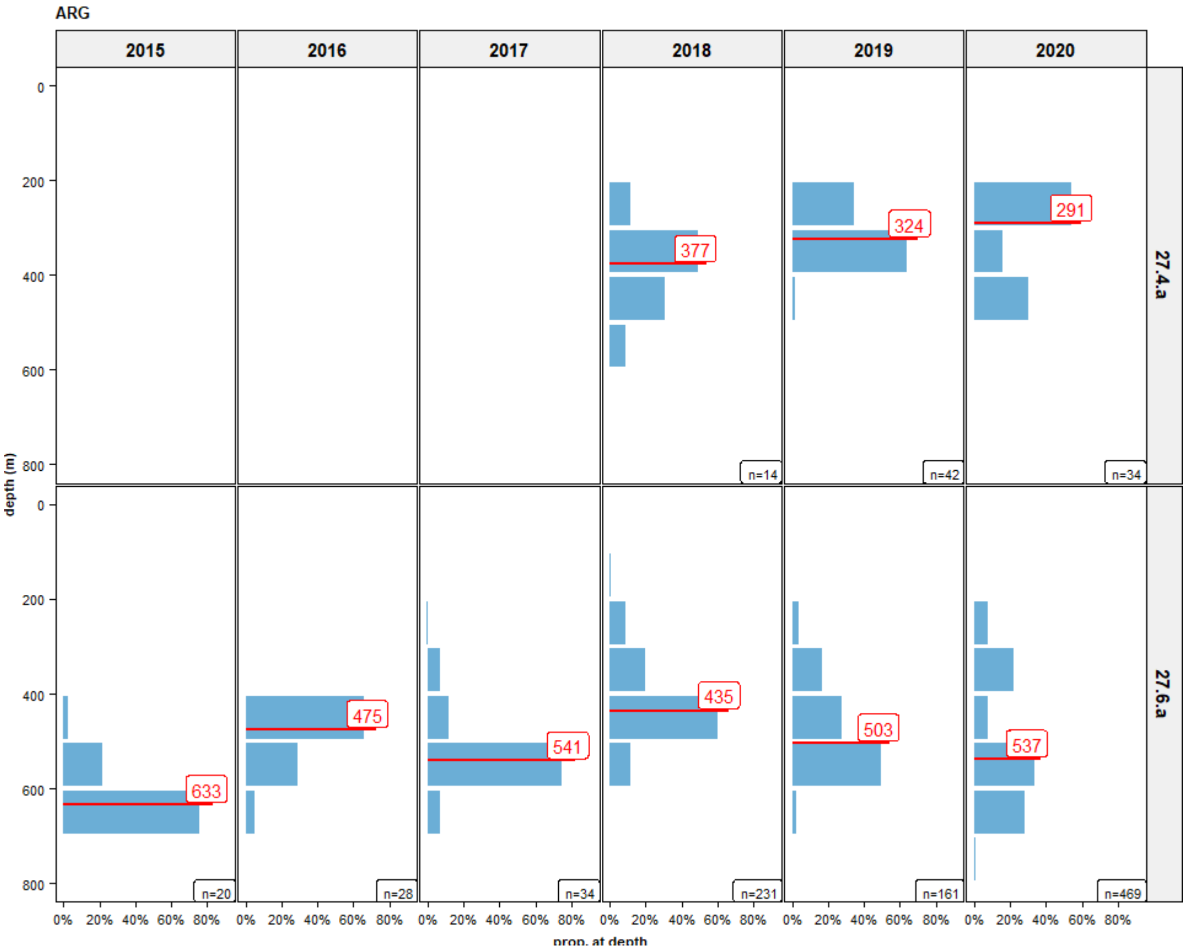


Figure 3.2.4: Argentines. Depth distributions by year and division. Nobs refers to the number of observations; median denotes the median length.

CPUE index

The catch rate in the fishery for argentines can be highlys fluctuating between hauls. Catch rate has been defined as catch (tons) per ICES rectangle and per day on a nominal scale. Catches have first been summed by vessel, year, week and rectangle and the number of hauls and fishing days have been calculated. Then the catches and effort (fishing days) have been summed over all vessels by year and week and the average depth has been calculated. CPUE was then calculated as the average catch per rectangle and per day. This follows the procedure explained in Quirijns and Pastoors (2020), although here only applied to the PFA fleet.

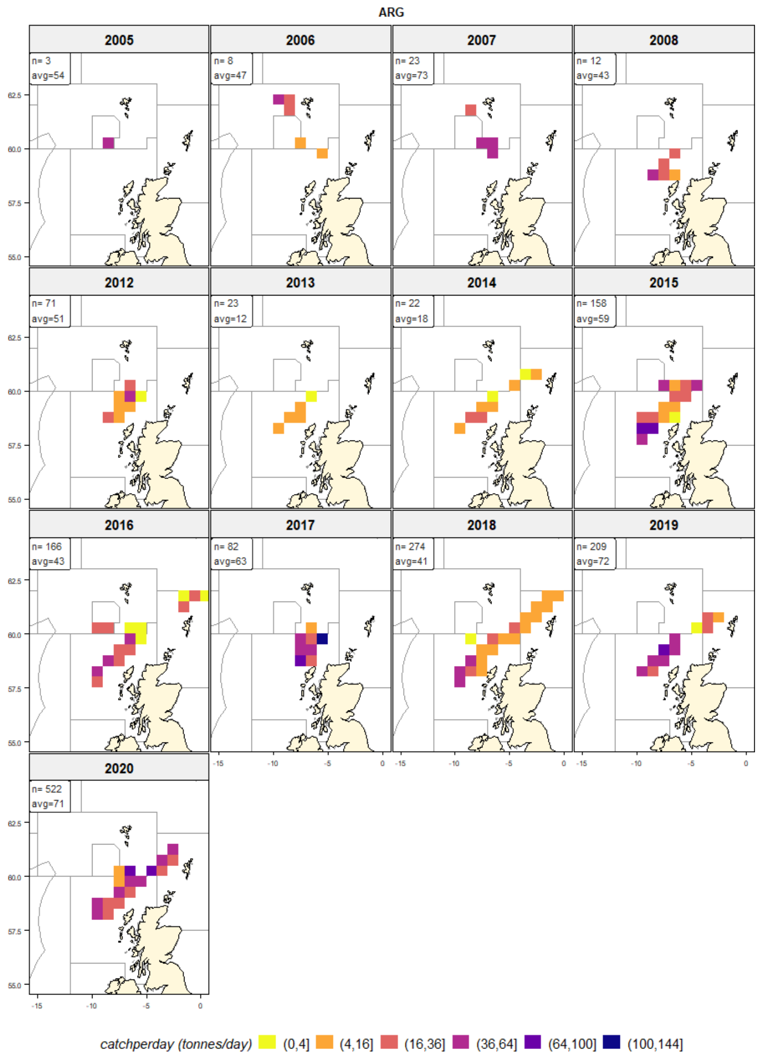
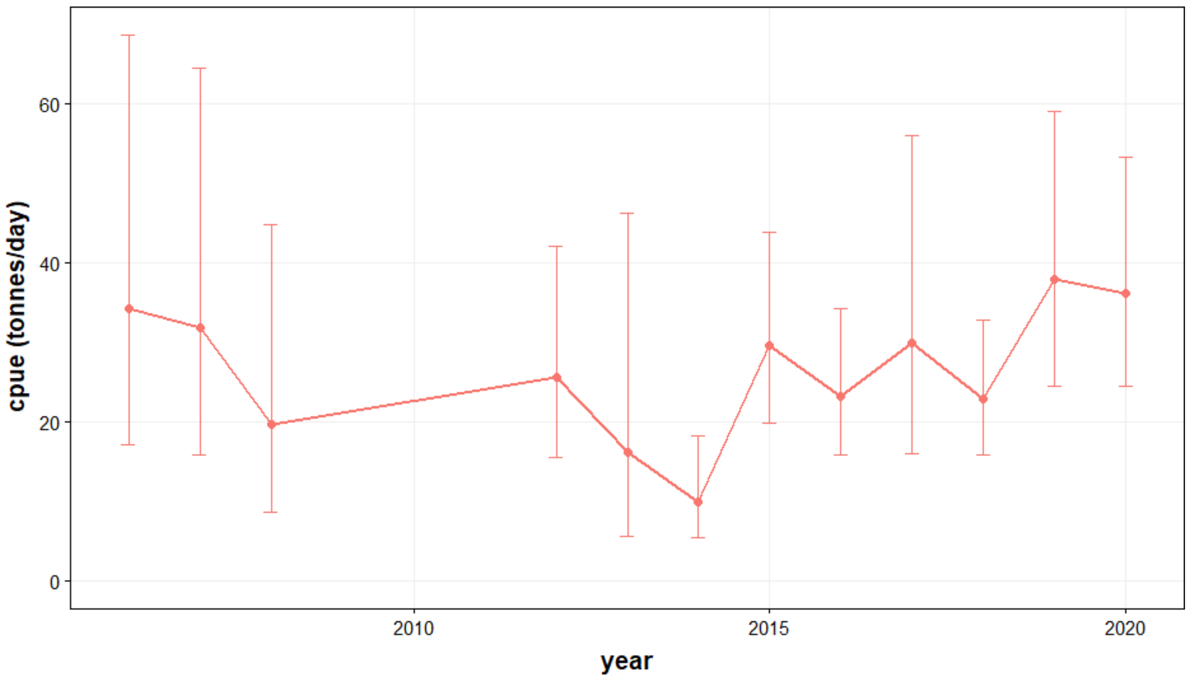


Figure 3.2.5: Argentines. Average catch per day per rectangle. N indicates the number of hauls; avg refers to the overall average catch per day.

The model used for standardization is: CPUE ~ year + week + depth, where CPUE is expressed as catch per day per rectangle. Catch rates in 2019 have been estimated higher than the preceding years, in line with reports from the skippers in the fleet.



4 Discussion and conclusions

By the end of 2019, all vessels were participating in the PFA self-sampling programme. Although the programme does not consist of a random selection of vessels – because the instructions to the vessel benefit from a continued application of data collection on the participating vessels – the overall fishing pattern does appear to represent the fisheries of the PFA vessels.

The definition of what constitutes 'a fishery' for a certain species is not well specified. In this report we selected all trips within divisions 27.2.a, 27.4.a, 27.5.b, 27.6.a and were the weekly catches had more than 50 tonnes of argentines and where the proportion of species in the catch of that week was at least 5%.

The standardized CPUE for the PFA fleet has now been included in the annual report. The standardized CPUE follows the approach documented in Quirijns and Pastoors 2020.

5 Acknowledgements

The skippers, officers and the quality managers of many of the PFA vessels have put in a lot of effort to make the PFA the self-sampling work. Without their efforts, there would be no self-sampling.

6 References

Quirijns, F. J. and M. A. Pastoors (2020). CPUE standardization for greater silversmelt in 5b6a. WKGSS 2020, WD03.

7 More information

Please contact Martin Pastoors (mpastoors@pelagicfish.eu) if you would have any questions on the PFA self-sampling program or the specific results presented here.

Update on Norwegian fishery independent information on abundance, recruitment, size distributions, and exploitation of roundnose grenadier (*Coryphaenoides rupestris*) in the Skagerrak and north-eastern North Sea (ICES Division IIIa)

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Introduction

The roundnose grenadier is a long-lived deepwater species which in the relevant study area reaches ages of 70 years or more and attains maturity at the age of 8-12 years (Bergstad 1990). It has a limited area of distribution within the Norwegian deep and in the deep Skagerrak basin (300-720m) (ICES Div. 4a & 3a). Analyses using microsatellite DNA have demonstrated that the Skagerrak grenadier is currently likely to be isolated from grenadier elsewhere in its North Atlantic distribution area (Knutsen *et al*., 2012). In 2003-2005 a major expansion of the previously quite minor targeted grenadier fishery occurred, and this expansion was followed by a complete closure of the fishery from 2006 onwards. Apart from previous targeted exploitation, grenadier is now a minor by-catch in the traditional trawl fishery for *Pandalus borealis* which is currently the major demersal trawl fishery in the area. Most shrimp fishing occurs shallower than the main distribution area of the grenadier.

This Working Document presents results derived from a research vessel bottom trawl survey conducted annually during the past 38 years (1984-2021). While the main objective of the survey is to monitor *Pandalus borealis,* the survey samples the entire depth range and distribution area of roundnose grenadier.

We report temporal variation in survey catch rates in terms of biomass and abundance (kg/hour and number/hour), length distributions, occurrence of recruits, and geographical distribution. We also attempt to estimate by-catch in the commercial shrimp fishery. Most of the information in this Working Document is an update of a WD first submitted to WGDEEP in 2009 (Bergstad *et al*. 2009). The survey series is currently the only information available to assess temporal variation and trends for the grenadier in this area. A full analysis of the time-series has been published (Bergstad *et al*., 2014), but this working paper extends the series to include the years 2014-2021.

Material and Methods

Data was collected from the annual *Pandalus borealis* shrimp survey performed by the Institute of Marine Research in the years 1984-2021 (Table 1). The survey is a depth stratified shrimp trawl survey with approximately 25% of the stations deeper than 300 m (depth range 117-534 m). The trawl used has small meshes overall and a 6mm cod-end liner and retains all sizes of grenadiers, including the smallest newly settled juveniles (Bergstad 1990, Bergstad and Gordon 1994). The stations are placed at random within strata and subareas, and the same sites area sampled every year. Although some changes occurred over the years (Table 1), the overall standardization was maintained throughout the time series (Bergstad *et al.* 2014).

Catch rates in terms of biomass and abundance were calculated for stations 300 m and deeper, i.e. excluding shallower survey depths where the species only occurs sporadically in small numbers (Bergstad 1990). Stations with zero catches were included, and the catches at non-zero stations were standardized by tow duration.

Annual length distributions were derived for the pooled standardized catches at 300m and beyond. In cases were catches were subsampled, length distributions were raised to the total catch prior to pooling.

Age data from selected surveys in 1987 and 2007-2019 were plotted as cumulative age distributions. Age and length data from 2008-2019 were analyzed for growth parameters.

Standardized mean catches by number of small juveniles of PAL ≤ 5 cm were calculated to show recruitment during the survey period.

A time series of maps showing geographical distributions by year were plotted, representing scaled catch rates at the actual sample sites for each survey year.

Data from the Norwegian reference fleet was collected to report bycatch on roundnose grenadier in the Norwegian shrimp fishery.
In an earlier first attempt to estimate commercial by-catch of grenadier, we derived a time-series of mean survey catch rate of grenadier from depths shallower than 400m (i.e. where shrimp fishing is carried out) and multiplied that with annual estimates of effort in the Norwegian shrimp fishery (extracted from Søvik and Thangstad, 2015). Most of the distribution area of grenadier lies within the Norwegian EEZ and the Norwegian trawler fleet is assumed to be predominant in that area.

Results

Biomass and abundance

The estimates of catch rates in terms of biomass (kg/h) and abundance (nos/h) varied substantially through the time series (Fig.1), but elevated levels were observed from 1998 to 2004. The decline from 2005 continued through the time series until 2017 which was the lowest on record. The observations from 2019-2020 remained low, but with a slight increase compared with 2017. For 2021, the catch rate has again declined and is now just slightly higher than the 2017 catch rate.

Size and age distributions

The time series of annual length distributions show a major shift in the early 1990s (Fig. 2). From 1992 the proportion of large fish with PAL>15cm declined to less than 10% which contrasts with the pre-1990 distributions dominated by large fish. From 1992, a pronounced mode of small fish can be followed in subsequent years, with modal length increasing through the time series.

The very recent distributions (2018-2021) contrasts with the pre-1990 distributions by having low proportions of large fish. The 2021 distribution is dominated with small fish but at low levels compared to the 1990's.

Age distributions and growth
The cumulative age distribution from the extracted data from 1987 (Bergstad, 1990) contrasts substantially with the distributions from 2007-2019 in terms of proportions of old fish (e.g. >20 years) (Fig. 3). In 1987, the proportion of fish > 20 years was over 50% (Table 4). In 2008, i.e. after the relatively large expansion in landings in 2003-2005 and ban on direct fishing introduced in 2006, only 8% of the aged fish were older than 20 years. In subsequent years the proportion of older fish apparently increased, and recent distribution from 2019 now show 36% fish > 20 years (Table 4). This is still very low compared with the 1987 situation.

Age at length was analyzed for the years 2008-2019 (Figure 9) and compared with data from 1987 (Bergstad, 1990) (Table 3). The growth rate coefficient (k) and the length infinity (L_∞) for females is in the same range as the data from 1987, but slightly lower for 2008-2019 data compared with data from 1987.

Occurrence of juveniles <5cm PAL
There is no indication of a pronounced recruitment pulse as that observed in the early 1990s, neither in the length distributions (Fig 2.), or in the time series of mean abundance of small fish < 5 cm (Fig. 4). The recruitment for 2021 is one of the lowest during the time series.

Geographical distribution
The area sampled in given year and the corresponding geographical distribution of grenadier catches is presented in Figure 5. The overall distribution area does not seem to have changed considerably during the time series 1984-2021. Catches of roundnose grenadier are restricted to the Norwegian Deep north to 59°N and extend eastwards into the Skagerrak basin. The highest catches were always found in the eastern Skagerrak part of the Norwegian Deep.

Commercial by-catch
For an assessment of the bycatch of roundnose grenadier in the Norwegian shrimp fishery, data from the Norwegian Reference fleet showed that < 1% of the tows with shrimp trawl caught roundnose grenadier (Table 5). The values for catch weights from the Reference fleet are low and in same level as the reported landings for the recent years. This indicates that the low reported Norwegian landings are realistic and that the landings are the bycatch amount taken by the Norwegian shrimp fishery.

The new data from the Norwegian Reference fleet suggest that the earlier attempt of estimating the bycatch in shrimp fishery is too high. The survey catches of shrimp (*Pandalus borealis*) drop off significantly by depth and few catches occur deeper than 400m (Fig. 6). The shrimp fishery is mostly conducted shallower than 300m. By-catch estimates derived using the mean annual survey catches of grenadier (at depths <400 m) and annual effort in the Subarea 3a and 4a Norwegian shrimp trawl fishery (Fig. 7) illustrate the likely historical variation in by-catch rates in the fishery. There is a recent trend towards very low levels (less than 100 tonnes), but by-catches in the shrimp fishery were probably historically less than 2000 tonnes/year yet probably higher in the mid-2000s when grenadier abundance appeared elevated.

Discussion

Despite high inter annual variability, the catch rates in terms of biomass and abundance from the survey suggest long term pattern of variation through the time series 1984-2021. An increase in biomass and abundance from the late 1980s until 1998-2004 seemed to be followed by a major decline from the mid-2000s onwards. In 2021 abundance and biomass estimates were still at low levels.

The survey catch rate declined in all areas, also where high survey catches were common, i.e. in the eastern part of the Skagerrak (Fig. 5).

The time-series of size distributions also suggest pronounced structural changes during the period 1984-2021. The distributions from the 1980s with a dominance of fish around 15 cm PAL contrasts with those from the late 1990s when the population was apparently rejuvenated by a pulse in recruitment from 1991-1992 onwards. The recruits from 1991-1992 can be tracked as a mode in the size distributions for 15 years until 2005. The distributions were dominated by old fish until 2012 although with consecutively low concentrations. From 2013 the distributions changed to younger fish primarily but still with low levels.

The difference in age distribution between 1987 and 2019 is primarily seen in the proportion of older fish, i.e. there is almost no fish older than 30 years in 2019 while almost 25% of the fish was older than 30 years in 1987. The most prominent difference between recent situation and that of 1987 concerning growth, was seen for females. It seems that the bulk of very large and old female individuals seen in 1987 is no longer present in recent years (Table 3).

High mean survey biomass coincided with very high commercial landings in 2004-05 (Fig. 8). The fishery may have utilized a period of elevated abundance resulting from what appears to be the single large pulse in recruitment in the 38 years surveyed. From recent length distributions no similar pulse in recruitment has been observed.

An interpretation of the patterns observed in the time-series of size and age distributions, the survey abundance index for small juveniles, and the survey index of all sizes combined is that the enhanced fishery in 2003-2005 had the combined effect of eroding both the accumulated fraction of older fish around 30 years that were found in the population in 1987 prior to the fishery and the younger fish resulting mainly from the recruitment pulse in the early 1990s. The very old fish never reappeared, and for three decades, recruitment has been consistently at a level well below the level observed in the single high event in the early 1990s. The recent recruitment has probably been too low to produce any increase in abundance.

The reported landings peaked in 2005 at about 11000 tonnes (Fig. 8) and have since declined to about a ton per year. From 2006 onwards this decline in landings is a result of regulations (Bergstad 2006) as the targeted fishery ceased. By-catches from shrimp fisheries still occur, however. The data from the Norwegian Reference fleet and our attempt to estimate by-catches suggests that current levels are minor, probably reflecting low grenadier abundance at relevant depths and introduction of sorting grids to the fishery.

The Norwegian bycatch of roundnose grenadier thus is well described through the reported landings. The Swedish and Danish fishery reports both landings and discards and therefore the bycatch from these fisheries should be counted for in the statistics. The level of landings and discards in recent years has been in total less than 2 tonnes per year.

Conclusion

The decline in abundance after 2005-2006 suggested by the survey catch rates may reflect the combined effect of the enhanced targeted exploitation in 2003-2005 and the low recruitment in the years following the single recruitment pulse in the early 1990s. The percentage of fish >15cm is now lower than recent years and there is no suggestion of a new recruitment pulse as seen in the 1990s. The current low abundance and truncated age structure in the population thus reflect both the exploitation and recruitment history spanning the past 2-3 decades. Since the targeted fishery has stopped and the by-catch in the shrimp fishery are low, there is a potential for recovery of the roundnose grenadier in Skagerrak. However, rejuvenation and growth of the population would at present seem unlikely due to low recruitment during the recent decades. The survey information suggests that it may be a feature of this population that only a single good recruitment event may be expected in a period of 3 decades.

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Søvik, G. and Thangstad, T. 2014. The Norwegian fishery for Northern shrimp (Pandalus borealis) in Skagerrak and the Norwegian Deep (ICES Division IIIa and Iva east), 1970-2014. NAFO SCR Doc. 14/063.

Table 1. Summary of data on the bottom trawl survey series, 1984-2021. Rg- rockhopper ground gear. ‘Strapping’ – maximum width of trawl constrained by rope connecting warps in front of otter doors. MS – RV Michael Sars, HM – RV Håkon Mosby, KB – RV Kristine Bonnevie. Data from 2021 survey is included. All trawls were fitted with a 6mm mesh cod-end liner.

YEAR	Survey month	Vessel	IMR Gear code	Additional gear info.	No. trawls >300m	No. trawls >400m	No. trawls survey
1984	OCT	MS	3230	Shrimp trawl (see text)	10	1	67
1985	OCT	MS	3230	“	21	5	107
1986	OCT/NOV	MS	3230	“	24	9	74
1987	OCT/NOV	MS	3230	“	35	14	120
1988	OCT/NOV	MS	3230	“	31	11	122
1989	OCT	MS	3236	Campelen 1800 35mm/40, Rg	31	7	106
1990	OCT	MS	3236	“	26	5	89
1991	OCT	MS	3236	“	28	9	123
1992	OCT	MS	3236	“	27	10	101
1993	OCT	MS	3236	“	30	10	125
1994	OCT/NOV	MS	3236	“	27	10	109
1995	OCT	MS	3236	“	29	12	103
1996	OCT	MS	3236	“	27	11	105
1997	OCT	MS	3236	“	25	6	97
1998	OCT	MS	3270	Campelen 1800 20mm/40, Rg	23	6	97
1999	OCT	MS	3270	“	27	8	99
2000	OCT	MS	3270	“	25	10	109
2001	OCT	MS	3270	“	18	4	87
2002	OCT	MS	3270	“	24	6	82
2003	OCT/NOV	HM	3230	Shrimp trawl (as in 1984-1988)	13	0	68
2004	MAY	HM	3270	Campelen 1800 20mm/40, Rg	17	6	65
2005	MAY	HM	3270	“	23	8	98
2006	FEB	HM	3270	“	10	0	45
2007	FEB	HM	3270	“	11	1	66
2008	FEB	HM	3271	Campelen 1800 20mm/40, Rg and strapping*	18	5	73
2009	JAN/FEB	HM	3271	“	25	7	91
2010	JAN	HM	3271	“	24	7	98
2011	JAN	HM	3271	“	22	7	93
2012	JAN	HM	3271	“	20	5	65
2013	JAN	HM	3271	“	28	8	101
2014	JAN	HM	3271	“	16	7	69
2015	JAN	HM	3271	“	28	9	92
2016	JAN	HM	3271	“	28	9	108
2017	JAN	KB	3271	“	30	9	128
2018	JAN	KB	3271	Campelen 1800 20mm/40, Rg and strapping**	27	8	111

Table 1. Continued

YEAR	Survey month	Vessel	IMR Gear code	Additional gear info.	No. trawls >300m	No. trawls >400m	No. trawls survey
2019	JAN	KB	3296	Campelen 1800 20mm/40, Rg and strapping***	27	8	108
2020	JAN	KB	3296	"	26	7	106
2021	JAN	KB	3296	"	27	8	113

* Path width of the tow constrained by a 10 m rope connecting the warps, 200 m in front of otter boards. ** Path width of the tow constrained to a 15 m rope connecting the warps, 100 m in front of the otter boards. *** Same trawl and strapping but from 2019 there are inserted several floaters on the trawl to lighten the trawl (Nordsjørigging).

Table 2. Mean biomass index and mean abundance index from shrimp survey 1984-2021. Missing data are from surveys that are not representable according to roundnose grenadier catches (few stations > 300 m). Data from 2016 are considered unreliable according to gear inconsistencies.
Mean biomass (kg/h), Mean abundance (n/h), Number (n) and Standard error (2SE)

Year	n	(kg/h)	2SE(kg/h)	(n/h)	2SE(n/h)
1984	10				
1985	21	108.12	38.32	149.95	49.43
1986	24	83.75	32.16	117.83	46.99
1987	35	76.15	13.56	125.80	24.60
1988	31	72.14	13.92	105.19	21.22
1989	31	122.69	43.48	195.94	73.07
1990	26	49.81	18.20	72.66	27.55
1991	28	107.14	22.27	176.86	38.75
1992	27	188.54	67.53	698.52	337.67
1993	30	58.59	19.42	190.33	74.15
1994	27	87.19	21.21	372.96	143.56
1995	29	118.30	32.36	440.62	144.41
1996	27	99.63	31.68	268.01	116.92
1997	25	113.86	66.47	362.72	222.08
1998	23	255.54	87.80	812.82	336.85
1999	27	149.30	42.85	388.83	122.54
2000	25	129.27	30.39	389.06	107.71
2001	18	105.33	51.84	272.99	151.99
2002	24	174.77	66.27	371.70	129.97
2003	13				
2004	17	324.38	125.48	1143.35	487.33
2005	23	193.65	93.81	550.42	260.94
2006	10				
2007	11				
2008	18	95.58	65.81	259.10	208.53
2009	25	72.72	39.81	207.41	121.84
2010	24	33.24	21.47	77.21	54.81
2011	22	26.84	12.61	54.76	27.05
2012	20	16.69	11.97	34.40	23.83
2013	28	11.48	4.92	35.06	16.90
2014	16	25.62	15.76	49.56	28.69
2015	28	7.28	4.59	21.19	12.14
2016	28				
2017	30	6.64	2.41	15.74	6.73
2018	27	12.88	6.60	41.91	26.13
2019	27	14.59	5.77	40.09	18.05
2020	26	18.72	11.48	63.02	38.07
2021	27	9.59	5.03	26.14	14.19

Table 3. Estimated parameters of von Bertalanffy growth function on data from Skagerrak shrimp survey 2008-2019 and Skagerrak survey in 1987 as reported by Bergstad 1990. k=growth coefficient, L_∞=asymptotic length, t_0=theoretical age when length is zero, SE=standard error				
	Estimated parameter			
Parameter	**Shrimp survey 2008-2018**		**Skagerrak survey 1987**	
	Females (SE)	**Males (SE)**	**Females**	**Males**
k	0,079 (±0,005)	0,083 (±0,013)	0,100	0,105
L_∞	16,6 (±0,296)	14,2 (±0,546)	18,1	14,7
t_0	-3,2 (±0,427)	-5,1 (±1,13)	-0,9	-1,5

Table 4. Cumulative percentages (%) for selected ages from 1987 and 2007-2019.					
	Age				
Year	**5**	**10**	**20**	**30**	**50**
1987	9	21	45	75	96
2007	10	23	83	94	96
2008	22	40	92	99	100
2009	14	30	88	93	100
2010	12	29	71	96	99
2011	6	23	65	94	99
2012	10	28	48	96	100
2013	14	28	56	92	99
2014					
2015	7	17	48	95	100
2016					
2017	14	52	81	94	99
2018	23	50	77	99	100
2019	8	37	64	92	100

Table 5. Proportion of tows with shrimp trawl that caught roundnose grenadier. Data from Norwegian Reference fleet.				
Year	Total number of shrimp trawl	Number of trawl hauls that caught roundnose grenadier	Catch of roundnose grenadier (kg)	% of the total catch
2013	243	0		0
2014	288	2		0,69
2015	1489	14		0.94
2016	4811	23		0,48
2017	3798	20	29	0,53
2018	2849	19		0,67
2019	1233	4	80	0,32

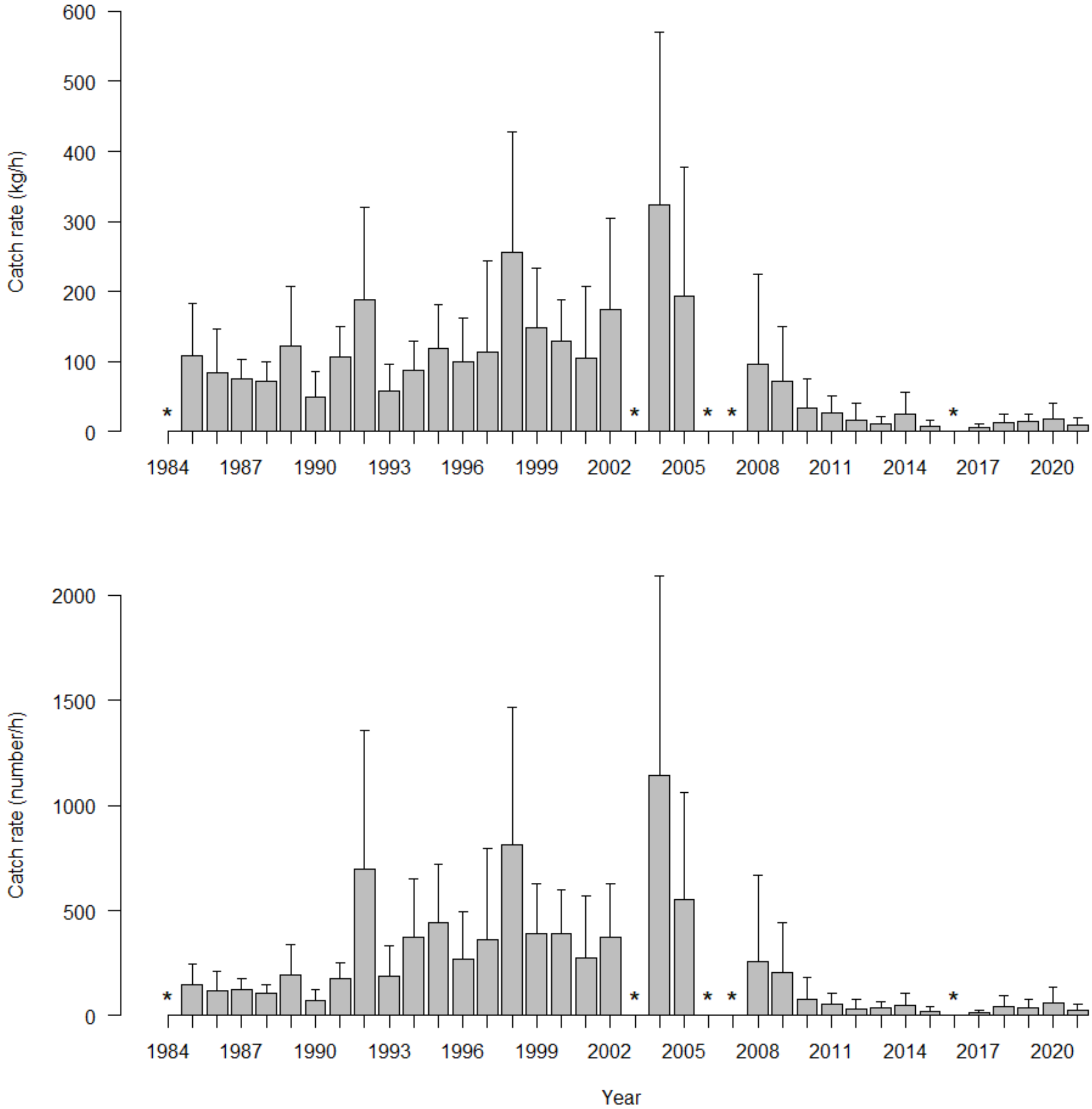


Figure 1. Standardized survey catch rates of grenadier, 1984-2021. Upper: Biomass (kg/h), Lower: Abundance (number/h). Standard error (2SE) shown by lines on top of bar. *In 1984, 2003, 2006 and 2007, only one single or no trawls were made deeper than 400 m, and data from those years were excluded; in 2016 data from shrimp survey is regarded as unreliable due to inconsistencies with trawling gear and data from that year should be excluded.

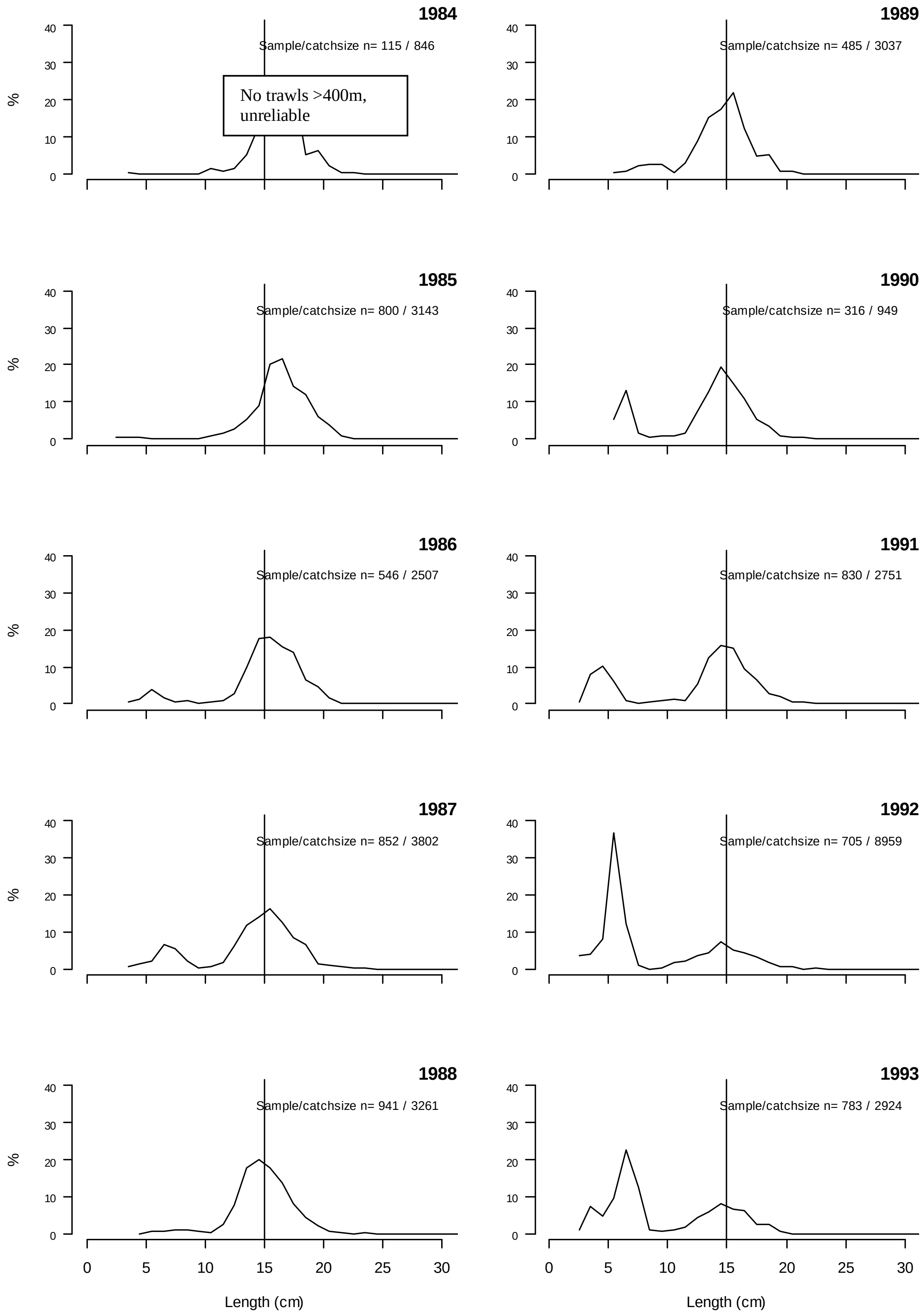
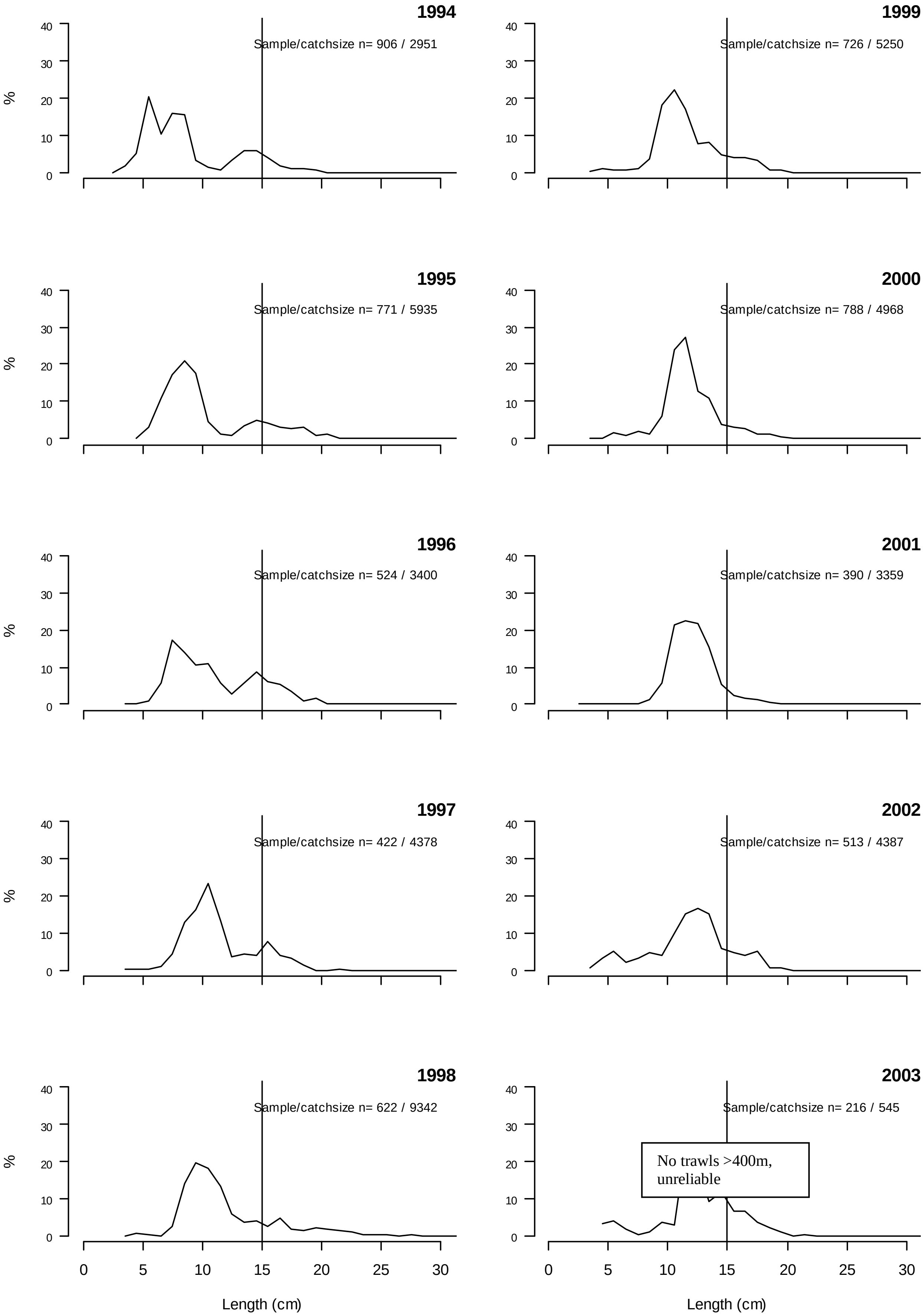


Figure 2. Length distributions of roundnose grenadier from annual *P. borealis* surveys, 1984-2021. Length is measured as PAL (cm). The length distributions are calculated as percentage number of fish in each centimetre length interval standardized to total catch number and trawling distance for each station each year. *In 1984, 2003, 2006 and 2007, only one single or no trawls were made deeper than 400 m, and data from those years should be excluded; in 2016 data from shrimp survey is regarded as unreliable due to inconsistencies with trawling gear and data from that year should be excluded.



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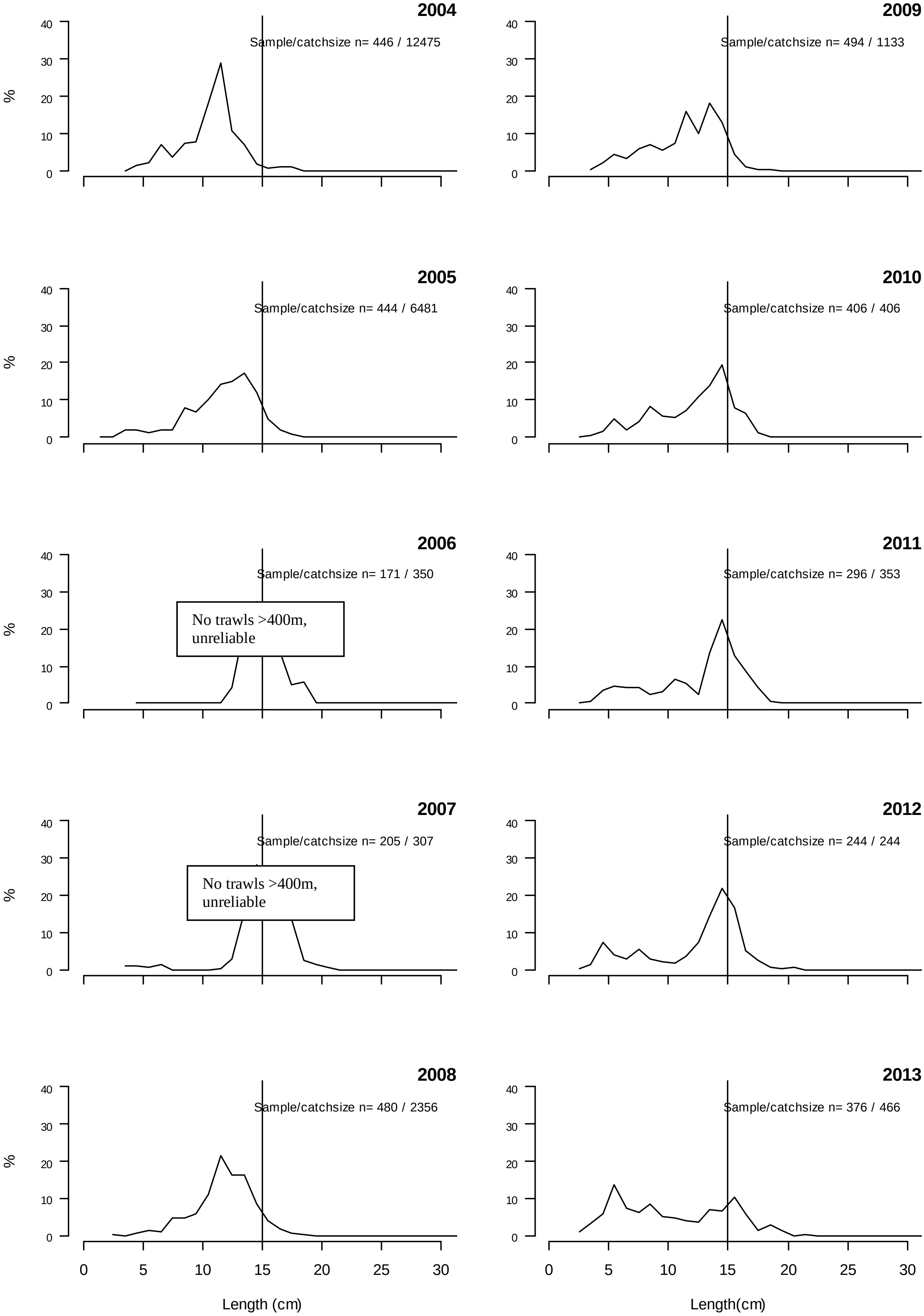

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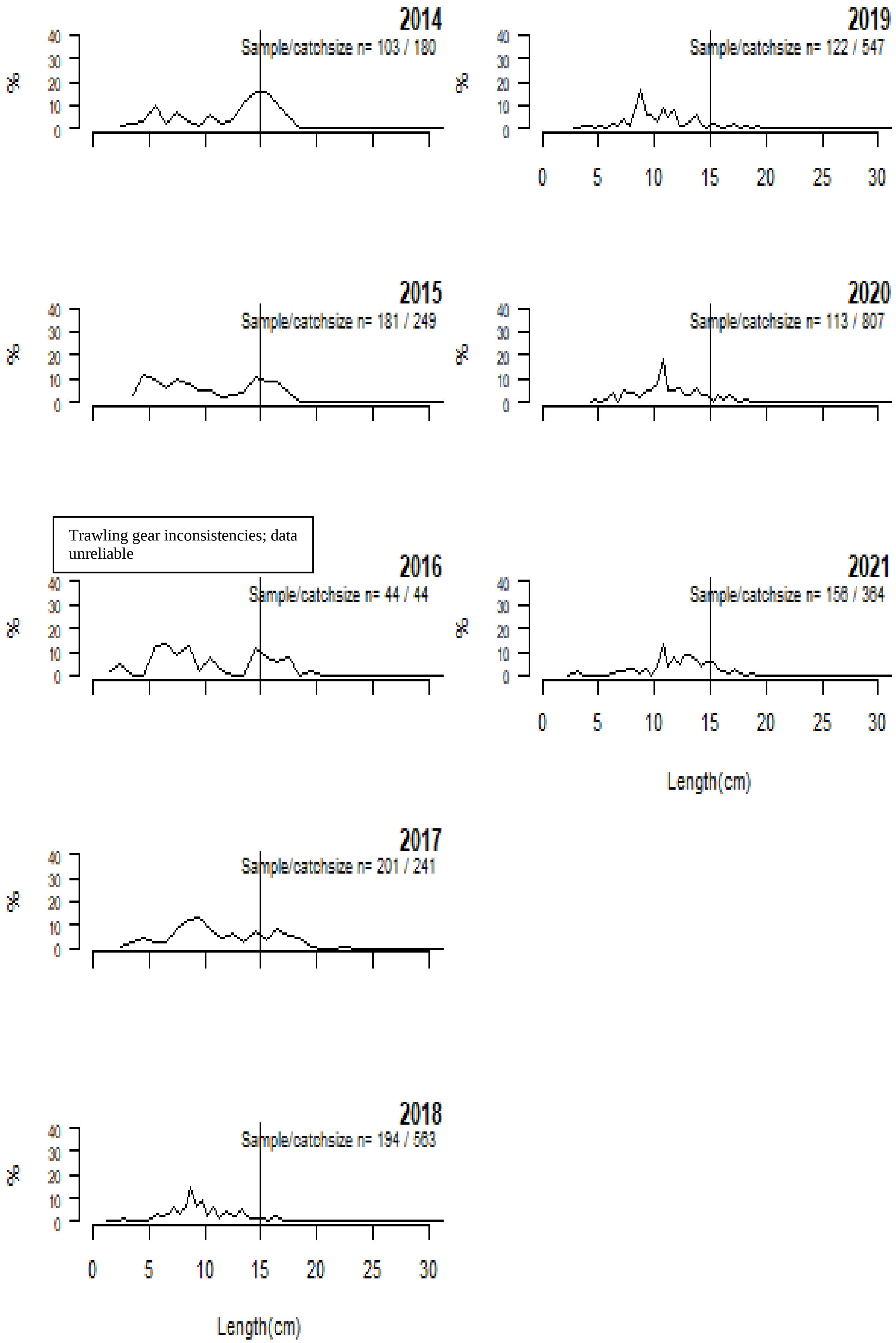


Figure 2. Continued

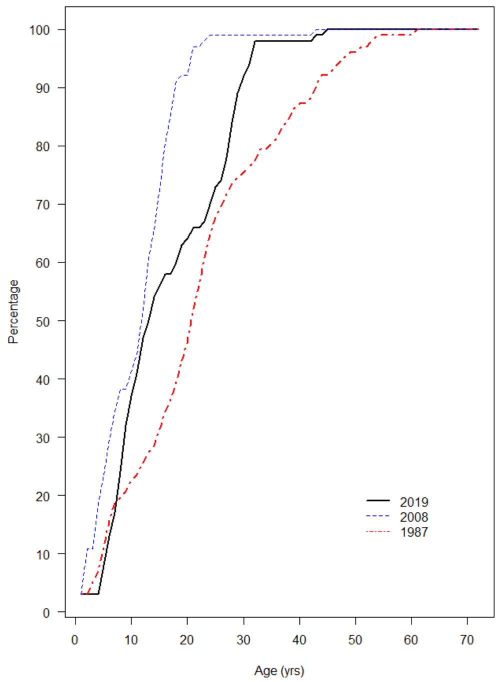


Figure 3. Cumulative age distributions of roundnose grenadier in the Skagerrak. Data from survey catches in Skagerrak in 1987, 2008 and 2019. The distribution from 1987 was modified from Bergstad (1990). Data from 2008 and 2019 was derived from the annual shrimp survey.

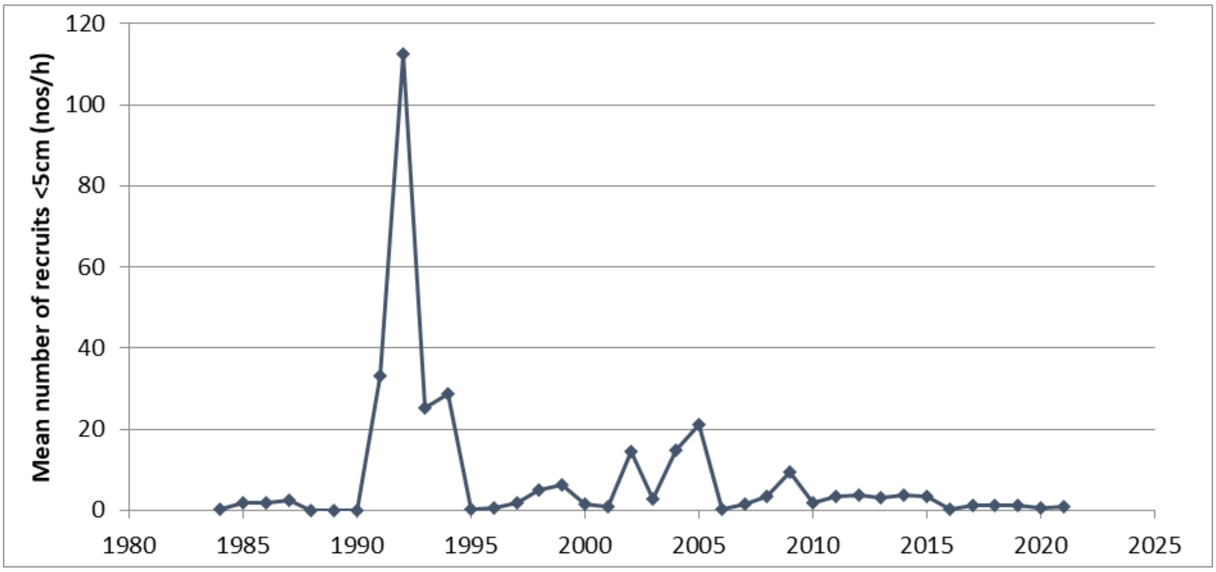


Figure 4. Mean catch rate of roundnose grenadier of PAL ≤ 5 cm, 1984-2021. Data from shrimp survey, trawls deeper than 300 m. *In 1984,2003,2006 and 2007, no trawls were made deeper than 400 m, and data from these years should be disregarded; in 2016 data from shrimp survey is regarded as unreliable due to inconsistencies with trawling gear and data from that year should be excluded.

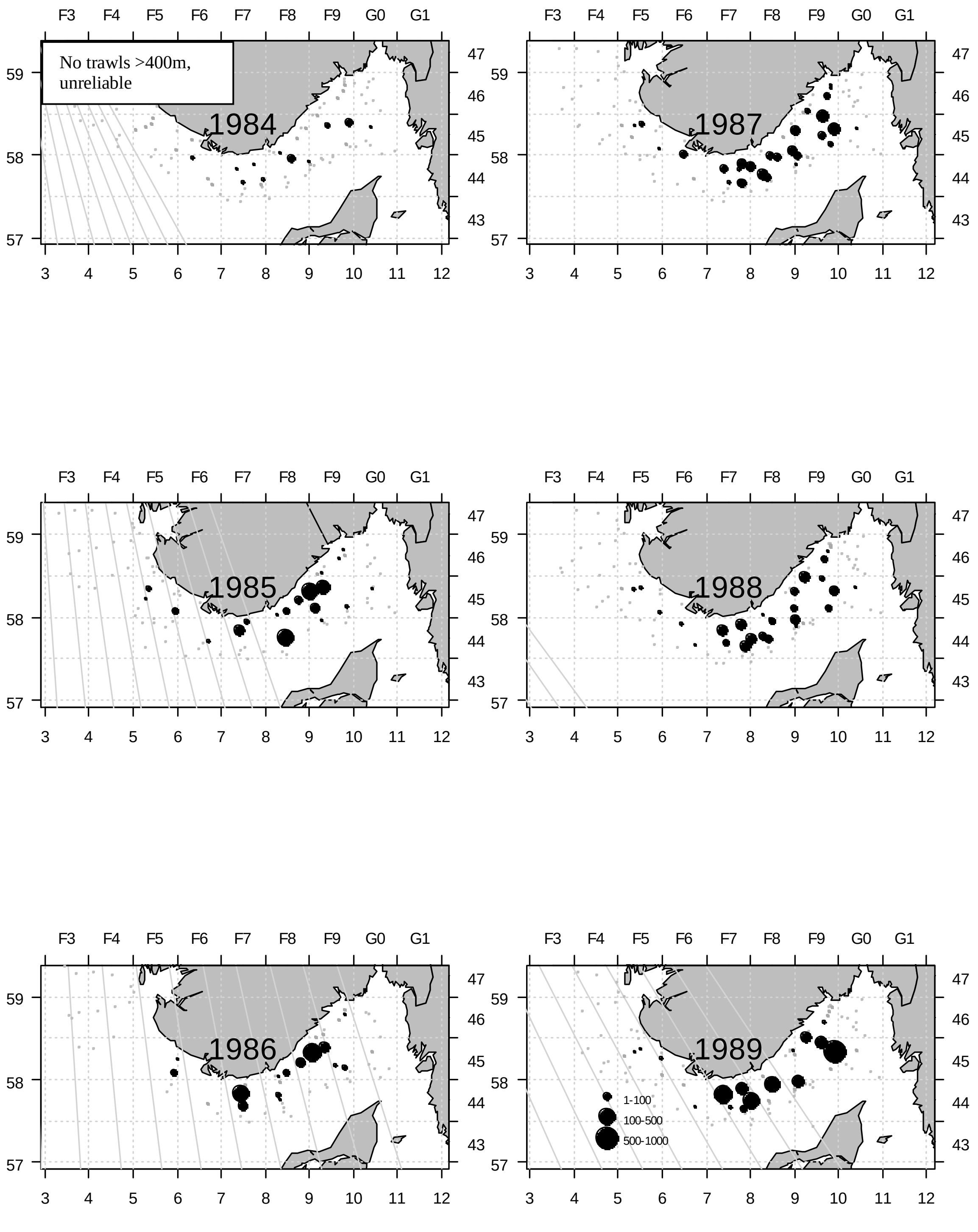
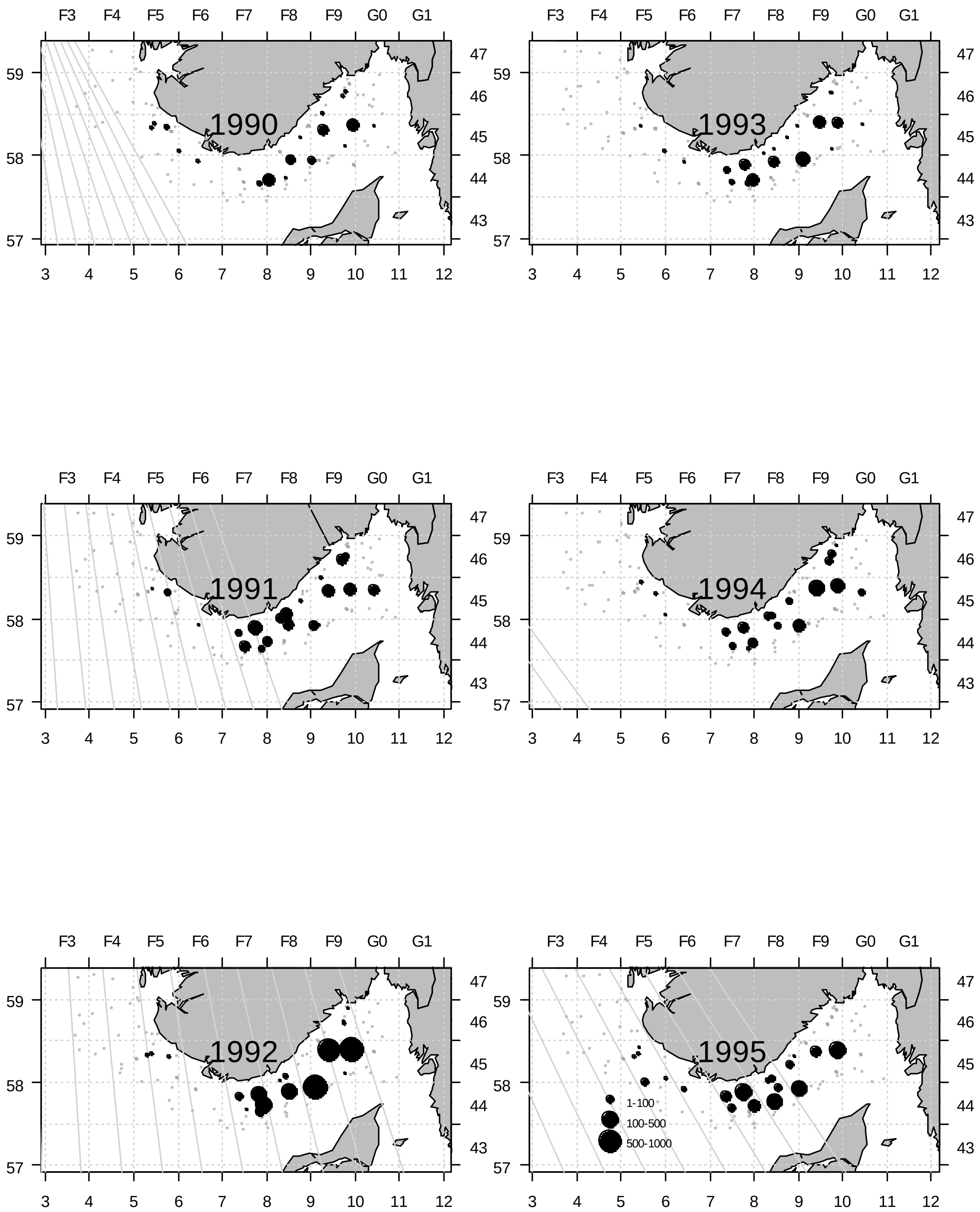


Figure 5. Geographical distribution of catches of roundnose grenadier (kg/h) from 1984-2021. Data from shrimp survey, trawls deeper than 300 m. Grey circles are trawls with no catch of grenadier. *In 1984, 2003, 2006 and 2007, only one single or no trawls were made deeper than 400 m, and data from those years should be excluded; in 2016 data from shrimp survey is regarded as unreliable due to inconsistencies with trawling gear and data from that year should be excluded.



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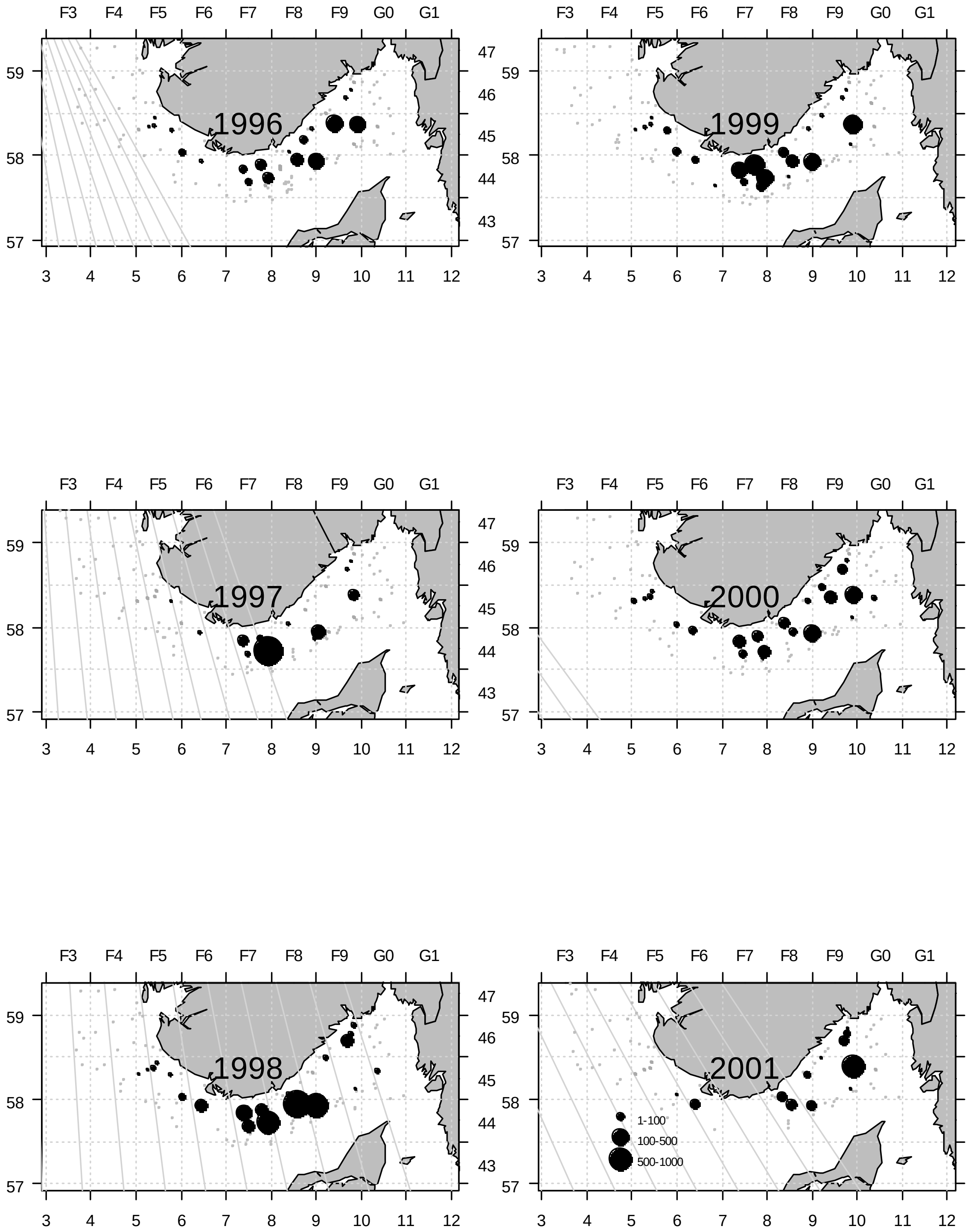

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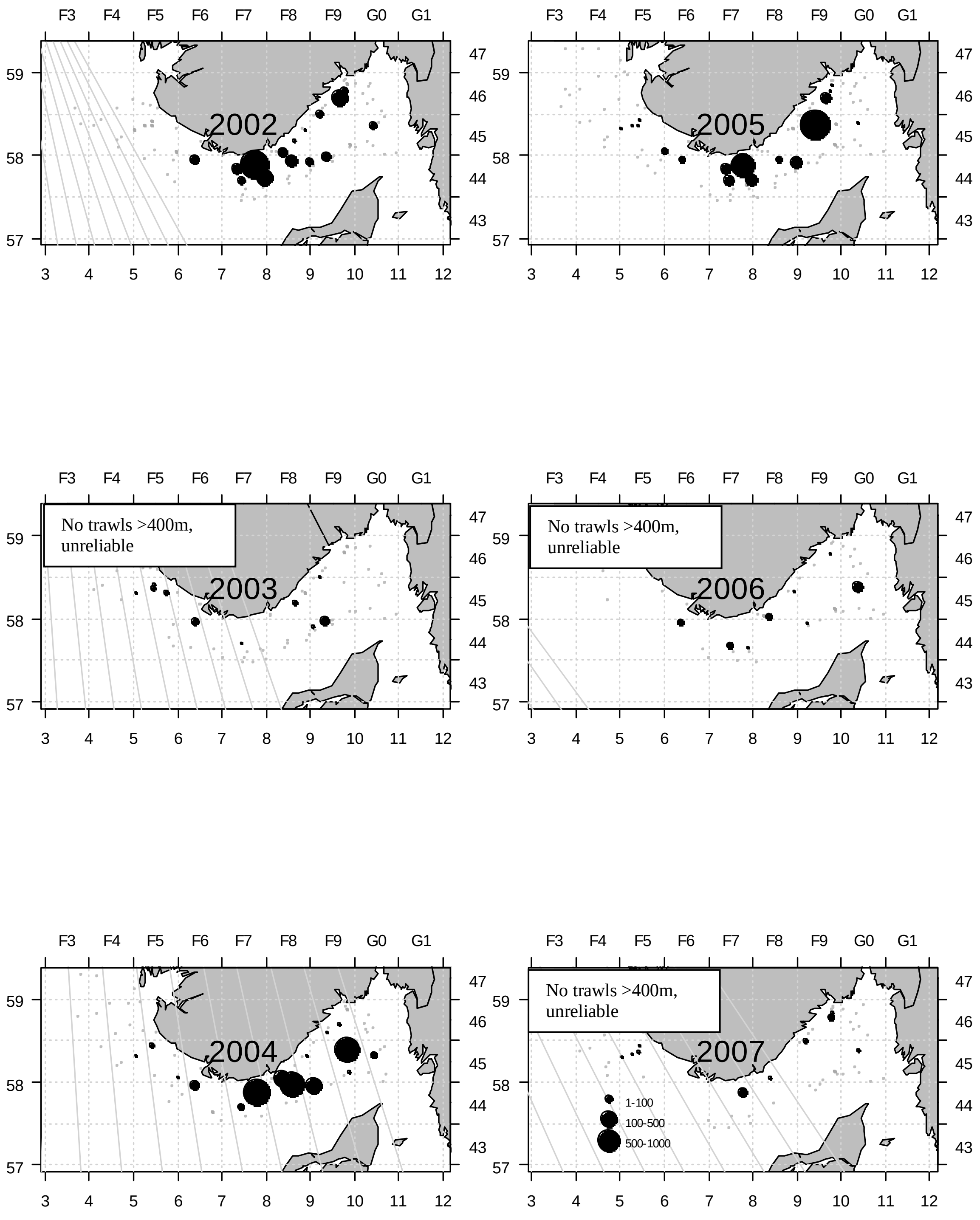

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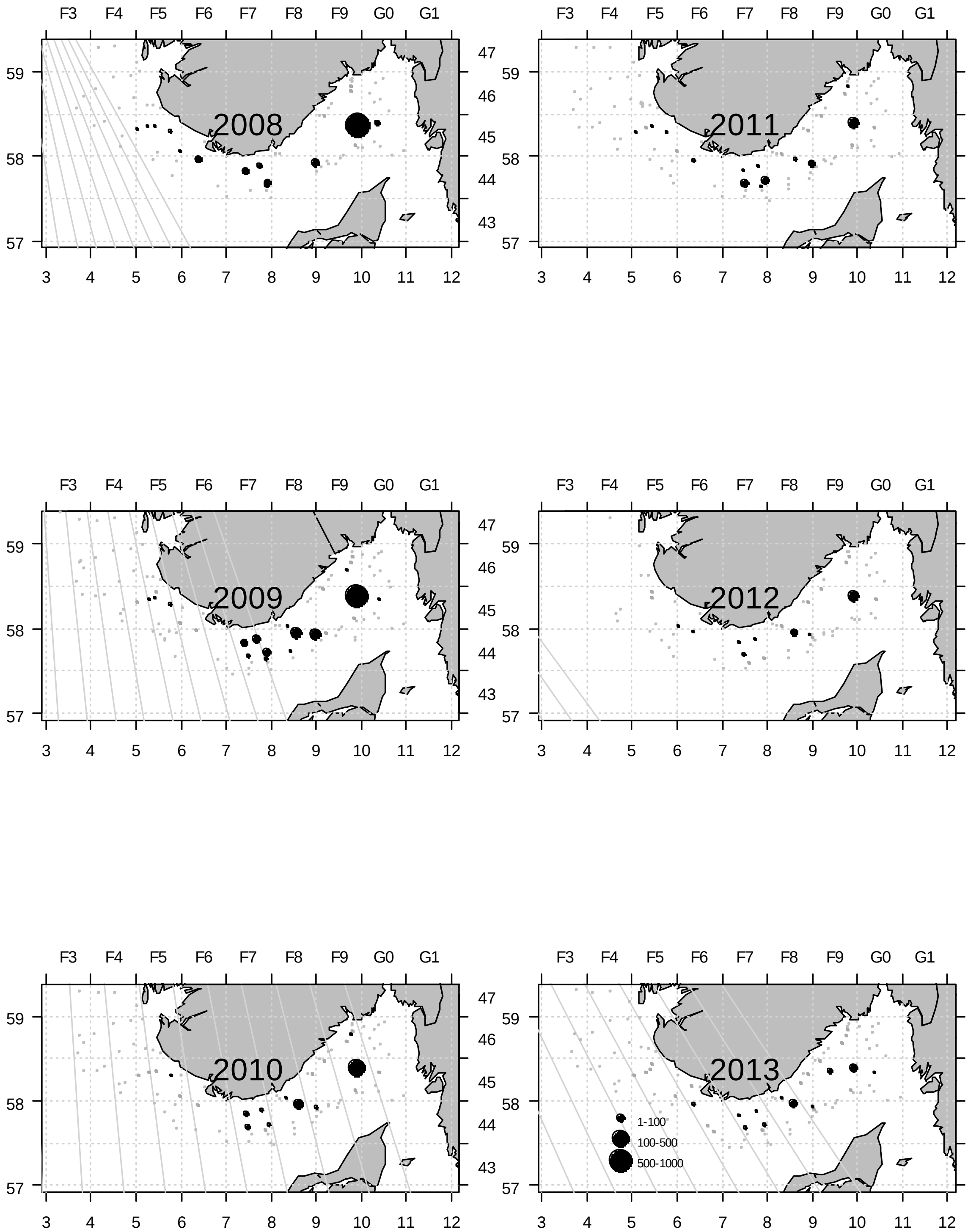

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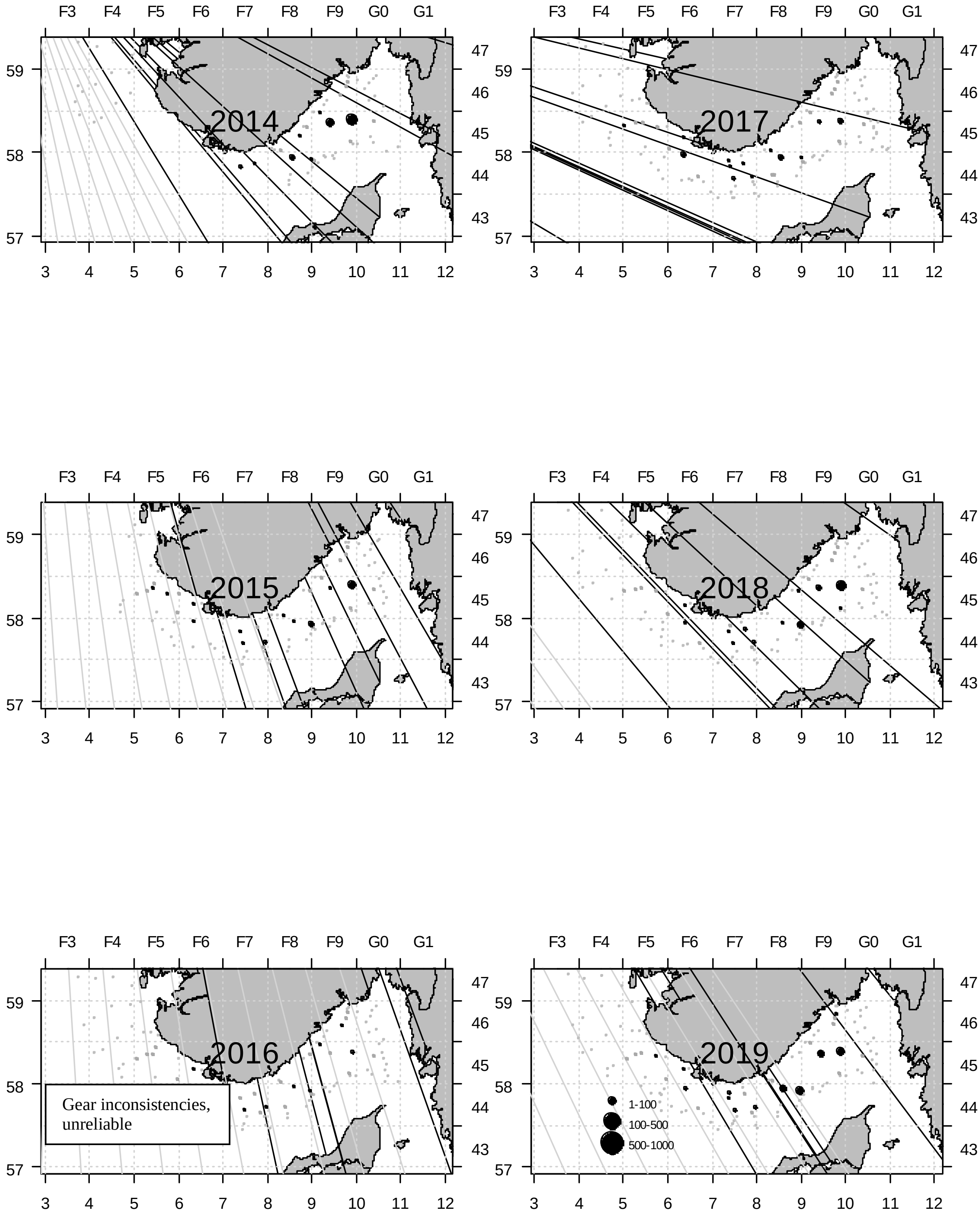

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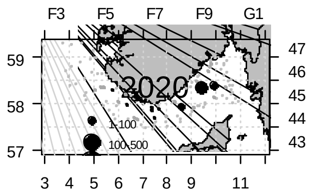

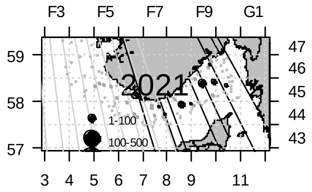

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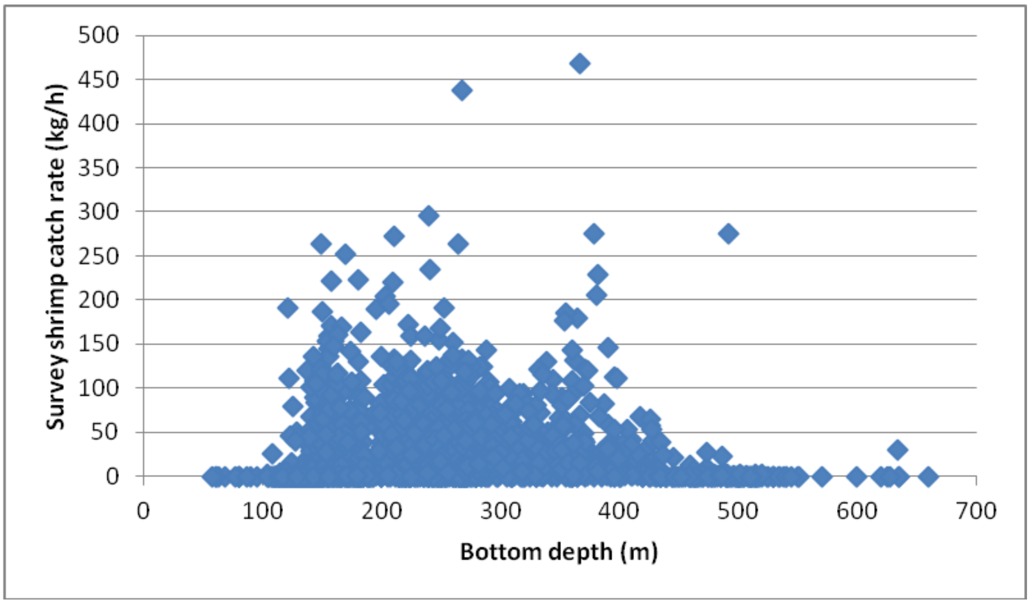

Figure 6. Depth distribution of deepwater shrimp (*Pandalus borealis*) as illustrated by catch rates in the Norwegian shrimp trawl survey, 1984-2013.

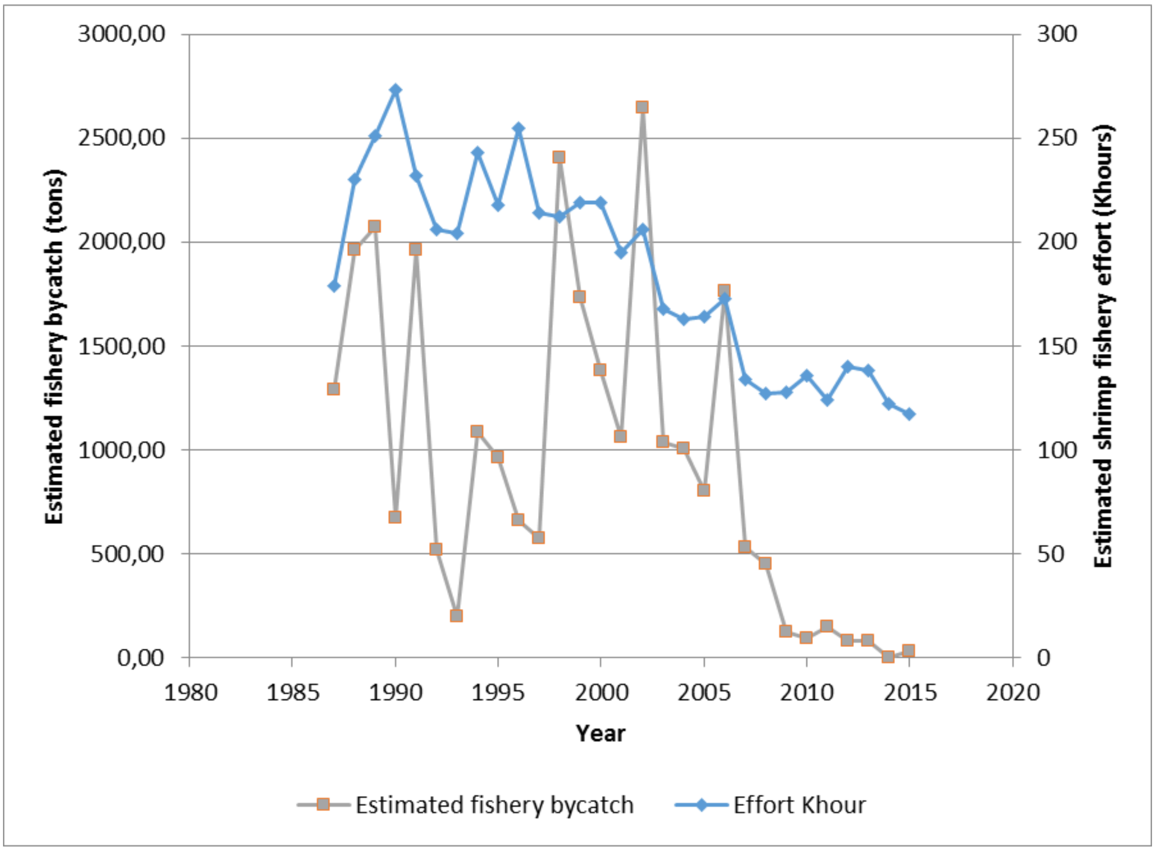

Figure 7. Estimated by-catch of roundnose grenadier in the Norwegian shrimp fishery in ICES Div. 3a and 4a, and the estimated commercial shrimp fishery effort in the same area. See text for explanation.

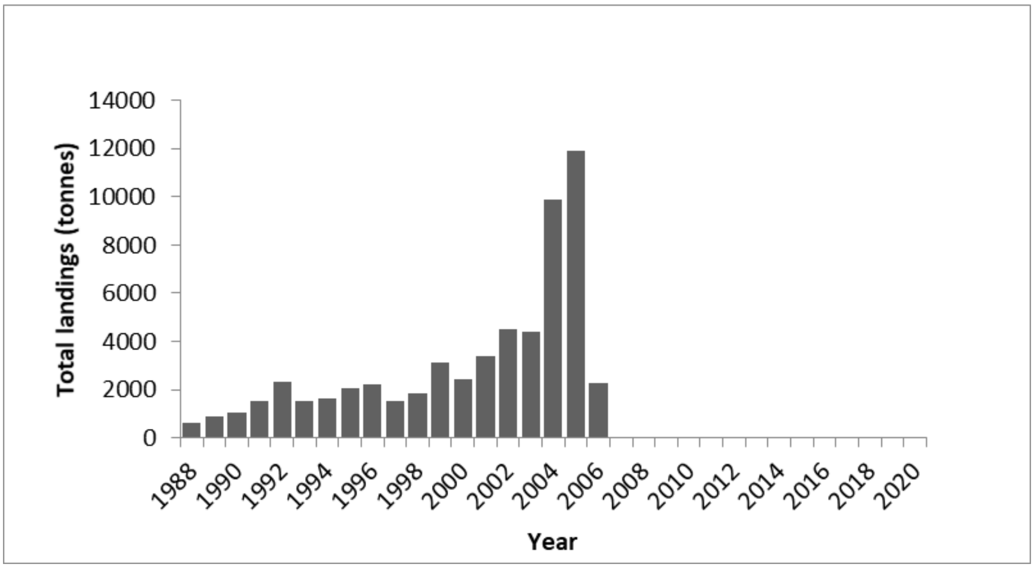

Figure 8. Total reported landings of roundnose grenadier in ICES Division 3a, 1988-2020. Landings from 2007 and later is very small and all less than 2 tons.

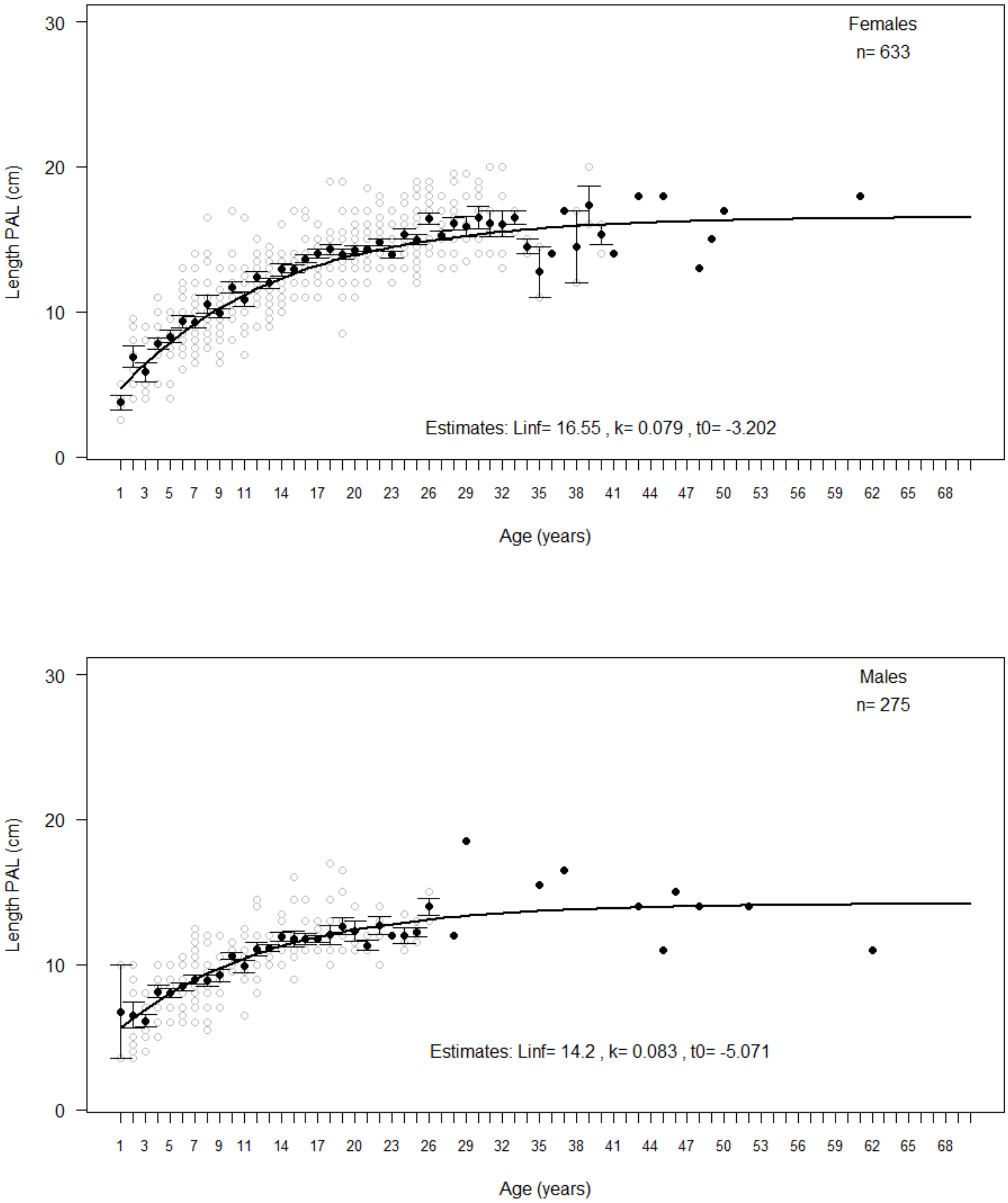

Figure 9. Length at age for female and male roundnose grenadier; data from Skagerrak 2008-2019. Mean values are estimated with ±SE where there is more than one value. Estimated von Bertalanffy growth curves with parameters for females and males.

Commercial catches of roundnose grenadier, roughhead grenadier, greater silver smelt, blue ling, tusk, black scabbard fish, ling and orange roughy in ICES division 14b in the period 1999-2020

By

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Introduction

This document present logbooks data of the commercial trawl and long line fishery in ICES 14b in the time period 1999 to 2020. The species presented here are roundnose grenadier (*Coryphaenoides rupestris*), roughhead grenadier (*Macrourus berglax*), greater silver smelt (*Argentina silus*), blue ling (*Molva dypterygia*), tusk (*Brosme brosme*), black scabbard fish (*Aphanopus carbo*) and ling (*Molva molva*). No information was available for orange roughy (*Hoplostethus atlanticus*).

Of the evaluated species, quotas have been set on grenadiers (roughhead grenadier and roundnose grenadier combined), tusk, blue ling and greater silver smelt. For grenadiers, TAC in 2007 was 3000 tons, in 2008-2009 it was 2000 tons and from 2010-2020 TAC has been 1000 tons. For greater silver smelt, TAC in 2013-2015 was 10.000 tons where after no qoutas have been set. For tusk, TAC in 2014 was 500 t and from 2015-2020 TAC has been set to 1500 tons. In 2014, TAC for blue ling was 500 tons but no quota has been made since. No scientific advice has been made for any of these species and the TAC is set by the Government of Greenland.

Materials and methods

Logbooks have been mandatory for vessels greater than 30'ft (9,4 m) since 2008. Data on all landings are reported to the Greenland Fishery License Authority (GFLK). Trawlers and longliners gather information on their fishery, including effort and location for individual fishing events and send the data to GFLK on a weekly basis. The data presented here is a mix of targeted catches and bycatch during fishery for Greenland halibut (*Reinhardtius hippoglossoides*).

Results and discussion

Roundnose grenadier (*Coryphaenoides rupestris*, RNG).

Catches of roundnose grenadier have been relatively stable (annual mean catch=89.2 tons) throughout the evaluated time period (1999 to 2020) ranging from 30.9 tons (2008) to 156.4 tons (2019) (**Table 1, Fig. 1**). In 2020, the bycatch was the lowest for more than 10 years reaching 42.2 tons. The majority of this is caught as bycatch by trawlers, whereas longlines conduct a smaller fraction (data not shown).

Due to the lack of survey in East Greenland in 2020, a survey document has not been made in 2021. However, from survey document from previous years (see WDs of 2019) it was established that roughhead grenadier (RHG) is much more common than roundnose grenadier in ICES 14b. Therefore, it is likely that there is misidentification of grenadier species confounding the logbook data of roundnose grenadier and roughhead grenadier. Regardless of this, the TAC of 1.000 tons for grenadiers in East Greenland (roughhead and roundnose combined) is not reached any years.

Roughhead grenadier (*Macrourus berglax*, RHG).

There are no catches of roughhead grenadier between 1999 and 2004. From 2005 to 2013 the average catch was 7.9 tons, whereas it increased to an average of 71.4 tons between 2014 and 2018. In 2019 catches dropped to only 1.0 tons and in 2020 is was 18. 4 tons (**Table 1, Fig. 1**). Before 2014, the catch is dominated by trawlers, but from 2014 and onwards catches are strongly dominated by longliners (data not shown). As mentioned for roundnose grenadier (RNG, see above), the catch of roughhead grenadier is possibly underestimated due to incorrect species identification. From 2014 until 2018 reported catches of roughhead grenadier on long lines are much higher, which might be linked to the onset of targeted long line fishery after tusk in 2014.

Greater silver smelt (*Argentina silus*, ARS).

There are no reported catches of greater silver smelt from 1999 to 2013. In 2014 to 2016 trawl catches ranged from 4.2 tons to 16.1 tons (increasing each year) and in 2017 and 2018 catches were 666.1 tons and 425 tons, respectively. In 2019, only 0.5 tons is reported, which increased to 22.1 tons in 2020 (**Table 1, Fig. 1**). The increase in 2017 and 2018, is due to the onset of targeted pelagic trawl fishery for the species since 2015. This targeted fishery ceased in 2019 thus low catches are reported since.

Blue ling (M*olva dypterygia*, BLI).

Catches of blue ling are relatively low and constant between 1999 to 2020(annual mean catch =13.1 tons, **Table 1, Fig. 1**). Blue ling is mostly caught in trawl fisheries and the composition between line and trawl catches remains relatively constant except in 2015, where the largest trawl catch of 65.5 tons is reported (data not shown).

Tusk (*Brosme brisme*, USK).

Catches of tusk have been low between 1999 to 2014 were much lower (mean annual catch=31.5 tons) compared to from 2015 to 2020 (mean annual catch =601.2 tons) (**Table 1, Fig. 1**). The catch is dominated by long lines throughout the time series (data not shown). The increase in catches corresponds with the initiation of targeted fishery in 2014 where TAC was 500 tons, which was increased by the Greenland government to 1500 tons from 2015 to 2019.

Ling (*Molva molva*, LIN).

Catches of ling is fluctuating between years with no apparent trend over time (**Fig. 1**). In 2005, 2006, 2008 and 2015 catches were above 15 tons, whereas catches were below 5 tons in 2000-2003, 2007, 2009-2010, 2013 and 2017-2020 (**Table 1, Fig. 1**). The majority of catches are from long lines (data not shown).

Black scabbard fish (*Aphanopus carbo*, BSF).

Catches of black scabbard fish has been zero all years except 2010 and 2011 where 100 and 300 kg were reported from trawl bycatch (**Table 1**).

Figures and tables

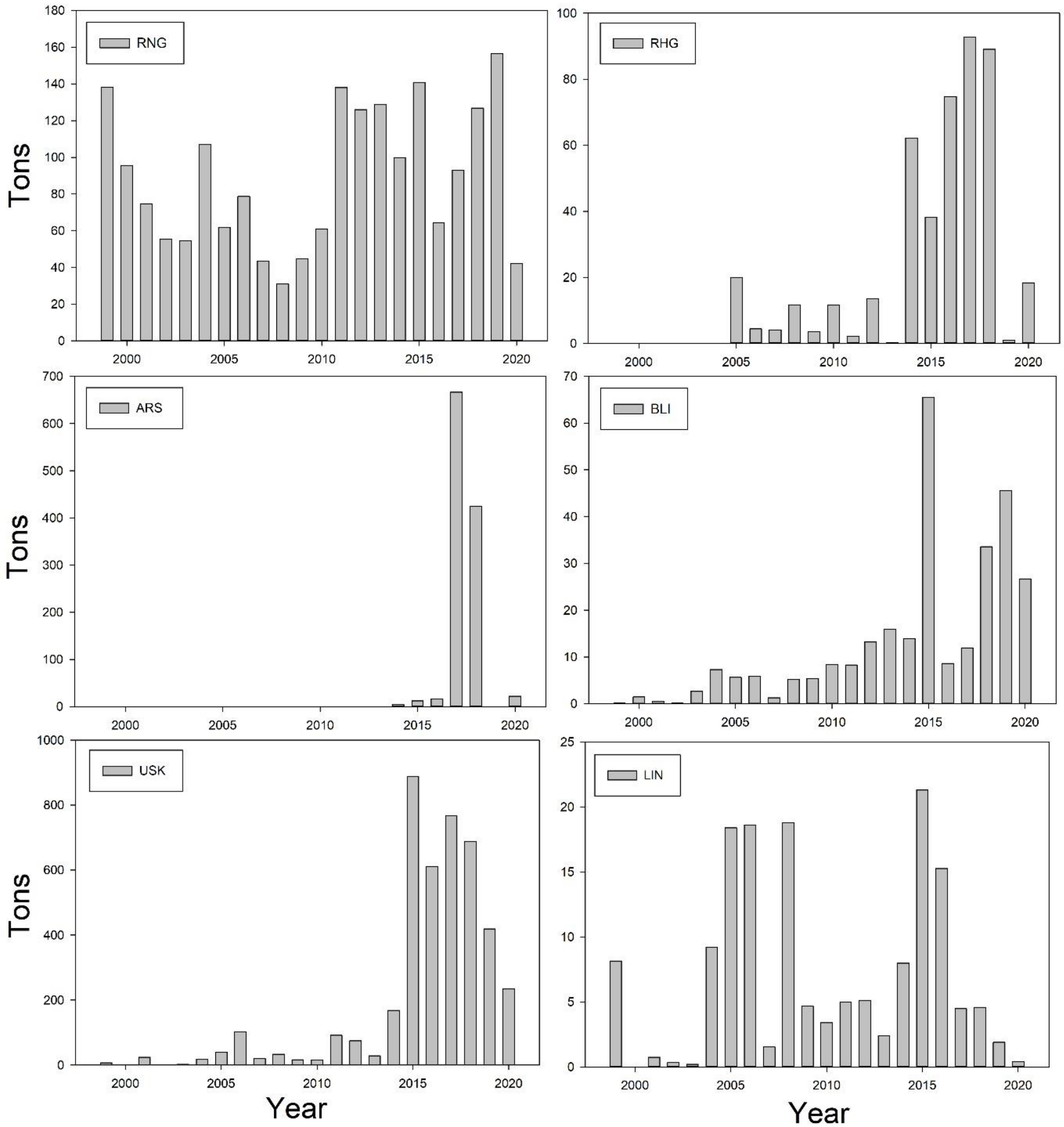

Fig. 1. Catches (trawl and longline combined) of roundnose grenadier (RNG), roughhead grenadier (RHG), greater silver smelt (ARS), blue ling (BLI), tusk (USK) and ling (LIN) from 1999 to 2020. Black scabbardfish can be seen in Table 1.

Table 1. Catches (tons) of roundnose grenadier (RNG), roughhead grenadier (RHG), greater silver smelt (ARS), blue ling (BLI), tusk (USK), black scabbard fish (BSF) and ling (LIN) from 1999 to 2020.

Year	RNG	RHG	ARS	BLI	USK	LIN	BSF
1999	138.1	0.0	0.0	0.2	7.2	8.2	0.0
2000	95.5	0.0	0.0	1.5	0.0	0.0	0.0
2001	74.7	0.0	0.0	0.6	23.6	0.7	0.0
2002	55.5	0.0	0.5	0.2	0.0	0.3	0.0
2003	54.5	0.0	0.0	2.7	2.2	0.2	0.0
2004	107.2	0.0	0.0	7.3	17.5	9.2	0.0
2005	61.9	20.0	0.0	5.7	40.2	18.4	0.0
2006	78.6	4.4	0.0	5.9	102.4	18.6	0.0
2007	43.4	4.1	0.0	1.3	20.0	1.5	0.0
2008	30.9	11.7	0.0	5.2	33.7	18.8	0.0
2009	44.6	3.6	0.0	5.4	16.4	4.7	0.0
2010	61.1	11.6	0.0	8.4	15.1	3.4	0.1
2011	138.0	2.2	0.0	8.3	91.1	5.0	0.3
2012	126.0	13.5	0.0	13.2	74.6	5.1	0.0
2013	128.9	0.3	0.0	15.9	28.2	2.4	0.0
2014	99.8	62.1	4.2	13.9	168.3	8.0	0.0
2015	140.8	38.2	12.2	65.5	887.8	21.3	0.0
2016	64.4	74.8	16.1	8.6	610.1	15.3	0.0
2017	92.9	92.8	666.6	12.0	768.3	4.5	0.0
2018	126.8	89.1	425.1	33.6	688.0	4.6	0.0
2019	156.4	1.0	0.5	45.6	419.0	1.9	0.0
2020	42.2	18.4	22.1	26.7	233.9	0.4	0.0

Working Document for the ICES Working Group on Biology and Assessment of Deep-sea Fisheries Resources

22th April -28th April 2021

Greater forkbeard *Phycis blennoides* in Portuguese waters (ICES Division 27.9.a)

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Instituto Português do Mar e da Atmosfera

Abstract

This working document updates the information presented in previous WGDEEP meetings for the greater forkbeard *Phycis blennoides* in ICES Division 27.9.a (mainland Portugal), particularly fishery dependent and independent data and MSY length-based indicators (LBI). A new standardized biomass index series based on daily landings of a predefined reference fleet was constructed for the period 2013-2020. Regarding fishery independent data the annual standardized biomass index was estimated for the 1997-2018 Portuguese crustacean surveys/Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) time series. Length-based indicators LBI used to classify the stocks according to conservation/sustainability, yield optimization and MSY were estimated for exploited population in Portugal mainland based on length samples collected under the Portuguese DCF program.

1. General considerations

The greater forkbeard *Phycis blennoides* (Brünnich, 1768) is a demersal species from the family Gadidae. This species is widely distributed in the northeast Atlantic from Norway and Iceland to Cape Blanc in West Africa and in the Mediterranean Sea (Massutí et al., 1996), and occurs preferentially along the continental shelf and slope, at depths ranging between 60 and 1000 m deep (Massutí et al., 1996; Casas and Pineiro 2000; Garcia et al., 2000).

The greater forkbeard has a discrete recruitment period along the year and is available to fishing at the first years of life (Ragonese et al., 2002). The size of transition from the pelagic to the demersal habitat occurs at lengths around 6 cm in Atlantic waters (Casas and Piñeiro, 2000) and at a smaller size (4.5-5.0 cm total length) in the Mediterranean (Ragonese et al., 2002). In the Gulf of Tunis, age parameters were estimated as TL_{inf} = 57.17 cm, k = 0.193 $year^{-1}$, t_0 = –1.578 year for females, and TL_{inf} =44.74 cm, k = 0.313 $year^{-1}$, and t_0 =–1.210 year for males. Females grow faster than males, and the latter did not exceed 45 cm (Romdhani et al., 2016).

1.1. The greater forkbeard in Portuguese waters from ICES Division 27.9.a

In Portuguese continental waters, the length structure and the biology of greater forkbeard, namely reproduction, suggests that it completes the whole life cycle in the area (Lagarto et al., 2017). As in other geographic areas where the species occurs (e.g., in the Mediterranean), a depth effect on specimen's size is observed (Massutí et al., 1996): larger specimens occur deeper (>600 m deep) (Fig.1).

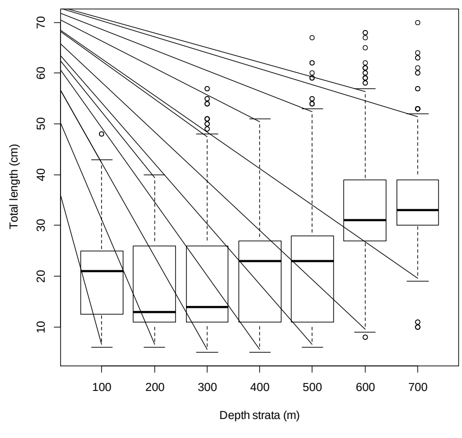

Figure 1. Inter-quartile total length range of *P. blennoides* by depth strata (m) caught during the Portuguese Crustacean Surveys/Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) undertaken between 1997 and 2016 (no survey was conducted in 2012).

2. Fishery dependent data in Portuguese waters from ICES division 27.9.a

In Portugal mainland there are no fisheries targeting greater forkbeard. This species is mainly caught as by-catch of other fisheries, particularly from the polyvalent fleet segment or multi-gear fleet, which is responsible for ~98% of the species total landings.

The Portuguese polyvalent segment includes vessels of different sizes usually licensed to operate with more than one fishing gear (e.g. gill and trammel nets, longlines, and traps). At each fishing trip, vessels belonging to this segment may deploy more than one fishing gear, depending on the targeted species and on the fishing grounds. The analysis of logbook data further indicates that, within the polyvalent segment, the greater forkbeard is mainly caught by demersal longlines.

Most greater forkbeard landings are reported at Peniche landing port, in the Centre of Portugal. A marked seasonal pattern on Portuguese landings is observed with higher values between May and July (Lagarto et al., 2017). Although the reasons for this seasonality are unknown, it is considered that they might be related to the dynamics of the fleets and particularly to changes on their target species.

2.1. Commercial landings

Official Portuguese annual greater forkbeard landing estimates in ICES division 27.9.a are presented in Table 1. It is worth mentioning that landings are likely to be biased due to species misidentification problems. It is admitted that greater forkbeard can be misidentified with its congener *Phycis phycis*. Moreover, the two *Phycis* species, and particularly at the beginning of time series, might be landed under the designation of *Phycis* spp. However, the fraction of *Phycis* spp. landings corresponding to *P. blennoides* is unknown and cannot be estimated as the level of DCF sampling coverage is insufficient.

Historically, the landings of greater forkbeard species are low, either because of its relatively low commercial value or to the low fishing effort at deeper fishing grounds.

Table 1. Official landings (ton) of *Phycis blennoides*, *Phycis phycis* and *Phycis* spp. by fleet from 2003 to 2020. *Phycis* spp. includes landings of *P. blennoides* and *P. phycis*. Source: DGRM (official landings).

	Phycis blennoides				*Phycis phycis*				*Phycis* spp.			
Year	TRAWL	PSEINERS	ARTISANAL	TOTAL	TRAWL	PSEINERS	ARTISANAL	TOTAL	TRAWL	PSEINERS	ARTISANAL	TOTAL
2003	0.08		10.87	10.95	0.75		5.69	6.44	7.87	0.50	314.14	322.51
2004	0.10	0.05	9.84	9.98	0.11		3.59	3.70	7.85	0.60	295.10	303.55
2005	0.17	0.03	14.00	14.20	1.06	0.02	83.49	84.57	5.68	0.13	183.03	188.84
2006	0.17		9.66	9.84	2.11	0.08	176.24	178.43	3.22	0.01	56.05	59.28
2007	0.10	0.02	13.40	13.52	2.69	0.28	215.65	218.62	4.01		25.20	29.21
2008	0.18	0.01	12.05	12.23	4.79	0.10	234.03	238.92	0.14		25.03	25.17
2009	0.10		14.64	14.74	11.20		452.92	464.13			18.61	18.61
2010	0.10		11.53	11.63	14.24		472.11	486.36			8.68	8.69
2011	0.04		13.43	13.48	7.08	0.01	450.68	457.76			5.91	5.91
2012	0.08		5.58	5.66	4.24	0.03	456.11	460.38			5.24	5.24
2013	0.11		7.67	7.78	4.22	0.92	274.22	279.35			3.78	3.78
2014	0.13		6.09	6.22	2.27	0.80	170.97	174.04			2.39	2.39
2015	0.04		7.39	7.43	5.32	0.73	154.72	160.77			1.58	1.58
2016	0.12		6.69	6.81	6.72	1.41	181.31	189.44			1.81	1.81
2017	0.20		8.85	9.05	4.13	1.69	172.38	178.21	0.00		1.27	1.28
2018	0.19		9.23	9.42	2.70	0.35	129.27	132.31			0.64	0.64
2019	0.02		7.12	7.14	2.03	0.313	133.35	135.69			1.34	1.34
2020	0.08		4.80	4.88	1.61	0.30	137.78	139.69			0.99	0.99

2.1. Biomass index

A standardized CPUE was developed for a reference fleet within the polyvalent fleet, based on fishery dependent data collected from commercial landings for the period 2009-2020, particularly the landed weight (in Kg) by fishing trip. A fishing trip is defined from the moment the vessel leaves the dock to when it returns to the dock.

To define the reference fleet only the daily landings data from 2013 onwards were considered, as in previous years landings under the generic *Phycis* spp. category were quite high (Table 1). Vessels with regular landings throughout this period were assigned to the reference fleet. Following this criterion, 9 vessels were selected.

The daily landings of the selected vessels (catch rate per trip) were explored. Figure 2 presents the histograms of the catch rate per trip (Fig. 2a) and of the log-transformed catch rate per trip (Fig. 2b) for the period 2013-2020.

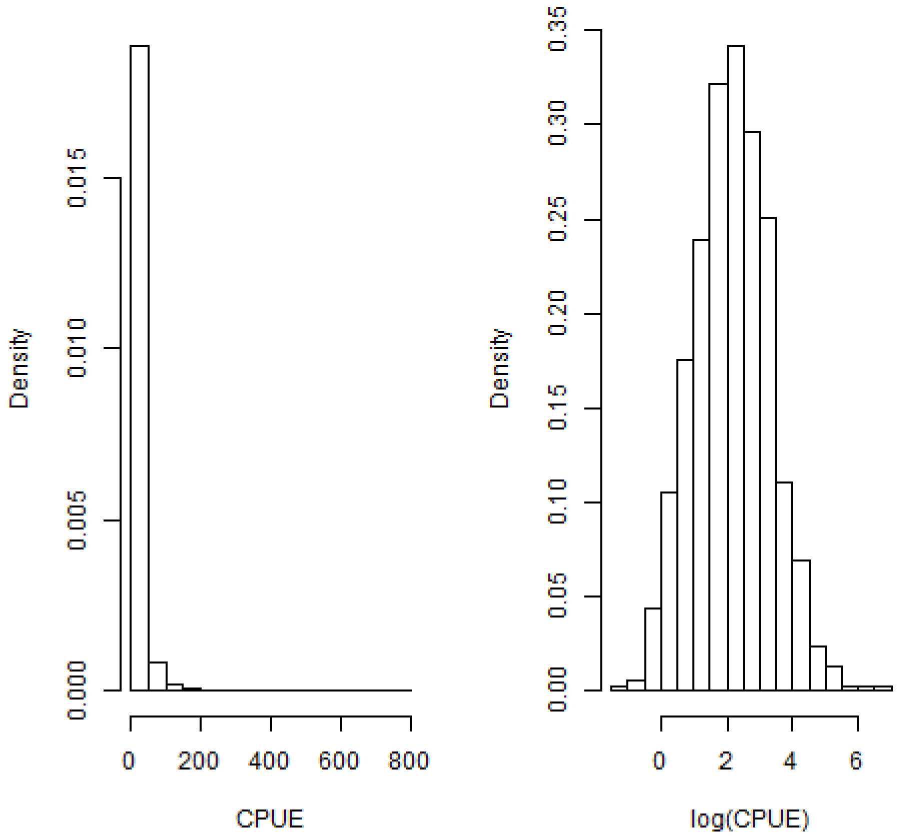

Figure 2. Reference fleet – Histogram of the daily landings of selected vessels (left) and of their log-transformed values (right) for 2013-2020.

Figure 3 presents a skewness-kurtosis plot as proposed by Cullen and Frey (1999) for the log-transformed empirical distribution. This plot is used as a tool to help choosing candidate distributions to fit the data. Values for common distributions are also displayed. While some distributions are just represented by a point on the plot, for others, areas of possible values are represented, consisting of lines (gamma and lognormal distributions, for example) or polygons (beta distribution, for example).

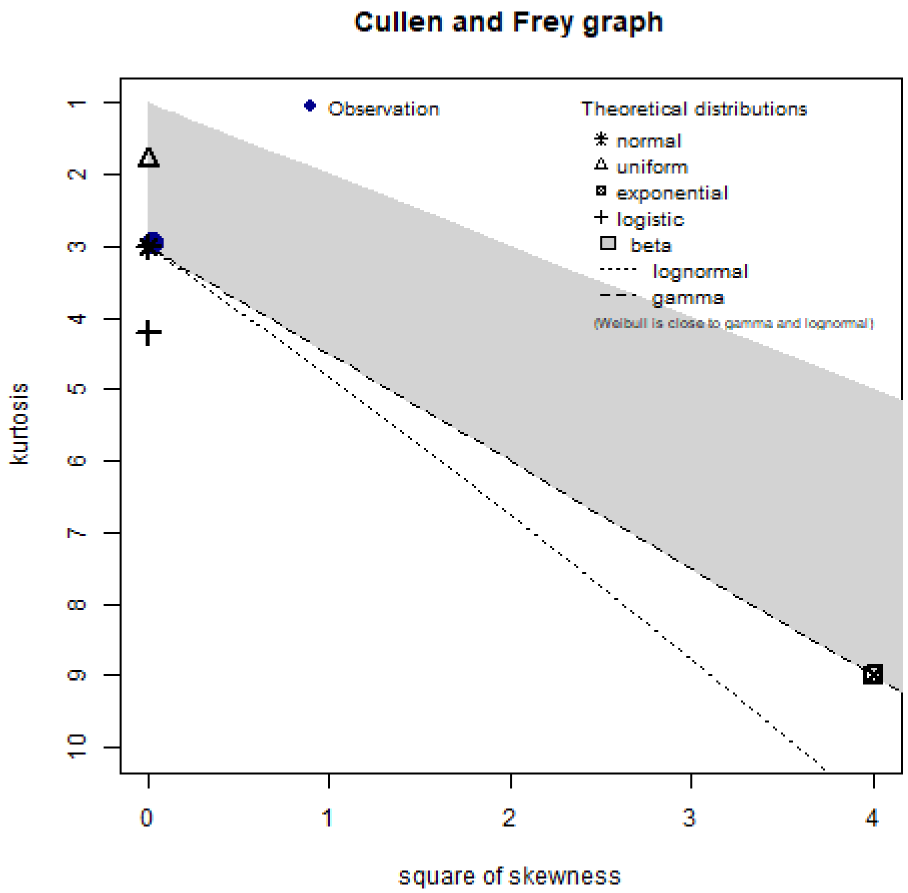

Figure 3. Reference fleet – Skewness-kurtosis plot as proposed by Cullen and Frey (1999) for the log-transformed catch rate (CPUE) empirical distribution.

The normal distribution indicates a better adjustment to the log-transformed catch by fishing trip data, CPUE (Fig. 3). The CPUE data were standardized through the adjustment of a generalized linear model (GLM). Several models were tested and the model with the best fit was selected based on the AIC criterion and residual analysis. The GLM model with a Normal distribution and an identity link function was selected as it was the one that provided the best fit for log-transformed CPUE. The variables considered in the selected model included Month, Vessel code and Year. The graphical analysis of the residuals suggests inexistence of strong violations of the model's assumptions (Fig. 4).

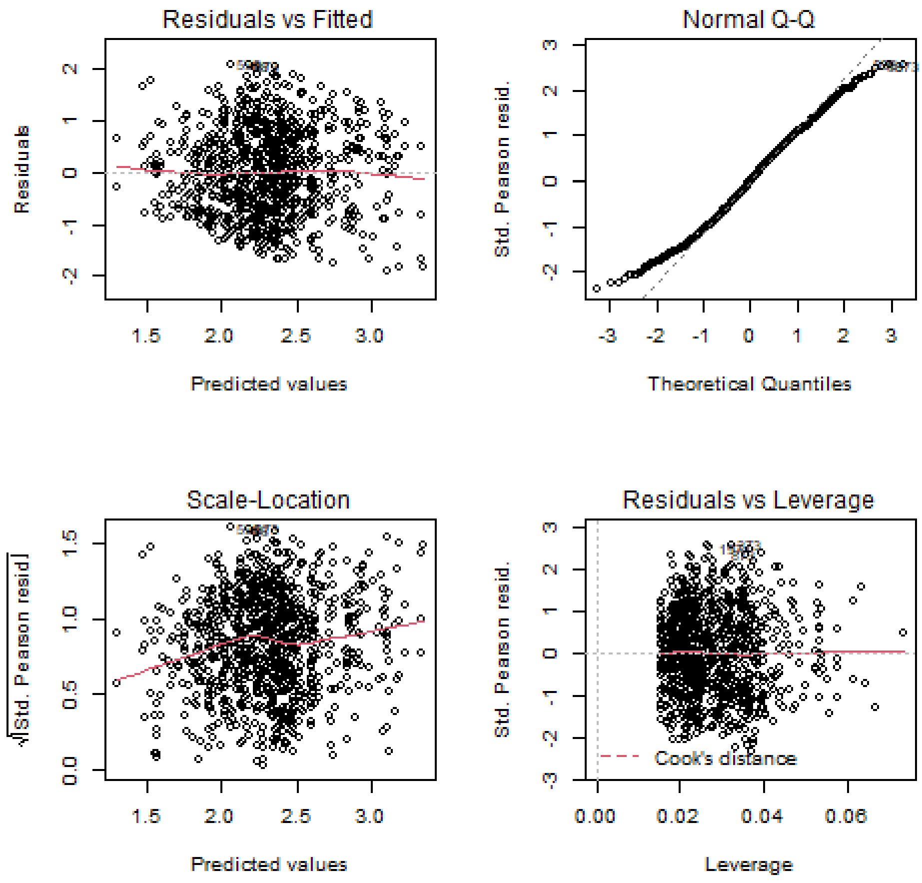

Figure 4. Reference fleet – Residual analysis plot of the selected model.

Figure 5 presents the CPUE estimates and the respective 95% confidence intervals of both log-transformed CPUE and the values in the original scale for the period 2013-2020. Estimated values on the original scale are presented in Table 2.

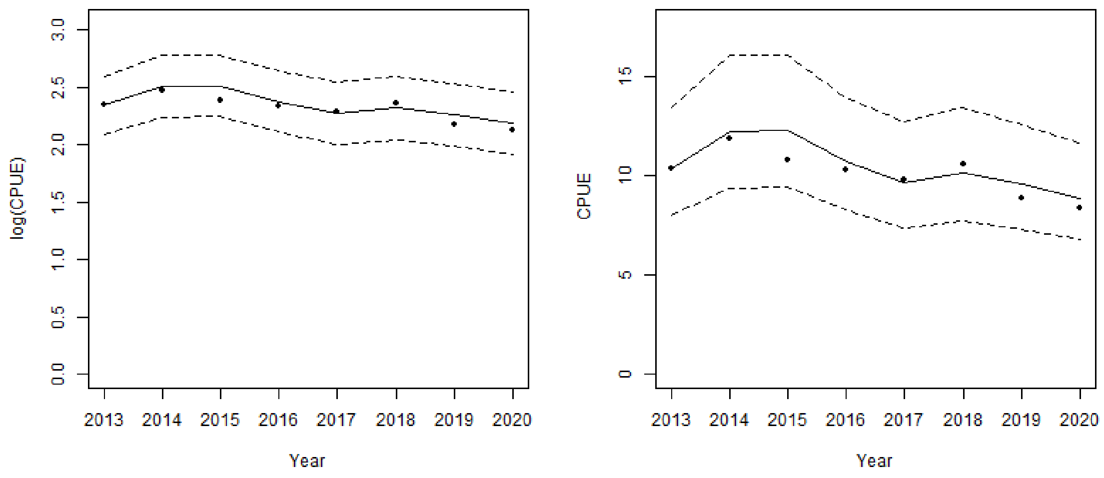

Figure 5. Reference fleet – CPUE (Kg/trip) estimates and 95% confidence intervals of log transformed catch rate and of values in on the original scale for the period 2013-2020. The black dots correspond to the observed mean annual catch rates.

Table 2. Reference fleet – Annual mean CPUE (Kg/trip) and GLM estimates, as well as, upper and lower limits of the 95% CPUE confidence intervals for the period 2013-2020.

Year	Observation Kg/trip	CPUE Upper limit	CPUE estimate Kg/trip	CPUE Lower limit
2013	10.39	13.43	10.39	8.04
2014	11.88	16.07	12.25	9.34
2015	10.83	16.09	12.32	9.43
2016	10.28	13.96	10.74	8.27
2017	9.81	12.72	9.68	7.37
2018	10.59	13.43	10.17	7.70
2019	8.83	12.56	9.57	7.29
2020	8.35	11.66	8.88	6.77

2.3. Length data

The greater forkbeard is sampled for length at several landing ports along the Portuguese continental coast under the national data collection program (PNAB/DCF). The total length of specimens sampled from 2014 to 2020 (under DCF market and onboard programs) ranged between 17 and 78 cm. The length frequency distributions slightly differed between the trawl and the polyvalent fleet segments (the length of specimens caught by trawlers are skewed to sizes smaller than those caught by polyvalent vessels) (Moura and Figueiredo, 2020). Given the very low landing values attributed to the trawl segment, it can be concluded that the length frequency distribution of the greater forkbeard exploited population is mainly derived from the polyvalent fleet segment catches.

Length-based indicators (LBI) screening methods were applied to the length frequency distributions of the greater forkbeard landed in Portugal mainland for the period 2014-2020. Due to the low number of samples available for 2018 and 2020, these years were excluded from the analysis.

The procedure followed the ICES Technical guidance for providing reference points for stocks in categories 3 and 4 (ICES, 2017). The L_{mat} and L_{inf} estimates adopted were those made available by Spain for sexes combined: 53.89 cm and 91.46 cm, respectively (ICES WGDEEP datacall, 2018). The length-weight relationship parameters ($Wt = 0.016\ TL^{2.843}$) were defined by Mendes et al. (2004).

Results from the LBI screening method are shown in Figure 6 and Tables 3a and 3b. Most of the ratios between indicators estimates are below the proposed expected values (see Table 4). These results are related to the poor representation, on landings, of all the size ranges of the population. Discards are known to occur but are unquantifiable. It is acknowledged that the largest specimens are discarded from the deep-water longline fisheries but numbers are relatively low (Lagarto et al., 2017). In addition, onboard data for this fleet is derived from a small area of the total stock distribution in the Portuguese continental waters. Thus, the fishing effort affecting the largest individuals is relatively low.

Table 3a. Results from LBI screening: indicator values.

Year	L75	L25	Lmed	L90	L95	Lmean	Lc	LFeM	Lmaxy	Lmat	Lopt	Linf	Lmax5
2012	41.5	34.5	37.5	46.5	48.5	40.09	34	48.365	37.5	53.9	61.0	91.46	50.8
2013	51.5	41.5	46.5	57.5	61.5	46.06	26	42.365	57.5	53.9	61.0	91.46	64.7
2014	49.5	36.5	44.5	53.5	59.5	44.40	30	45.365	50.5	53.9	61.0	91.46	63.1
2015	55.5	40.5	50.5	59.5	61.5	48.84	30	45.365	55.5	53.9	61.0	91.46	63.9
2016	49.5	33.5	39.5	54.5	58.5	45.22	34	48.365	50.5	53.9	61.0	91.46	61.6
2017	50.5	36.5	42.5	53.5	55.5	45.45	34	48.365	52.5	53.9	61.0	91.46	59.4
2019	51.5	45.5	49.5	58.5	63.5	52.57	46	57.365	51.5	53.9	61.0	91.46	66.5

Table 3b. Results from LBI screening: indicator ratios. Ref., Reference expected values from ICES (2017).

	MSY	Optimal yield	Conservation (immatures)		Conservation (large individuals)		
	L_{mean} / $L_{F=M}$	L_{mean}/L_{opt}	$L_{25\%}$ / L_{mat}	L_c/L_{mat}	$L_{95\%}$ / L_{inf}	$L_{max5\%}$ / L_{inf}	**Pmega**
year	**≥ 1**	**~1**	**>1**	**>1**	**>0.8**	**>0.8**	**>0.3**
2012	0.83	0.74	0.64	0.63	0.66	0.62	0.56
2013	1.09	0.85	0.77	0.48	0.76	0.94	0.71
2014	0.98	0.82	0.68	0.56	0.73	0.83	0.69
2015	1.08	0.91	0.75	0.56	0.80	0.91	0.70
2016	0.93	0.84	0.62	0.63	0.74	0.83	0.67
2017	0.94	0.84	0.68	0.63	0.75	0.86	0.65
2019	0.92	0.98	0.84	0.85	0.86	0.84	0.73

Table 4. Selected indicators for LBI screening plots. Indicator ratios in bold used for stock status assessment with traffic light system (from ICES, 2017).

Indicator	Calculation	Reference point	Indicator ratio	Expected value	Property
$L_{max5\%}$	Mean length of largest 5%	L_{inf}	$L_{max5\%}$ / L_{inf}	> 0.8	Conservation (large individuals)
$L_{95\%}$	95th percentile		$L_{95\%}$ / L_{inf}		
P_{mega}	Proportion of individuals above L_{opt} + 10%	0.3–0.4	Pmega	> 0.3	
$L_{25\%}$	25th percentile of length distribution	L_{mat}	$L_{25\%}$ / L_{mat}	> 1	Conservation (immatures)
L_c	Length at first catch (length at 50% of mode)	L_{mat}	L_c/L_{mat}	> 1	
L_{mean}	Mean length of individuals > L_c	$L_{opt} = {}^2/_3\, L_{inf}$	L_{mean}/L_{opt}	≈ 1	Optimal yield
L_{max_y}	Length class with maximum biomass in catch	$Lopt = {}^2/_3\, L_{inf}$	L_{maxy} / L_{opt}	≈1	
L_{mean}	Mean length of individuals > L_c	$L_{F=M}$ = $(0.75L_c+0.25 L_{inf})$	L_{mean} / $L_{F=M}$	≥ 1	MSY

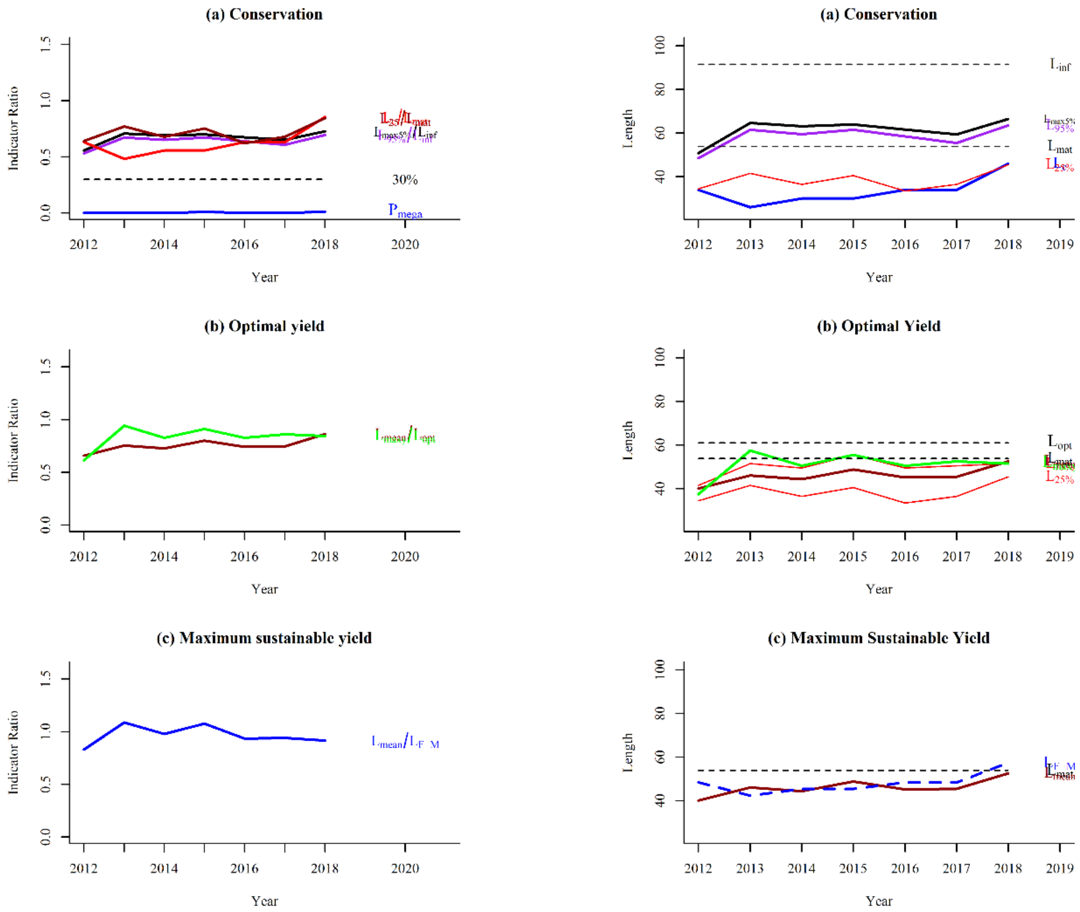

Figure 6. Results from LBI screening.

3. Fishery independent data in Portuguese waters from ICES division 27.9.a

Fishery independent data are available from two survey series (see Annex I for further information). From these, the Portuguese Crustacean Surveys/ Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) provided the best information to investigate the species dynamics in the Portuguese continental coast, given depth range of operation, which goes down to 750 m deep. The information collected on the species during these surveys has been used to estimate standardized relative biomass index. In 2019 and 2020, the PT-CTS (UWTV (FU 28-29)) survey was not performed, so the information here presented covers the time range from 1997 to 2018.

The spatial and bathymetric distribution of species in Portuguese waters was firstly investigated. An exploratory analysis using the data collected at PT-CTS (UWTV (FU 28-29))) surveys performed from 1997 to 2015 was conducted. Given the uncertainty in species identification at the beginning of the time series (it is possible that misidentification problems with *Phycis phycis* have occurred in the past), the analysis was conducted by restricting the depth to the range 500 and 750 m deep. In addition, given the low number of hauls, two geographical areas (or sectors) were not considered (Lisboa and Arrifana).

After the initial exploratory analysis, sector Milfontes was selected to provide the standardized relative biomass index estimates. For the considered time series, this sector is the one that presents a better temporal sampling coverage and also because it is not a zero inflated catch rate data sector.

The estimation of the standardized biomass index estimates was performed following the methodology described in Annex II.

For the time series 1997-2018, the biomass model results are presented in Figure 7 and Table 5. The standardized biomass index of the species increases in 2018 and is above the overall mean. The abundance index for 2017–2018 (2.05 $Kg.h^{-1}$) was 5% higher than the mean observed in the preceding three years (1.95 $Kg.h^{-1;}$ 2014–2016).

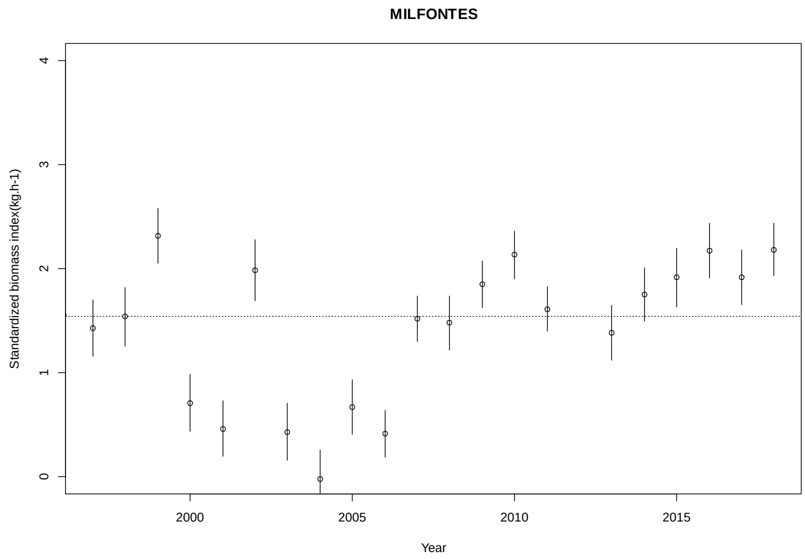

Figure 7. Standardized biomass index (kg.hour^{-1}) for the Portuguese Crustacean Surveys/Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) undertaken between 1997 and 2018. CPUE values estimated for the sector "Milfontes".

Table 5. Standardized biomass index (kg.hour-1) for the Portuguese Crustacean Surveys/Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) undertaken between 1997 and 2018 (no survey was conducted in 2012). Number of hauls included in the analysis by year and CPUE values estimated for the sector "Milfontes".

Year	n hauls [200, 750[m	Milfontes (kg.hour^{-1})	s.e.
1997	36	1.43	0.27
1998	51	1.54	0.28
1999	23	2.31	0.26
2000	45	0.71	0.27
2001	48	0.46	0.27
2002	48	1.98	0.29
2003	54	0.43	0.27
2004	51	0.00	0.28
2005	59	0.67	0.26
2006	59	0.41	0.23
2007	61	1.52	0.22
2008	62	1.48	0.26
2009	58	1.85	0.22
2010	47	2.13	0.23
2011	43	1.61	0.21
2012	---	---	---
2013	65	1.38	0.26
2014	66	1.75	0.26
2015	53	1.91	0.28
2016	64	2.17	0.26
2017	57	1.92	0.26
2018	47	2.18	0.25

The length range *P. blennoides* specimens caught in the PT-CTS (UWTV (FU 28-29))) surveys varied between 5 and 70 cm (Figure 8). For most of the years, two modes were observed. The modes were consistently registered at about 10 and 25 cm.

Regarding the smaller specimens and given the existence of just one spawning season for the species and the growth model proposed for the species, it is likely that the Portuguese survey data mainly reflects the juvenile biomass. Since the species spawning period occurs from October to December (data from the northwest of the Iberian coast, also ICES divisions 27.8.c and 9.a; Casas and Piñeiro, 2000), it is likely that the smaller specimens caught in the Portuguese survey taking place in May/June have grown about 10 cm in 6-9 months.

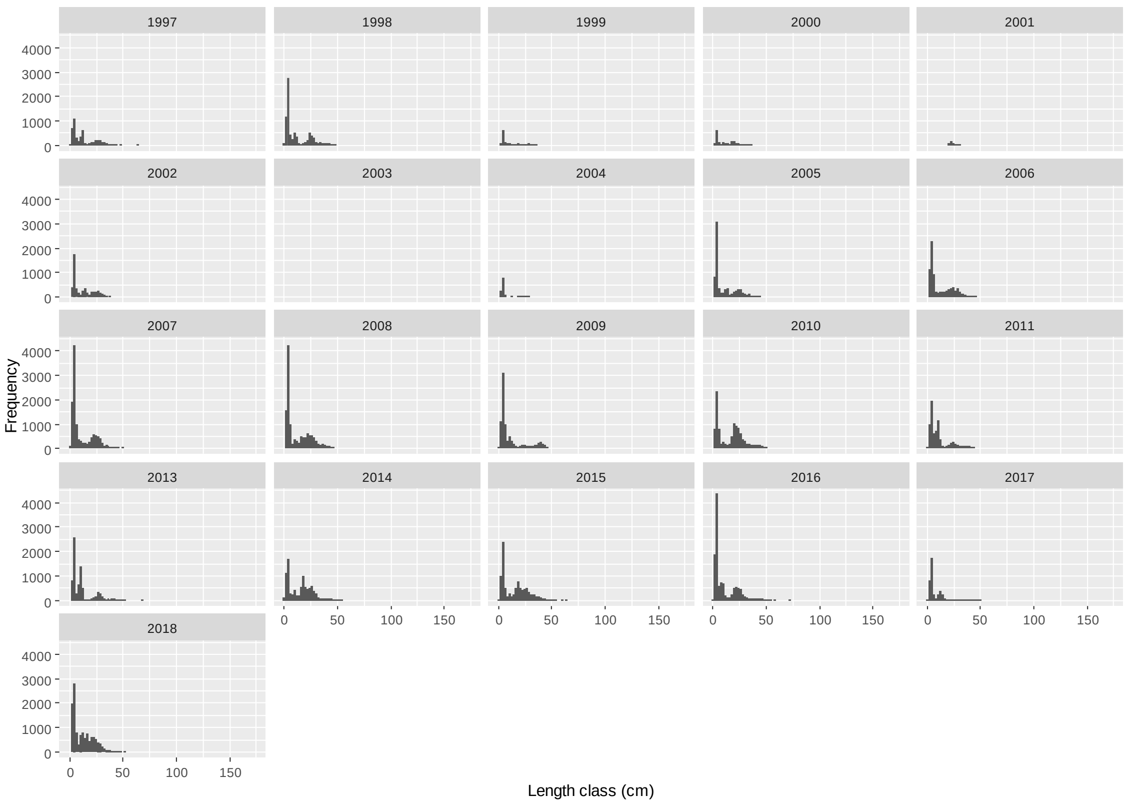

Figure 8. Length frequency distribution by year of the greater forkbeard in the PT-CTS (UWTV (FU 28-29))) survey.

4. Conclusions

The two standardized CPUE series based on commercial data suggest that the status of the greater forkbeard population inhabiting the Portuguese continental waters in recent years has been stable.

In recent years the standardized survey biomass estimates, which represents a relatively long time series, have been well above the overall mean and show an increasing trend. For the period between 1997 and 2016, an increasing trend was also observed for the juvenile component of the population, indicating that the fishing pressure over the Portuguese population has not seriously impaired the recruitment (Lagarto et al., 2017).

LBI screening results, particularly that of MSY, is close to the expected values, suggesting that the stock is in a fair status.

Given the fact that this species is not targeted by any fishery, the results obtained suggest that the Portuguese fisheries are not impairing the population of greater forkbeard, whose information for the Portuguese waters further indicates that the species is able to complete the whole life cycle in the area.

Worth to mention that the relative low fishing impact of the Portuguese fisheries in deeper grounds reduces the impact over the fraction of larger specimens of the population, as the species tends to be larger at greater depths.

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Annex I

Description of the Portuguese Crustacean Survey (PT-CTS (UWTV (FU 28-29))

The PT-CTS (UWTV (FU 28-29) have been conducted by the Portuguese Institute for the Sea and Atmosphere (IPMA, former PIMAR) and the main objective is to monitor the abundance and distribution of the main crustacean species, namely the Norway lobster *N. norvegicus*, the rose shrimp *P. longirostris* and the red shrimp *A. antennatus*. PT-CTS (UWTV (FU 28-29)) have been conducted during the 2^{nd} quarter (May-July) of the year and cover the southwest coast (Alentejo, FU 28) and south coast (Algarve, FU 29). The surveys have been carried with the Portuguese RV "Noruega", which is a stern trawler of 47.5 m length, 1500 horse power and 495 GRT. A regular grid composed by 22 rectangles in FU 28 and 59 rectangles in FU 29 is used, with one station within each rectangle. Each rectangle has 6.6´ of latitude x 5.5´ of longitude for the SW coast and *vice-versa* for the south coast, corresponding approx. to 33 nm^2. The grid was designed for a trawl survey to cover the main crustacean fishing grounds within the range of 200-750 m. The hauls fishing operations are carried out during daytime with a speed of 3 knots and the duration of each tow change in 2005 from 60 to 30 min. Although the crustacean species are the target (Norway lobster, rose shrimp and red and blue shrimp), data from all other taxa and species are also collected, as well as marine litter. Details about this survey can be found on Silva and Borges (2014) and ICES (2016).

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Annex II

Stock indicator for the greater forkbeard in Portuguese waters (ICES Division 27.9.a)

Generalized linear models (GLM) were adjusted to catch rates and several factors were used as explanatory variables. In the essayed models the catch rate of the species in each haul (Kg.h^{-1}) was the response variable. Apart from factor year, the remaining predictors were selected depending on their significance after the model adjustment. GLM models were adjusted through the use of package 'MASS' (Venables and Ripley, 2002) implemented in R software. In the model, error of the catch rate was assumed to follow a tweedie random variable, whose probability density function is expressed as:

$$f(y:\mu,\sigma^2,p) = a(y:\sigma^2,p)exp\left\{-\frac{1}{2\sigma^2}d(y:\mu,p)\right\}$$

where μ is the location parameter (mean of the distribution); σ^2 is the diffusion parameter and; p is the power parameter.

The Tweedie family of distributions is a family of exponential models with variance Var(Y) = $\sigma^2.\mu p$; depending on the p value it includes several distributions (Dunn and Smyth, 2008; Jørgensen, 1997). When $1<p<2$ the distribution corresponds to mixed distributions known as compound Poisson models (Jørgensen, 1997), which, in the present case and due to the high frequency of zeroes, seems to be the most appropriate distribution to use.

The estimation of the p parameter was done following the procedure proposed by Shono (2008). According to this, the p parameter is estimated by maximizing the profile log-likelihood across the grid values of p in the range of $1 < p < 2$ through the explicit form of the probability density function. The package 'Tweedie' (Dunn, 2009) implemented in R was used to estimate p.

Standardized biomass index model included the factors Year and Sector and the continuous variable Depth:

$$\text{CPUE= Year+Sector+Depth -1}$$

Model´s adequacy was verified through the analysis of residuals. Fitted values were transformed ($2\mu^{1-(p/2)}$) to the constant information-scale, so that the expected pattern for the compound Poisson distribution was a straight line (McCullagh and Nelder, 1989; Draper et al., 1998; Ortiz and Arocha, 2004). Residuals were also analysed using Tweedie quantiles, and the graphical tools for residuals set with the tweedie distribution (qqplots) were constructed. Three types of plots were examined: (i) histogram of the deviance residuals; (ii) deviance residuals and Pearson residuals against the standardized fitted values to check for systematic departures from the assumptions underlying the statistical distribution; and (iii) Tweedie QQ-plot (with Tweedie quantiles) for deviance residuals and for Pearson residuals.

For the selected statistical model annual biomass index predictions in the original scale were obtained following the procedure referred in Candy (2004). The estimates of the variance of the sum of linear predictors used to estimate the approximate confidence intervals of annual indices were determined using the delta method implemented at the R package 'msm' (Jackson, 2013). The delta method is an approach for computing confidence intervals for functions of maximum likelihood estimates. This method allows finding approximations of the variance of functions of random variables based on Taylor series (Oehlert, 1992).

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Pagellus bogaraveo in Portuguese continental waters (ICES Division 27.9.a)

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1. Introduction

Pagellus bogaraveo (Brünnich, 1768), the blackspot seabream, distributes between southern Norway and Cape Blanc, in the Mediterranean Sea, and in the Azores, Madeira, and Canary Archipelagos (Desbrosses, 1932; Pinho and Menezes, 2005).

Spawning occurs in shallow waters, where juveniles of age groups 0 and 1 are reported to remain at depths lower than 170 m, close to the coast, in the Azores (Menezes et al., 2001), the Bay of Biscay (Lorance, 2011), and the Mediterranean Sea (Biagi et al., 1998; Félix-Hackradt et al., 2013). When juveniles reach 150–180 mm total length (TL), they migrate along the slope to depths deeper than 200 m, following an ontogenetic migration towards deeper waters (Olivier, 1928; Desbrosses, 1932; Morato et al., 2001; Spedicato et al., 2002). Nevertheless, fish with sizes larger than 40 cm have been occasionally caught in coastal waters (Priol, 1932).

In Cadiz waters, the main spawning period occurs during the 1st quarter (Gil, 2010), whereas in the Azores spawning is from March to April (Martins *et al.*, 2007).

The blackspot seabream is a protandric hermaphrodite – individuals are first functional males and then develop into functional females (Buxton and Garratt, 1990; Krug, 1990; Gil, 2006). In the Azores, the age of first maturity is about 8 years old for females (Krug, 1990).

In the Northeast Atlantic, *P. bogaraveo*'s stock structure is still unknown. Genetic studies showed a restricted gene flow among the populations located in the Azores (ICES Division 27.10.a.2) and those on the Portuguese continental slope (ICES Division 27.9.a) and Madeira (CECAF FAO Division 34.1.2) (Stockley *et al.*, 2005; Pinera et al., 2013). Mitochondrial control region showed similar genetic diversity among sampling sites in the NE Atlantic and the Mediterranean, and no differentiation between the Azores and the remaining locations (Robalo et al., 2021).

Despite the poor knowledge on the species stock structure, ICES adopts three management components for management purposes: (a) Subareas 27.6, 27.7, and 27.8; (b) Subarea 27.9; and (c) Subarea 27.10 (Azores) (ICES, 2007). These components were established to better record the available information and do not have implicit the existence of three different stocks of *P. bogaraveo*. There is no evidence of movements between the northernmost component and the southern part of Subarea 27.9 where a targeted fishery takes place in the Strait of Gibraltar (ICES, 2019).

The Spanish longline fishery operating in the Strait of Gibraltar has been managed as a regulated open-access fishery since its initial exploitation, in 1983 (Gil et al., 2019). In 2001, Moroccan longliners started a target fishery in the same area. Therefore, two directed fisheries are presently taking place in the Spanish and Moroccan Exclusive Economic Zone (EEZ) (ICES, 2017a).

Total Allowable Catch (TAC), Portuguese quota, and official landings are presented for continental Portugal (ICES Division 27.9.a) between 2014 and 2020 (Table 1).

Table 1. *Pagellus bogaraveo* Total Allowable Catch (TAC) and Portuguese quota and official landings in ICES Subarea 27.9, between 2014 and 2020.

Year	TAC EU ICES Subarea 27.9	Portugal quota ICES Subarea 27.9	Official Portuguese landings ICES Division 27.9.a
2014	780	166	59
2015	374	80	66
2016	183	39	70
2017	174	37	69
2018	165	35	58
2019	149	32	36
2020	149	32	43

1.1. Fishery in Portugal continental

In continental Portugal, *P. bogaraveo* is mainly caught as by-catch of fisheries targeting other species, although some vessels are licensed to target the species.

Fishery data and information collected through enquiries made to Peniche (Portuguese central western coast) skippers with experience on *P. bogaraveo* fishing has shown that: (i) the species tends to gather at specific fishing grounds with particular seamount-like topographic features, being mainly caught at depths around 250 m; (ii) the fishing grounds substrates are mainly composed by muddy sand, rock, and sand; (iii) the species length range is not different between the different fishing grounds. Some skippers additionally referred that, during winter, the species migrates, driven by environmental factors or biological conditions, such as reproduction (Araújo et al., 2016).

Information on blackspot seabream collected from 1990 to 2018 in the Portuguese Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) and the Portuguese Autumn Groundfish Surveys (PT-GFS) conducted by the Portuguese Institute for the Sea and Atmosphere (IPMA) supports the hypothesis of a patchy distribution, as the species is more frequently caught at specific grounds (Farias and Figueiredo, 2019). It is important to note that the PT-CTS (UWTV (FU 28-29)) survey design is considered inadequate to estimate the species abundance or biomass, as the species distributes preferentially at non-trawlable areas. Fishery independent information has not been updated since 2018 since no survey was performed in 2019 and 2020.

2. Methodology

1.1. Fishery dependent data

1.1.1. Landings and mean price in continental Portugal

Portuguese landings in ICES Division 27.9.a were characterized. Fishery dependent data were collected from commercial landings for the period between 2009 and 2020.

Pagellus bogaraveo total landings in weight (ton) and value (euro) were analysed by year, fishing segment and NUTS (Nomenclature of Territorial Units for Statistics). The EU NUTS classification system (https://ec.europa.eu/eurostat/web/regions/background) is a regional system that divides each EU Member States territorial area into units, providing a harmonised hierarchy between regions. Following the criteria adopted under this system, continental Portugal is divided into 5 different NUTS II (level 2) corresponding: North; Centre; Lisbon Metropolitan Area; Alentejo; and Algarve.

1.1.2. Landings and mean price by fleet and selected NUTS II

Pagellus bogaraveo total landings in weight (ton) and value (euro) were analysed throughout the year, between 2009 and 2020, by fishing segments (polyvalent and trawl), considering the NUTS II with the most representative landings of the species: North, Centre, and Algarve.

1.1.3. Landings in the most important Portuguese continental ports

Pagellus bogaraveo total landings in weight (ton) were analysed throughout the year, between 2009 and 2020, by fishing segments (polyvalent and trawl) for NUTS II landings ports with the highest landings of the species. Matosinhos port belongs to NUTS II North; Aveiro, Nazaré, and Peniche ports belong to NUTS II Centre; and Sagres belongs to NUTS II Algarve.

1.2. LPUE

1.2.1. Reference fleet

Reference fleets for the polyvalent and for the trawl fishing segments were defined for the main landing port, Peniche. The criteria adopted for the selection of fishing vessels were defined according to the number of fishing trips with positive landings of the species and the number of months of the year with positive landings of the species, during the period between 2015 and 2020.

For the polyvalent fishing segment, the criteria adopted for the selection of fishing vessel were: more than 9 fishing trips per year and more than 6 months with positive landings of the species.

For the trawl fishing segment, the criteria adopted for the selection of fishing vessel where: more than 9 fishing trips per year and more than 5 months with positive landings of the species.

1.2.2. CPUE adjustment

For each selected vessel, data available at fishing trip level was further analysed. The landed weight of the species (in kg) per fishing trip corresponds to the total weight landed by the vessel after each trip. A trip is defined from the moment the vessel leaves the dock to when it returns to the dock.

The landed weight per fishing trip was considered as an indicator of biomass index, further referred as CPUE. Important to note that discards of the species are negligible in Portuguese continental fisheries.

CPUE data were standardized through the adjustment of generalized linear models (GLM). The model with the best adjustment was selected based on the AIC criterion and on the analysis of residuals.

1.3. Length distribution

Pagellus bogaraveo DCF length sampling data available for the polyvalent and the trawl segments for Portugal continental were analysed by year in the period between 2014 and 2020. Numbers-at-length were raised to the total landings.

1.4. LBI

Length-based indicators (LBI) screening methods were applied to *P. bogaraveo* length data for Portugal continental. The procedure followed the ICES Technical guidance for providing reference points for stocks in categories 3 and 4 (ICES, 2017b). The L_{mat} and L_{inf} estimates were adopted from Krug (1990).

The length-weight relationship parameters ($W = 1.17542e\text{-}05 \times L^{3.0366}$) were estimated based on biological sampling data collected in 2020 and following the procedure in fishR Vignette (Ogle, 2013).

Selected indicators, reference points, indicator ratios and their expected values are presented in Table 2 (ICES, 2017b).

Table 2. Selected indicators for LBI screening plots (ICES, 2017b).

Indicator	Calculation	Reference point	Indicator ratio	Expected value	Property
$L_{max5\%}$	Mean length of largest 5%	L_{inf}	$L_{max5\%} / L_{inf}$	> 0.8	Conservation (large individuals)
$L_{95\%}$	95th percentile		$L_{95\%} / L_{inf}$		
P_{mega}	Proportion of individuals above L_{opt} + 10%	0.3–0.4	Pmega	> 0.3	
$L_{25\%}$	25th percentile of length distribution	L_{mat}	$L_{25\%} / L_{mat}$	> 1	Conservation (immatures)
L_c	Length at first catch (length at 50% of mode)	L_{mat}	L_c/L_{mat}	> 1	
L_{mean}	Mean length of individuals > L_c	$L_{opt} = {}^2/_3\, L_{inf}$	L_{mean}/L_{opt}	≈ 1	Optimal yield
L_{max_y}	Length class with maximum biomass in catch	$Lopt = {}^2/_3\, L_{inf}$	L_{maxy} / L_{opt}	≈1	
L_{mean}	Mean length of individuals > L_c	$L_{F=M} = (0.75L_c+0.25L_{inf})$	$L_{mean} / L_{F=M}$	≥ 1	MSY

2. Results and discussion

2.1. Fishery dependent data

2.1.1. Landings and mean price in continental Portugal

In the period between 2009 and 2020, the species was landed in all five NUTS II of the Portuguese continental coast (Figure 1). Landing ports in central Portugal (NUTS II “Centro”) showed the highest landings in weight followed by the Algarve (South Portugal), that was around four times lower, and the North (NUTS II “Norte”) that was up to 8 times lower. Similar proportions were found between the NUTS in terms of value of the species (Figure 2).

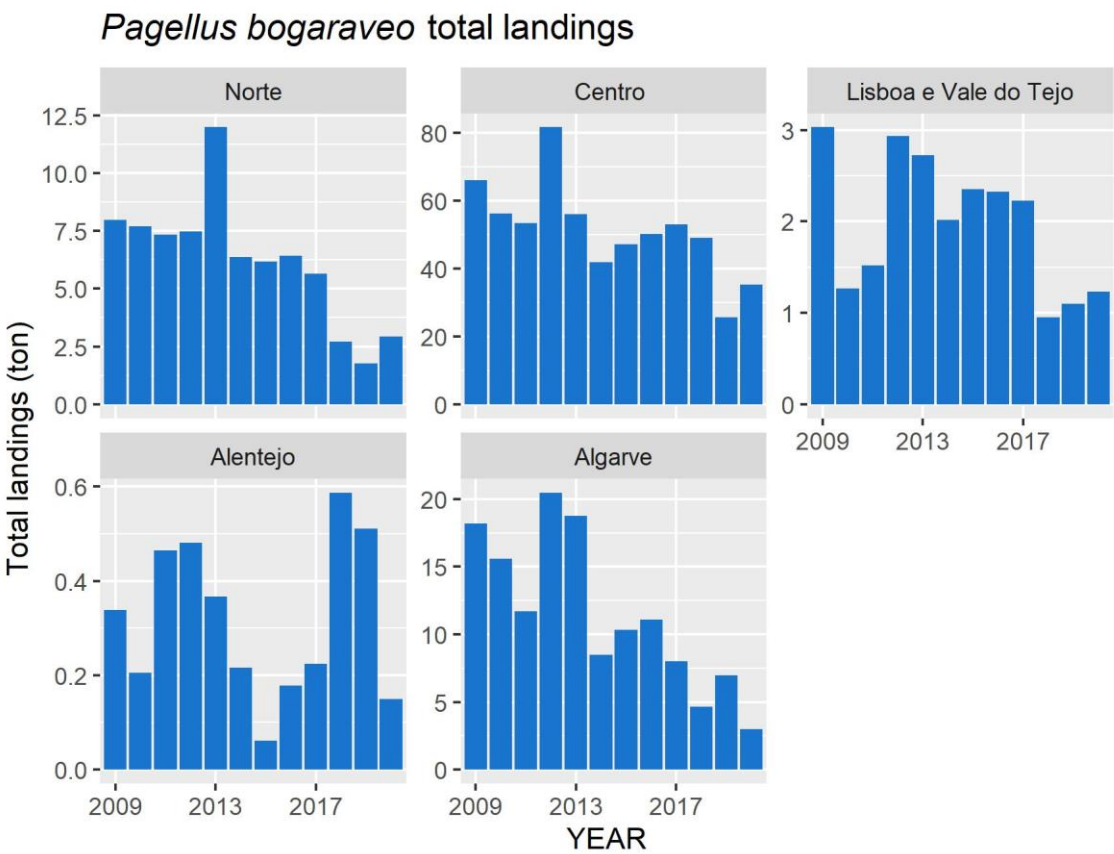

Figure 1. *Pagellus bogaraveo* total landings in tonnes in each NUTS II in continental Portugal between 2009 and 2020.

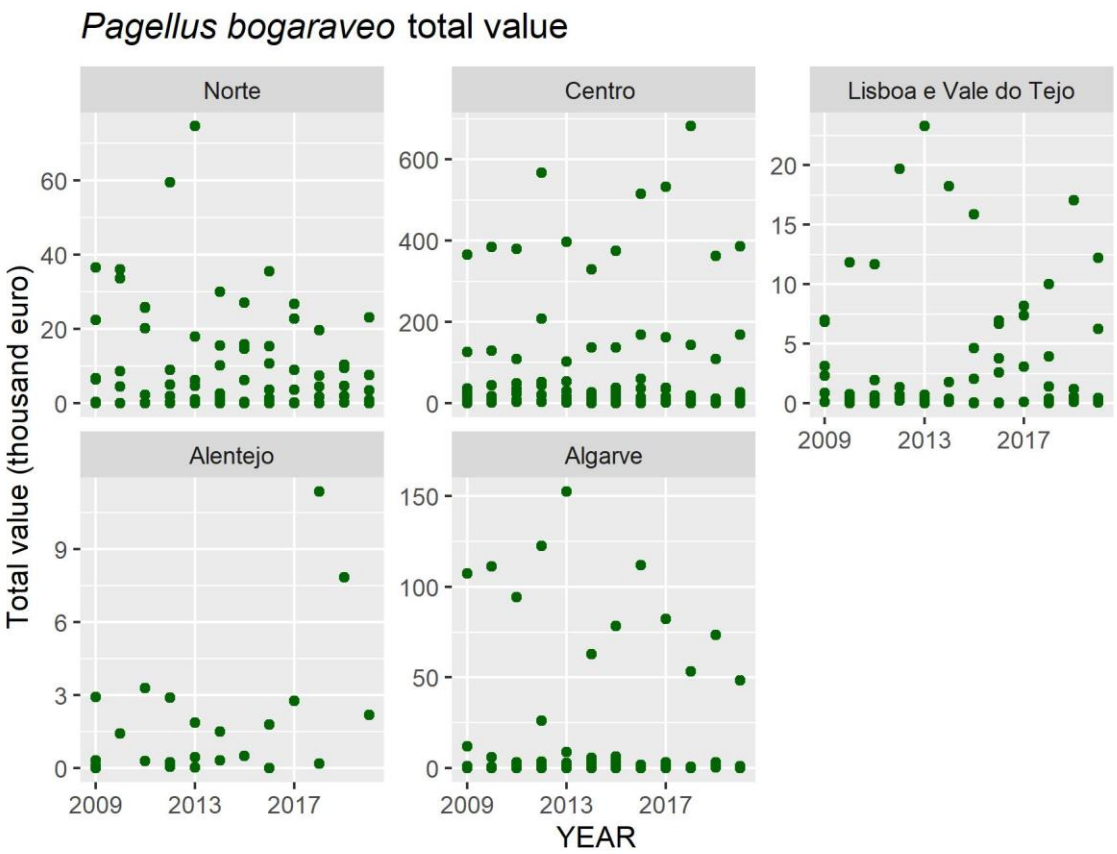

Figure 2. *Pagellus bogaraveo* total value in thousands of euros in each NUTS II in continental Portugal between 2009 and 2020.

In all NUTS II, the polyvalent fishing segment presented the highest landing values, followed by the trawl segment, with purse seine showing nearly negligible landings (Figure 3). These differences were more evident in central Portugal (NUTS II “Centro”), where the polyvalent represented around 60% of the species landings, the trawl segment represented nearly 40%, and the purse-seine fishery less than 1%.

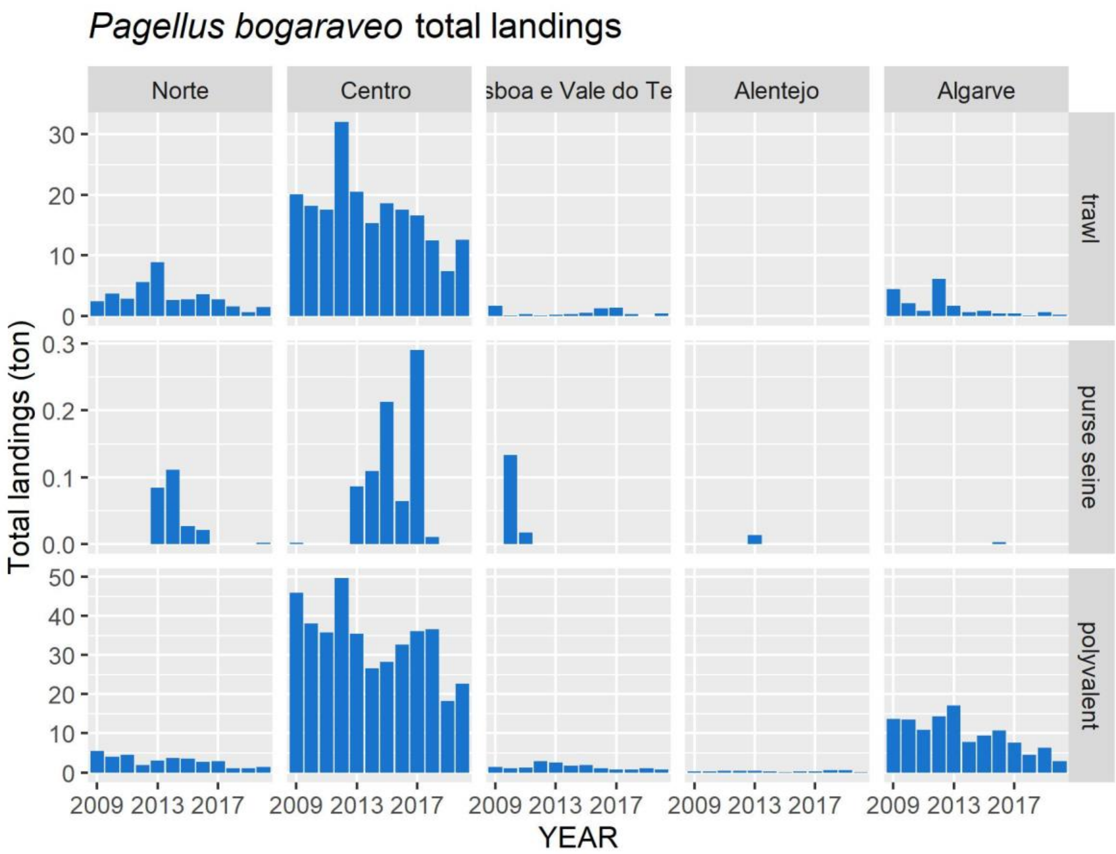

Figure 3. *Pagellus bogaraveo* total landings in tonnes by fishing segment (trawl, purse seine, and polyvalent) in each NUTS II in continental Portugal between 2009 and 2020.

The number of vessels landing *P. bogaraveo* was higher for the polyvalent fishing segment than for the trawl segment in all NUTS II (Figure 4). For the period between 2009 and 2019, a decreasing trend in the number of vessels landing the species was observed, which is probably associated with the continuous EU TAC reduction in Subarea 27.9 since 2004 (ICES, 2017a). However, the number of vessels landings *P. bogaraveo* has increased in 2020 in the North and Centre (NUTS II "Norte" and "Centro", respectively).

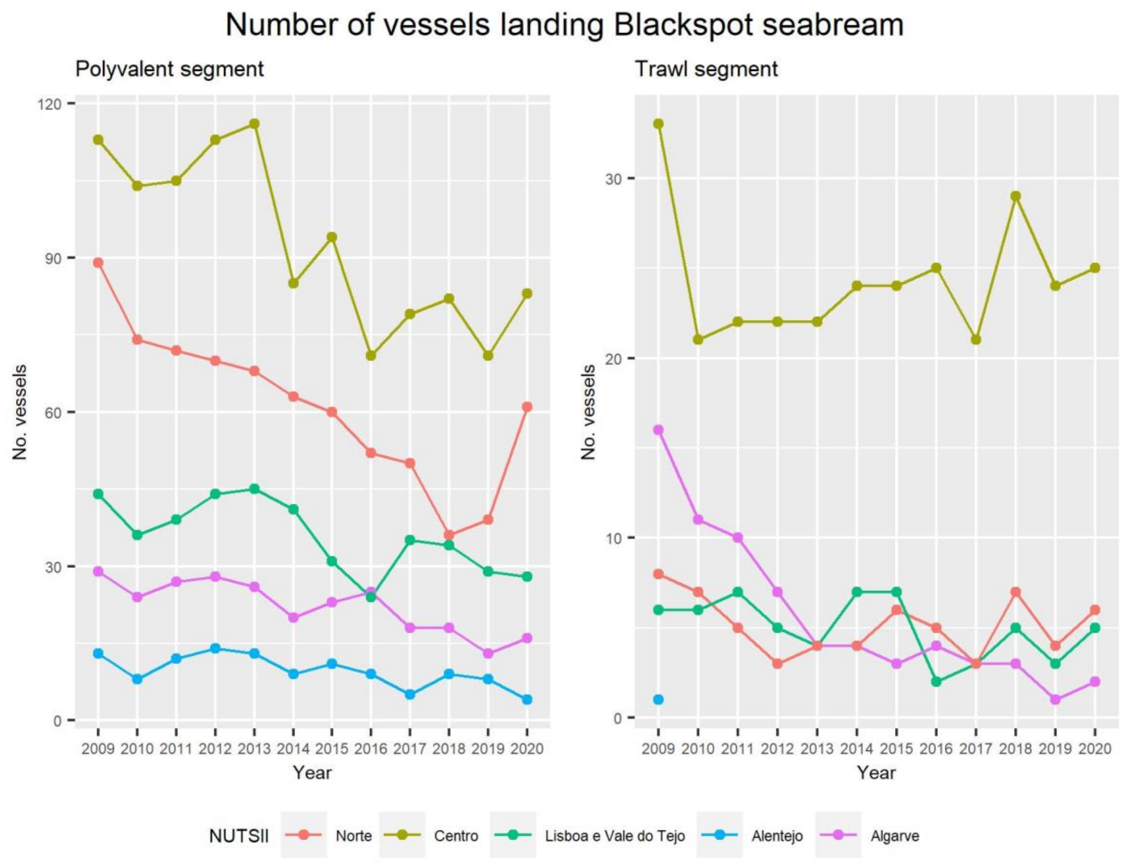

Figure 4. Number of vessels landing *Pagellus bogaraveo* in each NUTS II in continental Portugal, by year and by fishing segment (polyvalent and trawl), from 2009 to 2020.

2.1.2. Landings and mean price by fleet and selected NUTS II

Polyvalent fishing segment landings were higher in the winter months (late and early months of the year), more accentuated in the Centre region (NUTS II "Centro") (Figure 5). In the North (NUTS II "Norte") and Algarve, some years showed a peak in summer months but with little effect in terms of total landings when considering all the regions. From 2009 to 2020, there was a decreasing trend in the species landings in the three considered NUTS II.

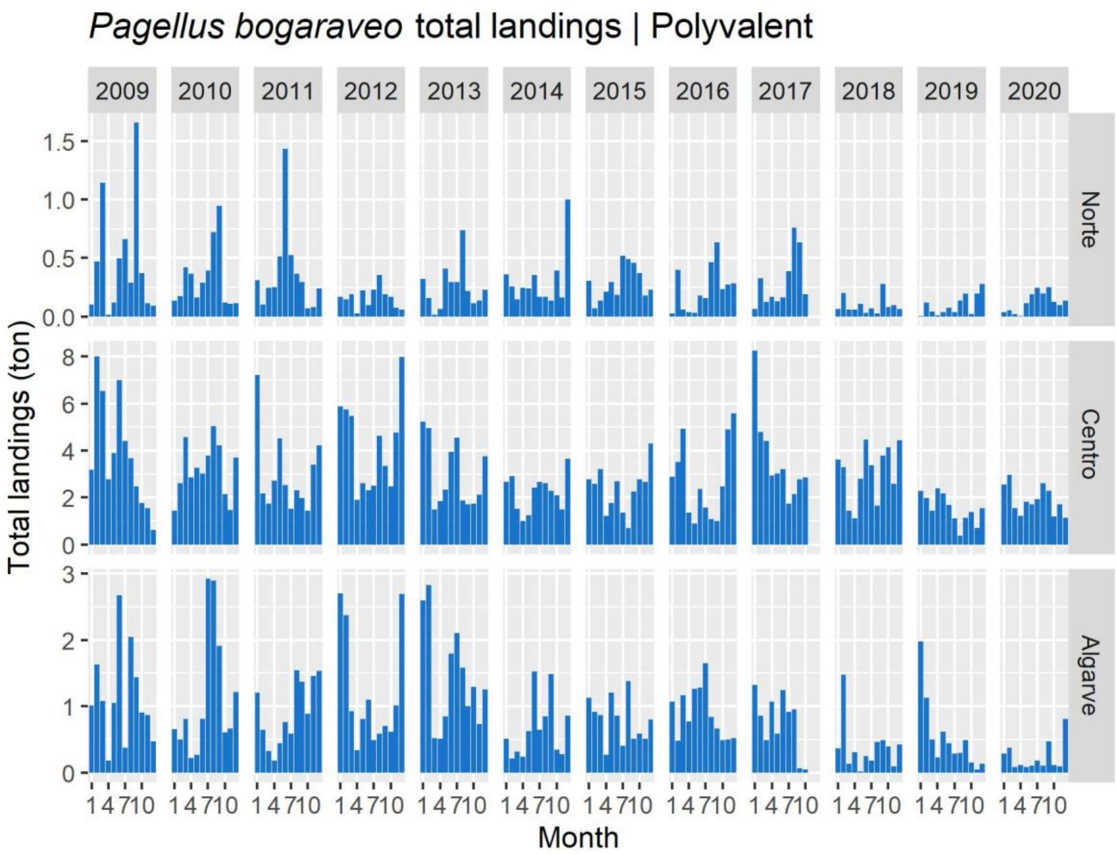

Figure 5. *Pagellus bogaraveo* landings (tons) from the polyvalent fleet by month and year at the three most important NUTS II in continental Portugal, from 2009 to 2020.

The trawl fishing segment shows a sharp decrease in total landings by month from 2013 to the 2020 (Figure 6). In the North (NUTS II “Norte”) and in the Centre (NUTS II “Centro”), landings were also higher at the beginning and end of the year. In the South (NUTS II “Algarve”), landings occurred mainly in the summer months from, 2009 to 2016, and in the winter in later years.

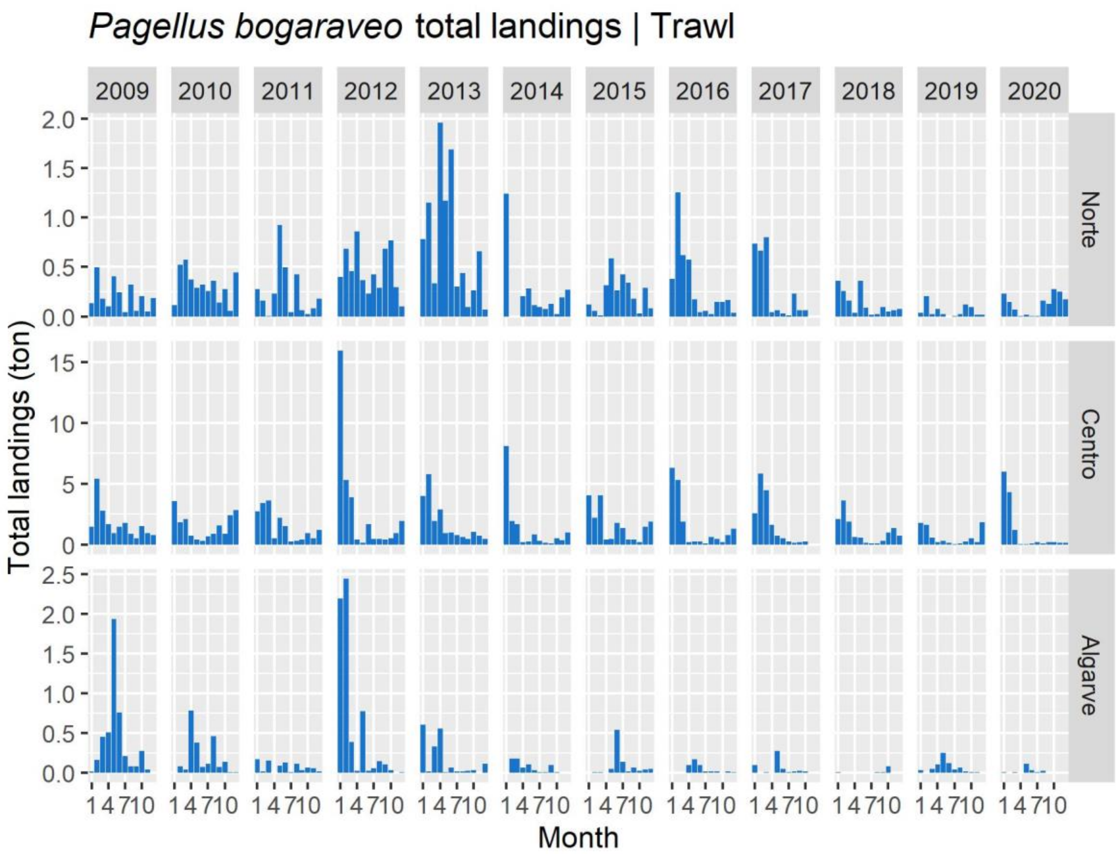

Figure 6. *Pagellus bogaraveo* landings (tons) from the trawl fleet by month and year at the three most important NUTS II in continental Portugal, from 2009 to 2020.

For the three main NUTS II, the mean price per Kg along the months of the year for the polyvalent fleet (Figure 7) and the trawl fleet (Figure 8) show variations and are more variable in the polyvalent segment and in the last months of the year, more markedly since 2015.

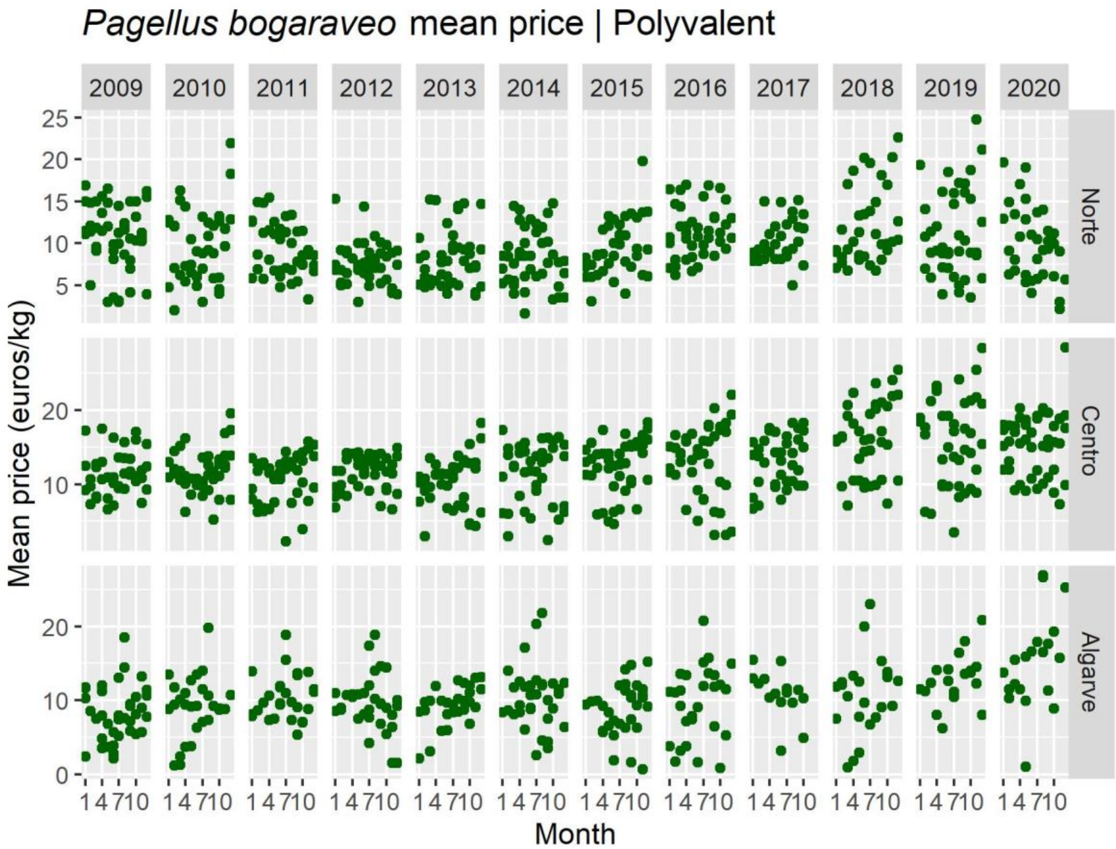

Figure 7. Mean price (in euro per Kg) of *Pagellus bogaraveo* landed by the polyvalent fishing segment by month and year for the three main NUTS II in continental Portugal between 2009 and 2020.

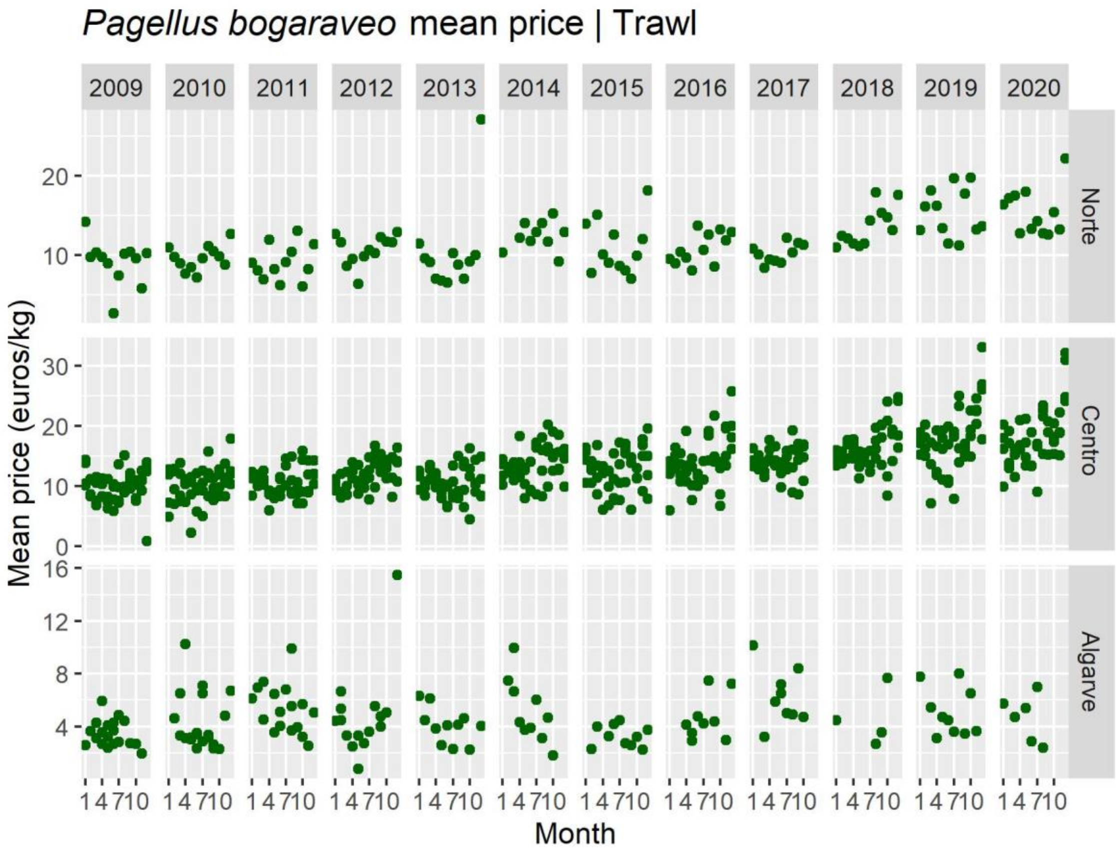

Figure 8. Mean price (in euro per Kg) of *Pagellus bogaraveo* landed by the trawl fishing segment by month and year for the three main NUTS II in continental Portugal between 2009 and 2020.

2.1.3. Landings in the most important Portuguese continental ports

P. bogaraveo landed weight by trip is presented in Figure 9 for the polyvalent segment and in Figure 10 for the trawl segment. Peniche port (Portuguese central western coast) was the most important landing port (landings between 1999 and 2020 represented nearly 50% of the Portuguese landings of the species in ICES Division 27.9.a) for both fishing segments. Extreme values were excluded from the plots for better visualization of data. In the later years, the highest landing values are registered between December and March.

P. bogaraveo total landings by most important ports and by fleet segment are summarised in Annex 1.

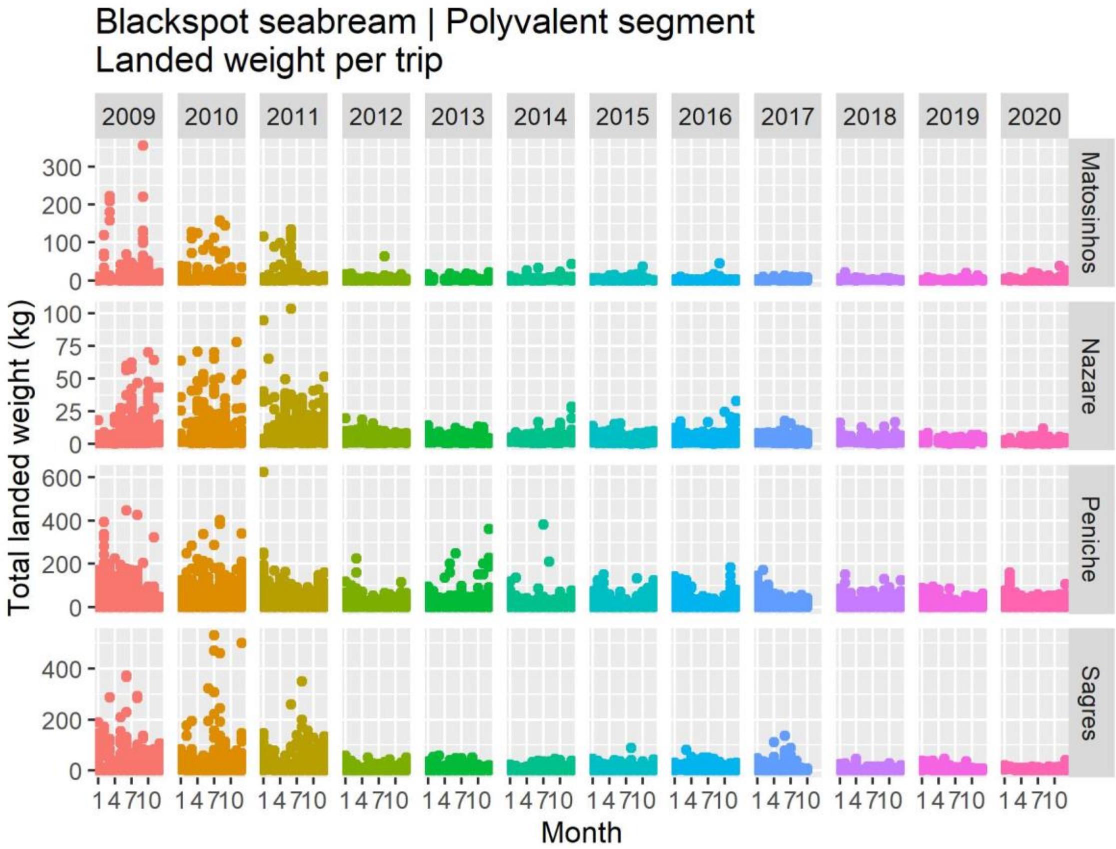

Figure 9. *Pagellus bogaraveo* total landed weight (kg) from the polyvalent fishing segment by month and year at the most important ports in Portugal continental, from 2009 to 2020.

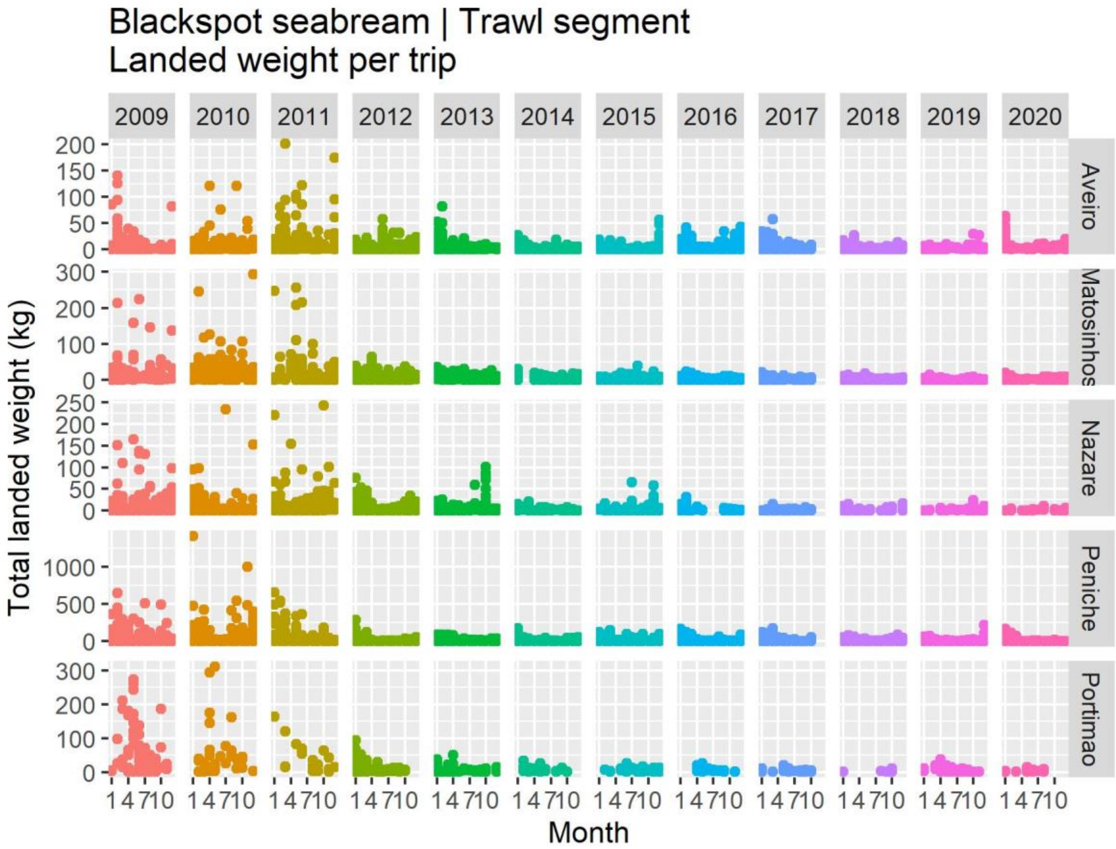

Figure 10. *Pagellus bogaraveo* total landed weight (kg) from the trawl fishing segment by month and year at the most important ports in continental Portugal, from 2009 to 2020.

2.2. LPUE

2.2.1. Reference fleet

A total of 40 fishing vessels were selected for the polyvalent fleet landing in Peniche port and a total of 21 fishing vessels were selected for the trawl fleet landing in Peniche port.

2.2.2. CPUE adjustment

GLM was adjusted to annual log-CPUE estimations for Peniche's polyvalent reference fleet considering a normal distribution and the identity link function. The GLM estimates of the annual CPUE for Peniche's polyvalent reference fleet for the selected model are presented in Figure 11 and Table 3. CPUE for the polyvalent reference fleet has been stable throughout the considered time period, showing a slight decreasing trend from 2017 to 2019, followed by a slight increase in 2020.

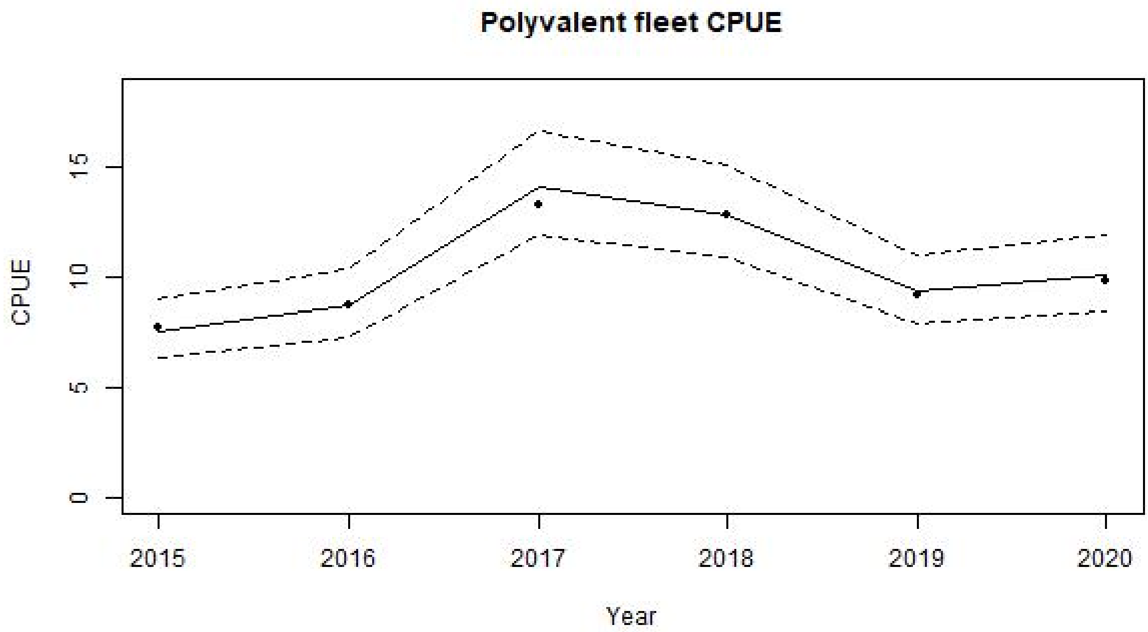

Figure 11. *Pagellus bogaraveo* standardized annual estimates of CPUE for Peniche polyvalent fishing segment reference fleet from 2015 to 2020.

Table 3. *Pagellus bogaraveo* CPUE series estimates for Peniche polyvalent reference fleet. 95% confidence interval.

Year	CPUE obs	CPUE pred. lower	CPUE pred	CPUE pred. upper
2015	7.72	6.37	7.59	9.05
2016	8.72	7.30	8.71	10.38
2017	13.30	11.94	14.11	16.69
2018	12.84	10.90	12.84	15.12
2019	9.19	7.92	9.35	11.04
2020	9.88	8.52	10.10	11.97

The analysis of the residuals of the fitted model is presented in Figure 12.

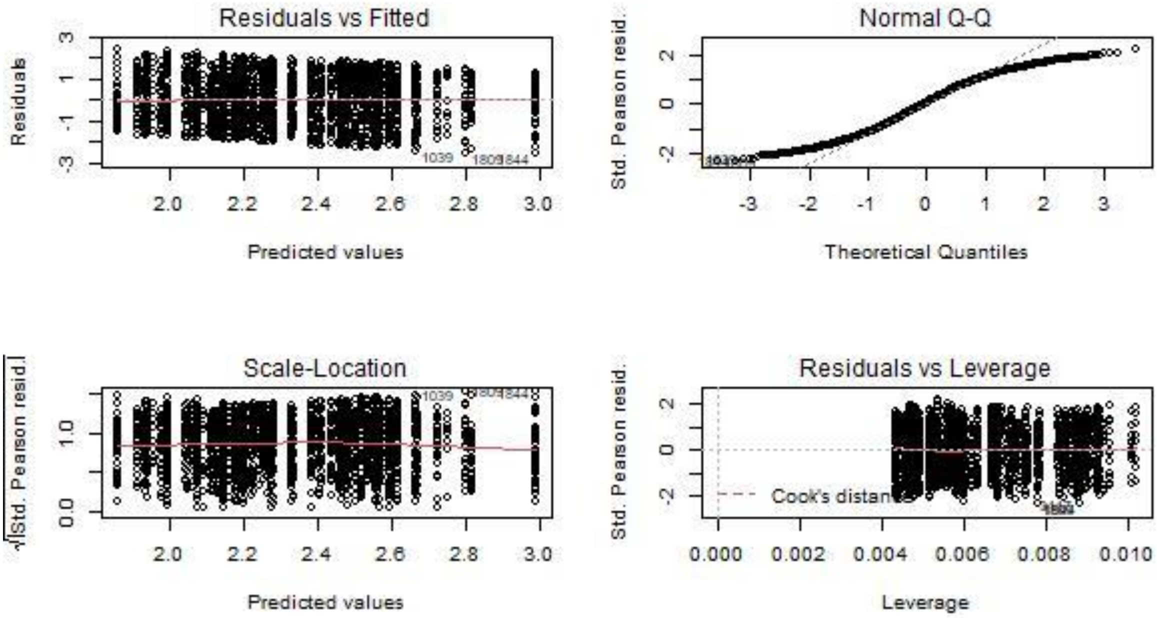

Figure 12. *Pagellus bogaraveo* analysis of the residuals of standardized annual estimates of CPUE for Peniche polyvalent fishing segment reference fleet from 2015 to 2020.

GLM was adjusted to annual log-CPUE estimations for Peniche's trawl reference fleet considering a normal distribution and the identity link function. The model was selected based on AIC and analysis of the residuals. The GLM estimates of the annual CPUE for Peniche's trawl reference fleet for the selected model are presented in Figure 13 and Table 4. CPUE for the trawl reference fleet has been relatively stable, with a slight fluctuation between 2015 and 2020.

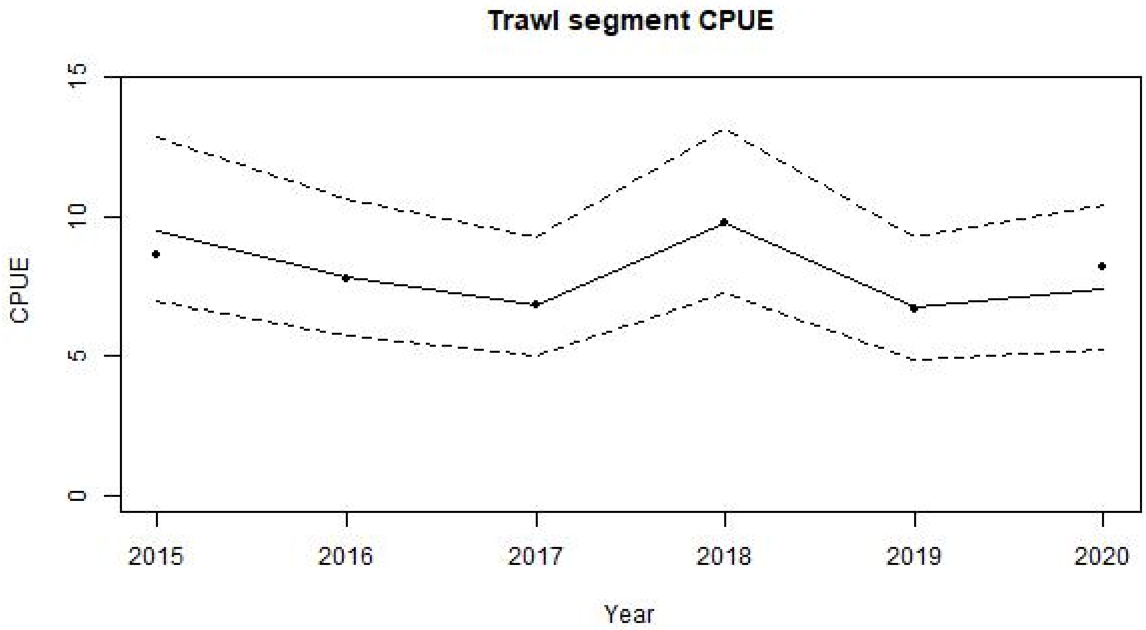

Figure 13. *Pagellus bogaraveo* standardized annual estimates of CPUE for Peniche trawl fishing segment reference fleet from 2015 to 2020.

Table 4. *Pagellus bogaraveo* CPUE series estimates for Peniche trawl reference fleet. 95% confidence interval.

Year	CPUE obs	CPUE pred. lower	CPUE pred	CPUE pred. upper
2015	8.65	6.99	9.49	12.89
2016	7.80	5.76	7.83	10.64
2017	6.85	5.04	6.84	9.29
2018	9.79	7.28	9.79	13.17
2019	6.68	4.88	6.72	9.26
2020	8.21	5.28	7.43	10.46

The analysis of the residuals of the fitted model is presented in Figure 14.

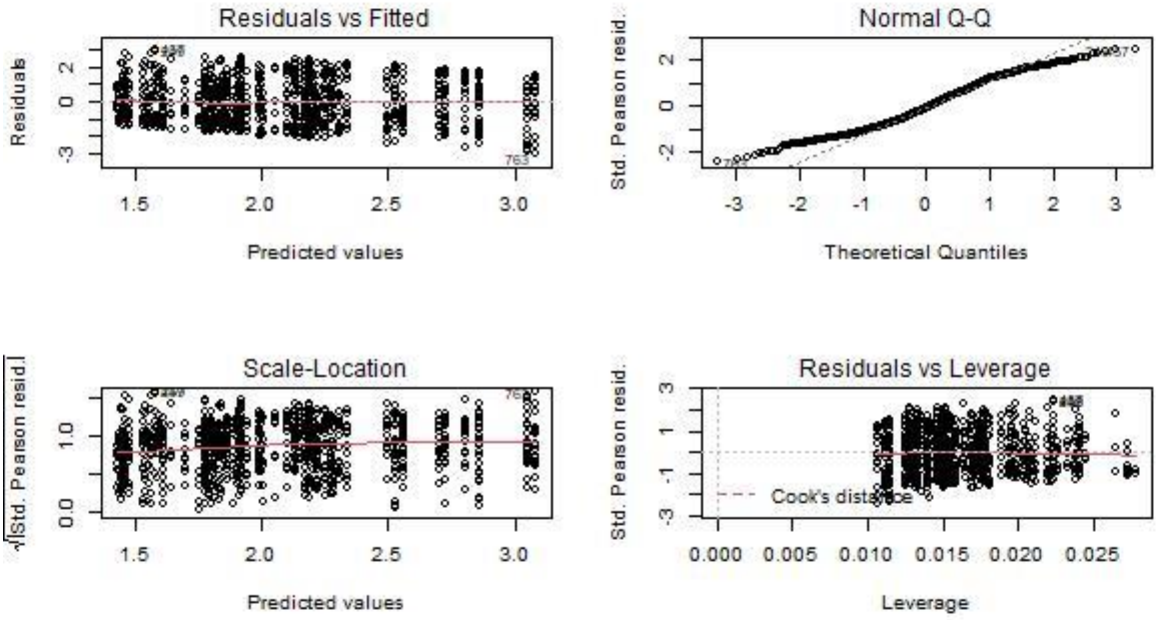

Figure 14. *Pagellus bogaraveo* analysis of the residuals of standardized annual estimates of CPUE for Peniche trawl fishing segment reference fleet from 2015 to 2020.

2.3. Length distribution

P. bogaraveo length distributions were extrapolated from DCF length sampling data available for the polyvalent (Figure 15) and the trawl (Figure 16) fishery segments for Portugal continental by year in the period between 2014 and 2020.

The smaller sizes are poorly represented probably because the minimum landing size of *P. bogaraveo* is 33 cm and the discards of specimens bellow that size are negligible given that the species shows a very high survival rate (Serra-Pereira et al., 2019).

In 2020, only 4 samples were measured from the polyvalent segment, which corresponded to 72 specimens, and only 4 samples from the trawl segment, which included 52 specimens.

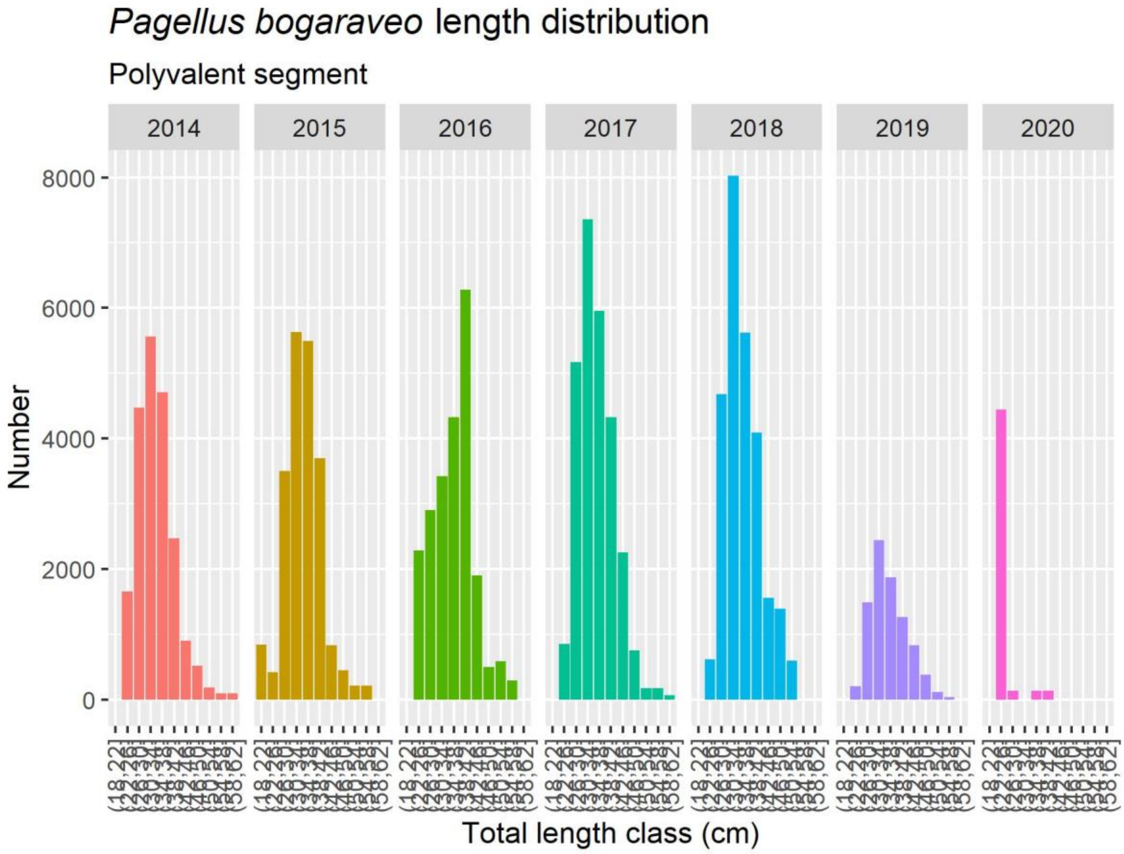

Figure 15. *Pagellus bogaraveo* extrapolated length frequency distributions for the polyvalent fishing segment for the years between 2014 and 2020. (4 cm total length classes)

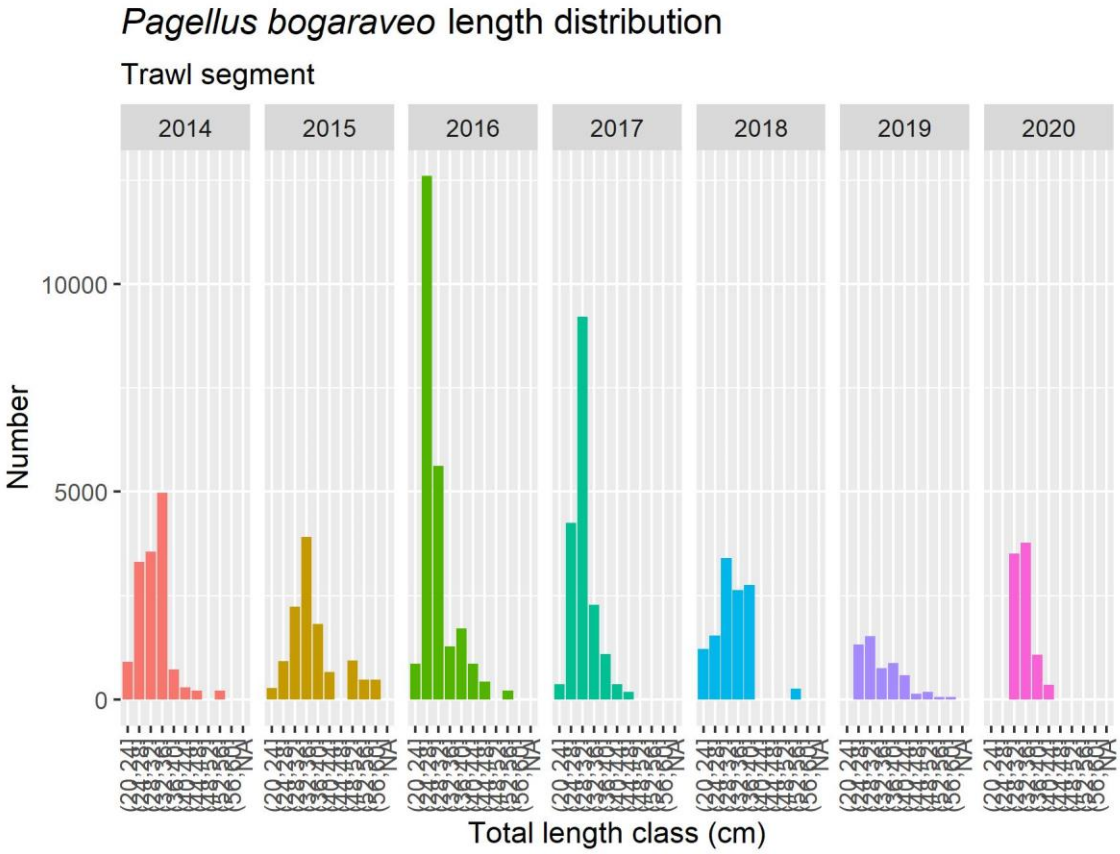

Figure 16. *Pagellus bogaraveo* extrapolated length frequency distributions for the trawl fishing segment for the years between 2014 and 2020. (4 cm total length classes)

Differences in length distribution between the polyvalent segment and the trawl segment result from the fact that polyvalent vessels operate in areas farther from the coast and at higher depths, where larger fish are more common (Farias et al., 2018).

2.4. LBI

Results from the LBI screening method are shown in Tables 5 and 6 and Figure 17. Nearly all LBI estimates decreased between 2019 and 2020.

Table 5. *Pagellus bogaraveo* in ICES Division 27.9.a. Results from LBI screening.

Year	L_{75}	L_{25}	L_{med}	L_{90}	L_{95}	L_{mean}	L_c	$L_{F=M}$	L_{maxy}	L_{mat}	L_{opt}	L_{inf}	$L_{max5\%}$
2014	36	29	33	39	42	33.39	26	35.42	34	39.1	42.45	63.68	46.88
2015	38	32	35	41	45	36.50	30	38.42	36	39.1	42.45	63.68	52.09
2016	38	27	31	42	45	33.52	26	35.42	40	39.1	42.45	63.68	49.58
2017	36	30	32	40	43	34.95	30	38.42	31	39.1	42.45	63.68	46.15
2018	38	31	34	41	44	35.78	30	38.42	37	39.1	42.45	63.68	47.60
2019	39	31	34	43	46	35.28	26	35.42	38	39.1	42.45	63.68	49.03
2020	34	25	32	37	38	33.35	26	35.42	34	39.1	42.45	63.68	41.42

Table 6. *Pagellus bogaraveo* in ICES Division 27.9.a. LBI screening ratios.

	Conservation						Optimizing Yield	MSY
	L_c/L_{mat}	$L_{25\%}/L_{mat}$	$L_{95\%}/L_{inf}$	L_{maxy}/L_{opt}	$L_{max5\%}/L_{inf}$	P_{mega}	L_{mean}/L_{opt}	$L_{mean}/L_{F=M}$
Ref.	> 1	> 1	> 0.8	≈ 1	> 0.8	>30%	≈ 1 (>0.9)	≥ 1
2014	0.66	0.74	0.66	0.80	0.74	2.5%	0.79	0.94
2015	0.77	0.82	0.71	0.85	0.82	4.8%	0.86	0.95
2016	0.66	0.69	0.71	0.94	0.78	3.5%	0.79	0.95
2017	0.77	0.77	0.68	0.73	0.72	1.8%	0.82	0.91
2018	0.77	0.79	0.69	0.87	0.75	2.8%	0.84	0.93
2019	0.66	0.79	0.72	0.90	0.77	4.0%	0.83	1.00
2020	0.66	0.64	0.60	0.80	0.65	0.00	0.79	0.94

Although some of the ratio estimates, particularly those of Conservation, are below the proposed expected values, MSY is consistence with an adequate exploitation.

Regarding the Conservation ratios, the results might reflect some of EU size measures, such as the adopted minimum landing size (MLS). L_c/L_{mat} and $L_{25\%}/L_{mat}$ estimates might be related with the fact that *P. bogaraveo* is a protandric hermaphrodite and the L_{mat} assumed in the screening was that of females, which is above the MLS.

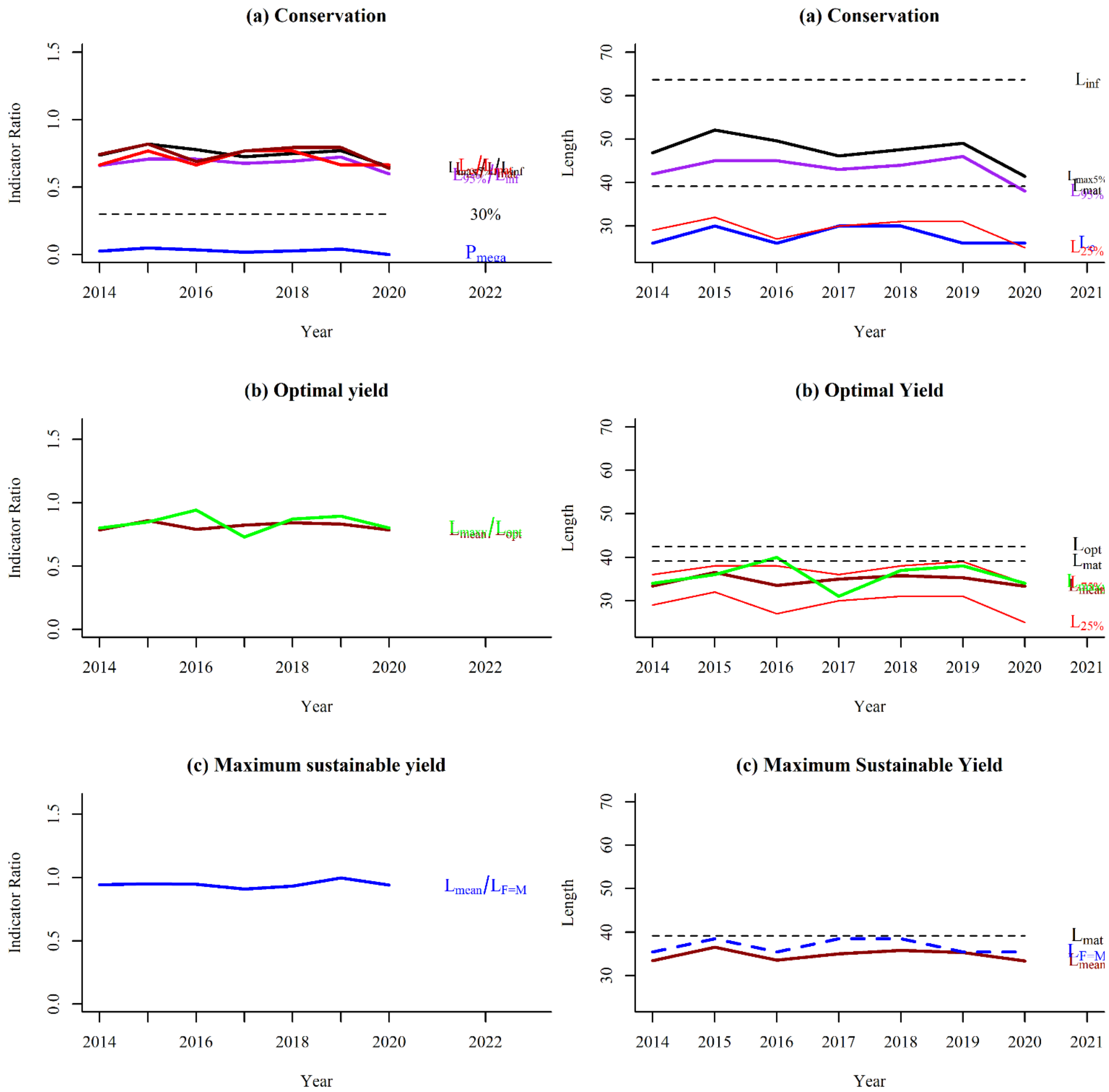

Figure 17. *Pagellus bogaraveo* in ICES Division 27.9.a. Results from LBI screening.

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ANNEX I

Table 7. *Pagellus bogaraveo* total landed weight (ton) by fleet segment in the six most important landing ports for the species. Ports are organized by NUTS II.

		North			Centre				Lisbon Metrop. Area	Algarve	
Year	Gear	Matosinhos	Povoa do Varzim	Viana do Castelo	Aveiro	Figueira da Foz	Nazare	Peniche	Sesimbra	Sagres	Portimao
2009	Polyvalent	4.24	0.66	0.5734	0.06	0.43	3.42	41.98	0.59	13.47	0.05
	Trawl	2.43	-	-	1.43	0.64	2.69	15.32	1.55	-	4.32
2010	Polyvalent	2.64	0.45	0.8427	0.09	0.50	3.83	33.65	0.91	13.33	0.05
	Trawl	3.73	-	-	1.12	1.05	1.47	14.50	0.05	0.00	1.90
2011	Polyvalent	2.27	0.34	1.8148	0.52	0.20	3.92	31.09	0.97	10.63	0.20
	Trawl	2.90	-	-	3.03	0.79	2.32	11.43	0.32	-	0.74
2012	Polyvalent	1.03	0.29	0.5313	0.53	0.24	3.99	44.85	2.18	13.88	0.05
	Trawl	5.56	-	-	3.63	1.80	5.33	21.29	0.09	-	6.14
2013	Polyvalent	1.55	0.52	0.6831	0.74	0.10	2.60	32.05	2.21	16.70	0.03
	Trawl	8.91	-	-	4.79	1.51	3.34	10.89	0.18	-	1.73
2014	Polyvalent	1.05	0.35	1.9169	0.36	0.02	1.80	24.36	1.55	6.89	0.41
	Trawl	2.62	-	-	1.09	0.48	1.11	12.61	0.31	-	0.62
2015	Polyvalent	1.32	0.80	1.3293	0.55	0.06	2.82	24.88	1.46	8.65	0.07
	Trawl	2.70	-	-	1.99	0.93	1.38	14.30	0.51	-	0.90
2016	Polyvalent	0.86	0.35	1.3854	0.34	0.09	2.28	29.87	0.49	10.45	0.02
	Trawl	3.62	-	-	3.68	0.70	0.95	12.26	1.26	-	0.40
2017	Polyvalent	1.73	0.43	0.775	0.55	0.09	2.43	33.04	0.58	7.35	-
	Trawl	2.71	-	-	2.78	1.12	0.57	12.09	1.41	-	0.46
2018	Polyvalent	0.54	0.19	0.4024	0.20	0.02	1.02	35.40	0.52	4.50	0.00
	Trawl	1.58	-	-	1.07	1.10	0.60	9.66	0.28	-	0.09
2019	Polyvalent	0.49	0.23	0.3601	0.31	0.03	0.49	17.35	0.95	6.25	-
	Trawl	0.63	-	-	0.58	0.44	0.35	6.08	0.02	-	0.66
2020	Polyvalent	0.90	0.14	0.3199	1.37	0.04	0.53	20.72	0.73	2.60	0.10
	Trawl	1.46	-	-	1.51	0.40	0.12	10.54	0.46	-	0.17

Working Document for the ICES Working Group on Biology and Assessment of Deep-Sea Fisheries Resources

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Demographic analysis of *Pagellus bogaraveo* population in Portuguese continental waters

(ICES Division 27.9.a)

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1. Introduction

Pagellus bogaraveo (Brünnich, 1768), the blackspot seabream, occurs between southern Norway and Cape Blanc, in the Mediterranean Sea, and in the Azores, Madeira, and Canary Archipelagos (Desbrosses, 1932; Pinho and Menezes, 2005). The blackspot seabream is a protandric hermaphrodite; individuals are first functional males and then develop into functional females (Buxton and Garratt, 1990; Krug, 1990; Gil, 2006). Spawning occurs in shallow waters and later, juveniles (with sizes around 150 to 180 mm total length, TL) migrate down to depths deeper than 200 m (Desbrosses, 1932).

In the Northeast Atlantic, *P. bogaraveo*'s stock structure is still unknown. ICES adopted, for management purposes, three management units: (a) Subareas 27.6, 27.7, and 27.8; (b) Subarea 27.9; and (c) Subarea 27.10 (Azores) (ICES, 2007). The definition of these management units was performed as way to better record the fishery information available and do not have implicit the existence of three different stocks of *P. bogaraveo*.

At the northern part of the ICES 27.9 management unit (continental Portugal) information of species spatial dynamics suggests the inexistence of movements between the northernmost and the southern part, where a target fishery takes place in the Strait of Gibraltar (ICES, 2019). In continental Portugal, the blackspot seabream is mainly caught as by-catch of fisheries although targeting occurs for some vessels. Peniche (Portuguese central western coast) is the most important landing port. For this area, fishery data on *P. bogaraveo* as well as information collected through enquiries made to Peniche skippers (Araújo et al., 2016) showed that:

(i) the species tends to gather at specific fishing grounds with particular seamount-like topographic features, being mainly caught at depths around 250 m;

(ii) the fishing grounds substrates are mainly composed by muddy sand, rock, and sand;

(iii) the species length range is similar between the different fishing grounds.

Information on blackspot seabream collected from 1990 to 2018 in the Portuguese Nephrops TV Surveys (PT-CTS (UWTV (FU 28-29))) and the Portuguese Autumn Groundfish Surveys (PT-GFS) conducted by the Portuguese Institute for the Sea and Atmosphere (IPMA) supports the hypothesis of a patchy distribution, as the species is more frequently caught at specific grounds (Farias and Figueiredo, 2019).

Given the inexistence of fishery independent data and the lack of long-term species-specific data for ICES 27.9 management unit, ICES advice has been based on biomass trend analysis derived exclusively from the Spanish target fishery, the "voracera" (ICES, 2020). The perception of stock status that supports ICES advice does not consider the aggregative characteristics of species spatial dynamics, although there are clear evidences that the species is capable of completing its life cycle in areas of higher aggregation. In those areas, the demographic structure includes all the ontogenic stages of the species' life cycle.

Demographic models provide an opportunity for better understanding dynamics of species populations even when limited data are available. Demographic analysis differs from traditional full stock assessment since the input is only biological information and it cannot make the harvest control rule or total annual catch directly (Geng et al., 2021). The principle for demographic analysis is changing harvest survival rate based on different management strategy, and finding a maximum harvest rate (HMSY) leading to a population growth rate (λ) equal to one where the stock can be sustained. These models allow the estimation of a variety of parameters that summarise a population's growth rate, generation length, reproductive outputs and stable-age distribution. In particular, matrix demographic models can be structured to examine either stage or age-classes – allowing them to be tailored to the information available – and the elasticities of individual matrix elements can provide useful information on the ages or life stages that will respond best to management measures (Heppell et al., 2000). In these models, λ is the dominant eigenvalue and the stable age or stage distribution and reproductive values are the corresponding right and left eigenvectors, respectively. The finite rate of population growth can be related to the intrinsic rate of population growth (r) as

$$\lambda = e^{r}.$$

Population growth is stable when λ=1, decreasing when λ<1 and increasing when λ>1 (Smart et al., 2017).

The present work uses static demographic models constructed using only life history parameters to provide management-relevant information on species, namely to assess the potential effects on the adoption of different management strategies.

2. Methodology

Life history parameters

Life history parameters relevant for the species were extracted from the literature to form the foundation of vital rates to use in demographic analyses (Table 1). Vital rates were defined as lower level components of the demographic estimates that underlie the stage matrix elements (Brault and Caswell, 1993).

Natural mortality and survivorship estimation

Natural mortality (M) was estimated using indirect methods. These included the age-independent equation proposed by Hewit and Hoenig (2005) invariant method and age-dependent method proposed by Charlov et al. (2012):

$$M_l = k\left(\frac{l}{L_\infty}\right)^{-1.5} = k\left(\frac{L_\infty}{l}\right)^{1.5}$$

where M_a is mortality at length *l*, *k* is the individual growth rate and L_∞ is the maximum body size (the last two are estimated from fitting the von Bertalanffy growth equation).

Estimates of natural mortality were used to calculate the stage specific natural mortality (M_{st}), which, in the case of varying natural mortality of a specific stage, is a weighted mean of number of specimens in the stage. The survival probability of stage-specific (S_{st}) was determined as

$$S_{st} = e^{-M_{st}}$$

Stage transition

For each stage, the individuals in one stage of the demographic matrix can survive in one of two ways: stay in the same stage, or transit to the next stage. The probability of staying in the same stage after one year is the time lag used in the present analysis and the probability of moving on to the next stage is calculated using the von Bertalanffy growth parameters from Gil (2006),

$$L_t = 58 \times \left(1 - e^{-0.169(t-(-1.1674))}\right).$$

Sex change

Within each stage the probability of males changing to females was estimated based on Krug (1998),

$$P_f = \frac{e^{-7.55+0.251L_F}}{1 + e^{-7.55+0.251L_F}}$$

where L_F is the fork length, which was converted to total length using $L_T = 1.13\ L_F - 0.04$ (Krug, 1989).

Reproduction

The annual contribution of new elements to the population was exclusively based on the mean number of eggs laid per female, by length class weighted by the number of elements in length classes from stage IV. The mean number of eggs laid by female is a function of length and was calculated using the expression from Krug (1989),

$$F = 1028.44\ e^{0.15L_F}$$

Demographic matrix model

A stage-structured matrix (Lefkovitch matrix) was built with the purpose of describing how blackspot seabream population changes over time as a function of the average vital rates. In this study, year is the time-lag unit considered for different stage-classes. Additionally, the impacts due to the density dependence on the vital parameters were not considered.

Blackspot seabream stage matrix model was constructed using the modular approach proposed by Buckland et al. (2004) and by considering a population vector of four stage classes: juvenile males with total length (TL) lower than 30 cm (n_1); males with TL varying between 30 and 39 cm; females with lengths varying between 30-39 cm and mature females with length larger than 39 cm.

For modelling the blackspot seabream population four sub-processes were considered: fertility (γ), survival (φ), growth (β), and sex change (α). It is assumed that sub-processes occur sequentially according to the following order Survival -> Growth -> Sex change -> Reproduction.

Following this modular approach, the population matrix is translated as

$$\begin{bmatrix} (1-\beta_1)\varphi_1 & 0 & \varepsilon\gamma_1\beta_3\varphi_3 & \varepsilon\gamma_1\varphi_4 \\ (1-\alpha)\beta_1\varphi_1 & (1-\alpha)\varphi_2 & 0 & 0 \\ \alpha\beta_1\varphi_1 & \alpha\varphi_2 & (1-\beta_3)\varphi_3 & 0 \\ 0 & 0 & \beta_3\varphi_3 & \varphi_4 \end{bmatrix}$$

where ε is the probability of surviving the first stage and entering the following stage.

Monte Carlo simulations

The estimates of vital rates are difficult to obtain and are subject to high uncertainty (Caswell et al., 1997). In the present work, uncertainty on vital rates was incorporated into demographic analyses. Monte Carlo simulations were used to stochastically vary specific vital rates and, by that, incorporate uncertainty into matrix projections and demographic parameters. This was done by randomly selecting vital rates from assumed statistical distributions and then perform demographic analyses for 10,000 simulations.

Management scenarios

The impact on fishing mortality on the population evolution in all stage-classes excluding the first class was evaluated by considering different stage-independent mortality rates (F), which were incorporated into the survivorship elements of the demographic matrix as:

$$S_{st} = e^{-(M_{st}+F)}$$

The effects of a stage-independent F were examined by calculating the limiting level of F that produces a stable population. This was estimated by systematically increasing F equally across all stages, excluding the first (which includes specimens with size lower than the minimum landing size adopted for the species). The exclusion of the first stage class is justified by the technical management, minimum landing size, settled by the EU (2019).

3. Results

Under the two different natural mortality estimation procedures (*i.e.*, constant survivorship and size-varying survivorship) the proportion of individuals in each stage class are presented (Fig. 1 and 2).

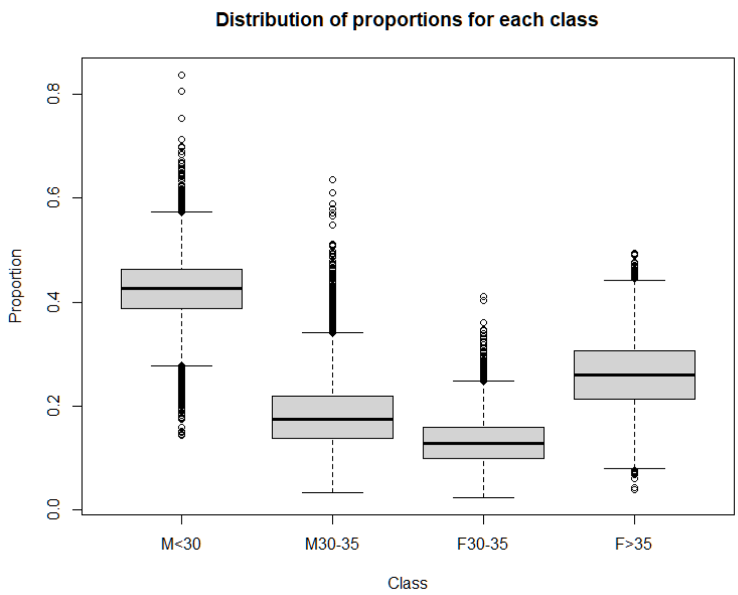

Figure 1. Distribution of proportions by stage class for invariant natural mortality.

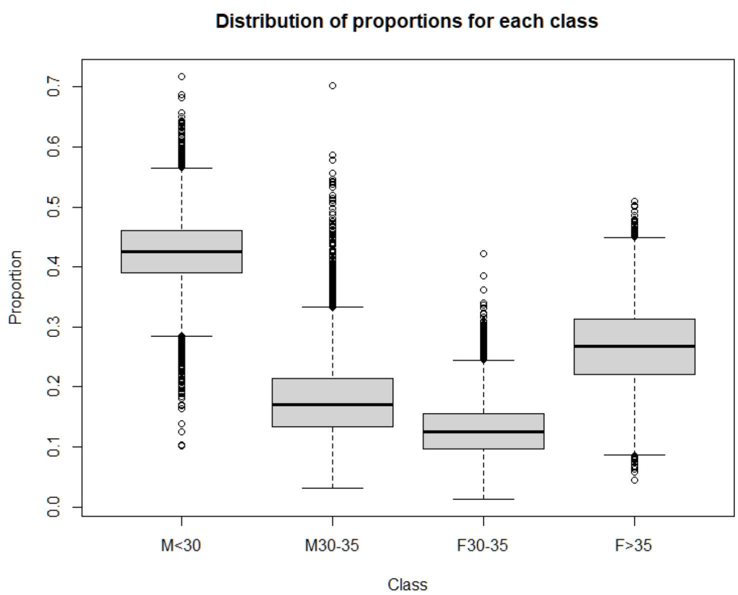

Figure 2. Distribution of proportions by stage class for size-varying survivorship.

Under different fishing mortalities, the 95% interquantile intervals of λ are presented for the two survivorships considered (Fig. 3 and 4).

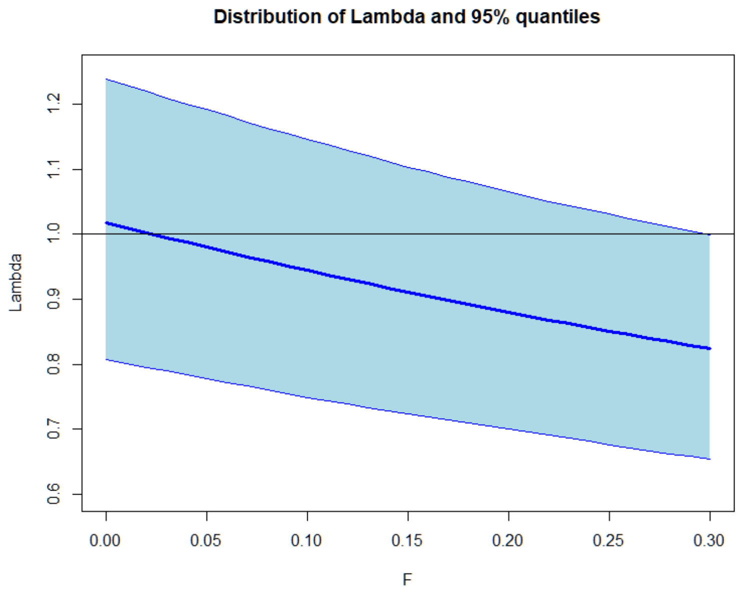

Figure 3. The relationship between the finite rate of population increase (λ) and instantaneous fishing mortality (F) for invariant survivorship. The shaded areas represent the 95% interquartile interval of the Monte Carlo simulations.

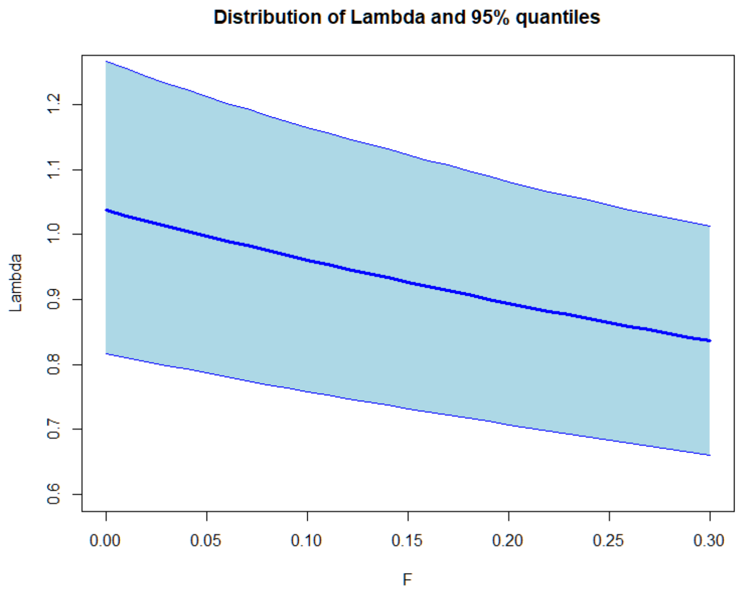

Figure 4. The relationship between the finite rate of population increase (λ) and instantaneous fishing mortality (F) for size-varying survivorship. The shaded areas represent the 95% interquartile interval of the Monte Carlo simulations.

The demographic estimates under different stage-independent fishing mortalities are presented in Table 1.

Table 1. Demographic estimates under different stage-independent fishing mortalities. Values in parentheses are the 95% interquartile interval of the Monte Carlo simulation.

Fishing mortality	Constant M	Variable M
0	1.02 (0.81 - 1.25)	1.04 (0.82-1.27)
0.01	1.01 (0.80 - 1.24)	1.03 (0.81-1.26)
0.05	0.98 (0.78 - 1.20)	1.00 (0.79-1.21)
0.1	0.95 (0.75 - 1.16)	0.96(0.76-1.16)
0.15	0.91 (0.73 - 01.12)	0.93 (0.73-1.12)
0.2	0.88 (0.70 -1.076)	0.89 (0.71-1.08)
0.3	0.83 (0.66 - 1.01)	0.84 (0.66-1.01)

Table 2 shows the proportion of $\lambda \geq 1$ in 10,000 simulations for the different F considered for the two different natural mortality estimation procedures (*i.e.*, constant survivorship and size-varying survivorship).

Table 2. Proportion of $\lambda \geq 1$ in 10,000 simulations for the different F considered for constant survivorship (Constant M) and size-varying survivorship (Variable M).

F	Constant M	Variable M
0	0.56	0.62
0.02	0.51	0.57
0.03	0.48	0.54
0.04	0.44	0.51
0.05	0.42	0.49
0.07	0.37	0.43
0.09	0.32	0.37

4. Discussion

The present work is preliminary and allowed us to perceive the impacts of different fishing scenarios on the finite rate of population increase. The results obtained led us to question the vital rates included as input in the demographic matrix, taking into consideration the fact that these estimates were derived from studies carried out on highly exploited populations (Azores and Strait of Gibraltar). The F values found were quite low when compared with growth rate of the species as well as the F reference values determined in other studies for congener species.

Finally, the stability of the index of biomass in recent years (2015-2020) derived for the reference fleet in continental Portugal (Farias and Figueiredo, 2021 WD) associated with low EU quotas assigned for Portugal will be considered in the next steps of the analysis. In particular, the analysis of vital parameters will be considered and contrasted with the length distribution of the population in Portuguese continental waters.

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ANNEX I

Pagellus bogaraveo total landed weight (ton) by fleet segment in the six most important landing ports for the species. Ports are organized by NUTS II (Farias and Figueiredo, 2021 WD).

		North			Centre				Lisbon Metrop. Area	Algarve	
Year	**Gear**	**Matosinhos**	**Povoa do Varzim**	**Viana do Castelo**	**Aveiro**	**Figueira da Foz**	**Nazare**	**Peniche**	**Sesimbra**	**Sagres**	**Portimao**
2009	Polyvalent	4.24	0.66	0.5734	0.06	0.43	3.42	41.98	0.59	13.47	0.05
	Trawl	2.43	-	-	1.43	0.64	2.69	15.32	1.55	-	4.32
2010	Polyvalent	2.64	0.45	0.8427	0.09	0.50	3.83	33.65	0.91	13.33	0.05
	Trawl	3.73	-	-	1.12	1.05	1.47	14.50	0.05	0.00	1.90
2011	Polyvalent	2.27	0.34	1.8148	0.52	0.20	3.92	31.09	0.97	10.63	0.20
	Trawl	2.90	-	-	3.03	0.79	2.32	11.43	0.32	-	0.74
2012	Polyvalent	1.03	0.29	0.5313	0.53	0.24	3.99	44.85	2.18	13.88	0.05
	Trawl	5.56	-	-	3.63	1.80	5.33	21.29	0.09	-	6.14
2013	Polyvalent	1.55	0.52	0.6831	0.74	0.10	2.60	32.05	2.21	16.70	0.03
	Trawl	8.91	-	-	4.79	1.51	3.34	10.89	0.18	-	1.73
2014	Polyvalent	1.05	0.35	1.9169	0.36	0.02	1.80	24.36	1.55	6.89	0.41
	Trawl	2.62	-	-	1.09	0.48	1.11	12.61	0.31	-	0.62
2015	Polyvalent	1.32	0.80	1.3293	0.55	0.06	2.82	24.88	1.46	8.65	0.07
	Trawl	2.70	-	-	1.99	0.93	1.38	14.30	0.51	-	0.90
2016	Polyvalent	0.86	0.35	1.3854	0.34	0.09	2.28	29.87	0.49	10.45	0.02
	Trawl	3.62	-	-	3.68	0.70	0.95	12.26	1.26	-	0.40
2017	Polyvalent	1.73	0.43	0.775	0.55	0.09	2.43	33.04	0.58	7.35	-
	Trawl	2.71	-	-	2.78	1.12	0.57	12.09	1.41	-	0.46
2018	Polyvalent	0.54	0.19	0.4024	0.20	0.02	1.02	35.40	0.52	4.50	0.00
	Trawl	1.58	-	-	1.07	1.10	0.60	9.66	0.28	-	0.09
2019	Polyvalent	0.49	0.23	0.3601	0.31	0.03	0.49	17.35	0.95	6.25	-
	Trawl	0.63	-	-	0.58	0.44	0.35	6.08	0.02	-	0.66
2020	Polyvalent	0.90	0.14	0.3199	1.37	0.04	0.53	20.72	0.73	2.60	0.10
	Trawl	1.46	-	-	1.51	0.40	0.12	10.54	0.46	-	0.17

Preliminary data on age and growth of Ling (*Molva molva*) in ICES divisions 7.d–j

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The present document refers to an update of data provided by the UK (England & Wales) to the ICES WGDEEP 2021 as a preliminary baseline information on biological parameters of ling (*Molva molva*) in the Celtic Seas Ecoregion. Age estimates varied from 2 to 17 years. The estimated values of von Bertalanffy growth function for ling were L_∞ = 148.81 cm, K = 0.11 year^{-1} and t_0 = –2.19 year.

Introduction

Ling (*Molva molva*) is regularly found in the northern North Sea and along the continental margin to the West of the British Isles, with the principal spawning grounds observed in the Bristol Channel and Irish Sea (Ellis et al., 2012). Despite being considered a deep-water species, ling typically lives at 100-400 m but may occur as deep as 1000 m. Juveniles may be found in shallow areas, migrating into deeper waters with increasing size (Hislop et al., 2015).

Historically, reported landings of ling in ICES Subarea 7 indicate an increasing trend from the 1960s, reaching a maximum in 1980s (Vieira et al., 2019). Data from recent years have shown a marked decline and most landings are from Spanish, French and Irish longline fleets, although the species is also regarded as a valued bycatch in other fisheries (Hislop et al., 2015; ICES, 2020). For this reason, ling has not traditionally been considered an important commercial species compared to others and consequently has not been subject to routine biological sampling.

Age and growth estimation is important to study and assess the status of marine resources, but this parameter remains poorly known for most deep-sea species (Bergstad, 1995; Vieira et al., 2019). Owing to limited information of ling life-history parameters, no stock-management reference points are defined for this stock and a precautionary approach was advised in 2018 for stocks in ICES subareas 6–9, 12, and 14, and in divisions 3.a and 4.a (ICES, 2020).

Additionally, estimated age distributions for the entire stock is based on data from the Norwegian Reference fleet for all areas combined. Here, we evaluated the age and growth of ling, landed in UK (England) ports between 2011 and 2020 and caught in ICES divisions 7.d–j, aiming to provide additional biological data to support the development of analytical assessments.

Methods

Data was collected from the market sampling programme by Cefas observers between 2010 and 2020 under the European Union's Data Collection Framework (DCF). Otoliths from 2541 individuals were collected in different seasons from the region (divisions 7.d-j) between 2011-2020 for age determination (Table I). Total length (TL) of each fish was measured to the nearest centimetre (cm). One random otolith was selected from the pair and mounted on a prepared mould, covered with black polyester resin, and thin sections cut transversally through the nucleus with a single blade low speed saw (Struers Accutom 50). Otolith sections were read under a stereo microscope with a combination of reflected and transmitted lights, and at various magnifications.

The von Bertalanffy growth function (VBGF) was fitted for pooled data (combined sexes) following the equation:

$$L_t = L_\infty\left[1 - e^{-K(t-t_0)}\right]$$

where L_t is size-at-age t, L_∞ is the asymptotic length, K is a curvature parameter and t_0 is the age at which the fish have a theoretical length of zero.

Results and discussion

This preliminary assessment provides estimates of age and growth of ling *Molva molva* from southwestern areas of the British Isles (ICES divisions 7.d–j), through the analysis of annual growth increments deposited on sagittal otoliths.

Age estimates ranged from 2 to 17 years (48 to 142 cm total length), with sampled fish consisting mainly of individuals less than 9 years old (Figure 1). The estimated values of von Bertalanffy growth function for ling were L_∞ = 148.81 cm, K = 0.11 year^{-1} and t_0 = – 2.19 year

(Table II). Comparison of estimated growth parameters with those obtained from available literature (e.g. Grotnes and Hareide, 1989; Magnussen, 2007; Drazen and Haedrich, 2012; Hislop et al., 2015; Priede, 2017), showed that ling has a relatively slow growth rate.

For the analysed size range, relatively simple ageing techniques provided relatively precise age readings (~70% agreement between readings). However, data presented here does not include validation of age readings through the analysis of edge growth (annual marginal increments), which remains an important aspect for future analysis and intercalibration exercises (Bergstad et al., 1998).

Growth in ling was previously examined by Bergstad and Hareide (1996) from different ICES divisions (2.a, 4.a, 5.b, 6.a and 6.b) and Magnussen (2007) in the Faroe Bank (Figure 2). This study reported growth rates of the species that were similar to those from our growth model (age range = 4–15; L_∞ = 119 cm; K = 0.136 year^{-1}). The parameters estimated here are also similar to those currently used when simulating fish stocks to evaluate management procedures (WKLIFE, 2020), where the growth coefficient K is regarded the most important factor influencing the sensitivity analysis of the operating models used to test catch rules for data-limited stocks (Fischer et al., 2020).

Table I. Summary of length-at-age data for *Molva molva* aged using otoliths.

Year	N	Age (years)		Total length (cm)	
		Min	Max	Mean (S.D.)	Min-Max
2011	333	3	17	83.0 (± 13.27)	59-140
2012	268	2	12	83.4 (± 14.46)	48-130
2013	280	2	10	82.9 (± 11.61)	61-119
2014	193	2	9	87.6 (± 15.07)	52-129
2015	222	2	11	90.5 (± 16.18)	50-129
2016	298	2	12	86.0 (± 15.08)	57-142
2017	187	3	11	90.3 (± 13.89)	62-136
2018	266	2	12	89.0 (± 14.16)	49-133
2019	276	2	10	87.1 (± 13.30)	52-123
2020	218	2	9	80.9 (± 11.46)	56-130
Total	**2541**				

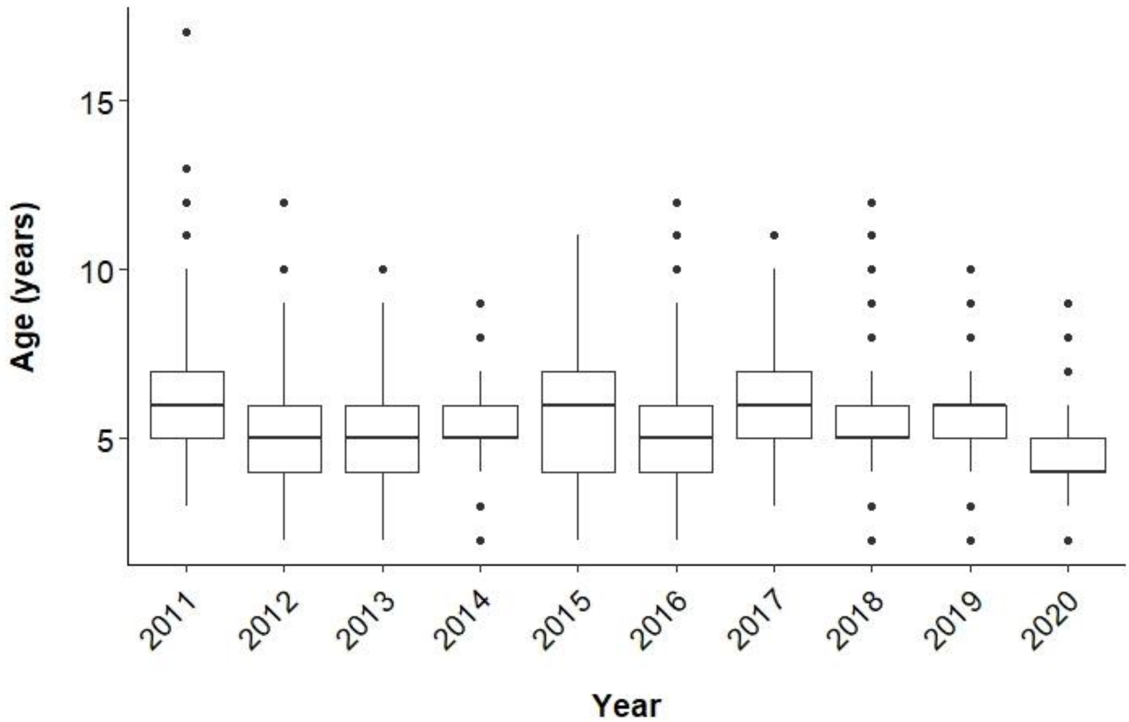

Figure 1. Age composition of *Molva molva* caught in ICES divisions 7.d–j between 2011-2020.

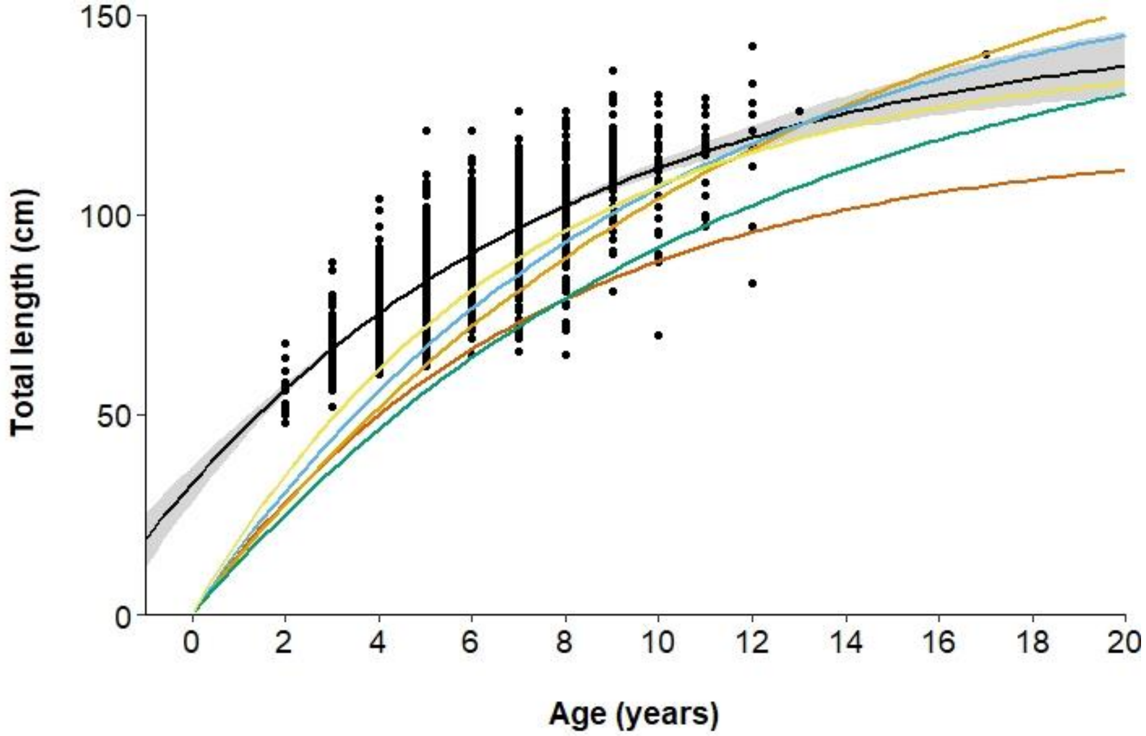

Figure 2. von Bertalanffy growth function for *Molva molva* caught in ICES divisions 7.d–j between 2011-2020, showing predicted mean lengths-at-age (black line) and the lower and upper confidence interval values for predicted mean lengths-at-age (shaded area). For comparison, growth functions extracted from literature are also shown: (—) Faroe Bank (Magnussen, 2007); (—) N. North Sea; (—) West of Scotland; (—) Rockall; (—) Norwegian Sea (based on data from Bergstad and Hareide, 1996).

Table II. Estimated parameters and bootstrap confidence intervals of von Bertalanffy growth function on data from ICES divisions 7.d-j between 2011-2020. L_∞ = asymptotic length (cm), K = growth coefficient (year^{-1}), t_0 = theoretical age when length is zero.

Estimated parameter		**2.5 % CI**	**97.5 % CI**
L_∞	148.81	135.61	168.13
K	0.11	0.09	0.15
t_0	–2.19	-2.84	-1.61

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The development of the Norwegian longline fleet's fishery for ling, tusk and blue ling during the period 2000-2020

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Introduction

Ling, tusk and blue ling were fished by Norway for centuries, and the amount landed has been recorded since 1896 (Figure 1). The major catches of these species are taken by longliners, and the catches are to a large degree bycatches. The fishery for these species is mainly influenced by the size of various quotas for other species, especially the quota for Arcto Norwegian cod. Therefore, total catch may not be a good indicator of the condition of these stocks (Figure 2).

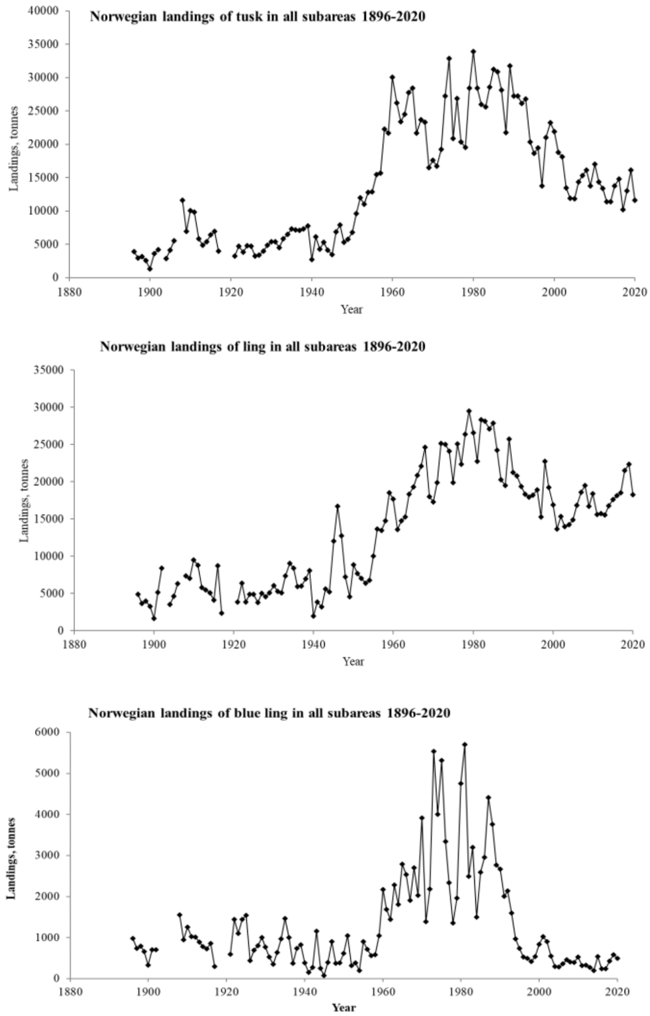

Figure 1. Reported Norwegian landings of tusk, ling and blue ling for the period 1896 -2020.

Scientific surveys do not cover the main habitats of ling, blue ling and tusk. Therefore, these stocks need to be monitored based on commercial data. One possible way to track their abundance, based only on commercial data, would be to develop a catch per unit of effort series for the fishery. But again, the major challenge for any cpue series: It is easy to generate a cpue series, and it is difficult to determine if the series track abundance.

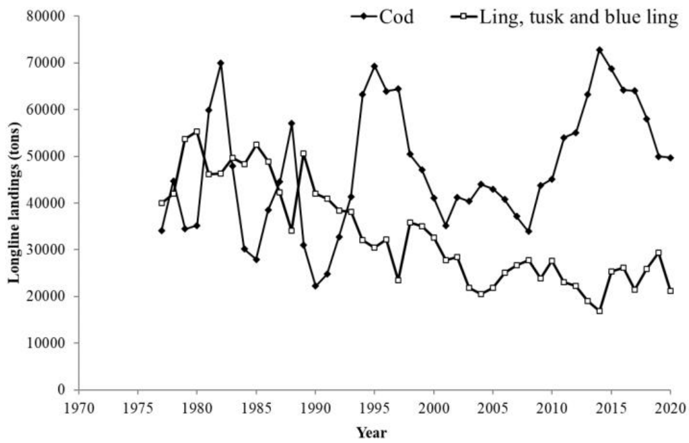

Figure 2. Total landings by longliners of cod (diamonds) and the combined total landings of ling, tusk and blue ling (open squares) for the period 1977- 2020.

Development of the Norwegian fleet of longliners, 1977- 2020

In addition to data on total landings*, the Norwegian Directorate of Fisheries (NDF) provides data on number of fishing vessels participated in the fishery, the gear employed, areas fished and changes in vessel ownership. In Table 1 are; the number of long liners during the period 1977 to 2020, the total landed catch by the fleet, and the average annual catch per vessel. The number of vessels increased from 36 in 1977 to a peak of 72 in 2000, and after that the number decreased to 25 in 2014-2017, the last few years the number of vessels have increased again and in 2020 there were 30 vessels fishing more than 8 tons ling, tusk and blue ling.

The number of vessels declined mainly because of changes in the law concerning the quotas for cod. The decrease the number of vessels was accompanied by a decrease in total catches until 2004; afterwards, the landings have been varying but stable (Figure 3a). The catch-per-vessel was relatively stable from 1980 until 2003. In the period 2003- 2019 there was a steady increase in catch-per-vessel with a sharp decrease in 2020 (Figure 3b).

In 2012 new regulations were initiated and the number of cod quotas each vessel from 3 to 5. This caused a further reduction in the number of long-liners; from 36 in 2012, to 25 in 2015 to 2018. In 2020 there were 30 vessels.

a) b)

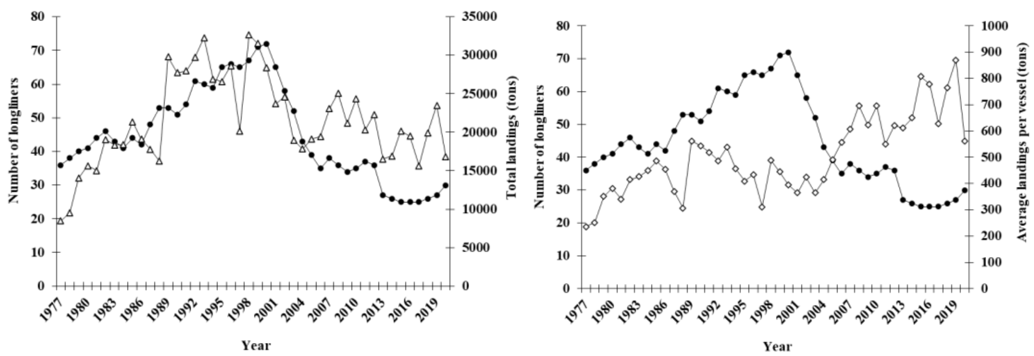

Figure 3. a) The number of long liners (filled circles) and the average landings per vessel of ling and tusk (open diamonds) in the period 1977-2020 and, b) the number of longliners and the total landings of ling and tusk (open triangles).

Logbooks

All available logbooks for the years 2000-2020 are now in the database, and the data have undergone extensive quality control procedures. The data for 2010 are incomplete because of problems getting some of the logbook data, both for the paper logbooks and for the electronic logbooks. In 2010, electronic logbooks were implemented for the longline fleet. The Norwegian Directorate of Fisheries has received the data, but because of lack of quality control, the 2010 data will not be released. Some fishermen didn’t send paper logbooks because they had delivered the data electronically. Because of this, logbooks from only 11 of 35 vessels are available for 2010. The quality of the logbooks varies considerably, and a serious problem is that some lack information on the number of hooks used per day. The data from 2011 are almost complete with data from 35 of 37 vessels. In 2012 to 2020 all logbooks are available, though some days have been deleted due to punching errors.

Days in the fishery

The Norwegian longline logbooks provide information on the geographical distribution of the fleet. In Table 2 are the average number of days a vessel spent fishing for tusk, ling and blue ling, jointly or separately, for all ICES Subareas and Divisions. After 2000, when new quota regulations for cod were introduced, the number of days each vessel fished for three-deep-water species increased, and by 2005 the number of days in the fishery was twice that was in 2000. The data for 2006 show that the number of days in the fishery has decreased by more than 20 percent compared with 2005 and 2007. The data were checked for errors, but none were discovered. The number of fishing days has trended downward since 2007, most

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[*] The data provided by the NDF are; the total landed catch, the logbook data, and the catch along with its location.

likely because of the record large stock of Arcto Norwegian cod. This trend changed dramatically in 2019 when the number of fishing days per vessels increased from 134 days in 2018 to 192 days in the tusk fishery and in the ling fishery it changed from 94 in 2018 to 125 in 2019. However, in 2020 the total number of fishing days had declined to 147.

Division 2a has been the main fishing grounds since 2000, followed by 4a and 5b (Table 2).

Average number of hooks per day

Table 3 are estimates of the average number of hooks used per day in each ICES area and in the total fishery for the 2000-2020. For all areas combined, there was a steady increase in the number of hooks used from 2000 through 2009. This is also the general trend for subareas (Figure 4). The combined time series for 1972-1994 (Bergstad and Hareide, 1996) and the series based on data from 2000-2012 show that the average number of hooks has increased from 10 000 hooks per day in 1972 to around 38 200 in 2020 (Figure 6).

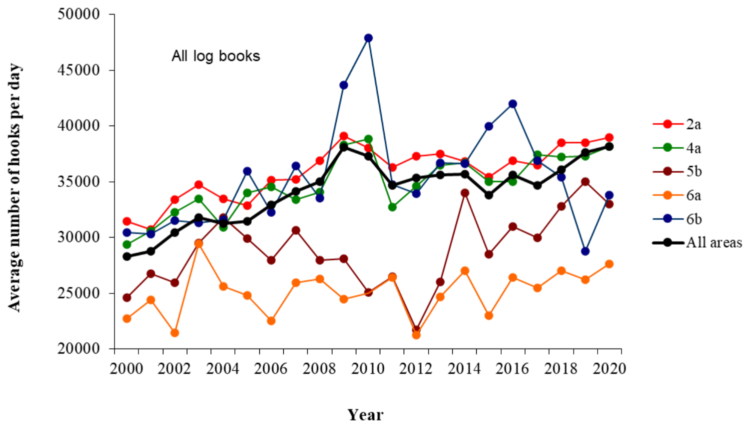


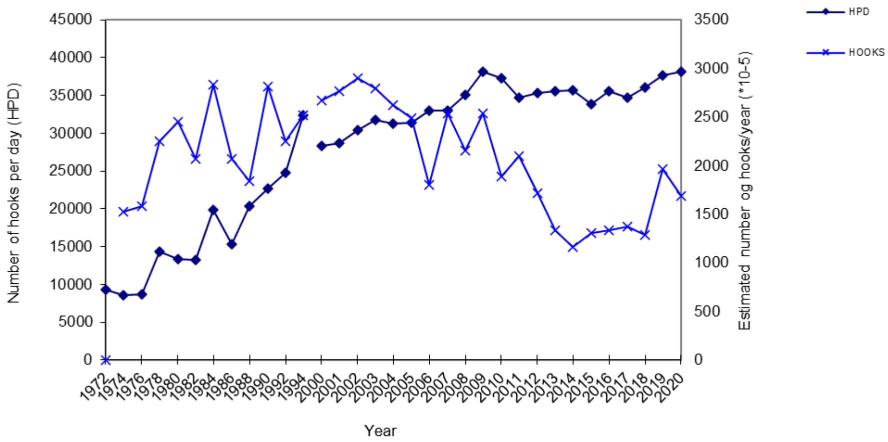
Figure 4. Average number of hooks the Norwegian longliner fleet used per day in each of the ICES subareas and in the total fishery for the years 2000-2020 for the fishery for tusk, ling and blue ling.

Total number of hooks per year

Based on the number of vessels, the number of hooks per day, and the number of days each vessel participated in the fishery, estimates of the total number of hooks used per year were generated (Tables 1, 2 and 3). Table 4 and Figure 5 show the estimated number of hooks (in thousands) set in each of the ICES subareas and in the total for all areas for the years 2000-2020. During the period 1974 to 2013 the total number of hooks per year has varied considerably, after this the number of hooks per year have been stable but with ab increase in 2019 and 2020 (Figure 6).

The total number of hooks per year takes into account; the number of vessels, the number of hooks per day, and the number of days each vessel participated in the fishery, may be a suitable measure of tracked applied effort. Based on this measure of effort, it appears that the average effort for the years 2011-2020 is 40% less than the average effort during the years 2000-2003.

a.



b.

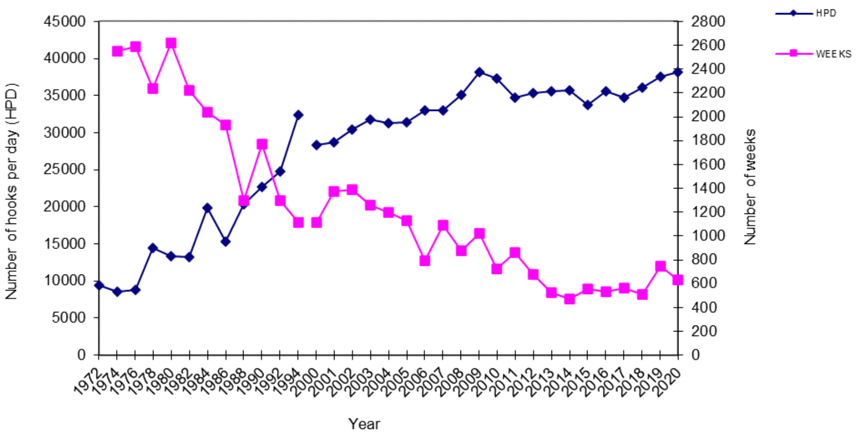


Figure 5. The combined time series for 1972-1994 (Bergstad and Hareide, 1996) and the series based on data from 2000-2020: a) The numbers of hooks used per day, and the total number of hooks used per year; b) The numbers of hooks used per day, and the total number of weeks the long liners participated in the fishery for ling and tusk.

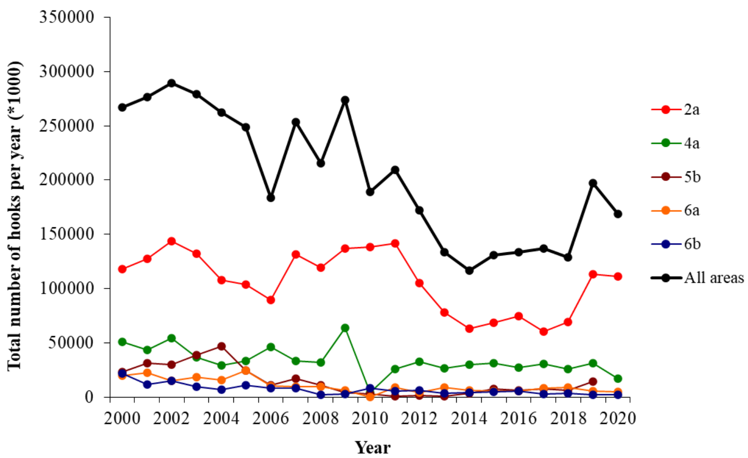


Figure 6. Estimated total number of hooks (in thousands) the Norwegian longliner fleet used in the ICES subareas with highest catches and in the total fishery for the years 2000-2020 for the fishery for tusk, ling and blue ling.

The size of the vessels

There was a steady increase in the average size of the vessels from 34 m in 1977 to 45.4 m in 2020. Figure 7 show the average size of the vessels and the smallest and the largest vessel in the fleet for the period 1977 to 2020.

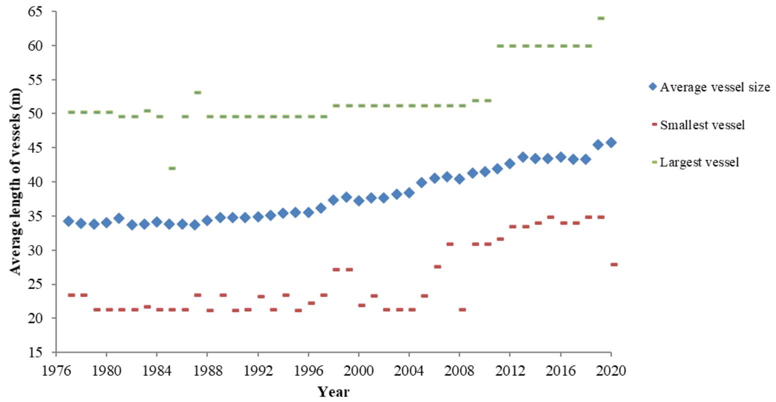


Figure 7. Average size of longliners >21 m for the period 1977-2020.

Fishing area

Approximately 65-70% of the commercial catches of ling are taken by vessels using demersal longlines, either target species or bycatch (Helle and Pennington, 2015), and the remains are taken by mainly gillnets but also some by trawlers. Although the tusk fishery takes place from Rockall to the southern Barents Sea (Helle and Pennington, 2004), between 70 to 80 percent of the catches by Norwegian vessels are from the Norwegian Economic Zone.

Figure 8 show all the catches of ling registered in the electronic logbooks by longliners in 2013-2020 in areas 1 and 2.

Tusk are mainly fished by longliners (approximately 90 percent of the total catch). Figure 9 show all catches of tusk registered in the electronic logbooks by longliners in Areas 1 and 2 during the period 2013 to 2020.

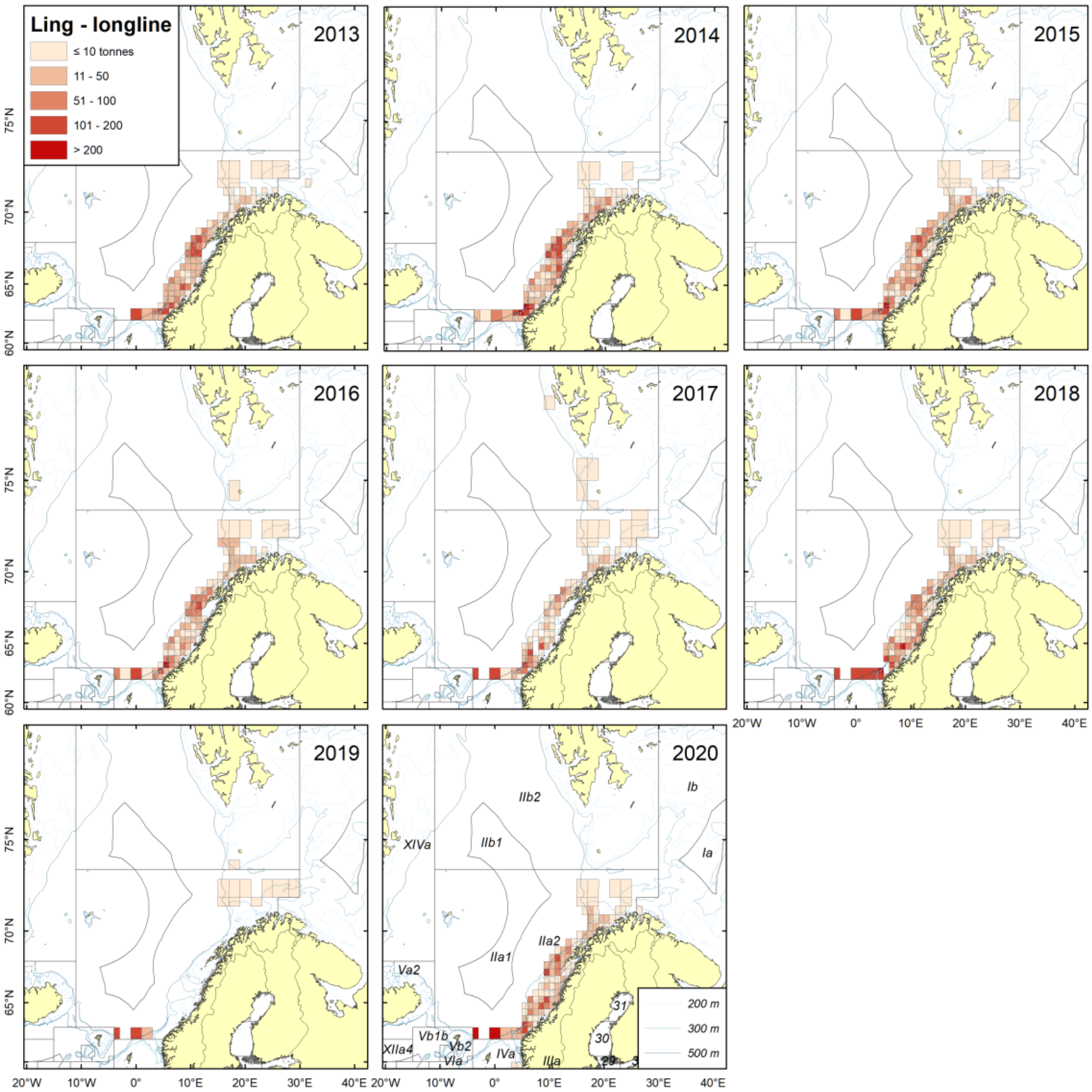


Figure 8. Distribution of the catches using longlines by the Norwegian fishery for ling in 2013 to 2020 in areas 1 and 2.

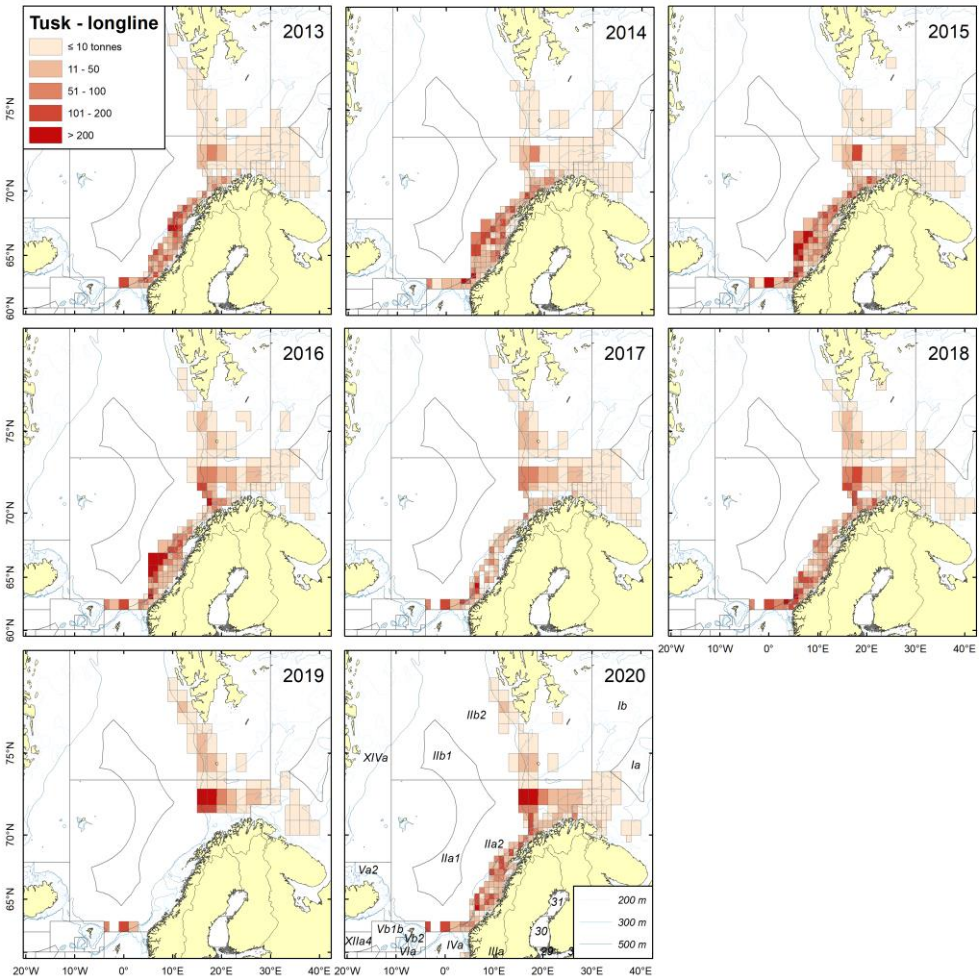


Figure 9. Distribution of the catches using longlines by the Norwegian fishery for tusk in 2013 to 2020 in areas 1 and 2.

CPUE

Based on methods described in Helle *et al*., 2015 to derive a cpue series were for ling and tusk calculated two ways; using all data available and catches for which ling and tusk were targeted (>30 percent of the daily total catch).

In Figures 11 and 13 are plots of the estimated cpue series for the most important ICES subareas for ling and tusk: based on all the available data, and a cpue series based on only those catches that ling or tusk appear to be targeted; included plots of estimated 95% confidence intervals.

Ling:

Both cpue series for ling in Area 2a indicate an upward trend for until 2017. After 2017, there have been a declining trend.

In Areas 4a there was a steady increase in cpue from 2002 until 2016 and were down in 2017 and 2018 but with a slight increase in 2019 and 2020.

In 6a and 6b there were also a positive trend from 2002 to 2016 with decreasing from 2017 to 2019. In 2020 there were a large increase in area 6a for both series.

When all ling data for Areas 3.a, 4, 6, are combined for a cpue series, and ling was targeted a cpue series, both indicate a steady increase since 2003 to 2017 and then a decline in 2018. In 2020 there were an increase. This increase is driven by an increase in areas 4a and 6a (Figure 12).

Tusk:

Both cpue series in Area 2a are relative stable since 2011.

The series in Area 4a based on all the catches indicates at first a stable series and then a slightly decreasing trend for the last four years, while the series based on the targeted fishery shows a clear and positive upward trend from 2002 until 2013, after this there was a declining trend, and this trend is especially clear for the targeted fishery.

The series in Area 5b shows a stable trend from 2000 to 2008, afterwards it increased until 2012, then decreased until 2017 and a relatively large increase in 2018 and a small decrease in 2019 and 2020.

In area 6a a cpue series based on the Norwegian longline data shows an increase in cpue from 2004 to 2008, afterwards it has remained at a high and slightly increasing level when all data are used, and a sharp increase from 2018 to 2019 for the targeted fishery followed by a decrease in 2020 (Figure 13).

The combined cpue series for areas 4a, 5b and 6a. shows an increasing trend from 2000 to 2010, after 2010 cpue was at a high and stable level, declined in 2017 but increased again in 2018 and 2019 with a decrease in 2020.

The cpue series for Area 6b when all data were used, a catch from longliners show a decrease from 2000 to 2006. After 2006, the cpue was low but at a stable level. There was no or insignificant direct fishery for tusk the last years.

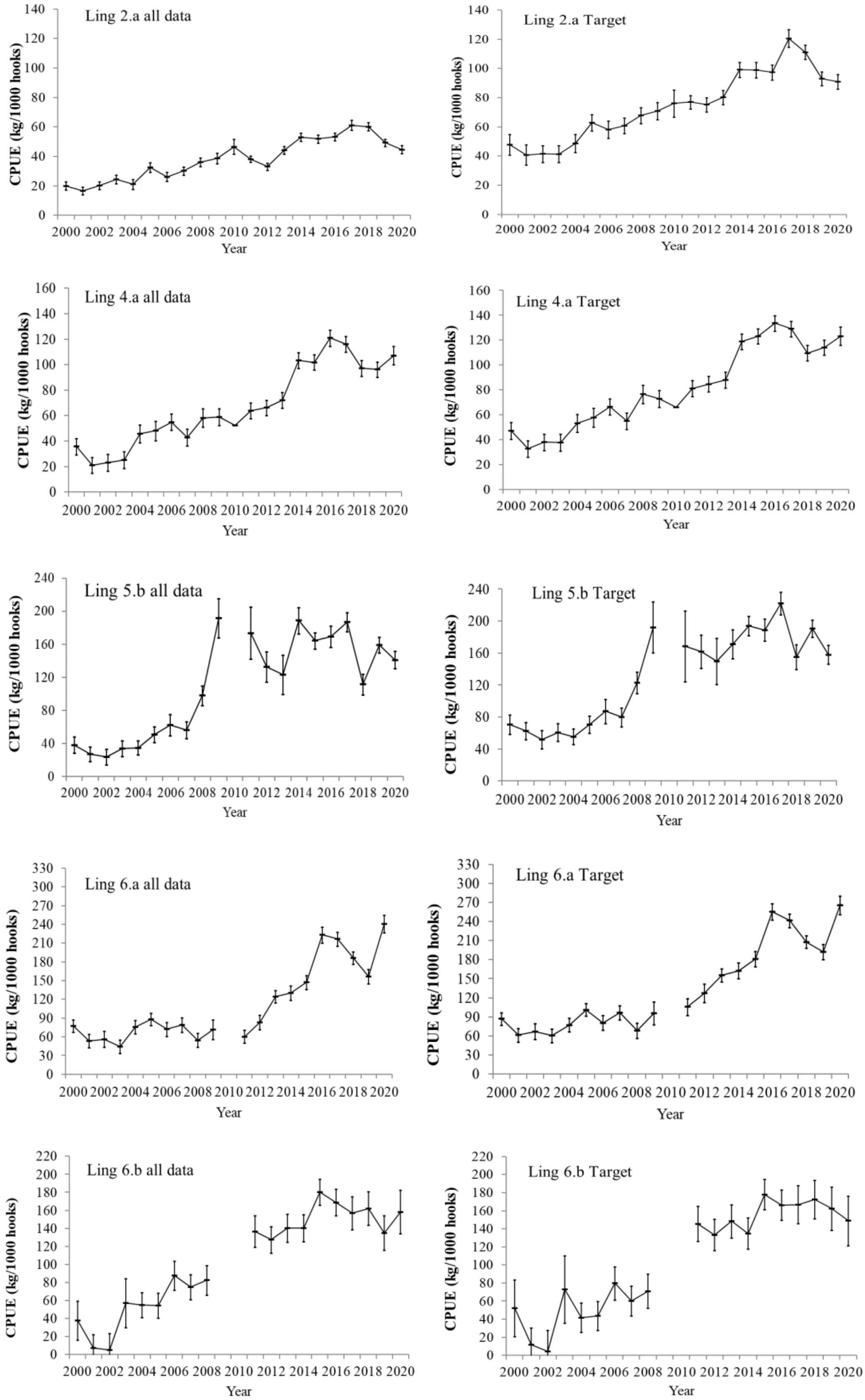


Figure 11. Estimated cpue (kg/1000 hooks) of ling in Subareas 2a, 4a, 5b, 6a and 6b based on skipper’s logbooks during the period 2000-2020. The bars denote the 95% confidence intervals.

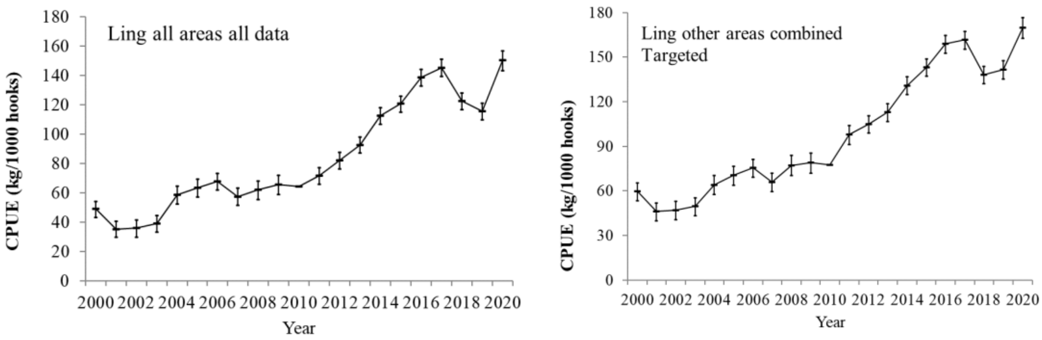


Figure 12. Ling areas combined (3, 4, 6) based on skipper's logbooks during the period 2000-2020. The bars denote the 95% confidence intervals.

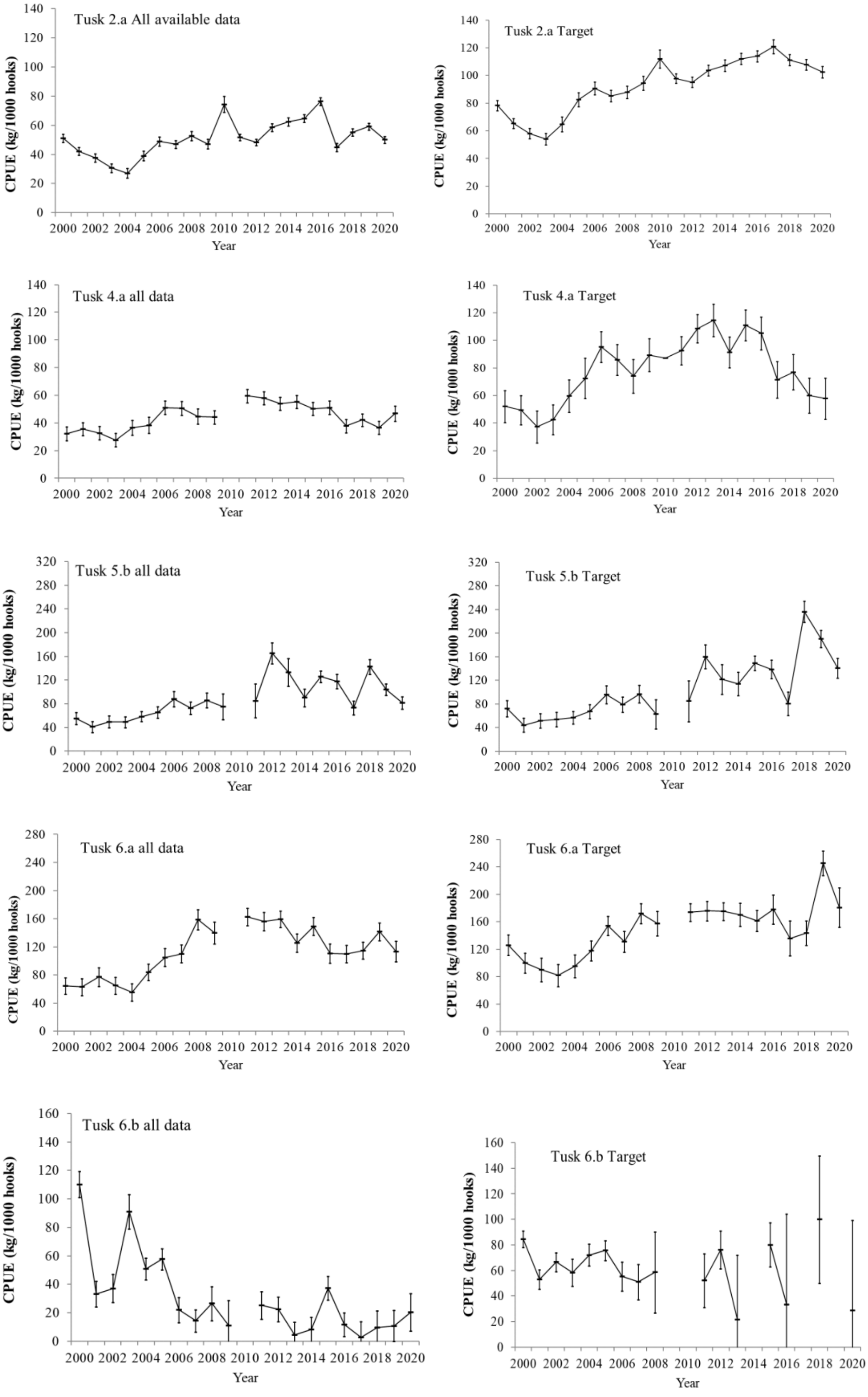


Figure 13. Estimated cpue (kg/1000 hooks) of tusk in Subareas 2a, 4a, 5b, 6a and 6b based on skipper's logbooks during the period 2000-2020. The bars denote the 95% confidence intervals.

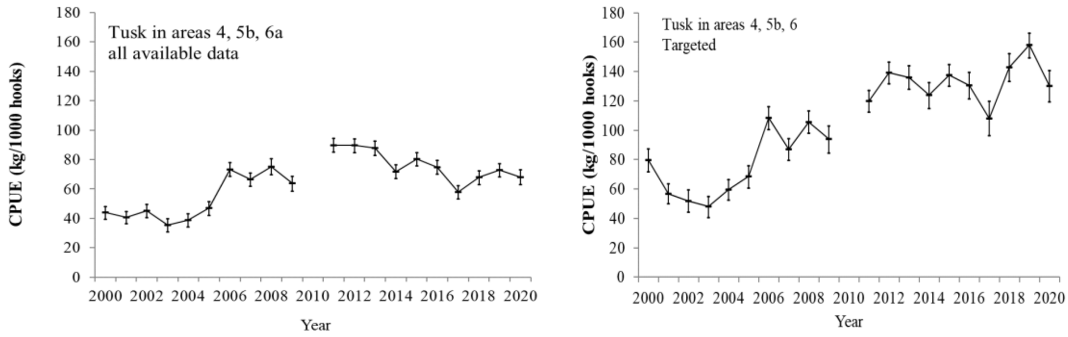


Figure 14. Tusk in other areas combined (4, 5b, 6a) based on skipper's logbooks during the period 2000-2020. The bars denote the 95% confidence intervals.

Blue ling

The cpue series for blue ling based on longline data shows a low and stable level for the Areas 1, 2, 3a and 4. Although there were no direct fishery in these areas, the stock doesn't seem to show any recovery.

A low and steady population for blue ling were in subareas 5a and 14 and in Areas 5b, 6 and 7. When only data from 6a, there was a positive trend from 2004 to 2015, after this the trend has been declining.

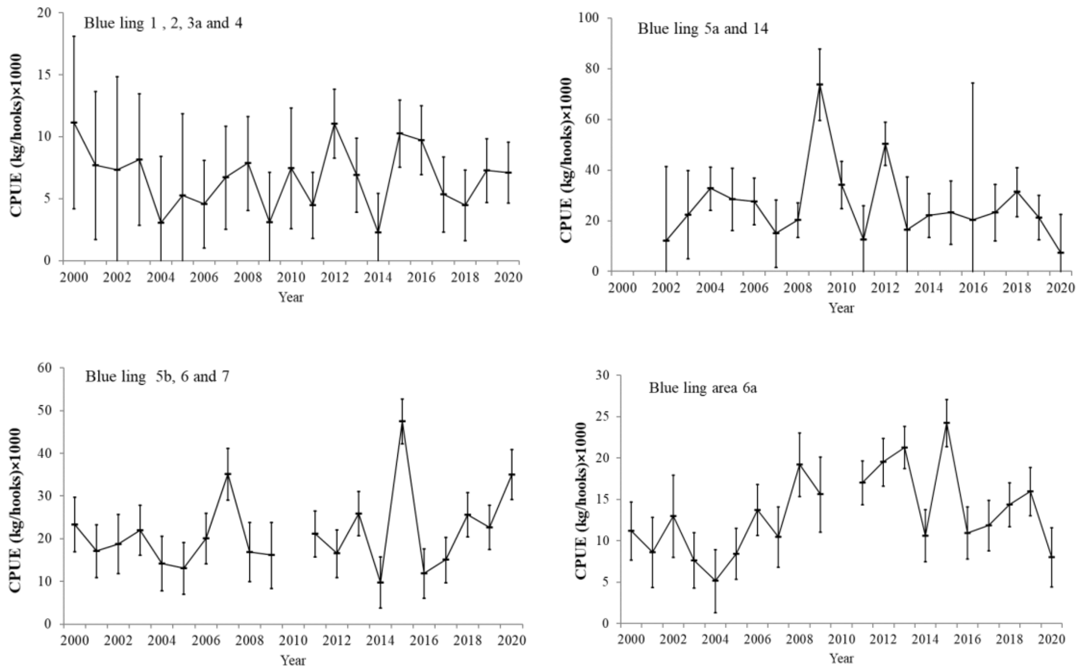


Figure 15. Estimated cpue (kg/1000 hooks) of blue ling in Subareas: 1, 2, 3.a; 4, 5.a; 14, 5.b, 6; 7; and in Subarea 6.a. All data from skipper's logbooks during the period 2000-2020. The bars denote the 95% confidence intervals.

Conclusions and discussion.

Legislation enacted since 2000 for regulating the cod fishery caused a continuous reduction in the number of longliners in the fishery for tusk, ling and blue ling, and by 2009, there were only 34 vessels above 21m in the fishery. Due to recent regulations, the number of vessels were 26 in 2018 and increased to 30 in 2020. Because of this decrease the number of vessels were 58 % fewer since 2000, the total number of hooks employed reduced, the total number of weeks fished, and until 2020, there were a significant reduction in effort. Compared with 2000, a decrease in total effort has occurred even though there was an increase in the number of hooks set per vessel/day until 2020. The large increase in effort in 2019 is probably due to reduction in cod quotas. This fishery should be monitored and reported to prevent overfishing (Figures 5 and 6).

During the period 1998 through 2003, the total landings declined from 32 675 to 19 000 tons, while the catch-per-vessel remained relatively constant. The total catches were stable during the years 2004 through 2006, but after that, there was a sharp increase in 2007 and 2008. The average catch-per-vessel has increased considerably during 2003- 2008, afterwards the catch has been relatively stable.

It should be noted that using the total landings as a measure of stock development can be very misleading. For example, there is a negative correlation between the landings of cod and the total landings of ling, blue ling and tusk (Figure 2), which is due to cod being the most valued species. Therefore, the decrease in total landings does not indicate a reduced stock size, but only an increase in cod quotas.

If a stock is not covered by a scientific survey, then a commercial cpue index is often used to track temporal trends in abundance. It is widely recognised that caution must be used when interpreting a cpue series based on commercial catch data. But by considering: the application and distribution of fishing effort; species specific knowledge, such as when a species is targeted or if it is a preferred species; patterns in the total catch by fleet and by vessel; etc., then based on all these factors, a reliable assessment of a stock’s condition.

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Table 1. Summary statistics for the Norwegian longliner fleet during the period 1995-2019 (vessels exceeding 21m).

Year	Number of longliners	Total landed catch by fleet	Catch per vessel (Tons)
1977	36	8471	235
1978	38	9563	252
1979	40	14038	351
1980	41	15651	382
1981	44	15002	341
1982	46	19079	415
1983	43	18338	426
1984	41	18398	449
1985	44	21364	486
1986	42	19080	454
1987	48	17788	371
1988	53	16253	307
1989	53	29816	563
1990	51	27726	544
1991	54	27979	518
1992	61	29718	487
1993	60	32290	538
1994	59	26908	456
1995	65	26571	409
1996	66	28645	434
1997	65	20173	310
1998	67	32675	488
1999	71	31528	444
2000	72	28391	394
2001	65	23681	364
2002	58	24619	424
2003	52	18969	365
2004	43	17815	414
2005	39	19106	490
2006	35	19475	556
2007	38	23060	607
2008	36	25069	696
2009	34	21158	622
2010	35	24360	696
2011	37	20344	550
2012	36	22302	620
2013	27	16522	612
2014	26	16907	650
2015	25	20189	808
2016	25	19478	779
2017	25	15663	627
2018	26	19895	765
2019	27	23498	870
2020	30	16827	561

Table 2. Average number of days that each Norwegian longliner operated in an ICES subarea/division.

All species	1	2a	2b	3a	4a	4b	5a	5b	6a	6b	7c	12	14b	All areas
2000	9	54	2	+	24	2		13	12	10	2	+	6	131
2001	5	64	9		22		1	18	14	6	1	5	3	148
2002	10	74	2		29			20	12	8		1	8	164
2003	12	73	3	1	21	1	3	25	12	6		3	9	169
2004	20	75	11		22		2	34	14	5	1	1	9	195
2005	23	81	14		25		2	21	25	8	0,4		5	203
2006	11	73	3		38		3	11	13	7				159
2007	15	101	21		27	3	2	15	10	6	1			201
2008	7	90	18	1	26		4	11	10	2			2	171
2009	19	103	20	1	49	1	2	4	7	2			3	211
2010	8	104	13		3		1	3		5			5	145
2011	12	103	4		21	3	2	1	9	4				159
2012	9	78	4		26	1	2	2	5	5	1		2	135
2013	6	63	2		22	2	2	1	11	4			1	114
2014	5	66	2		31	1	2	4	9	4			2	126
2015	8	77	4		36	1	2	11	9	5			2	155
2016	4	81	7		31	1	2	8	8	5			3	150
2017	12	66	15		33		2	10	13	3			4	158
2018	4	69	6		27	1	2	7	13	4			4	137
2019	5	109	14		31	1	2	15	8	3			6	194
2020	6	95	7		15		2	11	6	2			3	147

Tusk	1	2a	2b	4a	4b	5a	5b	6a	6b	7c	12	14b	All areas
2000	3	34	1	18	1		11	12	4	2	1	2	88
2001	1	57		22		1	18	14	6	1	3	1	124
2002	5	66	2	28			20	12	8			2	141
2003	5	58		19	2	3	25	12	5			1	130
2004	6	60	1	21		2	34	14	5	1		3	148
2005	5	69	2	25		2	21	23	8	0		3	158
2006	1	67	1	37		3	11	13	7				140
2007	5	89	3	26		2	15	10	6	0			157
2008	4	92	4	30		4	14	15	5				169
2009	6	87	2	56	2	2	4	7	2			1	159
2010	4	93	2	2		3			4			2	112
2011	12	103	4	21		2	1	9	4				155
2012	9	78	4	25		2	2	5	4	1		2	132
2013	6	63	2	22		2	1	11	3			1	111
2014	5	66	2	31		2	4	9	3			2	125
2015	8	77	4	36	1	2	11	9	5			2	154
2016	4	81	7	30		2	8	8	5			3	148
2017	12	66	15	31		2	10	13	2			3	154
2018	4	69	6	26		2	7	13	3			4	134
2019	5	109	14	30	1	2	15	8	2			6	192
2020	6	95	7	15		2	11	6	2			3	146

Ling	2a	3a	4a	4b	5a	5b	6a	6b	7c	14b	All areas
2000	23	+	19	1		12	13	4	3		76
2001	40		22	+	1	17	13	5	1		100
2002	50		29			18	11	7			114
2003	40	1	20	1	3	24	12	4			104
2004	37		22		2	34	14	5	1		115
2005	51		25		2	21	23	8	+		126
2006	54		38		3	11	13	7			126
2007	65		27	3	2	15	10	6	1		128
2008	52	1	25		4	11	9	2			104
2009	65	1	49		2	4	7	2			130
2010	70		3		3			7			83
2011	73		21	3	4	2	8	4			113
2012	59		26	1	2	2	5	5	1		98
2013	44		22	1	2	1	11	4			85
2014	53		31	1	2	4	9	4		1	106
2015	54		37	1	2	11	9	5		1	122
2016	55		31	1	2	7	8	5		1	111
2017	27		33		2	10	13	3			88
2018	41		27	1	2	6	13	4			94
2019	66		31	1	2	14	8	3			125
2020	47		15		2	10	6	2			83

Blue ling	2a	4a	5a	5b	6a	6b	12	14b	All areas
2000	1	1		4	9	1	2	+	18
2001	1	+	1	3	6	1	5		15
2002	1	1		4	4	2		+	11
2003	1		1	5	8	2	2	+	14
2004	+	1	2	5	6	+		+	14
2005	+	1	1	1	10			+	14
2006	1	2	2	4	8	+			18
2007	1	2	1	5	6	1			16
2008	2	4	3	4	10			1	25
2009	1	4	2	3	6			1	17
2010	2	1	2					2	7
2011	2	2		1	7				12
2012	1	2		2	5			1	12
2013	1	2		1	8				13
2014	1	3	1	2	5	1		1	12
2015	3	4	1	5	7				20
2016	1	4		3	6				15
2017	1	3		5	7			1	17
2018	1	3		4	8			1	17
2019	4	3		6	6			2	21
2020	6	4		3	4				17

Table 3. Average number of hooks that the Norwegian longliner fleet used per day in each of the ICES subareas/divisions and in the total fishery for the years 2000-2016 in the fishery for tusk, ling and blue ling. n is the total number of days with hook information contained in the logbooks.

All		**1**	**2a**	**2b**	**3a**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7c**	**12**	**14b**	**All areas**
2000	**Average**	31688	31439	35409	30250	29378	30263		24594	22763	30471	29600	18136	2815	28325
	n	353	1916	71	4	685	38		411	435	227	80	22	191	4429
2001	**Average**	33325	30703	34638		30553	33500		26760	24419	30340	33108	17548	2465	28743
	n	163	2196	315		727	10		613	447	140	37	175	135	4958
2002	**Average**	35432	33431	34756		32291	33867		25939	21484	31557			9458	30432
	n	263	2031	45		667	15		475	186	149			251	4083
2003	**Average**	35045	34766	34776	33037	33484	32559	22605	29513	29421	31325		13063	11515	31794
	n	376	1839	67	27	510	34	38	515	302	97		48	228	4081
2004	**Average**	32431	33475	31859		30934		25815	31804	25636	31559	25250		12474	31285
	n	433	1389	217		439		54	693	308	111	28		105	3777
2005	**Average**	32671	32861	35082		34039		23100	29885	24807	35949	33429		18960	31438
	n	316	1248	207		331		30	374	369	137	7		91	3110
2006	**Average**	33182	35140	39298		34561		21526	27943	22504	32273				32959
	n	187	1252	57		673		57	159	248	139				2711
2007	**Average**	34380	35207	37881	35000	33414	38086	25414	30681	25958	36400	31071			34110
	n	318	2103	328	8	587	58	58	355	249	145	14			4223
2008	**Average**	36833	36890	39650	36467	34056	31500	32704	27968	26319	33514			9464	35042
	n	96	1500	297	15	395	10	71	188	138	35			45	2790
2009	**Average**	39184	39142	43744	34636	38299	30167	26106	28123	24455	43645			7034	38127
	n	267	1419	281	11	680	6	33	57	99	31			38	2922
2010	**Average**	40519	38057	41607		38838		20182	25067		47904			7672	37296
	n	19	1089	135		37		11	30		52			58	1491
2011	**Average**	37205	36260	35280	35275	32737	37343	28062	26492	26424	34727			25750	34668
	n	411	3622	126	8	740	104	63	24	310	137			4	5549
2012	**Average**	36434	37298	38357		34639		33647	21702	21249	33934	39064		9091	35381
	n	307	2817	157		933		68	63	196	176	22		59	4765
2013	**Average**	39500	37500	42000		36500	43000	30900	26000	24700	36700	31000		27500	35600
	n	211	2073	81		710	34	69	34	351	132	10		36	3678
2014	**Average**	37699	36782	39660		36715	44614	35015	34000	26979	36551			22374	35676
	n	112	1501	44		707	22	46	101	214	97			65	2909
2015	**Average**	36100	35400	43500		35000	40800	31600	32400	30700	29000			29800	33800
	n	209	1902	91		908	33	54	276	222	130			53	3878
2016	**Average**	40000	36900	42000		35000	35000	37000	31000	26400	42000			31400	35600
	n	100	2025	175		775	25	50	200	200	125			75	3750
2017	**Average**	41700	36500	43000		37400	40300	33700	30000	25500	36900			25400	34700
	n	302	1660	374		815	11	54	260	320	78			89	3963
2018	**Average**	42800	38500	42000		37200	44500	42600	32800	27000	35400			35400	36100
	n	99	1776	142		692	34	51	148	295	96			105	3738
2019	**Average**	43000	38500	44300		37300	43800	38400	35000	26200	28800			26800	37600
	n	123	2956	381		842	31	63	393	218	79			172	5258
2020	**Average**	44600	39000	45900		38200		41400	33000	27600	33800			23300	38200
	n	168	2853	221		464		59	315	181	56			88	4405

Table 4. Estimated total number of hooks (in thousands) that the Norwegian longliner fishery for tusk, ling and blue ling used in each of the ICES subareas/divisions and in the total area for the years 2000-2020.

All	**1**	**2a**	**2b**	**3a**	**4a**	**4b**	**5a**	**5b**	**6a**	**6b**	**7c**	**12**	**14b**	**All areas**
2000	20534	117708	5099	218	50765	4358		23020	19667	21939	4262	1306	1216	267161
2001	10831	127724	20263		43691			31309	22221	11833	2152	5703	481	276508
2002	20551	143486	4032		54313			30089	14953	14642			4389	289469
2003	21868	131972	5425	1718	36565	1693	3526	38367	18359	9773		2038	5389	279406
2004	27891	107957	15069		29264		2220	46497	15433	6785	1086		4827	262325
2005	29306	103808	19155		33188		1802	24476	24187	11216	521		3697	248895
2006	12775	89783	4126		45966		2260	10758	10239	7907				183567
2007	19081	131569	29434		33381	4228	1881	17028	9604	8081	1150			253676
2008	9282	119524	25693	1313	31876		4709	11075	9475	2413			681	215719
2009	25313	137075	29746	1178	63806	1026	1775	3825	5820	2968			717	273523
2010	11345	138527	18931		4078		706	2632		8383			1343	189277
2011	16965	141922	5363		26124	4257	2133	1007	9037	5279				209464
2012	11805	104733	5523		32422	1230	2423	1566	3825	6108			655	171952
2013	7821	77963	2772		26500	1419	2039	858	8966	3633			1815	133752
2014	4901	63118	2062		29592	1160	1821	3536	6313	3801			1163	116875
2015	7220	68145	4350	0	31500	1020	1580	8910	6907,5	3625	0	0	1490	130975
2016	4000	74722	7350	0	27125	875	1850	6200	5280	5250	0	0	2355	133500
2017	12510	60225	16125	0	30855		1685	7500	8288	2768	0	0	2540	137065
2018	4451	69069	6552	0	26114	1157	2215	5970	9126	3682	0	0	3682	128588
2019	5805	113306	16745	0	31220	1183	2074	14175	5659	2333	0	0	4342	196949
2020	8028	111150	9639	0	17190	0	2484	10890	4968	2028	0	0	2097	168462

Working Document to be presented to the Working Group on the
Biology and Assessment of Deep Sea Fisheries Resources

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Results on greater forkbeard (*Phycis blennoides*), Spanish ling (*Molva macrophthalma*), roughsnout grenadier (*Trachyrincus scabrus*), bluemouth (*Helicolenus dactylopterus*) and other scarce deep water species on the Northern Spanish Shelf Groundfish Survey

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Abstract

This working document presents the results on the most significant deep fish species on the Spanish Groundfish Survey on the northern Spanish shelf in 2020. Biomass, abundance, length distributions and geographic ranges were analysed for greater forkbeard (*Phycis blennoides*), Spanish ling (*Molva macrophthalma*), roughsnout grenadier (*Trachyrincus scabrus*), bluemouth (*Helicolenus dactylopterus*) and other scarce deep sea species. The biomass of *M. macrophthalma* and *T. scabrus* decreased whereas *P. blennoides* and *H. dactylopterus* increased. *Aphanopus carbo, Beryx spp*. and *Pagellus bogaraveo* were scarce as usual and *Coryphaenoides rupestris* was not found in this last survey.

Introduction

The bottom trawl survey on the Northern Spanish Shelf has been carried out every autumn since 1983, except in 1987, to provide data and information for the assessment of the commercial fish species and the ecosystems on the Galician and Cantabrian shelves (ICES Divisions 8c and 9a North).

The aim of this working document is to update the results (abundance indices, length frequencies and geographic distribution) of the most common deep water fish species on the bottom trawl surveys on the Northern Spanish Shelf after the results presented previously (Blanco *et al*. 2019, Fernández-Zapico *et al*. 2020). The species analyzed are *Phycis blennoides* (greater forkbeard), *Molva macrophthalma* (spanish ling), *Trachyrincus scabrus* (roughsnout grenadier), *Helicolenus dactylopterus* (bluemouth), and some other scarce species as *Aphanopus carbo* (black scabbardfish), *Coryphaenoides rupestris* (roundnose grenadier), *Beryx spp.* (alfonsinos) and *Pagellus bogaraveo* (blackspot seabream). Although results on *Helicolenus dactylopterus* were not included in the ICES data call, they are also updated considering its remarkable abundance and geographical distribution in the surveyed area, and the fact that these indices were used in the WGDEEP report when reviewing the abundance and status of the stock on the north-eastern Atlantic.

Material and methods

The area covered in the Northern Spanish Shelf Groundfish Survey on the Cantabrian Sea an Off Galicia (Divisions 8c and Northern part of 9a; SPNGFS) extends from longitude 1° W to 10° W and from latitude 42° N to 44.5° N, following the standard IBTS methodology for the western and southern areas (ICES, 2017). The sampling design is random stratified with five geographical sectors (MF: Miño-Finisterre, FE: Finisterre-Estaca de Bares, EP: Estaca de Bares - Peñas, PA: Peñas - Ajo, AB: Ajo - Bidasoa) and three depth strata (70-120 m, 121-200 m and 201-500) (Figure 1, ICES, 2017). The shallower depth stratum was changed in 1997 from 30-100 m to 70-120 m, due to the small area and scarcity of trawlable shallower grounds.

Nevertheless, some extra hauls are carried out every year, if possible, to cover shallower (<70 m) and deeper (>500 m) grounds. These additional hauls are plotted in the distribution maps, although they are not included in the calculation of the stratified abundance indices since the coverage of these grounds (shallower and deeper) are not considered representative of the area. However, the information from these depths is considered relevant due to the changes in the depth distribution of fishing activities in the area (Punzón et al. 2011) and these hauls are also used to define the depth range of the species.

The standardized indices of the deep water fishes analyzed in this report probably underestimate its real biomass due to the fact that most of its catches might happen out of the standard stratification area, in additional hauls deeper than 500 m. For this reason, the catches in standard and deeper additional hauls were plotted in this report.

Results

This last survey was carried out under the COVID-19 pandemic situation, therefore participants were decreased and the objectives were rearranged. Nonetheless, 123 valid hauls were carried out, 109 of these were standard hauls and 14 additional hauls (2 of them shallower than 70 m and 12 of them between 500 m and 800 m) (Figure 1).

The total stratified catch per haul increased considerably in 2020, recovering the high values of the time series (Figure 2).

In 2020, as usual, most of the biomass of *P. blennoides, M. macrophthalma*, *T. scabrus, A. carbo* and *Beryx spp*. was found in the additional deep water hauls (>500 m) in contrast to *H. dactylopterus* which was mainly found in standard hauls. *P.bogaraveo* was scarcely found out the stratification in the shallow area (<70 m). The biomass of *P. blennoides* increased slightly whereas *M. macrophthalma* and *T. scabrus* decreased. The biomass of *H. dactylopterus* increased reaching the highest value of the time series, but the abundance decreased and small specimens were not as abundant as previous years. Only a few specimens of *A. carbo, Beryx spp*. and *P. bogaraveo* were found and *C. rupestris* was not.

Phycis blennoides (greater forkbeard)

In 2020, 41% of the hauls where *P. blennoides* was found were additional hauls deeper than 500 m and contained 77% of the biomass. This last year the biomass in standard hauls remained low similarly to the values of the three previous years whereas the biomass in additional deep hauls remained being high, after the increase in 2019 (Figure 3).

The geographical distribution of *P. blennoides* remained similar to previous years, being widespread in the sampling area (Figure).

The length distribution in standard hauls remained showing low abundances per size and even fewer small (13-19 cm) and large (24-45 cm) specimens than in 2019 (Figure 5). The largest individuals which ranged from 26 cm to 65 cm were found in the additional deeper hauls, although specimens around 35 cm were more abundant (Figure 6).

***Molva macrophthalma* (Spanish ling)**

This last year, the biomass of *M. macrophtalma* decreased sharply in standard hauls whereas increased slightly in additional hauls (Figure 7). Most of the biomass (91%) was found in these deeper hauls (> 500 m) which were 45% of the total hauls with *M. macrophtalma*.
The species kept on being widespread in the study area but present in fewer spots this last survey (Figure 8).
The little abundance of specimens in standard hauls was strikingly evident this last survey (Figure 9). Only 31 specimens which ranged from 21 cm to 73 cm were found there, most of them around 21 and 29 cm. In contrast, in additional deeper hauls larger specimens, up to 115 cm, were found (Figure 10).

***Trachyrincus scabrus* (roughsnout grenadier)**

T. scabrus has been found mostly in additional hauls (>500 m) in the last decade. In 2020, all the biomass was found in these deep hauls and catches decreased slightly (Figure 11).
The geographical distribution showed fewer spots of biomass this last survey, but in the usual deep areas of Galicia and the northeastern Cantabrian Sea (Figure 12).
Specimens ranged from 80 mm to 265 mm, although more abundance of large specimens (200-210 mm) was found (Figure 13).

***Helicolenus dactylopterus* (bluemouth)**

Although bluemouth is not requested for ICES DCF Data Call, the biomass and abundance are significant in the area and useful for the assessment of the stock (ICES, 2017).
H. dactylopterus has been mainly found in standard hauls, therefore the catches of the additional deeper hauls are not plotted.
In 2020, the biomass slightly increased reaching the highest value of the time series whereas the abundance decreased, although it remained among the medium-high values of the time series (Figure 14).
The geographical distribution of *H. dactylopterus* remained similar to the previous year, with greater biomass in the Galician area, although bigger spots near Finisterre than previous years, and the usual spot in the easternmost Ajo-Bidasoa sector (Figure 15).
Length distribution showed fewer recruits than the previous year and a smooth mode around 15 cm, after the remarkable mode of 12 cm in 2019 (Figure 16).

Other scarce deep water species

Other species scarcely caught in the survey were *Aphanopus carbo*, *Coryphaenoides rupestris, Beryx spp.* and *Pagellus bogaraveo.* They have been mainly found out of the standard stratification, the first three species in deeper additional hauls (>500 m) whereas *P. bogaraveo* in shallower additional hauls (< 70 m).
This last survey *C. rupestris* was not found.

A. carbo was caught in two hauls at 847 m in Galician area and at 530 m in eastern Cantabrian Sea (Figure 17 and Figure 18), with a total of eleven specimens which ranged from 87 to 109 cm.

Beryx spp. were found in three hauls at 140 m, 530 m and 607 m in the Cantabrian sea (Figure 19 and Figure 20). Four specimens were *B. decadactylus* and two *B. splendens* and all of them ranged from 26 to 30 cm.

Only one specimen of *P. bogaraveo* of 18 cm was found at 58 m depth near Peñas Cape (Figure 21 and Figure 22).

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Figures

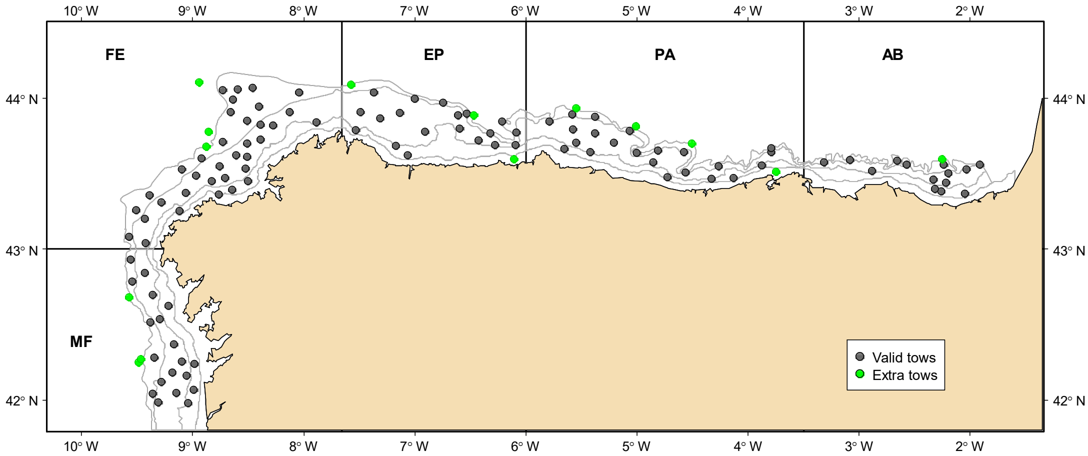


Figure 1 Stratification design and hauls on the Northern Spanish shelf groundfish survey in 2020; Depth strata are: A) 70-120 m, B) 121 – 200 m and C) 201 – 500 m. Geographic sectors are MF: Miño-Finisterre, FE: Finisterre-Estaca, EP: Estaca-cabo Peñas, PA: Peñas-cabo Ajo, and AB: Ajo-Bidasoa

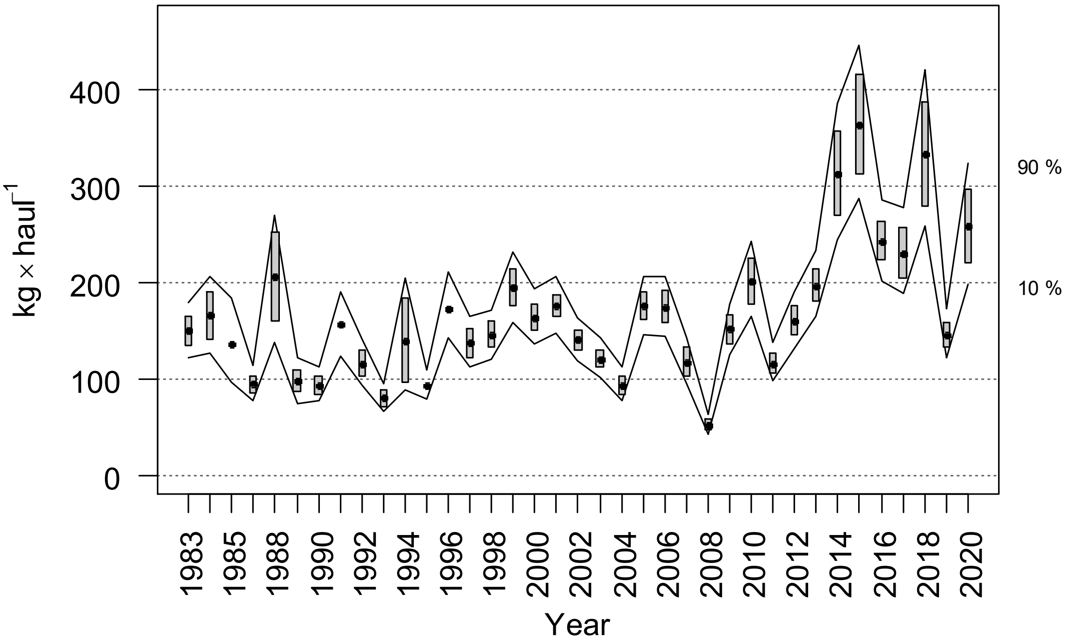


Figure 1 Evolution of the total catch in biomass on the Northern Spanish shelf groundfish survey

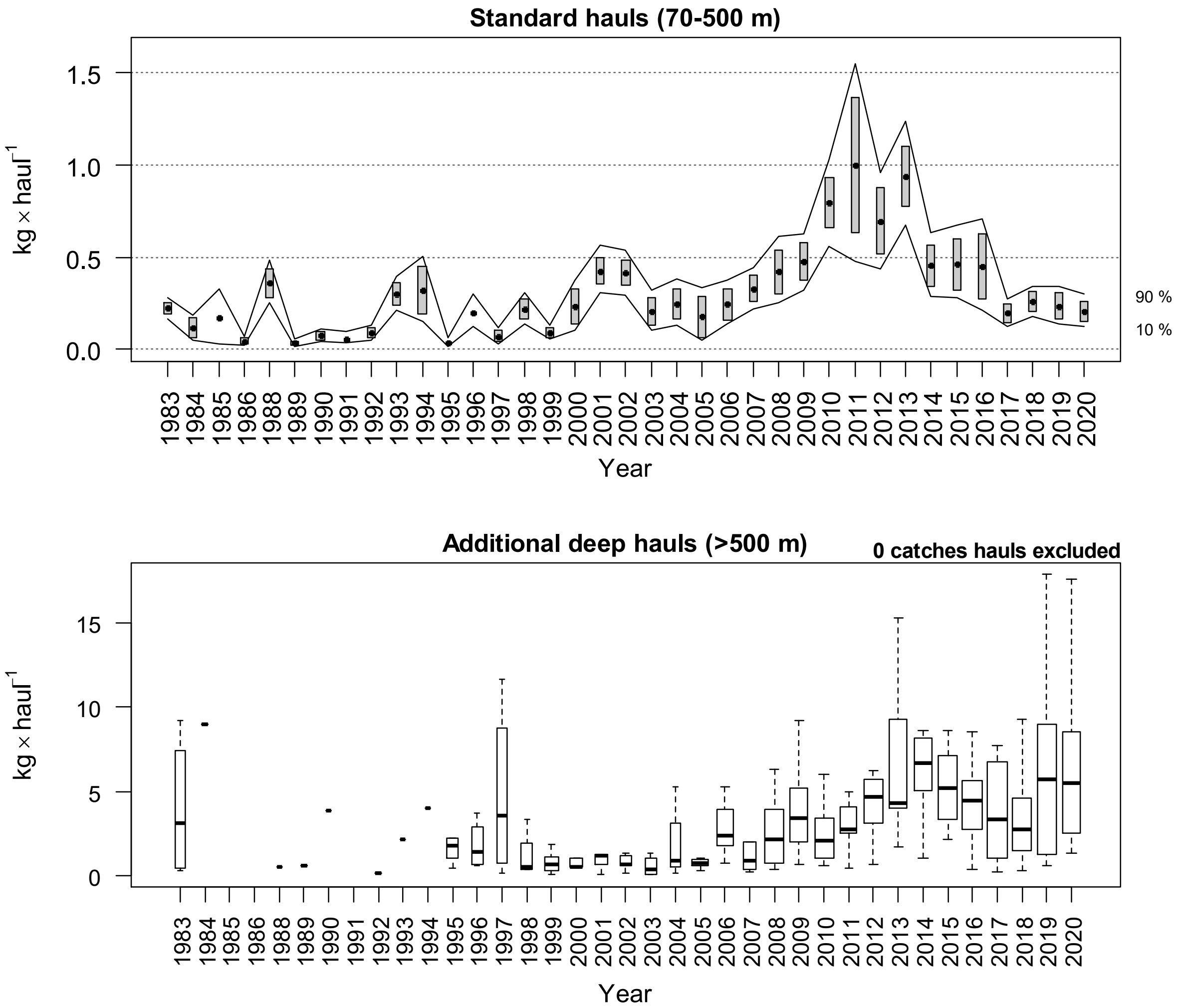


Figure 3 Evolution of *Phycis blennoides* stratified biomass index in standard hauls and additional deep hauls during the North Spanish shelf bottom trawl survey time series. For the standard hauls boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α= 0.80, bootstrap iterations = 1000). For the additional deep water hauls boxplots represent the median and interquartiles of the biomass catches in the deep hauls performed.

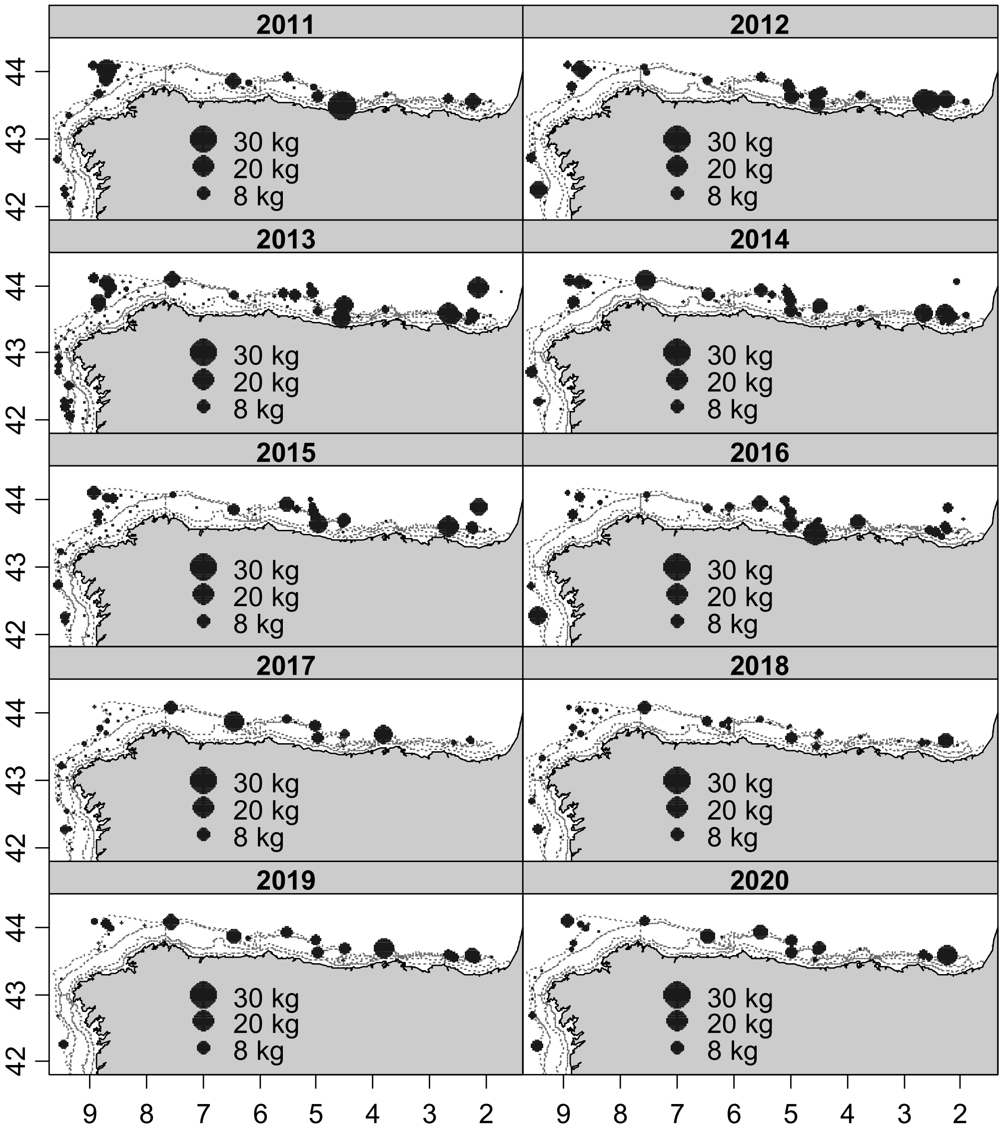


Figure 4 Geographic distribution of *Phycis blennoides* catches (kg·haul^{-1}) in the Northern Spanish Shelf bottom trawl surveys in the last decade

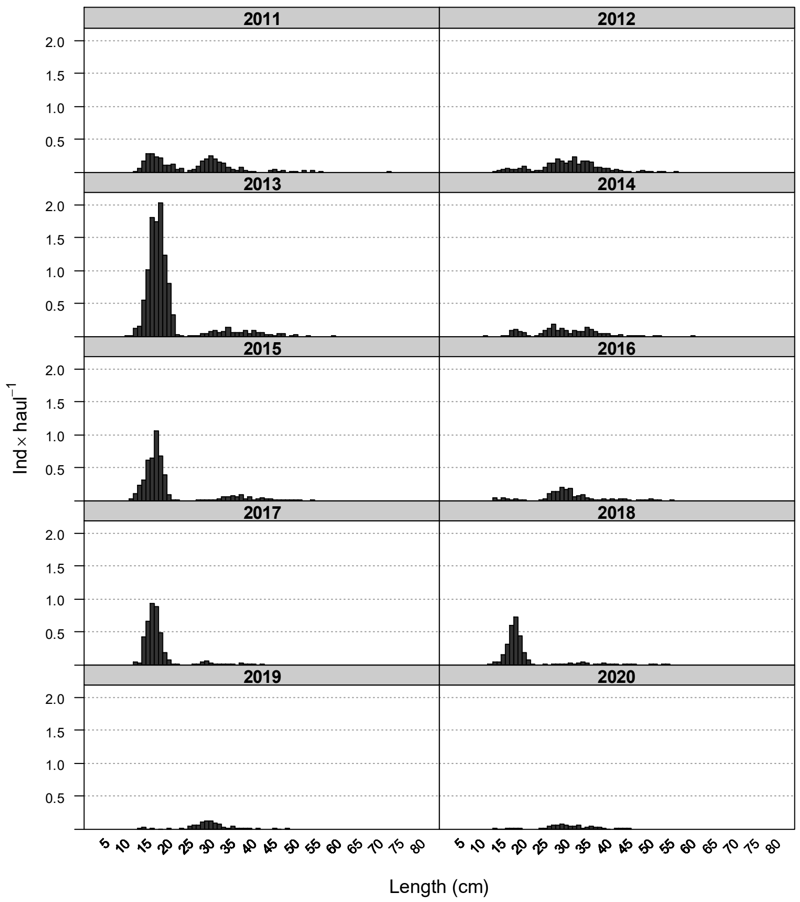
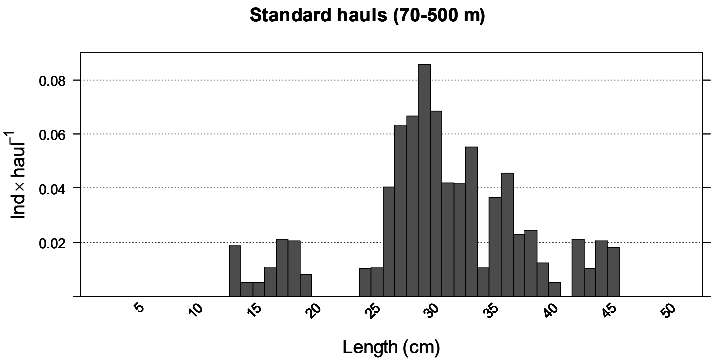


Figure 5 Mean stratified length distributions of *Phycis blennoides* in Northern Spanish Shelf surveys in the last decade



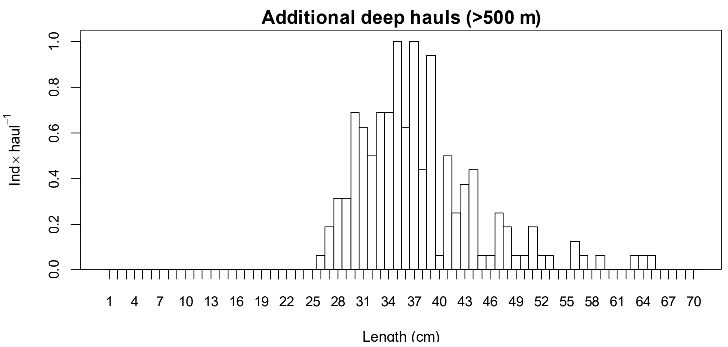


Figure 6 Mean length distributions of *Phycis blennoides* in additional hauls (>500 m) and in the standard hauls (70-500 m) in the North Spanish Shelf survey 2020

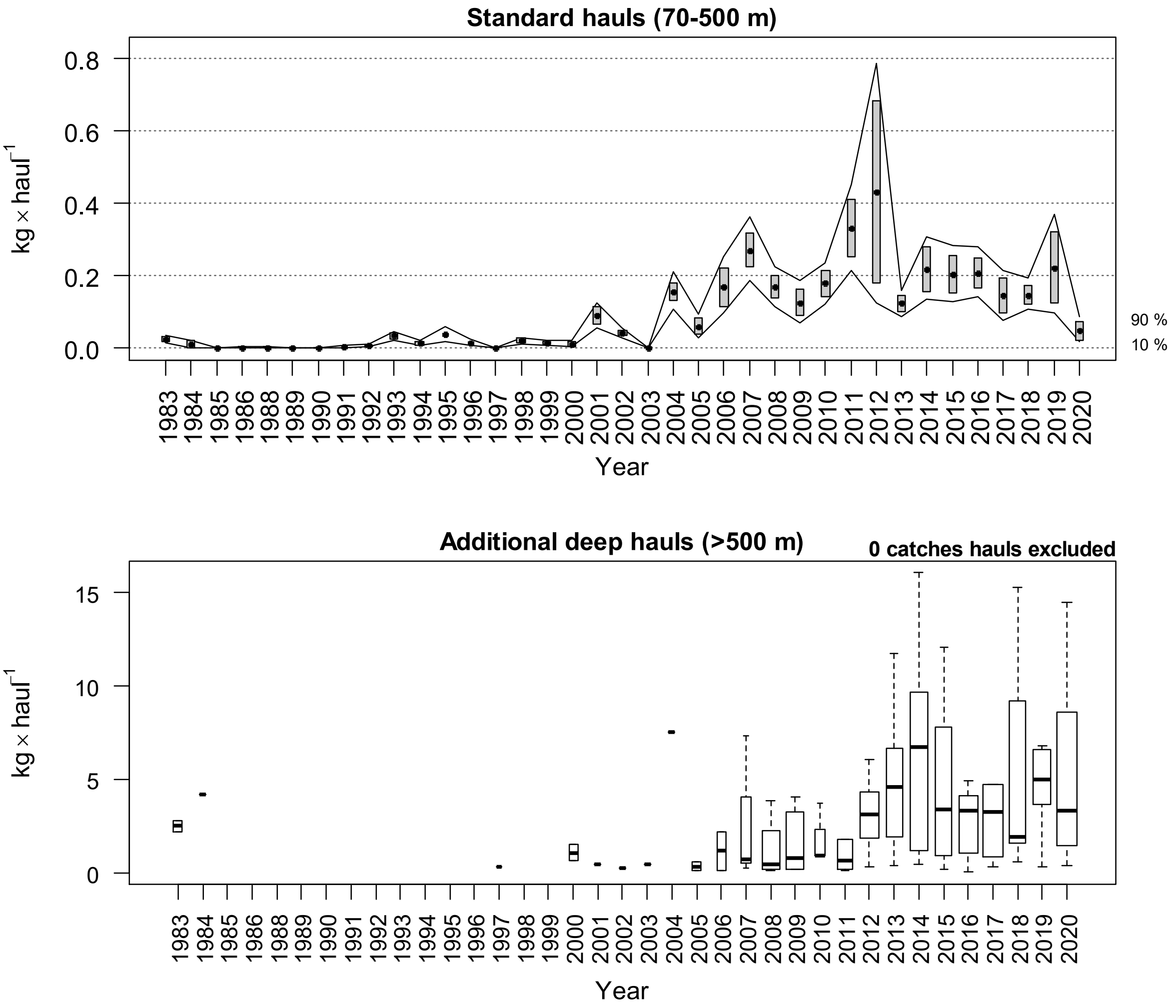


Figure 7 Evolution of *Molva macrophtalma* stratified biomass index in standard hauls and additional deep hauls during the North Spanish shelf bottom trawl survey time series. For the standard hauls boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α= 0.80, bootstrap iterations = 1000). For the additional deep water hauls boxplots represent the median and interquartiles of the biomass catches in the deep hauls performed.

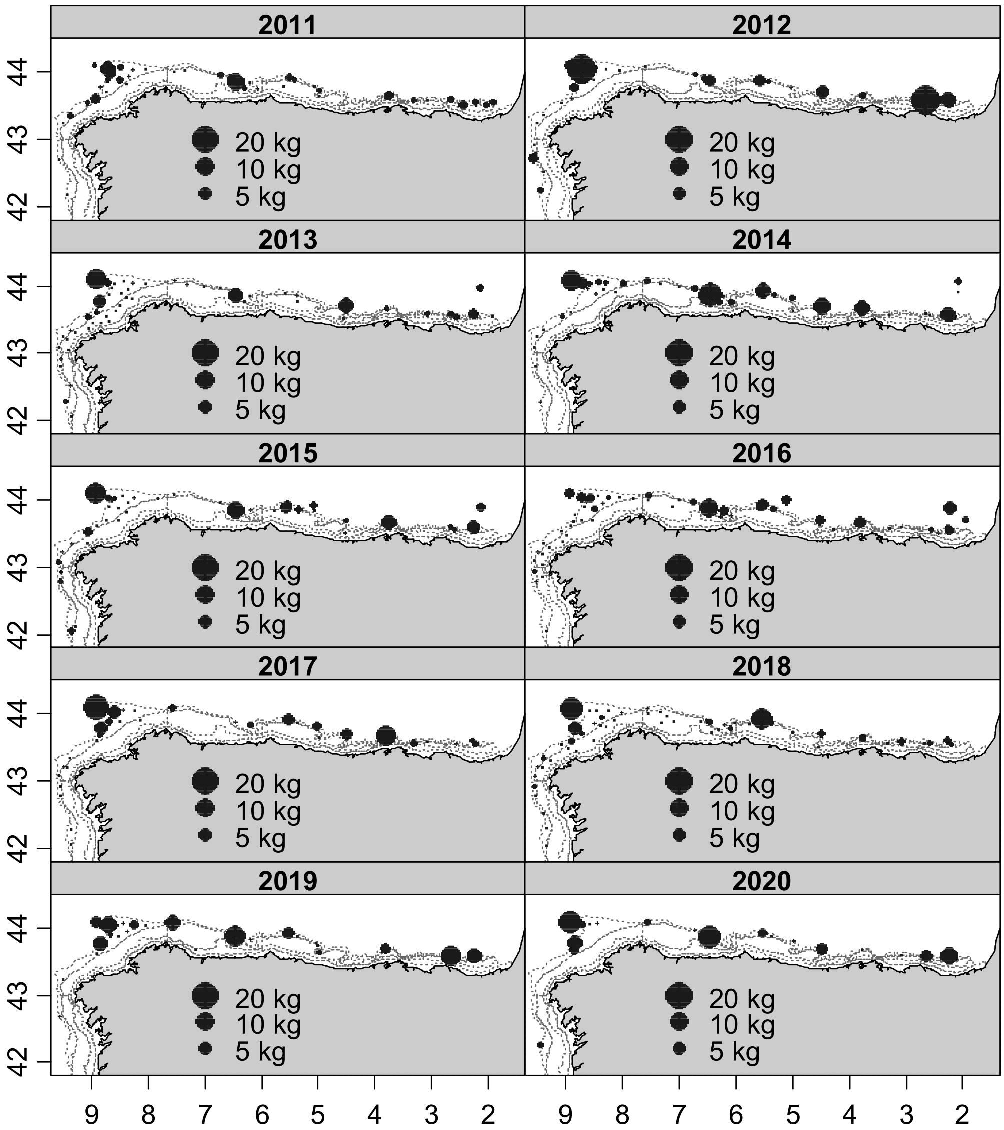


Figure 8 Geographic distribution of *Molva macrophtalma* catches (kg·haul^{-1}) in the Northern Spanish Shelf bottom trawl surveys in the last decade

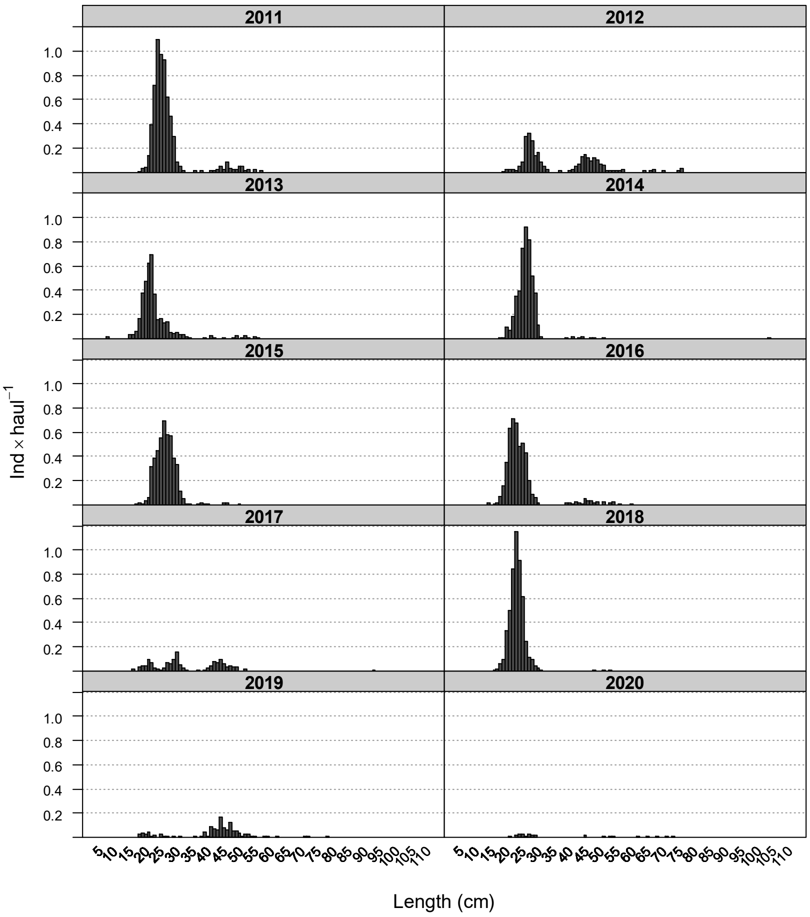


Figure 9 Mean stratified length distributions of *Molva macrophtalma* in Northern Spanish Shelf surveys in the last decade

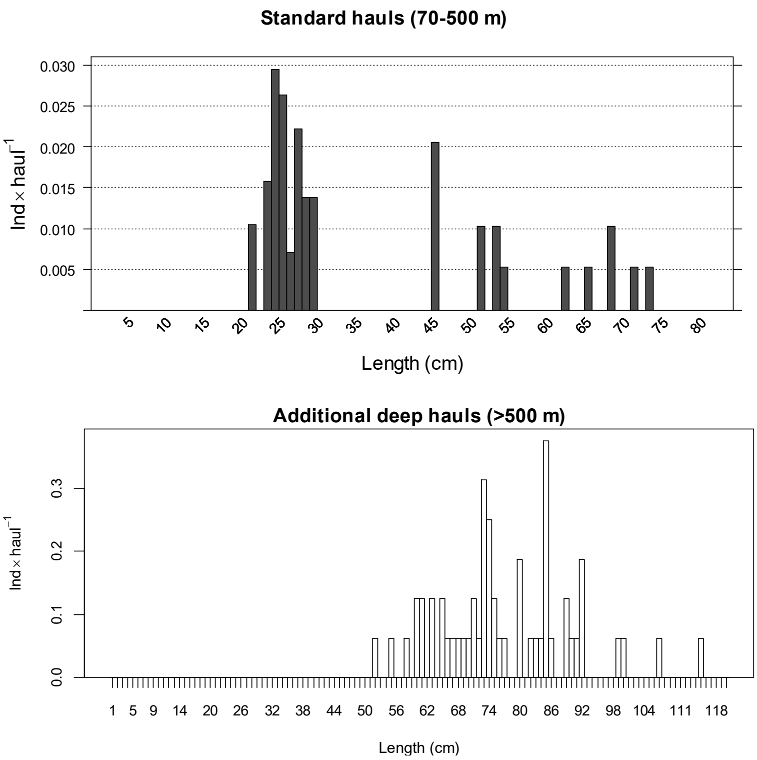
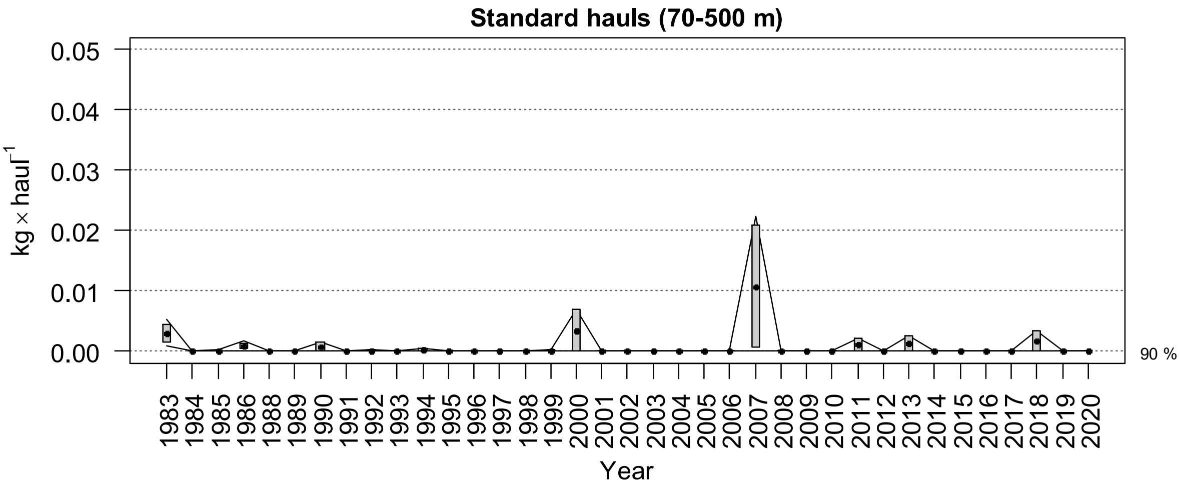


Figure 10 Mean length distributions of *Molva macrophtalma* in additional hauls (>500 m) and in the standard hauls (70-500 m) in the North Spanish Shelf survey 2020



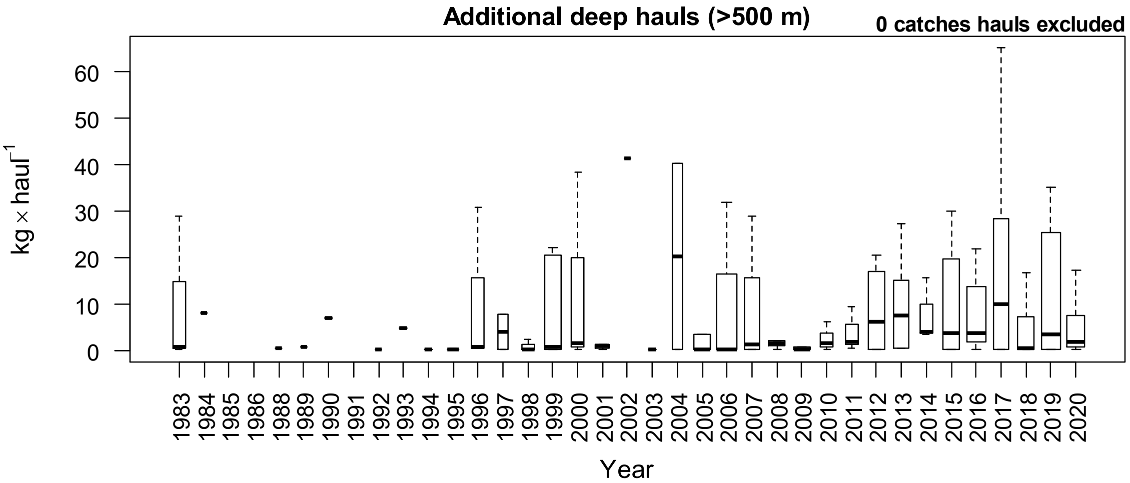


Figure 11 Evolution of *Trachyrincus scabrus* stratified biomass index in standard hauls and additional deep hauls during the North Spanish shelf bottom trawl survey time series. For the standard hauls boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α= 0.80, bootstrap iterations = 1000). For the additional deep water hauls boxplots represent the median and interquartiles of the biomass catches in the deep hauls performed.

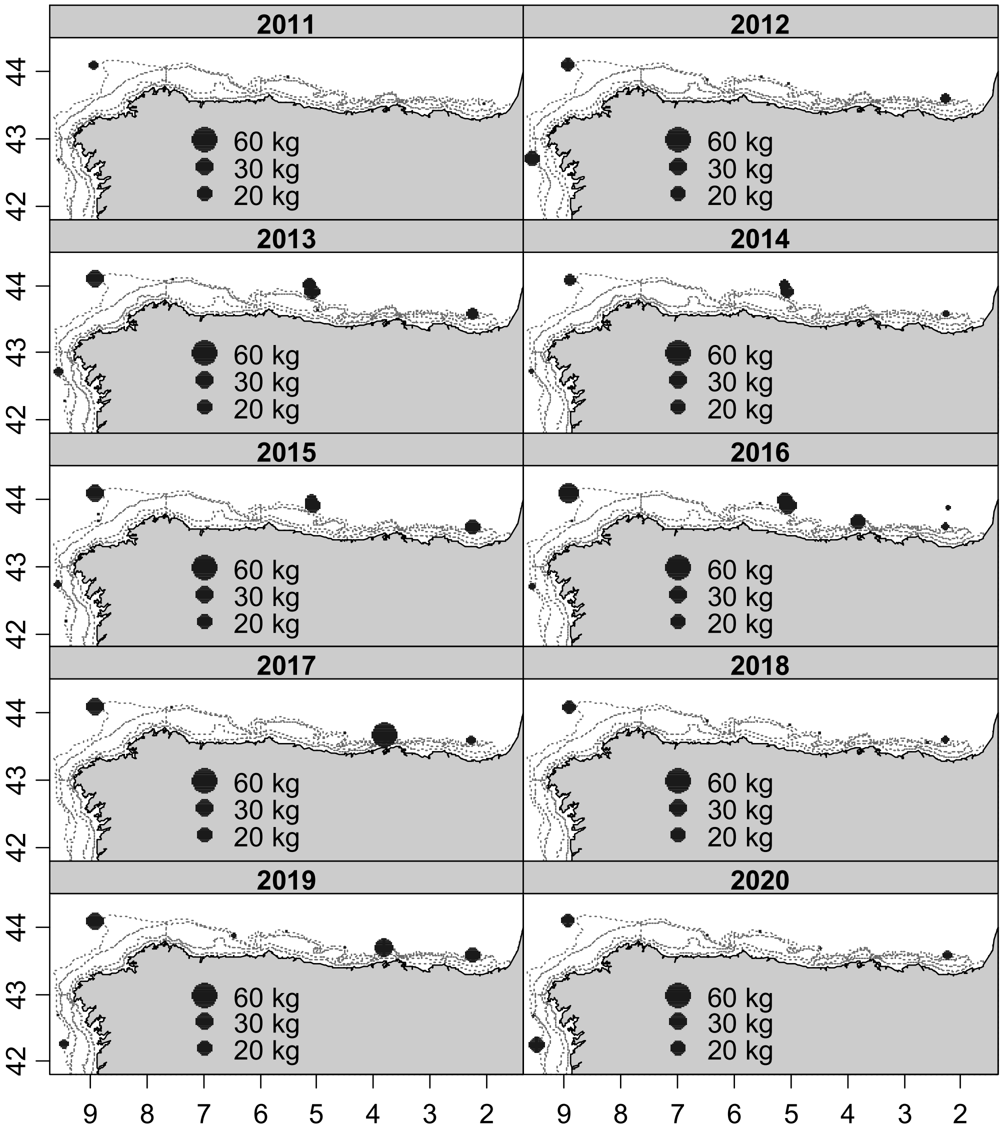


Figure 12 Geographic distribution of *Trachyrincus scabrus* catches (kg·haul^{-1}) in the Northern Spanish Shelf bottom trawl surveys in the last decade

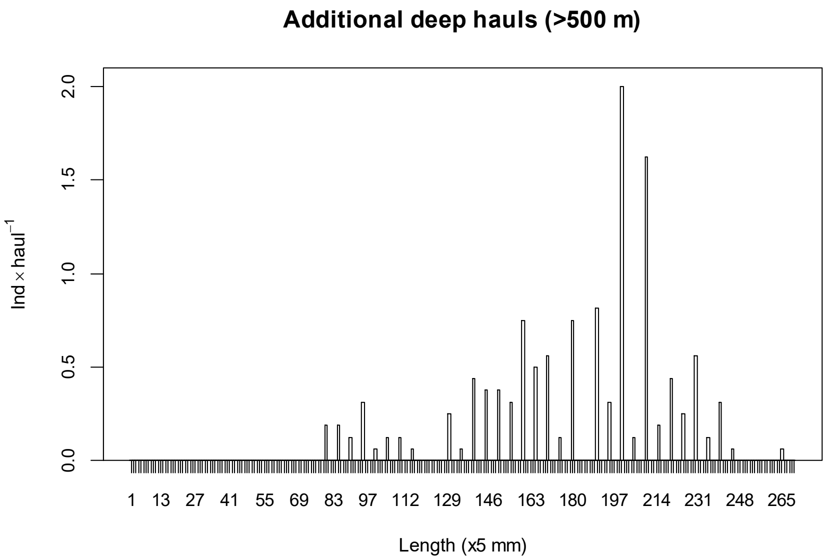


Figure 13 Mean length distributions of *Trachyrincus scabrus* in additional hauls (>500 m) in the North Spanish Shelf survey 2020

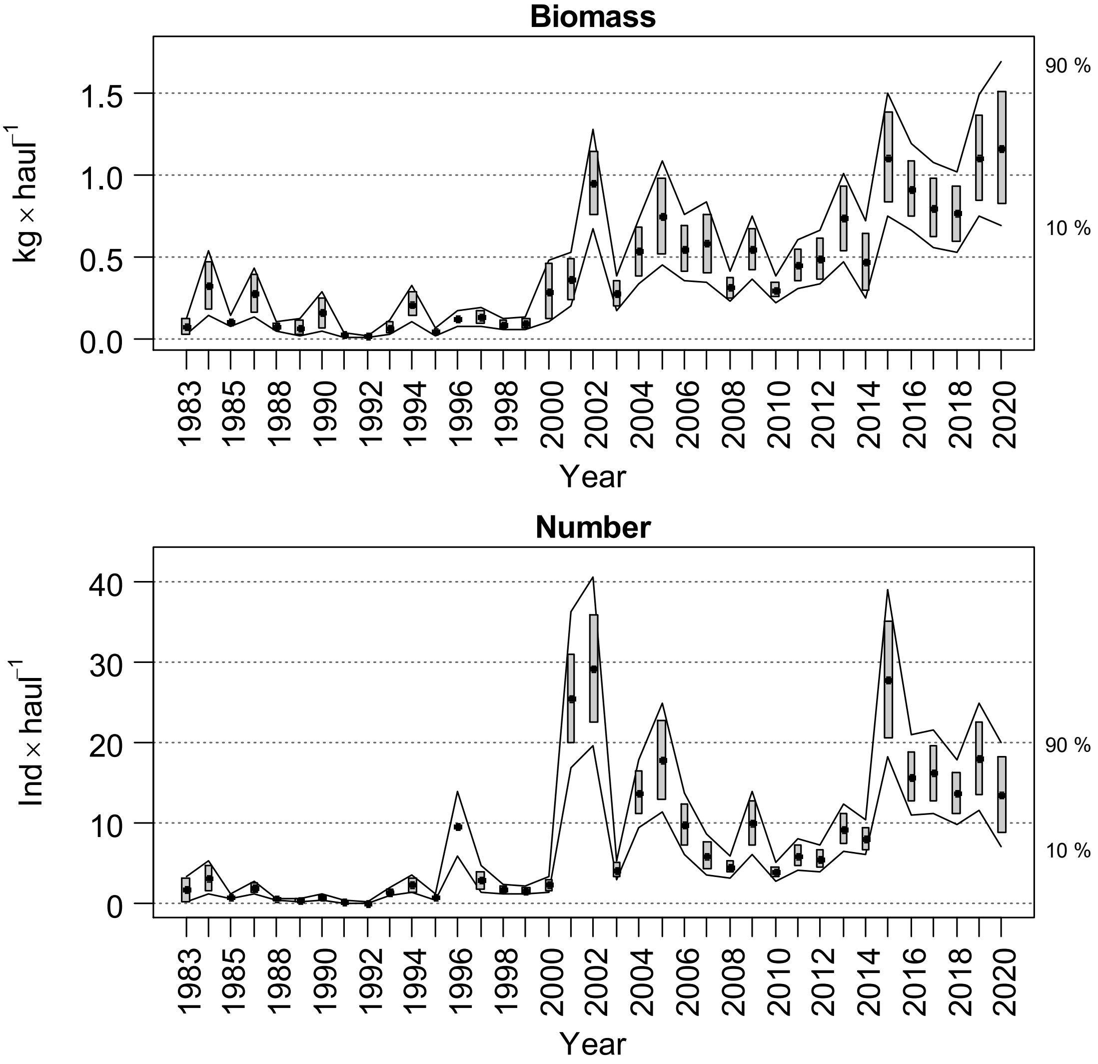


Figure 14 Evolution of *Helicolenus dactylopterus* mean stratified biomass and abundance in Northern Spanish Shelf surveys time series. Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α= 0.80, bootstrap iterations = 1000)

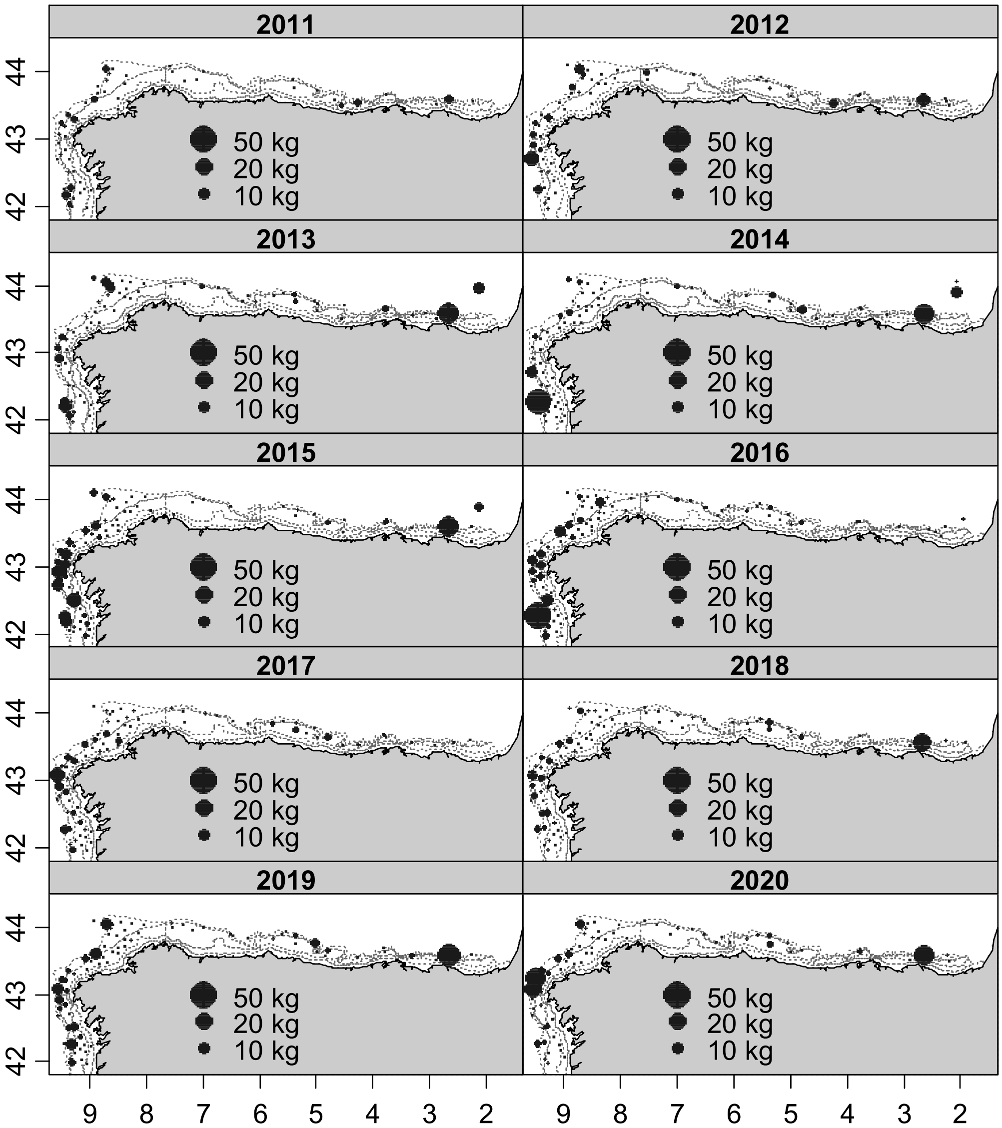


Figure 15 Geographic distribution of *Helicolenus dactyloperus* catches (kg·haul^{-1}) in the Northern Spanish Shelf bottom trawl surveys in the last decade

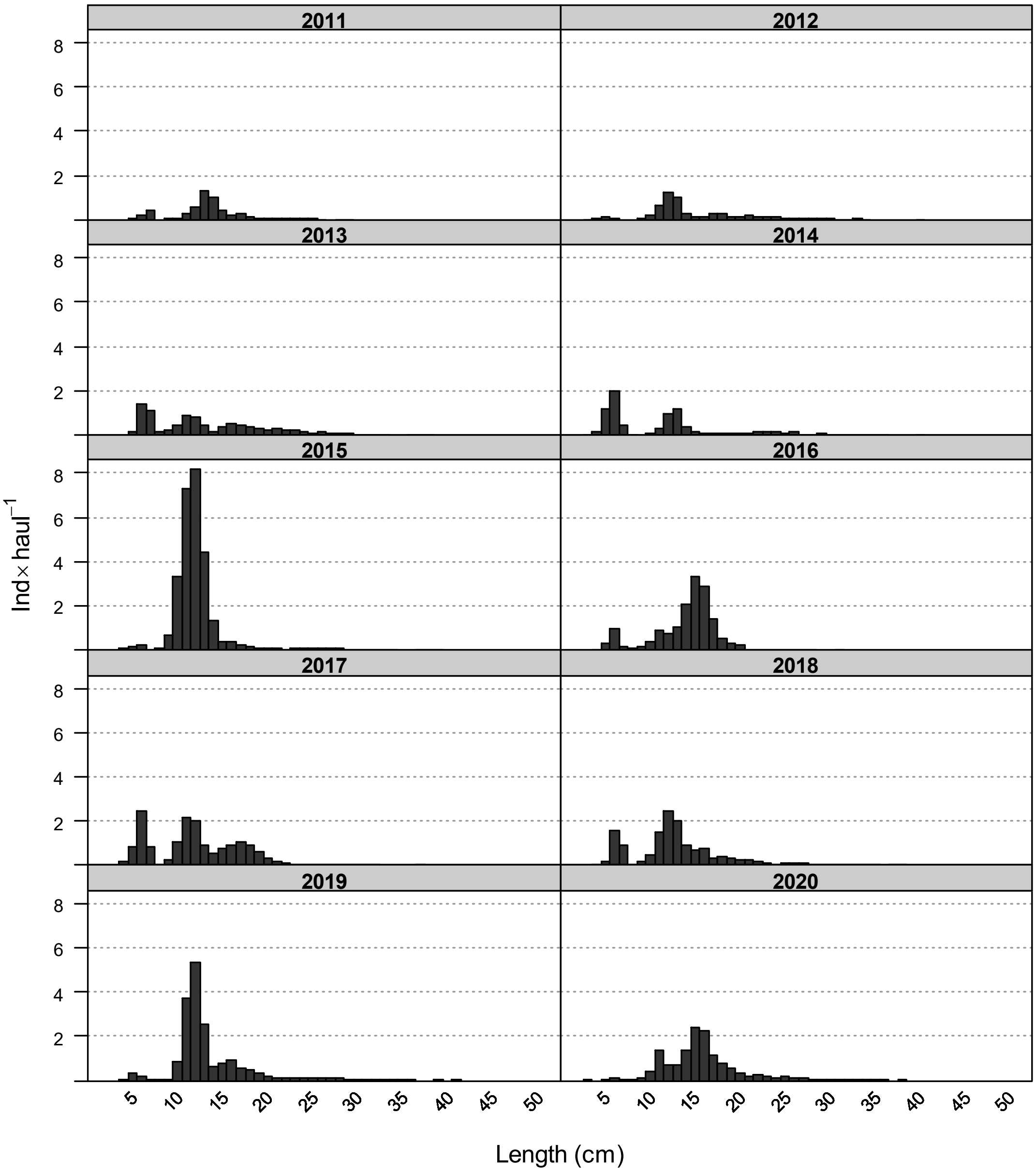


Figure 16 Mean stratified length distributions of *Helicolenus dactyloperus* in Northern Spanish Shelf surveys in the last decade

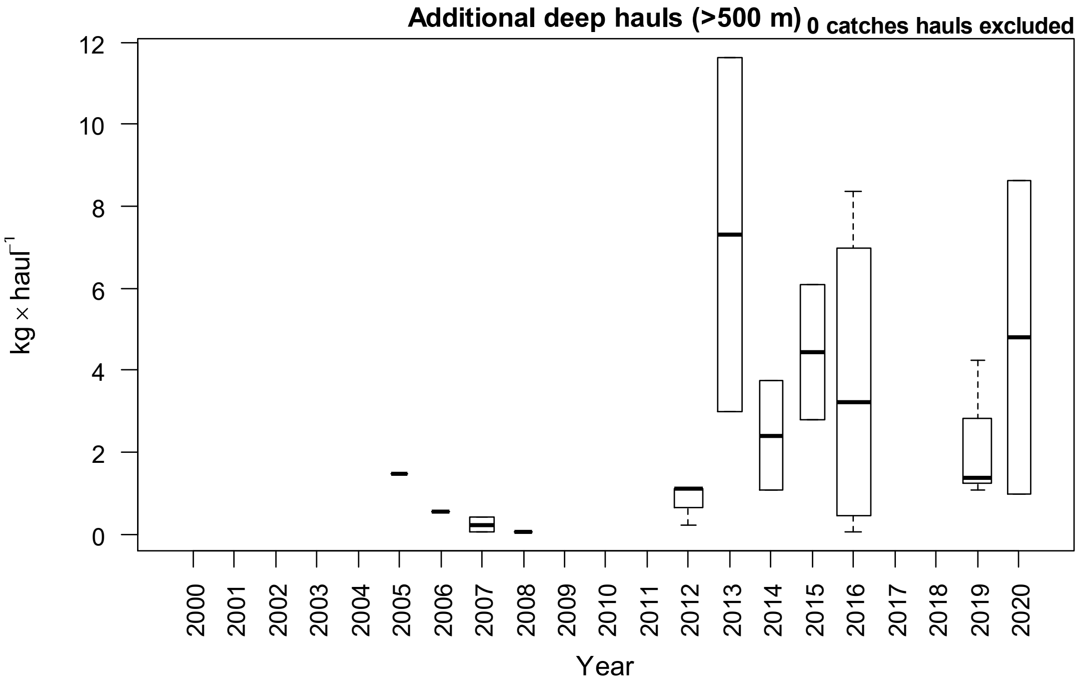


Figure 17 Evolution of *Aphanopus carbo* biomass in additional deep hauls during the North Spanish shelf bottom trawl survey time series. Boxplots represent the median and interquartiles of the biomass catches in the deep hauls performed.

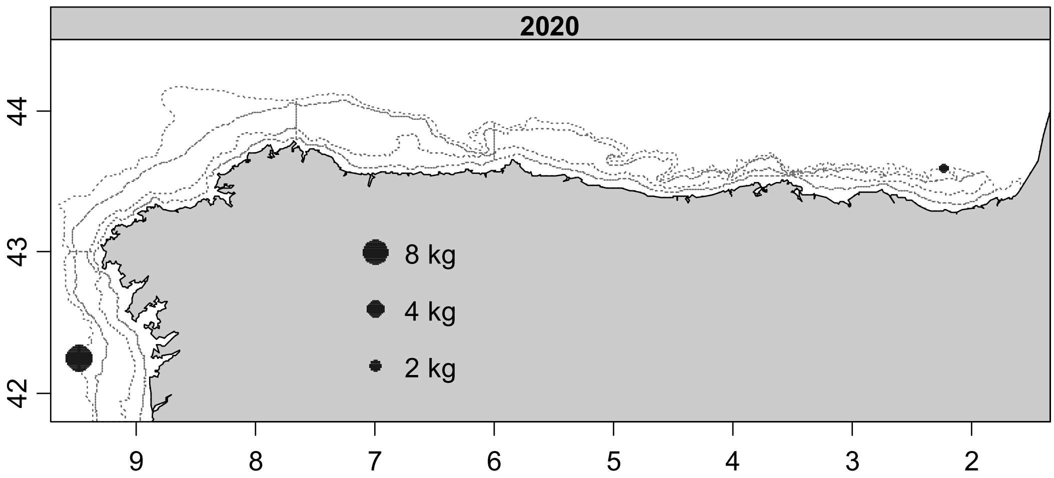


Figure 18 Geographic distribution of *Aphanopus carbo* catches (kg·haul^{-1}) in the Northern Spanish Shelf bottom trawl survey 2020

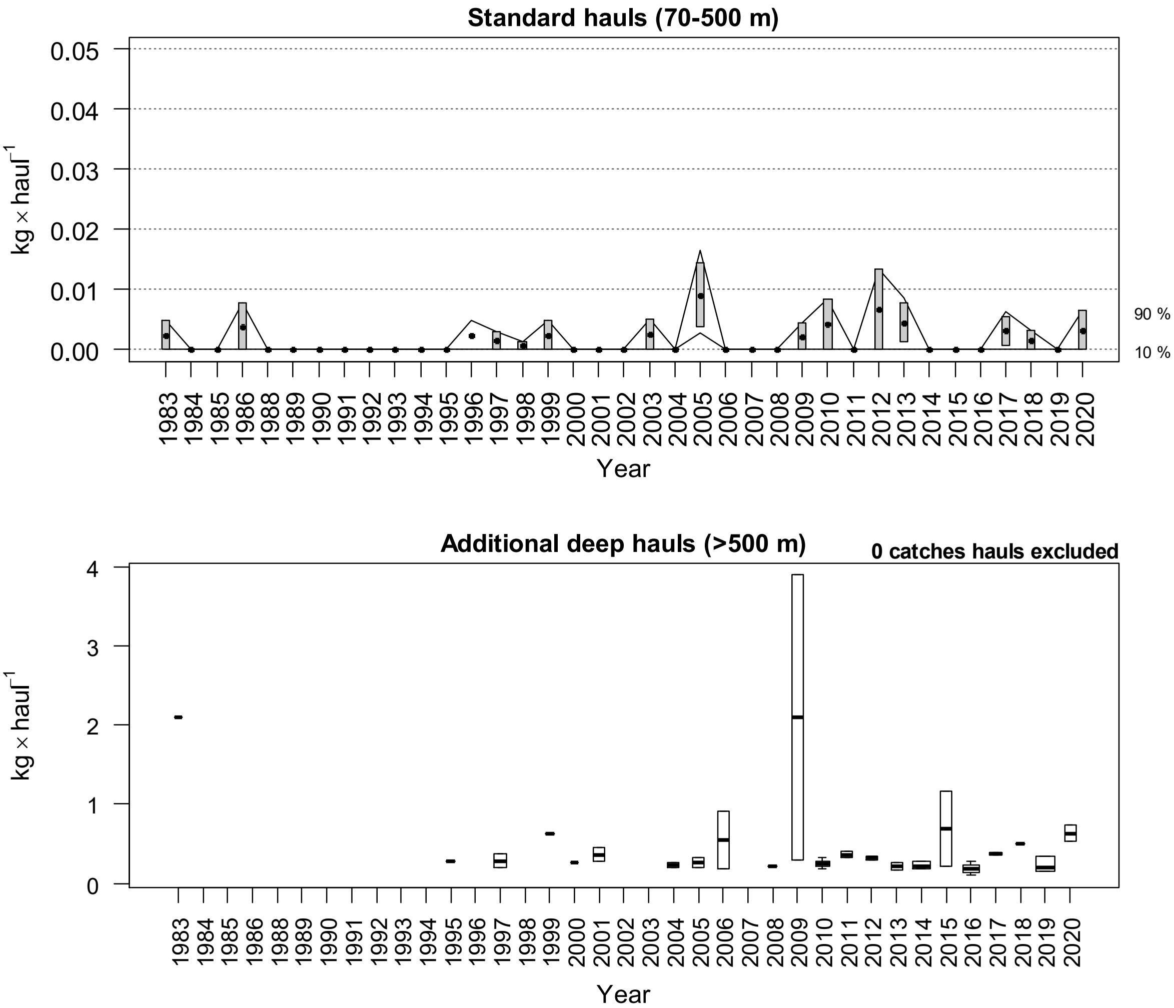


Figure 19 Evolution of *Beryx spp.* stratified biomass index in standard hauls and additional deep hauls during the North Spanish shelf bottom trawl survey time series. For the standard hauls boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α= 0.80, bootstrap iterations = 1000). For the additional deep water hauls boxplots represent the median and interquartiles of the biomass catches in the deep hauls performed.

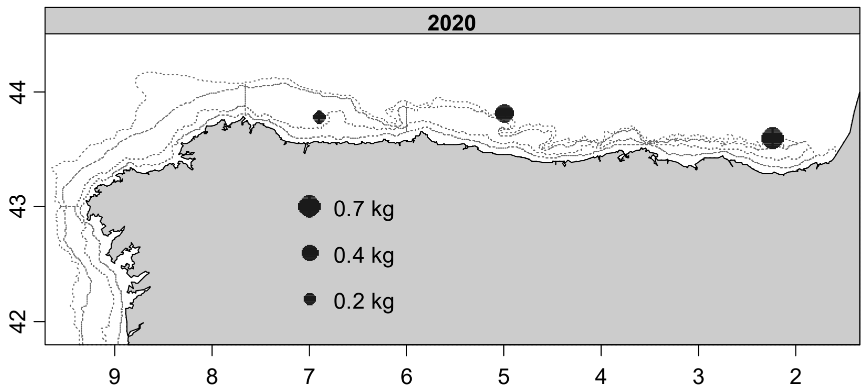


Figure 20 Geographic distribution of *Beryx* spp. catches (kg•haul-1) in the Northern Spanish Shelf bottom trawl survey 2020

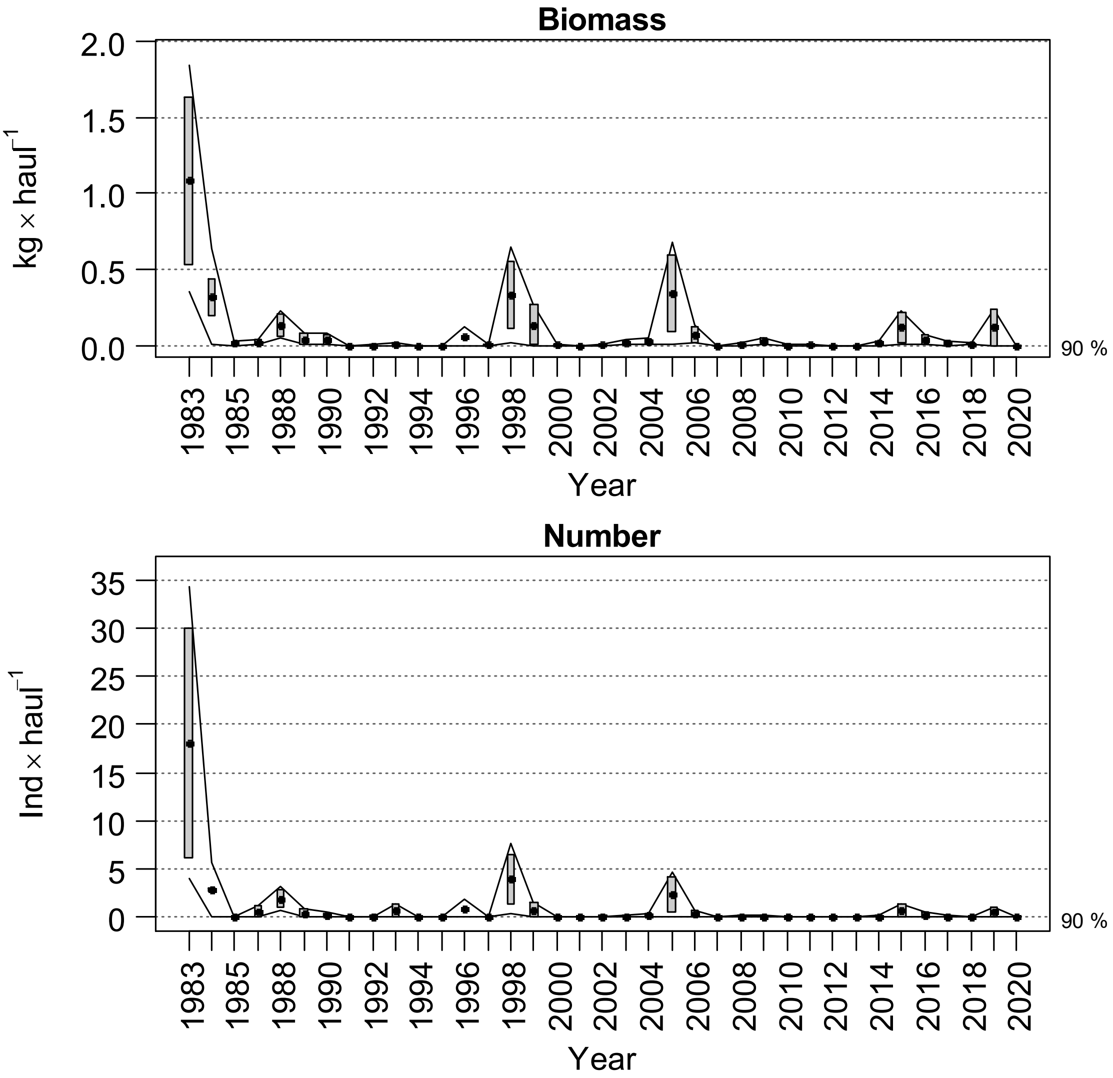


Figure 21 Evolution of *Pagellus bogaraveo* mean stratified biomass and abundance in Northern Spanish Shelf surveys time series. Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (α= 0.80, bootstrap iterations = 1000)

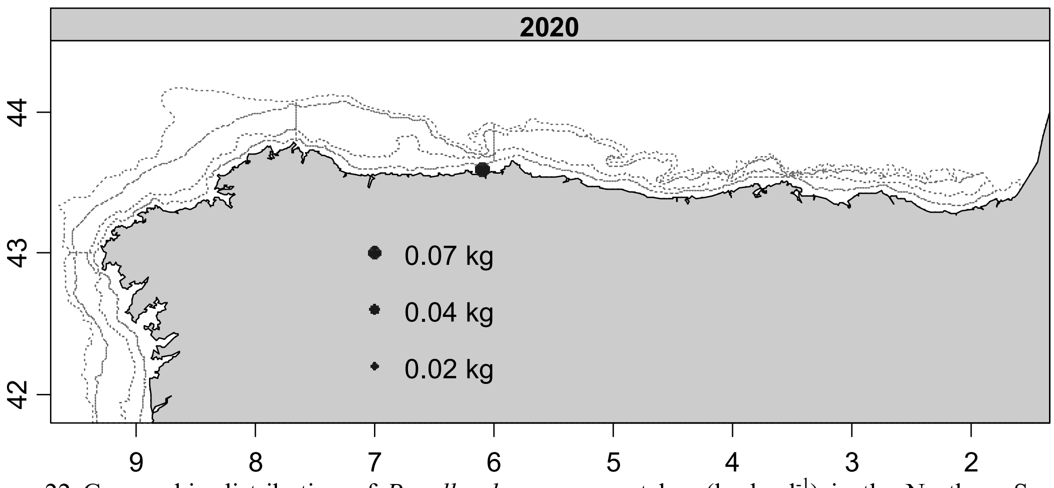


Figure 22 Geographic distribution of *Pagellus bogaraveo* catches (kg·haul^{-1}) in the Northern Spanish Shelf bottom trawl survey 2020

Results on silver smelt (*Argentina silus* and *A. sphyraena*), bluemouth (*Helicolenus dactylopterus*), greater forkbeard (*Phycis blennoides*), roughsnout grenadier (*Trachyrincus scabrus*), Spanish ling and ling (*Molva macrophthalma* and *Molva molva*) from the Porcupine Bank Survey (NE Atlantic)

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Abstract

This working document presents the results of the most significant deep fish species caught in 2020 on the Porcupine Spanish Groundfish Survey (SP-PORC-Q3). Biomass, abundance, geographical distribution and length ranges were analysed for silver smelt (*Argentina silus* and *A. sphyraena*), bluemouth (*Helicolenus dactylopterus*), greater fork-beard (*Phycis blennoides*), roughsnout grenadier (*Trachyrincus scabrus*), Spanish ling and ling (*Molva macrophthalma* and *Molva molva*) and other scarce deep sea species. The biomass of most of these species decreased this last survey, only *A. silus* and *P. blennoides* increased, althought *H. dactylopterus* increased in abundance. Signs of recruitment have been found for *H. dactylopterus* and *T. scabrus*.

Introduction

The Spanish bottom trawl survey on the Porcupine Bank (ICES Divisions 7c and 7k) has been carried out annually on the third-quarter (September) since 2001 to study the distribution, relative abundance and biological parameters of commercial fish in the area (ICES 2017).

The aim of this working document is to update the results (abundance indices, length frequency and geographic distributions) of the most common deep water fish species on the Porcupine bottom trawl surveys after the results presented previously (Baldó *et al.* 2008, Velasco *et al.* 2009, 2011, 2012, 2013, Fernández-Zapico *et al.* 2015, 2017, Ruiz-Pico *et al.* 2016, 2018, 2019, 2020). The species analysed were: *Argentina silus* (greater silver smelt), *Argentina sphyraena* (lesser silver smelt), *Helicolenus dactylopterus* (bluemouth), *Phycis blennoides* (greater forkbeard), *Trachyrincus scabrus* (roughsnout grenadier), *Molva molva* (ling), *Molva macrophthalma* (Spanish ling) and some other scarce deep sea species as *Aphanopus carbo* (black scabbardfish), *Coryphaenoides rupestris* (roundnose grenadier) and *Beryx spp.* (alfonsinos).

Material and methods

The Spanish Ground Fish Survey on the Porcupine Bank (SP-PORC-Q3) has been annually carried out since 2001 onboard the R/V "*Vizconde de Eza*", a stern trawler of 53 m and 1800 Kw. The area covered extends from longitude 12° W to 15° W and from latitude 51° N to 54° N, following the standard IBTS methodology for the western and southern areas (ICES 2017). The sampling design was random stratified to the area (Velasco and Serrano, 2003) with two geographical sectors (Northern and Southern) and three depth strata (< 300 m, 300 – 450 m and 450 - 800 m) (Figure 1). Hauls allocation is proportional to the strata area following a buffered random sampling procedure (as proposed by Kingsley et al., 2004) to avoid the selection of adjacent 5×5 nm rectangles. More details on the survey design and methodology are presented in ICES (2017).

The tow duration is 20 min since 2016, but the results were extrapolated to 30 min of trawling time to keep up the time series.

Results and discussion

In spite of the problems created by the pandemic and the COVID-19 disruption, the Porcupine Groundfish Survey was carried out without major problems, apart from an initial of 9-day delay that did not affect the overall survey duration.

In 2020, 81 valid standard hauls and 10 additional hauls were carried out. Among the additional hauls, three of them have been carried out into the standard stratification, to improve coverage in the gaps left by random sampling and seven of them, between 839 and 1425 m, to explore the continuity of the fish community in Porcupine Seabight (Figure 1).

The total stratified catch per haul increased significantly in 2020 compared to the previous year, becoming the second highest catch in the historical series below the year 2015 (Figure 2). Fish represented 96% of the total catch, and the selected deep water fish represented 14% of that total fish catch, with the following percentages per species: *Argentina silus* (61%), *Helicolenus dactylopterus* (17%), *Argentina sphyraena* (9%), *Trachyrincus scabrus* (5%), *Phycis blennoides* (5%), *Molva macrophtalma* (2%) and *Molva molva* (0.1%).

In 2020, only the biomass of *A. silus* and *P. blennoides* increased compared to the previous year. The rest of the species decreased. However, *H. dactylopterus* increased in abundance due, in part, to a high number of individuals smaller than 11cm, although they were also less than last year. Signs of recruitment have also been found for *T. scabrus*. Only a few specimens of *A. carbo, Beryx spp*. and *C. rupestris* were found.

Argentina silus (greater silver smelt) and *Argentina sphyraena* (lesser silver smelt)

In 2020, both the biomass and the number of *A. silus*, which is the species that historically contributes the most to the genus in the Porcupine survey, increased considerably, breaking the downward trend of recent years and staying in the medium-high values of the historical series. *A. sphyraena*, by contrast, decreased sharply, getting medium-low values of the time series (Figure 3; Figure 4 and Figure 5).

Both species were found in the north of the bank, where the decline of *A. sphyraena* and the increment of *A. silus* with respect to the previous year were observed, and *A. silus* was also present in the south part of the bank, as usual (Figure 6 and Figure 7).

The abundance of small individuals of *A. silus* decreased compared to the previous year, although a mode at 17 cm was appreciated, whereas the abundance around a second mode at 22 cm increased greatly. *A. sphyraena* kept a similar size distribution to the 2019 survey, with a single mode at 22 cm (Figure 8).

***Helicolenus dactylopterus* (bluemouth)**

Although bluemouth is not requested in the ICES DCF Data Call, biomass and abundance are significant in the area and useful for the assessment of the species (ICES, 2015).

The abundance of this species has continued to increase since 2017, reaching the highest value of the time series in 2020. The biomass, however, has decreased slightly in the last survey, keeping medium values in the series (Figure 9). Recruitment broke the increasing trend of the last three years but still has a relatively high value (Figure 10).

The geographical distribution of *H. dactylopterus* was similar to that of the previous year, although the biomass points were more widely distributed throughout the bank, Recruits distributed both on the Irish shelf and in the southeast area of the bank, barely deeper than 500 m (Figure 11).

The figure 12 shows two well defined modes in 8 cm and 14 cm. A slight decrease in the abundance of the largest sizes (25 to 39 cm) can also be seen.

***Trachyrincus scabrus* (roughsnout grenadier)**

T. scabrus has been included in this report since last year.

Biomass and abundance are significant in the area. In the last three years they were among the highest values of the time series, although in this last survey, both biomass and abundance decreased slightly (Figure 13).

The species was found in the deepest southeast area and in the deepest west area, as usual in the time series (Figure 14).

The length distribution in 2020 showed a small mode at 7 cm and a more abundant one at 18.5 cm (Figure 15).

***Phycis blennoides* (greater fork-beard)**

The biomass and abundance of *P. blennoides* followed the pattern observed last year, but they increased slightly in this last survey, although the values still remain among the lowest in the time series. (Figure 16).

Biomass patches were widely found in the south, west and east area, but scarcely in the north, as in previous years (Figure 17).

A small mode is seen at 20 cm and two more abundant at 31 cm and 40 cm (Figure 18).

***Molva molva* (ling) and *Molva macrophthalma* (Spanish ling)**

These two species were comparatively analysed in this working document as in previous reports.

M. molva was scarcer than *M. macrophtalma* in the area, as usual. Both species have followed a downward trend since 2014, although *M. macrophthalma* broke that trend last year with a slight increase, dropping again slightly this last survey. However, *M. molva* continued to decline, reaching the lowest value of the time series in 2020 (0.13 kg haul^{-1} and 0.06 ind. haul^{-1}) (Figure 19).

M. molva showed a scarce geographical distribution in this latest survey, whereas *M. macrophtalma* showed biomass patches around the bank, especially in the south part of the study area (Figure 20).

The size distribution of *M. macrophtalma* showed a mode around 56 cm. On the other hand, the smallest and the largest individuals of *M. molva* from last year were not found, the few specimens of this species presented sizes of 50 cm, 53 cm, 67 cm, 69 cm and 70 cm (Figure 21).

Other deep water fish species

In 2020, the deep water species *Aphanopus carbo, Coryphaenoides rupestris* and *Beryx splendes* have been scarcely found in the study area.

The species *A. carbo* and *C. rupestris* were found only in the deep hauls between 839 and 1425 m carried out to explore the continuity of the fish community in Porcupine Seabight, out of the standard stratification, in the southeast part of the bank.

Two individuals of the species *B. splendens*, with sizes 25 and 34 cm, were found in the standard stratification, in the southern part of the bank, in two hauls.

Beryx decadactylus, which was scarcely found other years, has not been caught in 2020.

Acknowledgements

We would like to thank the *R/V Vizconde de Eza* crew and the IEO scientific teams that made thePorcupine Spanish Groundfish Survey possible. They are included in the ERDEM project, whichhas been co-funded by the EU through the European Maritime and Fisheries Fund (EMFF) withinthe National Program of collection, management and use of data in the fisheries sector and supportfor scientific advice regarding the Common Fisheries Policy.

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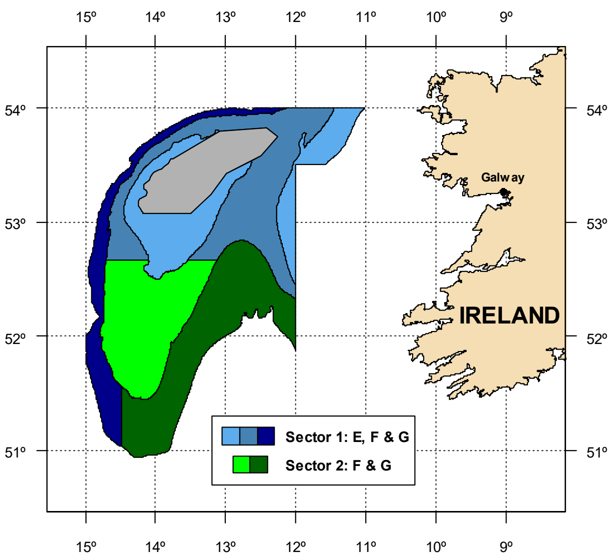
Figures



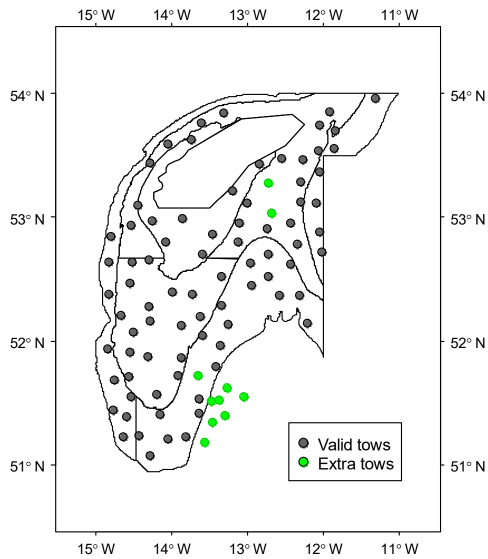


Figure 1. Left: Stratification design used in Porcupine surveys from 2003, previous data were re-stratified. Depth strata are: E) shallower than 300 m, F) 301 – 450 m and G) 451 – 800 m. Grey area in the middle of Porcupine bank corresponds to a large non-trawlable area, not considered for area measurements and stratification. Right: distribution of hauls performed in 2020.

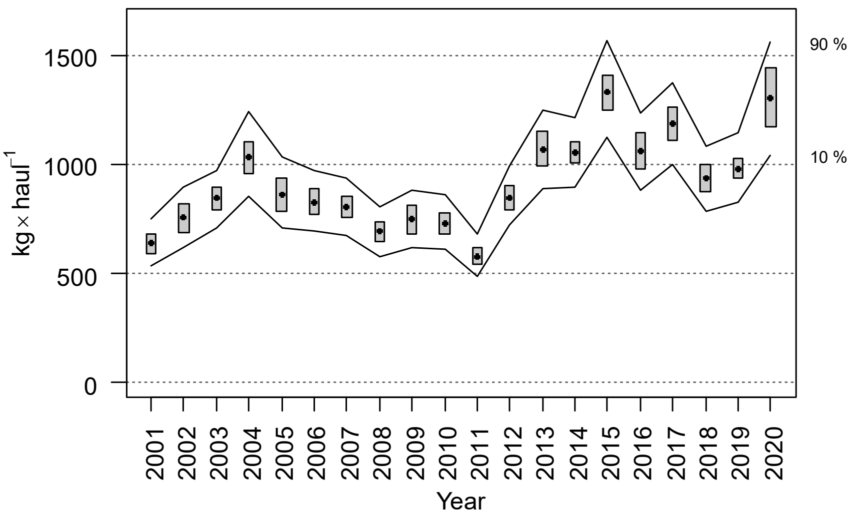


Figure 2. Evolution of the total catch in Porcupine surveys (2001-2020)

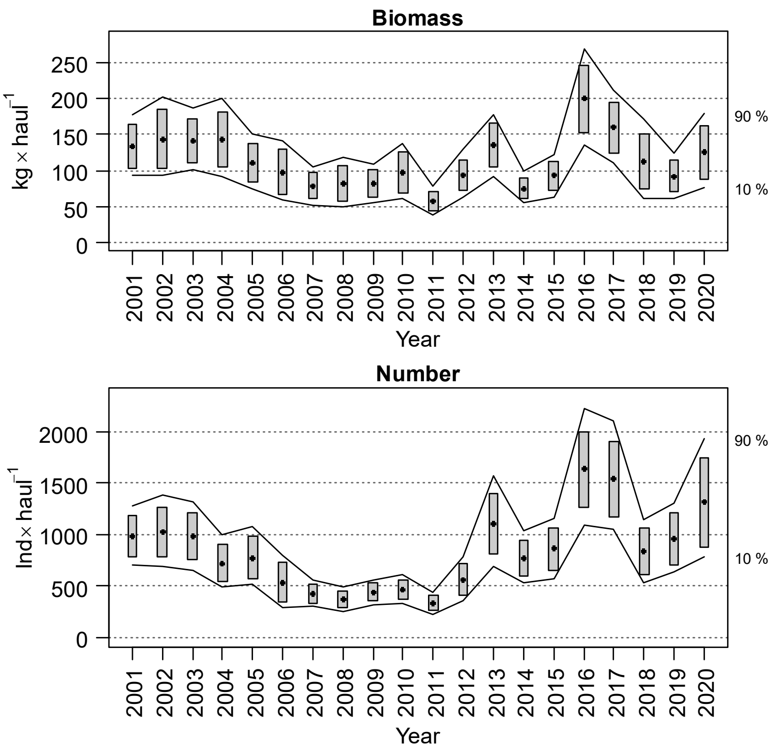


Figure 3. Evolution of *Argentina* spp. (mainly *Argentina silus*) biomass and abundance indices in Porcupine surveys (2001-2020). Boxes mark parametric standard error of the stratified abundance index. Lines mark bootstrap confidence intervals (α = 0.80, bootstrap iterations = 1000)

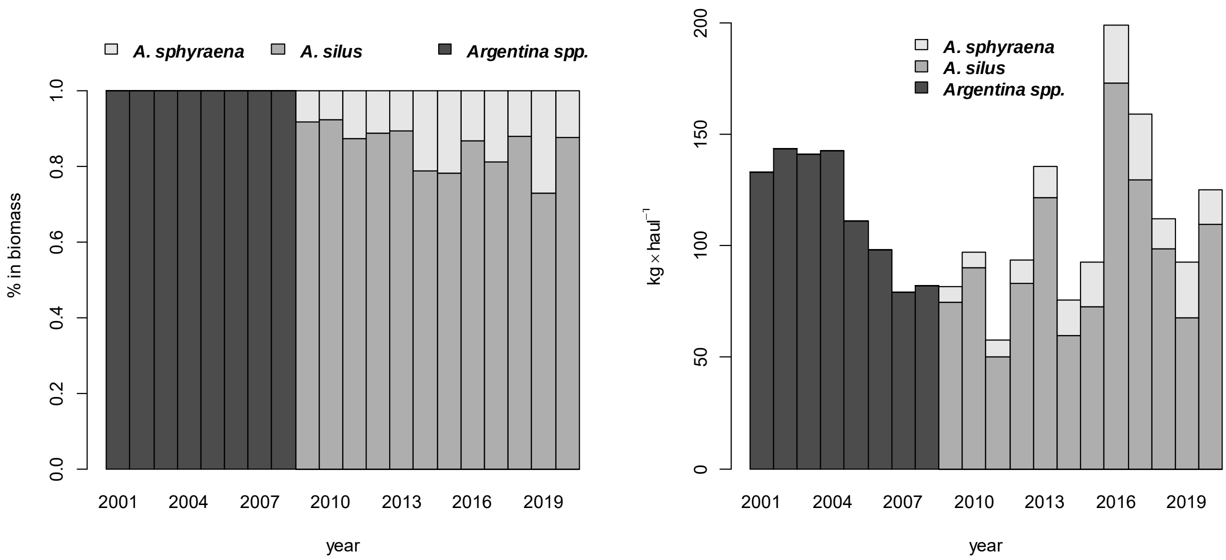


Figure 4. Share and abundance of Argentine species in Porcupine surveys (2001-2020)

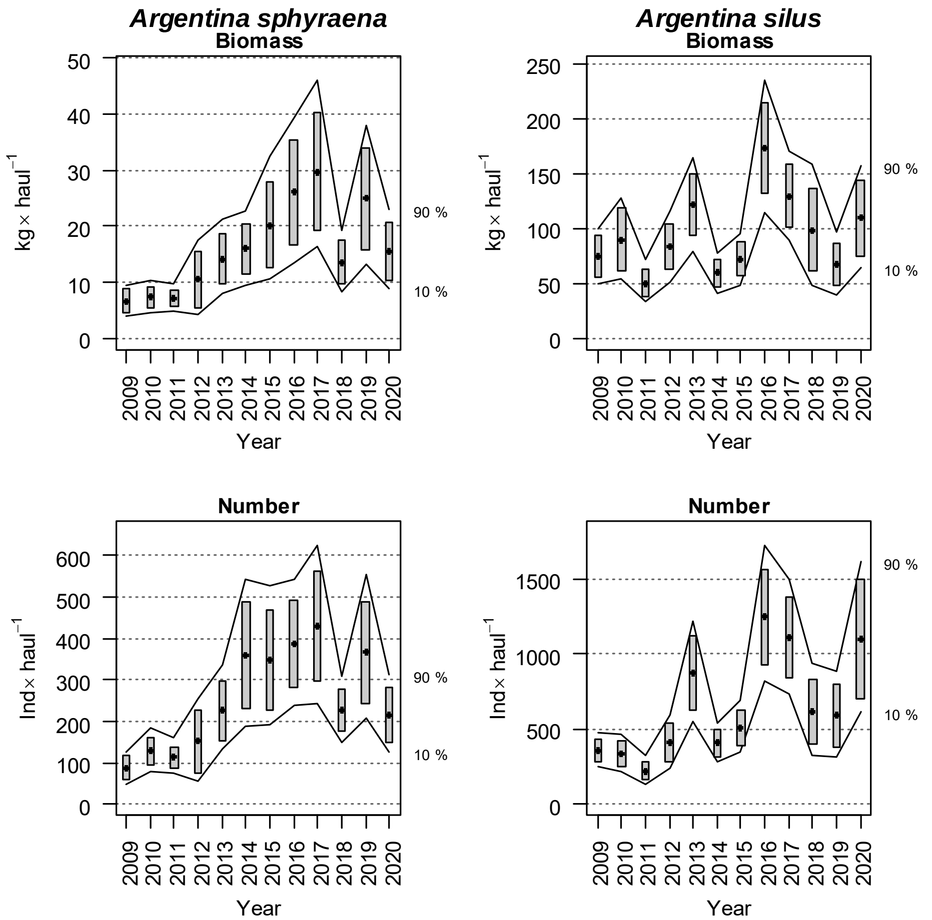


Figure 5. Evolution of *Argentina sphyraena* and *Argentina silus* biomass and abundance indices in Porcupine surveys (2009-2020). Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (a = 0.80, bootstrap iterations =1000)

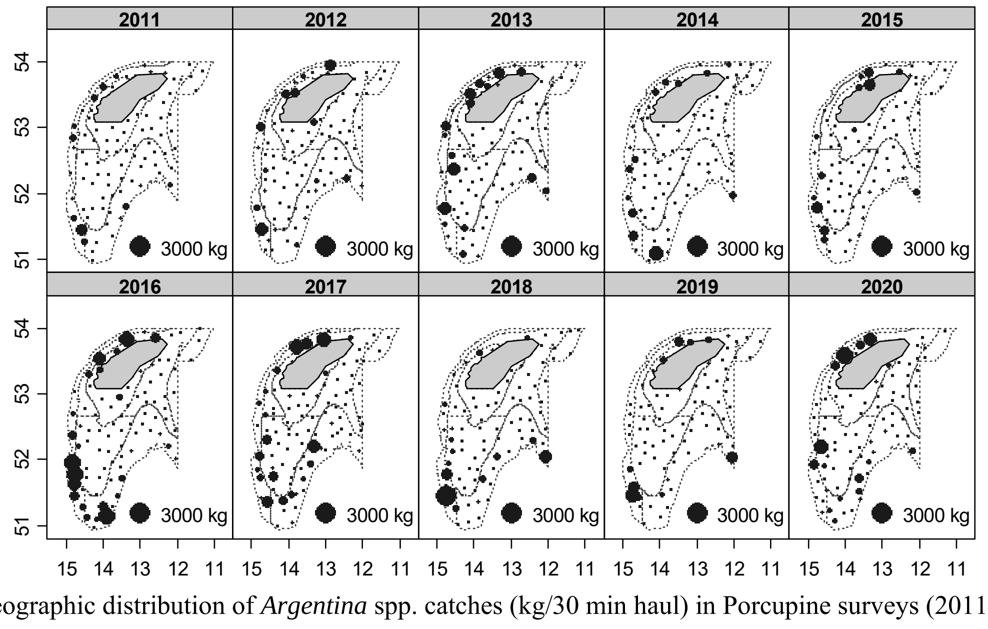


Figure 6. Geographic distribution of *Argentina* spp. catches (kg/30 min haul) in Porcupine surveys (2011-2020)

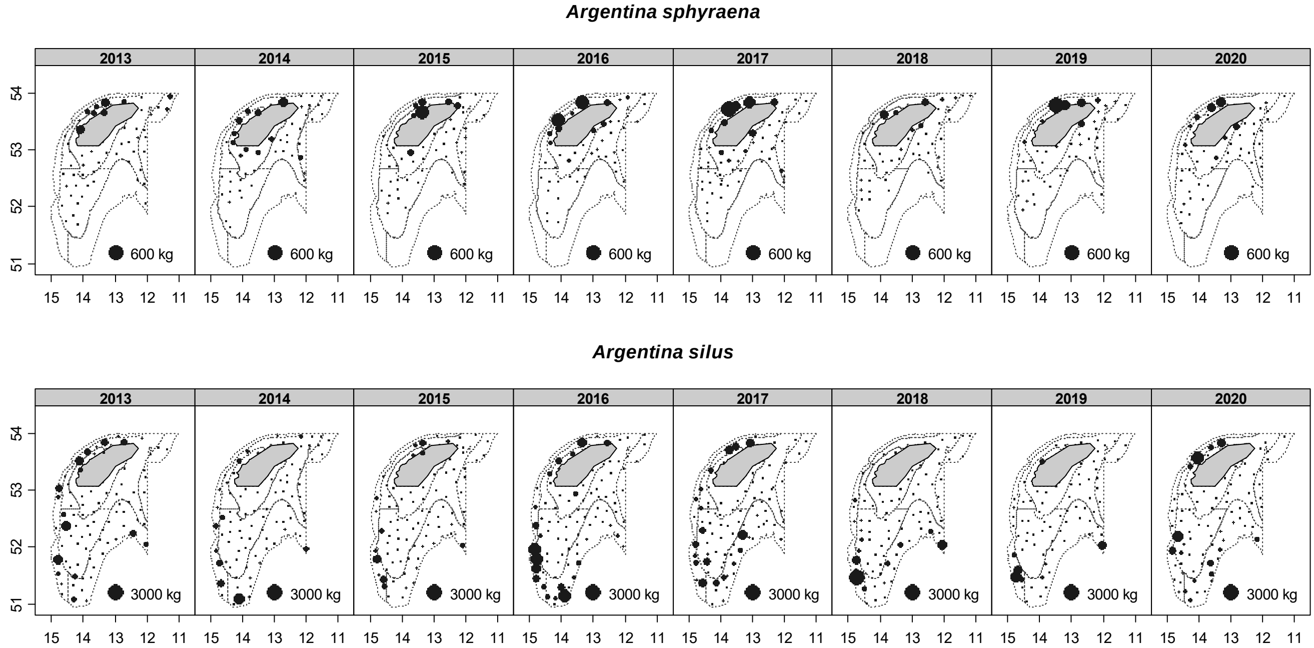


Figure 7. Geographic distribution of *Argentina sphyraena* and *Argentina silus* catches (kg/30 min haul) in Porcupine surveys (2013 - 2020)

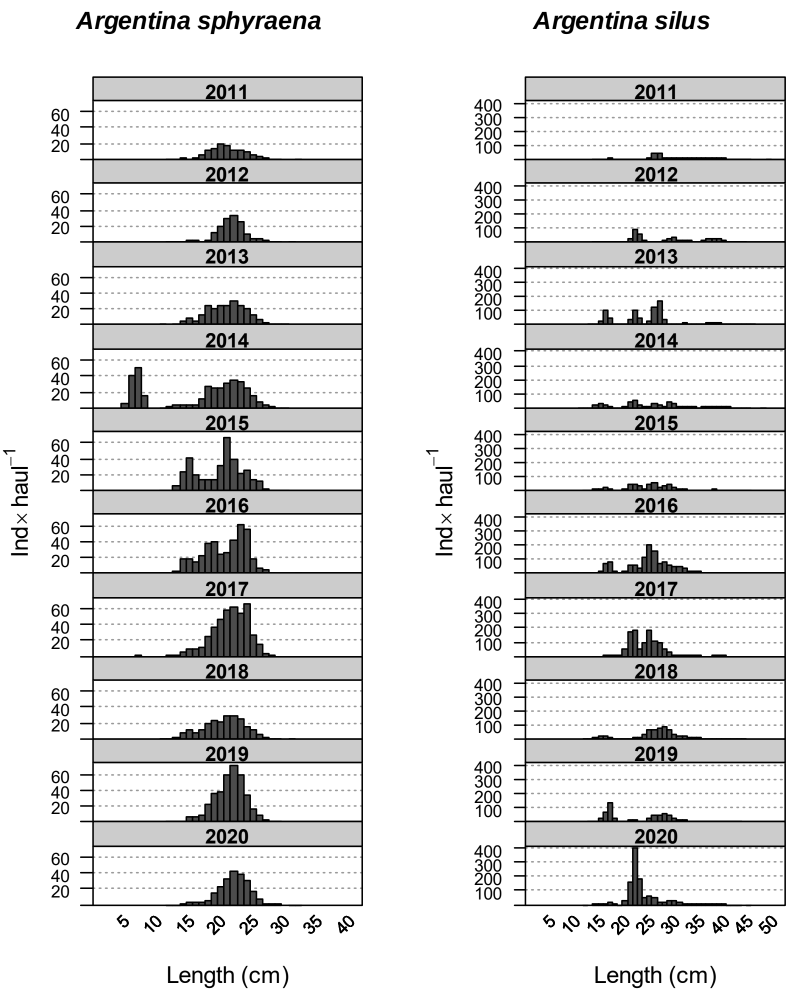


Figure 8. Mean stratified length distributions of *Argentina sphyraena* and *Argentina silus* in Porcupine surveys (2011-2020)

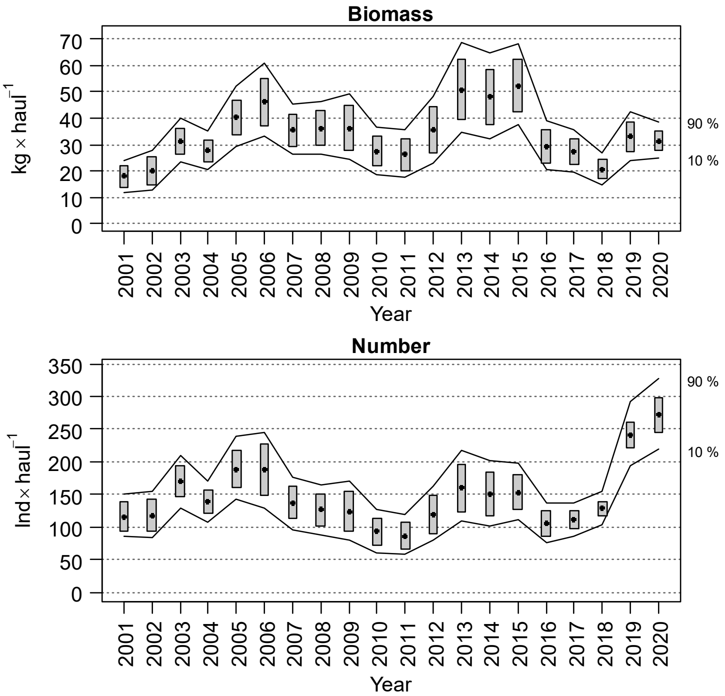


Figure 9. Evolution of *Helicolenus dactylopterus* biomass and abundance indices in Porcupine surveys (2001-2020). Boxes mark parametric standard error of the stratified abundance index. Lines mark bootstrap confidence intervals (α = 0.80, bootstrap iterations = 1000)

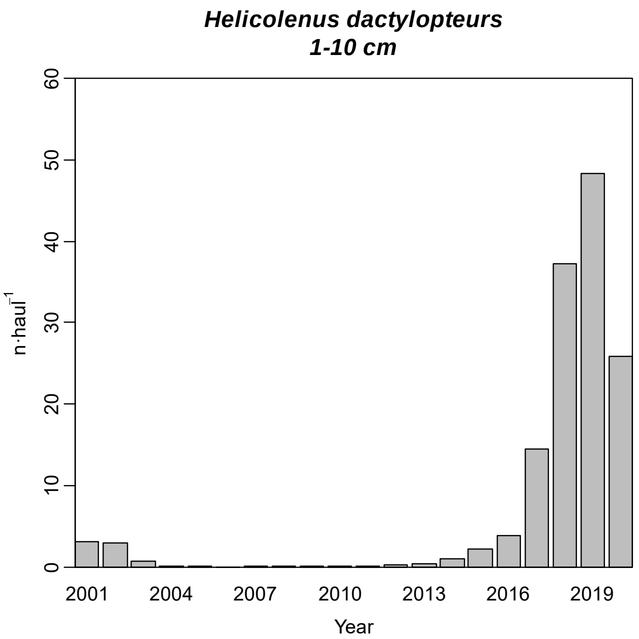


Figure 10. Mean stratified abundance of *Helicolenus dactylopterus* recruits (1-10 cm) in Porcupine surveys (2001-2020)

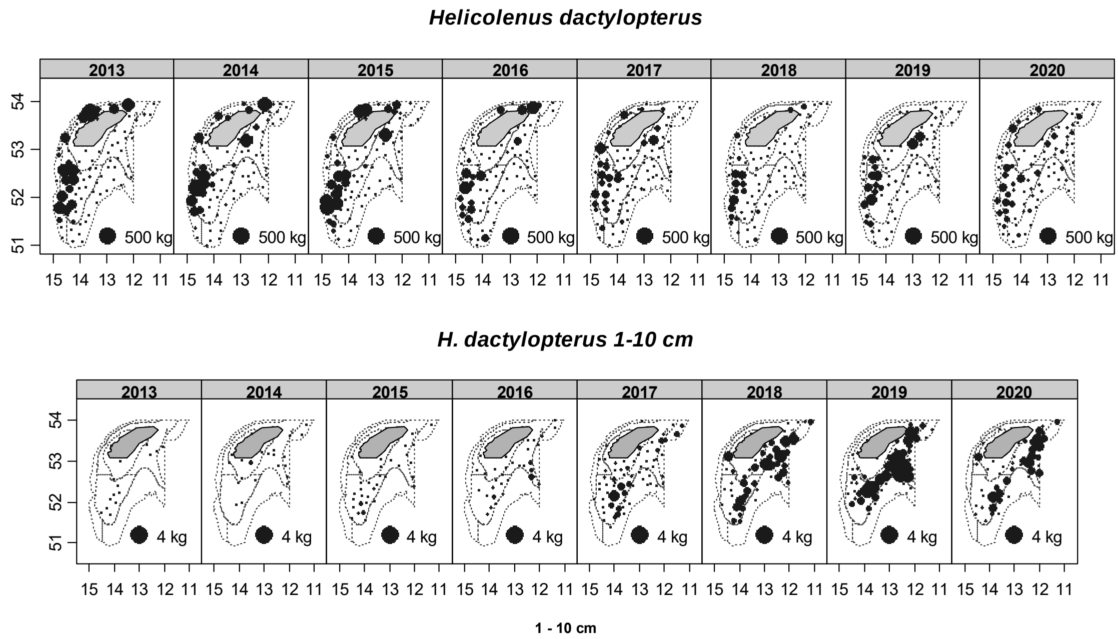


Figure 11. Geographic distribution of *Helicolenus dactylopterus* catches (kg×30 min haul-1) and recruits (1-10 cm) in Porcupine surveys (2013-2020)

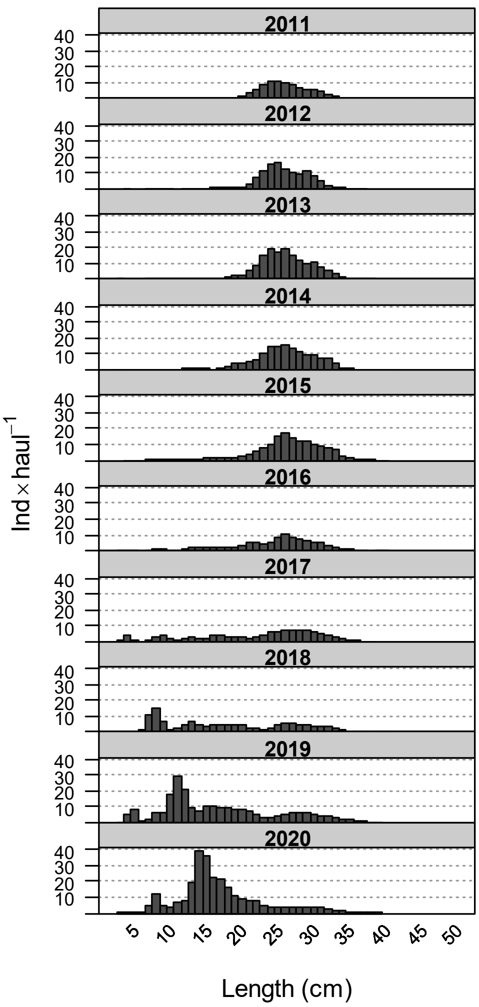


Figure 12. Mean stratified length distributions of *Helicolenus dactylopterus* in Porcupine surveys (2011-2020)

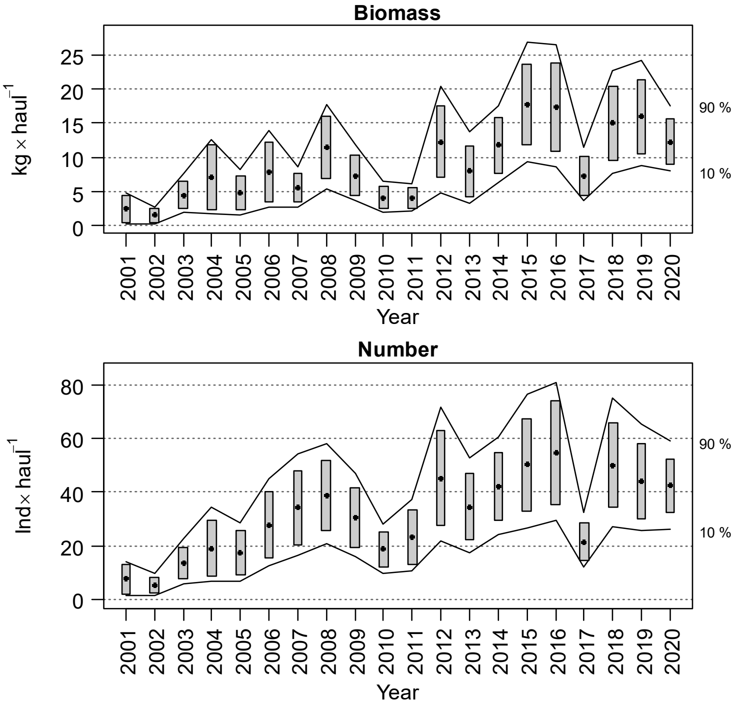


Figure 13. Evolution of *Trachyrincus scabrus* biomass and abundance indices in Porcupine surveys (2001-2020). Boxes mark parametric standard error of the stratified abundance index. Lines mark bootstrap confidence intervals (α = 0.80, bootstrap iterations = 1000)

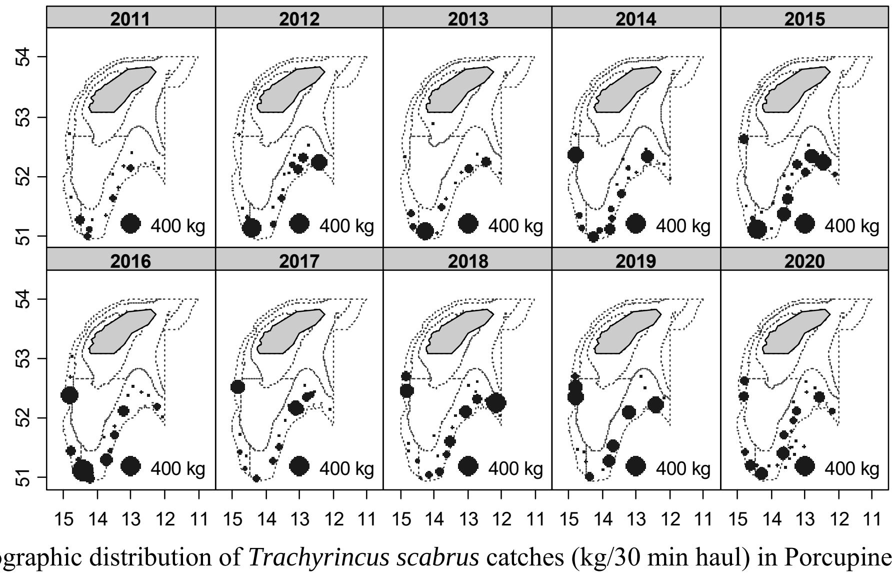


Figure 14. Geographic distribution of *Trachyrincus scabrus* catches (kg/30 min haul) in Porcupine surveys (2011-2020)

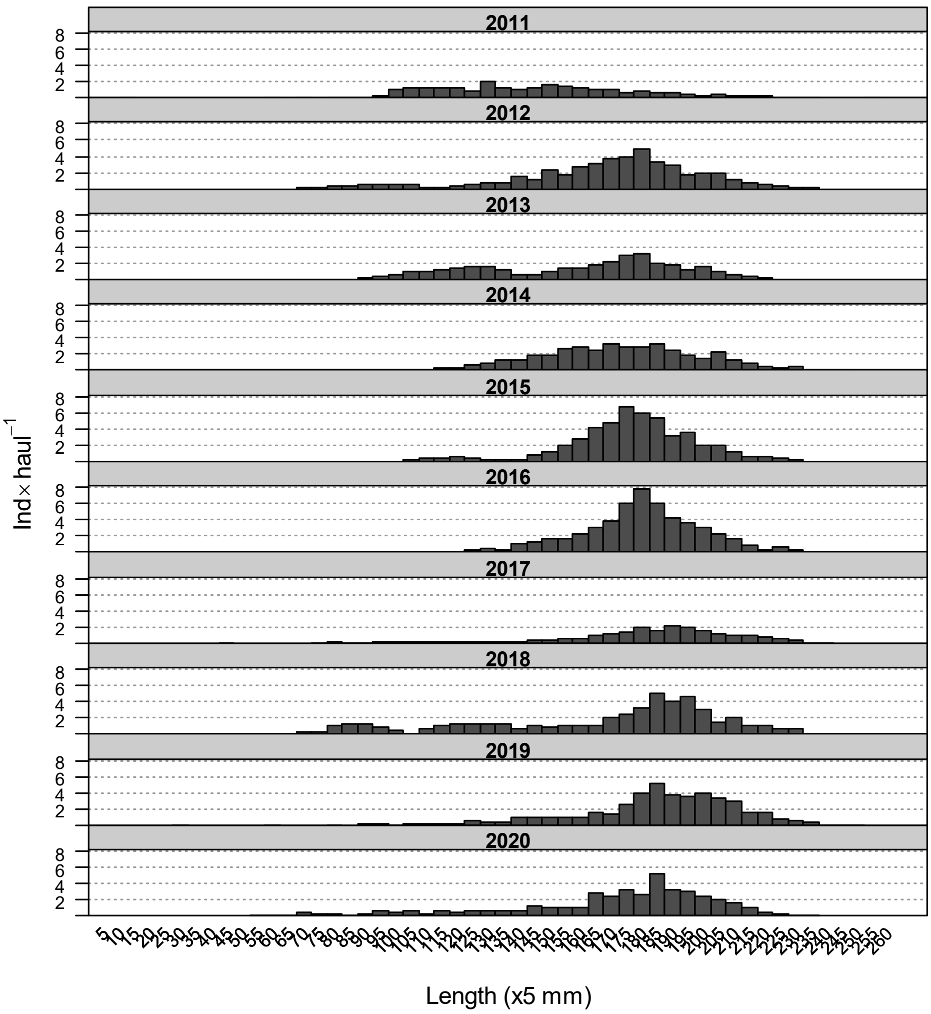


Figure 15. Mean stratified length distributions of *Trachyrincus scabrus* in Porcupine surveys (2011-2020)

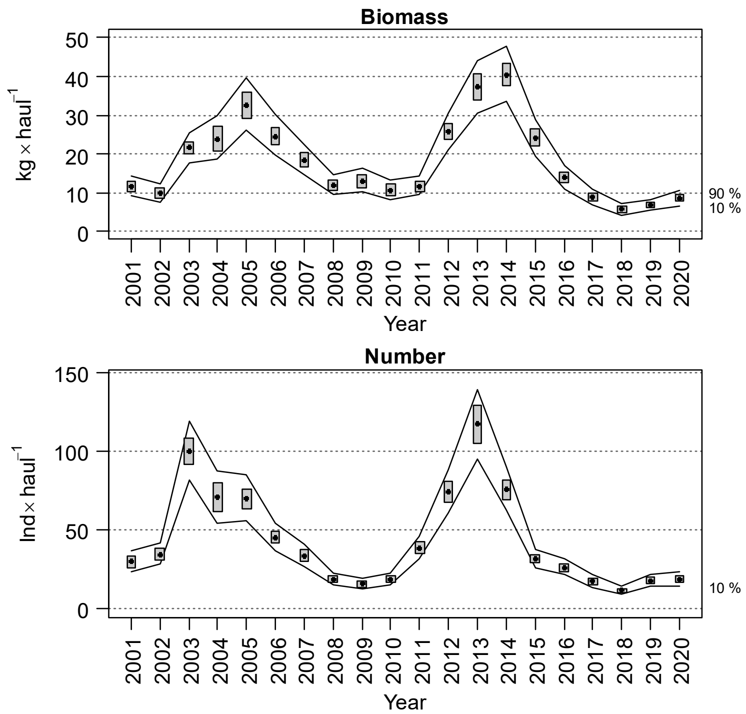


Figure 16. Evolution of *Phycis blennoides* biomass and abundance indices in Porcupine surveys (2001-2020). Boxes mark parametric standard error of the stratified abundance index. Lines mark bootstrap confidence intervals ($\alpha = 0.80$, bootstrap iterations = 1000)

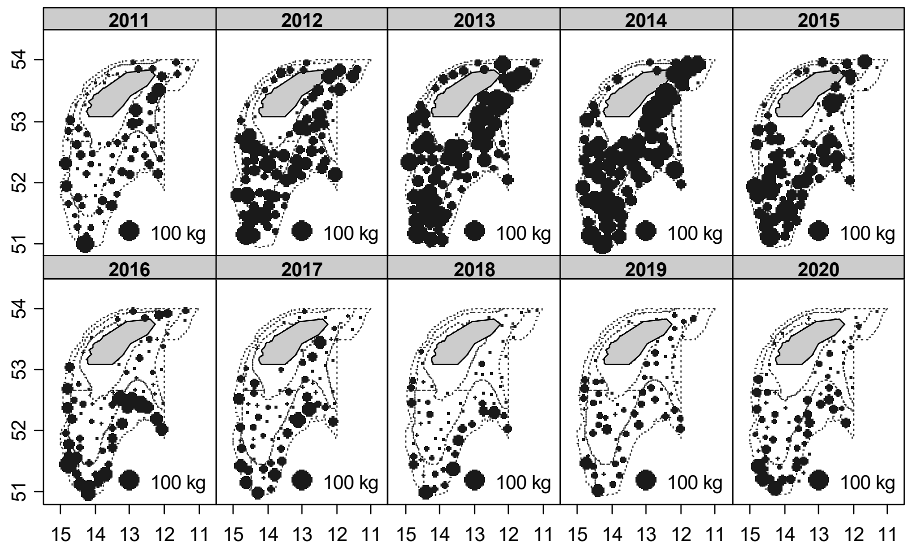


Figure 17. Geographic distribution of *Phycis blennoides* catches (kg×30 min haul^{-1}) in Porcupine surveys (2011-2020)

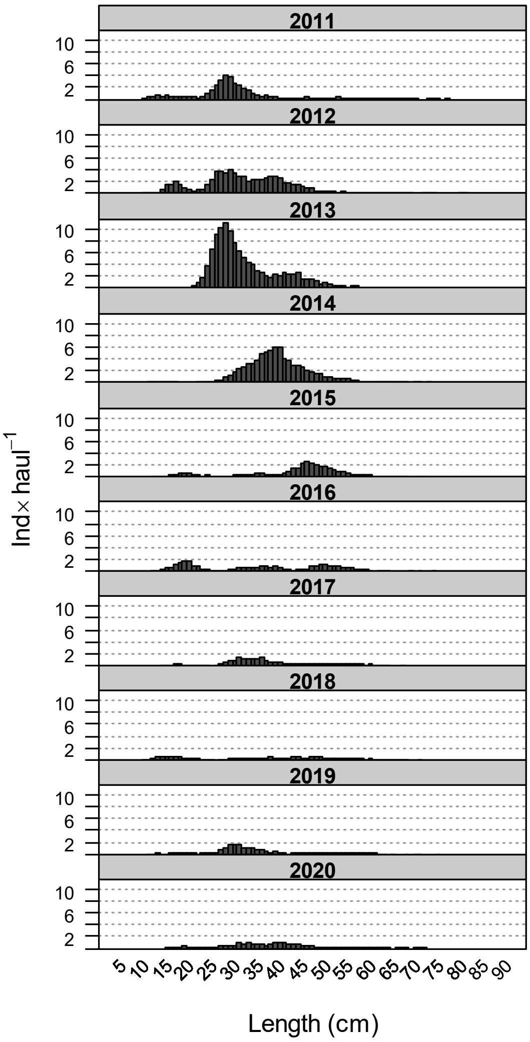


Figure 18. Mean stratified length distributions of *Phycis blennoides* in Porcupine surveys (2011-2020)

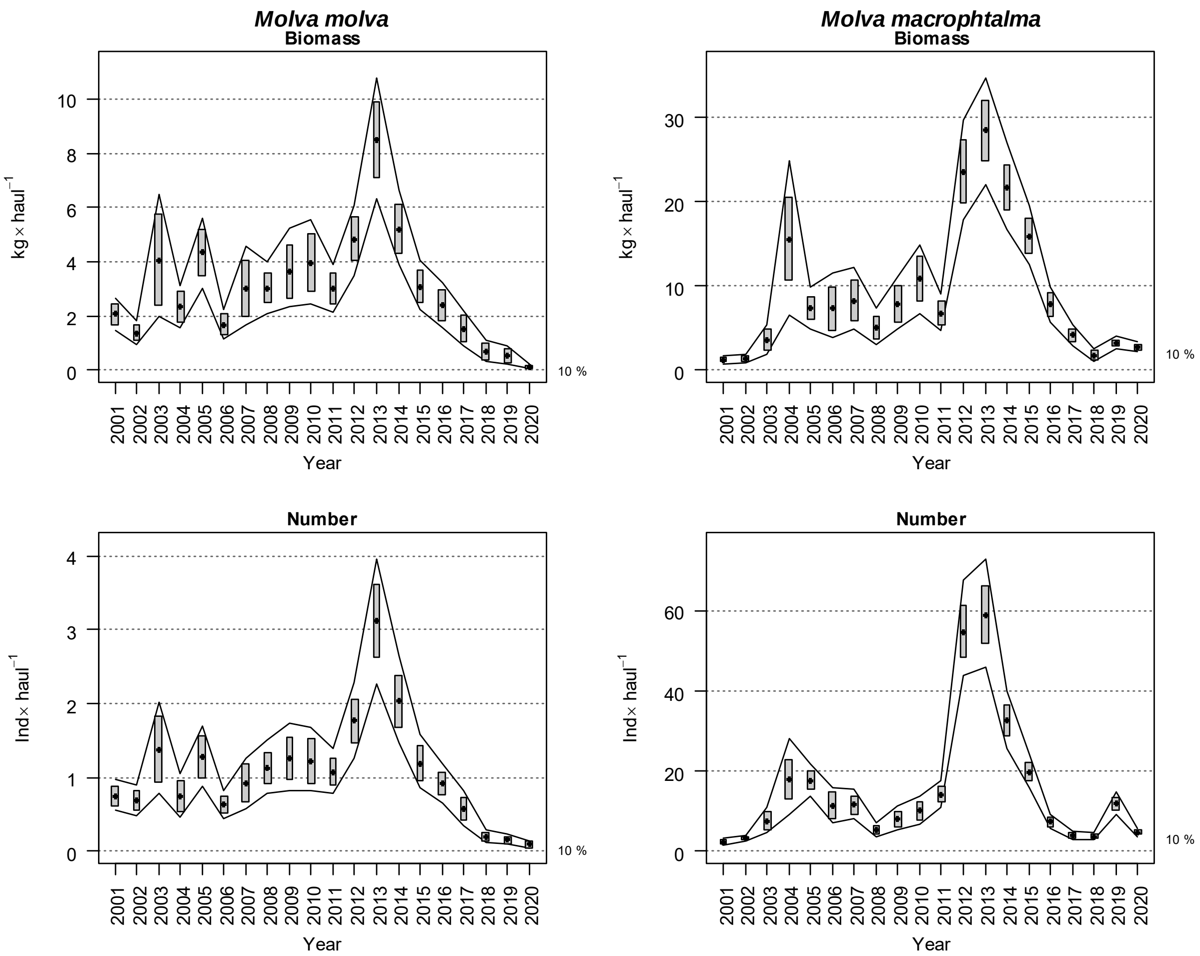


Figure 19. Evolution of *Molva molva* and *Molva macrophtalma* biomass and abundance indices in Porcupine surveys (2001-2020). Boxes mark parametric standard error of the stratified abundance index. Lines mark bootstrap confidence intervals (α = 0.80, bootstrap iterations = 1000)

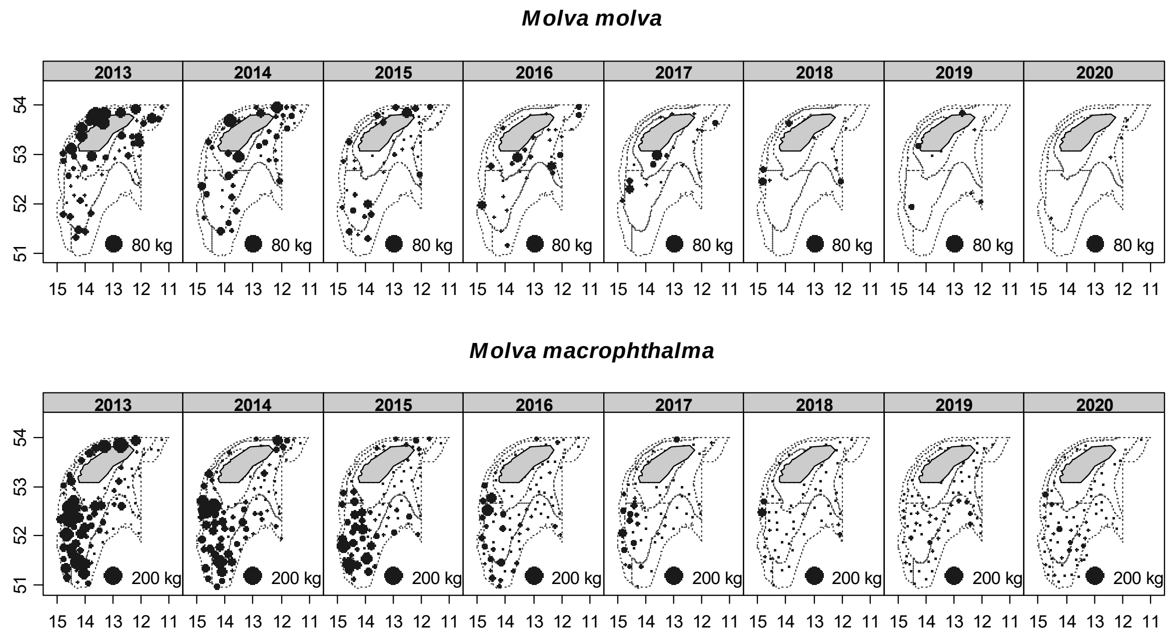


Figure 20. Geographic distribution of *Molva molva* and *Molva macrophtalma* catches (kg×30 min haul^{-1}) in Porcupine surveys (2013-2020)

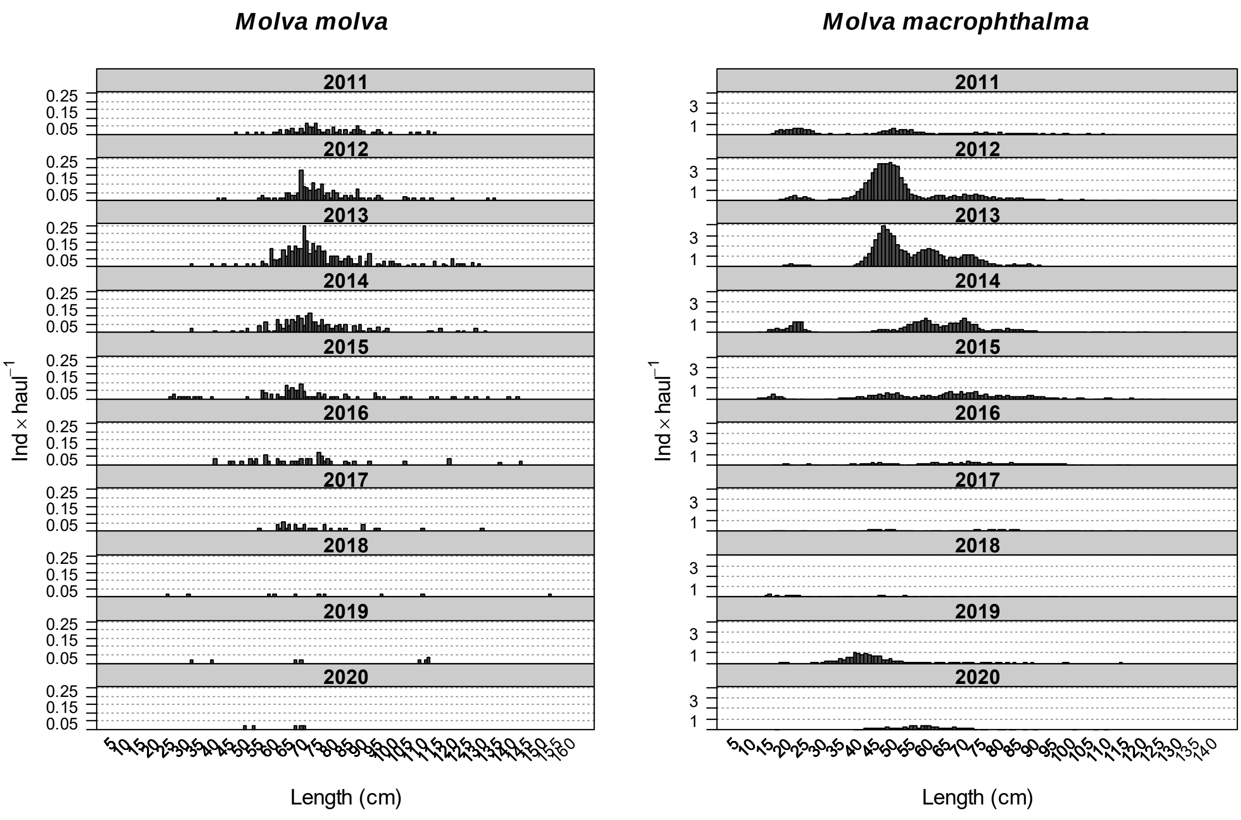


Figure 21. Mean stratified length distributions of *Molva molva* and *Molva macrophtalma* in Porcupine surveys (2011-2020)

Working Document presented to the ICES Working Group on the
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This Working Document has not been peer-reviewed by ICES WGDEEP and should not being interpreted as the view of the Group. The Working Document is appended for information only.

The Blackspot seabream Spanish target fishery of the Strait of Gibraltar: updating the available information

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Abstract

This paper includes the available information of the Blackspot seabream (Pagellus bogaraveo) Spanish "voracera" target fishery of the Strait of Gibraltar. The documents presented in previous years were updated with the 2020 information: data about landings, fishing effort, CPUEs and landings length frequencies are presented to its discussion within the 2021 WGDEEP.

1. Introduction and fishery description

Since the earlies 1980´s a Spanish artisanal fishery targeting to Blackspot seabream (*Pagellus bogaraveo*, namely "*voraz*") have been developed in the Strait of Gibraltar area (ICES 9a South). This fishery has already been broadly described in previous Working Documents presented to the ICES WGDEEP (Gil *et al*., 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019 and 2020). Spanish Blackspot seabream fishery in the Strait of Gibraltar is almost a mono-specific fishery with a clear target species which represents the 74% from the total landed species which constitutes a fleet component by itself (Silva *et al*., 2002).

In 2006, 2008, 2010, 2012 and 2016 different trials were attempted to assess this resource within the ICES WGDEEP (ICES, 2006, 2008, 2010, 2012, 2016, 2018 and 2020). Finally, 2020 scientific advice was based on abundance indexes (DLS category 3). All the available information from this target fishery (including the abundance index used as the basis for the assessment) was updated with 2020 data.

Thus, the main objective of this paper is to provide to the 2021 ICES WGDEEP a summary of the available information of this deep-water fishery located in a very narrow place in the ICES area 9 South East boundary line.

2. Material and methods

Fishery information from the sale sheets was gathered for the period 1983-2020: monthly landings, monthly number of sales (as a proxy of fishing trip) and the number of days in which those sales were carried out. Moreover, landings length distributions was also estimated from the data collected by IEO monitoring programme (Gil *et al*., 2000).

Geo-referenced information from SLSEPA devices (a sort of Vessel Monitoring System) on the "*voracera*" fleet operating at the Strait of Gibraltar were more recently available (from 2009 onwards): this monitoring system, locally called "green boxes" (to differentiate them from the EU VMS "blue boxes"), send every three minutes to a control centre several information about the fishing boat: time, positions, course and speed. Data were filtered and analyzed, according to the protocols proposed by Burgos *et al*. in 2013, to estimate fishing effort and catch rates of the Blackspot seabream Spanish target fishery.

3. Results and discussion

- <u>Landings data</u>: Figure 1 shows a continuous increase of Spanish landings from the beginning of the time series to reach a maximum in 1994. Since then landings´ trend decreased till 2002, despite the peaks in 1996 and 1997. Again, it shows an increasing trend from 2003 to 2009, decreasing afterwards except for a slight increase in 2014. Landings in 2018 show the lowest values of the series, with only 8 tons landed from the Spanish "voracera" fleet.

Until now, discards can be assumed to be zero or negligible. However, the established minimum landing size of 33 centimeters for the species (both for NE Atlantic and Mediterranean Sea) and the landing obligation (EU Regulation 2013/1380) don´t might have an effect on the discards of this target fishery because its high survival exemption.

Hence landings are currently being used as a proxy of catches. However, it should be noted that not all the Spanish catches/landings come exclusively from ICES area 9 but they are considered from the same stock unit because the fishing area (Strait of Gibraltar) is placed between different Advice bodies/Regional Fisheries Organizations (ICES, GCFM and CECAF) boundaries.

Data from Moroccan longliners fishing Blackspot seabream in the Strait of Gibraltar area are available since 2001. The information are available on FAO GFCM statistics (WGSAD-SAC and SRC-WW) so, when possible, it is included in the WGDEEP landings estimates because

Moroccan boats target the same population sharing the main fishing grounds with Spain (ICES, 2016).

- <u>CPUEs</u>: Nominal abundance index shows ups and downs throughout the historical series (Figure 2). It is important to emphasize that the effort unit chosen (number of sales) may not be appropriate as does not consider the missing effort. So in the most recent years, when the resource is not quite abundant, the missing effort might increase substantially (fishing boats with no catches and no sale sheet records). Therefore, the LPUE trend since the first fishery´s decline (1997) should be interpreted with caution because it cannot be a real image of the resource abundance. A severe decreasing trend is observed since 2010, whereas it increases in the last two years (2014 and 2015),similarly to landings. But, like in landings in 2016 - 2018 the signal fall again and start recovering since then.

Table 1 updates the available information from regional VMS (SLSEPA), following the data compilation and its process described by Burgos *et al*. in 2013.

Table I. Estimates of fishing effort and CPUEs (2009-2020) from the "*voracera*" fleet targeting Blackspot seabream based on regional VMS (SLSEPA) and fishery statistics (sales sheets).

Data source		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
VMS	**Landings (k)**	459,010	274,882	190,786	79,163	37,799	94,261	137,344	73,508	24,716	4,402	4,825	1,579
	No. Sales	7,200	5,863	4,711	2,946	2,086	2,989	3,079	1,873	1,017	309	248	62
	Fishing days (fishing trips)	8,373	7,238	6,160	3,686	2,695	4,191	4,234	2,724	1,740	1,046	607	125
	CPUE 1 (landings/No. sales)	64	47	40	27	18	32	45	39	24	14	19	25
	CPUE 2 (landings/fishing days)	55	38	31	21	14	22	32	27	14	4	8	13
	Missing effort	14	19	24	20	23	29	27	31	42	70	59	50
TOTAL	**Landings (k)**	579,140	316,365	239,790	126,006	66,159	137,623	166,440	99,726	42,991	7,633	18,693	12,838
	No. Sales	8,892	6,932	5,659	3,638	2,222	3,527	3,384	2,418	1,308	429	794	525
	CPUE 1 (landings/No. sales)	65	46	42	35	30	39	49	41	33	18	24	24

CPUE 1 (nominal) estimated from total landings and number of sales decreased in the period 2009-2013 from 65 to 30 k fishing trip^{-1} for the total "*voracera*" fleet as well as the (nominal) CPUE 1 for the fleet equipped with the SLSEPA device (64 to 19 k fishing trip^{-1}). Afterwards, it increases till 49 and 45 k fishing trip^{-1} in 2015, respectively. As expected, CPUE 2 (landings/fishing days), where the effort is estimated from the VMS device also declined with lower values than CPUE 1 because the fact of the missing effort. So, as expected, 2009 - 2019 CPUEs estimates from VMS analysis shows the same trend but lower values than the nominal one, from sale sheets (Figure 2).

- <u>Length frequencies</u>: The mean length of landings seems to have decreased in two different periods: from 1995 to 1998 and from 2009 to 2013 (Figure 3). Knowledge about the geographic and bathymetric distribution related to length of the species is scarce. Last years' median value is quite stable and above the 33 cm minimum reference size for this species in the Atlantic and Mediterranean European waters.

4. Main conclusions

The general trend for the time series of both, landings and CPUEs, continues showing a decreasing pattern during the last years, exhibiting the lowest values of the whole series in 2018. This might be a consequence of an overexploitation status of the stock, which is addressing the fishery into a critical situation.

It should be noted that GFCM started a work plan to establish a management plan for this target fishery in 2019 (Recommendation GFCM/41/2017/2 on the management of blackspot sea bream fisheries in the Alboran Sea, geographical subareas 1 - 3, for a two-year transition period).

Acknowledgments

We would like to express our most sincere gratefulness to all those Institutions and people for their collaboration in the execution of the monitoring of the Spanish "*voracera*" fishery: Spanish Institute of Oceanography (IEO), Consejería de Agricultura y Pesca de la Junta de Andalucía, Tarifa´s Fishermen Brotherhood and its 1st sale fishmarket staff.

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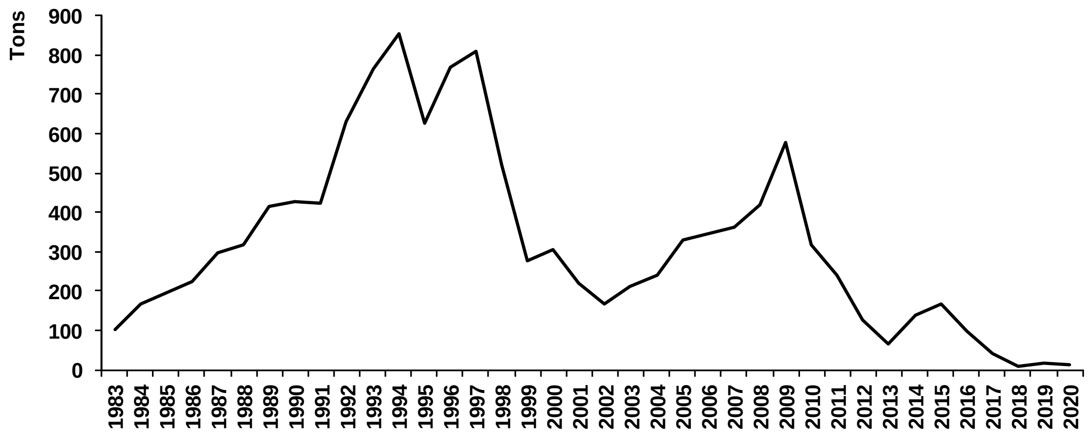

Figure 1. Blackspot seabream Spanish "*voracera*" fishery of the Strait of Gibraltar: total landings in tones (1983-2020).

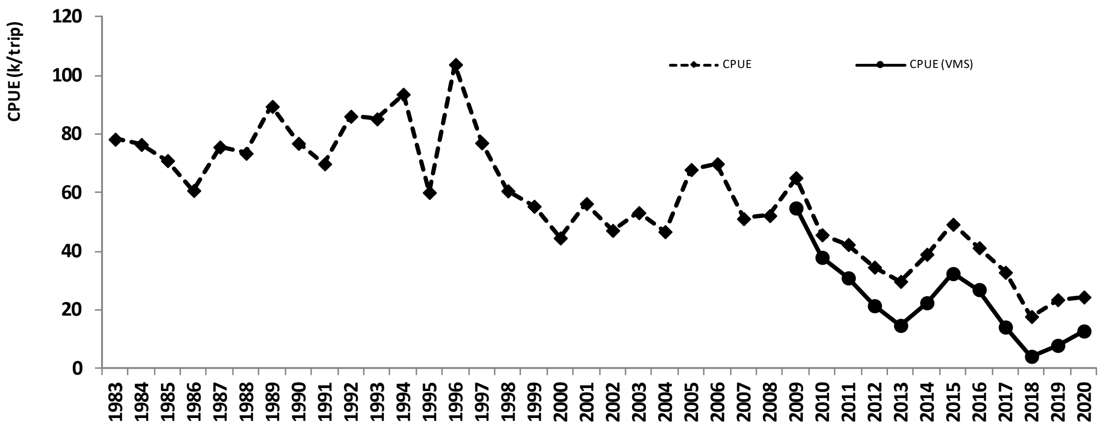

Figure 2. Blackspot seabream Spanish "*voracera*" fishery of the Strait of Gibraltar: sale sheets CPUE (1983-2020) and VMS CPUE (2009-2020).

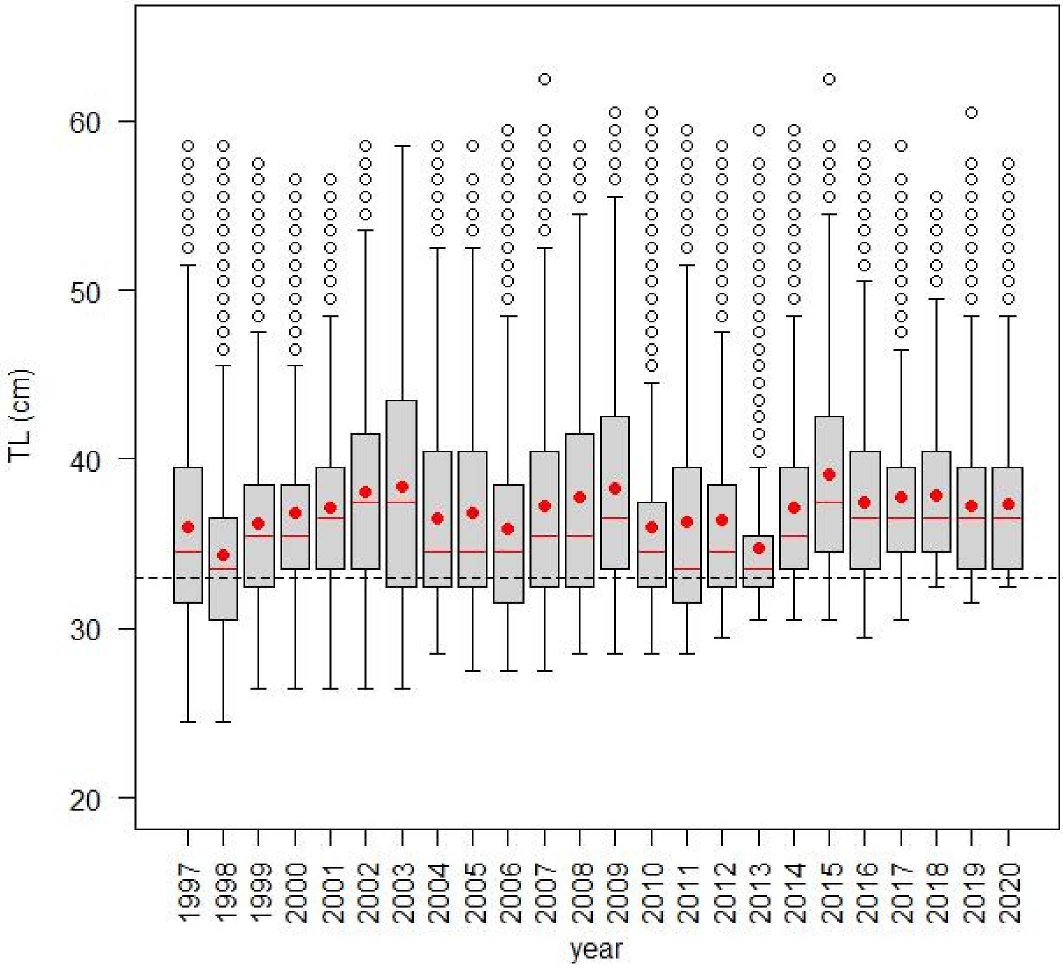

Figure 3. Blackspot seabream Spanish "*voracera*" fishery of the Strait of Gibraltar: 1997 – 2020 landings length distribution descriptive statistics (red dot: mean value, red line: median value, box and whiskers: Interquartile Range plus Q_1-3IQR and Q_3+3IQR, circles: outliers).

Blue ling unwanted catch estimates for Scotland

Jess Craig, Liz Clarke & Elisa Barreto, Marine Scotland Science

RE: MSS WGDEEP 2021 submission of blue ling (*Molva dypterygia*; BLI) discard weights for stocks bli.27.nea and bli.27.5b67.

Estimates of unwanted catch (termed discards by ICES) of blue ling for Scotland have been updated. This correction has resulted in a substantial increase in the estimated discard weight relative to previous Scottish BLI discard weight submissions. Table 1 provides a comparison of the 2015-2020 BLI discard weights estimated with and without the correction. The correction does not affect the landed weights. Although the relative shape of the landings length frequency distributions (LFDs) remains the same, the correction reduces the mean weight per length by 6%. The relative shape of the discard LFDs is not affected by the correction.

We propose updating the 2015-2019 BLI submissions to InterCatch at a time convenient to the blue ling stock assessors

Table 1. 2015 – 2020 blue ling (BLI) Scottish catch weights by year and stratum, with a comparison of estimated discard weight before and after the correction. Including only strata with non-zero values 2015 – 2020.

Stratum	Year	Landed weight (tonnes)	Discard weight (95% CI) with correction (tonnes)	Discard weight (95% CI) without correction (tonnes)
27.4.a TR1†	2020	10.090	* 0	0
	2019	4.348	14.110 (0 - 50.161)	0.023 (0 – 0.073)
	2018	3.582	0.774 (0 - 2.225)	* 0.002 (0 – 0.005)
	2017	4.849	2.403 (0 - 7.993)	* 0.117 (single trip)
	2016	6.365	0	* 0
	2015	2.560	0	0
27.6.a TR1	2020	710.116	* 9.239 (0 – 28.199)	0.015 (0 – 0.045)
	2019	718.094	29.598 (0 – 128.998)	0.031 (0 – 0.144)
	2018	734.798	14.746 (0 – 69.208)	* 0.017 (0 – 0.070)
	2017	640.454	0	0
	2016	272.461	18.130 (0.399 – 58.651)	* 0.036 (0.002 – 0.080)
	2015	370.186	11.439 (0 – 59.720)	* 0.056 (0 – 2.272)
27.6.b.2 TR1	2020	0	* 2.869 (0 – 10.624)	0.007 (0 – 0.026)
	2019	0	0	0
	2018	1.369	11.641 (0 – 22.524)	* 0.015 (0 – 0.029)
	2017	0	0	0
	2016	0	0.0913 (0 – 0.192)	0
	2015	0	0	0

* Current submission in InterCatch
† TR1 is allocated to fleet OTB_DEF_>=120_0_0_all in InterCatch

Stock bli.27.5b67

The discard weight estimates for '27.6.a TR1' and '27.6.b.2 TR1' contribute to the stock bli.27.5b67. The total catches estimated by ICES for bli.27.5b67 have been in excess of 10,000 tonnes since 2017 (Table 2), therefore the revised discard weights represent less than 0.3% of the catch during this time. In 2015 and 2016, the catches for bli.27.5b67 were < 5046 tonnes, therefore the revised discard weights represent ca. 0.2 % and 0.4 % respectively.

Stock bli.27.nea

Stratum '27.4 TR1' contributes to the stock bli.27.nea, for which zero catches have been advised since 2018. Total catches estimated by ICES for bli.27.nea in 2018 were 348 tonnes, for which the revised discard weight represents 0.2 %. In 2017 the bli.27.nea catch was 280 tonnes, and the revised discard weight represents 0.9 %.

Table 2. ICES Blue ling (BLI) advice, catches and discards 2015 to present.

Stock (Advice ref.)	Catch advice (Year: tonnes)	ICES catches (Year: tonnes)	Discards (tonnes)
bli.27.nea (ICES, 2019)	2020-2023: 0 2018-2019: 0 2017: - 2016: - 2015: -	 2018: 348 (Area 4.a: 60) 2017: 280 (Area 4.a: 74) 2016: 205 (Area 4.a: 87) 2015: 208 (Area 4.a: 83)	Negligible (2018: 0.302) (2017: 0.925)
bli.27.5b67 (ICES, 2020)	2020: 11150 2019: 11778 2018: 10763 2017: 11314 2016: 5046 2015: 5046	2020: ≤ 11150 2019: ≤ 11778 (EU landings: 3218) 2018: ≤ 10763 (EU landings: 3322) 2017: ≤ 11314 (EU landings: 2669) 2016: < 5046 (EU landings: 3059) 2015: < 5046 (EU landings: 2748)	Negligible

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ICES. 2020. Blue ling (*Molva dypterygia*) in subareas 6–7 and Division 5.b (Celtic Seas and Faroes grounds). In Report of the ICES Advisory Committee, 2020. ICES Advice 2020, bli.27.5b67. https://doi.org/10.17895/ices.advice.5819.

ICES. 2019. Blue ling (Molva dypterygia) in Subareas 1, 2, 8, 9, and 12, and Divisions 3.a and 4.a (other areas). In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, bli.27.nea, https://doi.org/10.17895/ices.advice.4813

Discards of deepwater species by the Portuguese bottom otter trawl fisheries in ICES Division 27.9.a

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Abstract

The information on discards produced by Portuguese vessels operating with bottom otter trawl fleet in Portuguese ICES Division 27.9.a is compiled. The sampling effort, species frequencies of occurrence and discard estimates are presented, for the period 2004-2019. The species included are the WGDEEP stocks black scabbardfish (*Aphanopus carbo*), alfonsinos (*Beryx spp*), roughhead grenadier (*Macrourus berglax*), blackspot(=red) seabream (*Pagellus bogaraveo*), greater forkbeard (*Phicys blennoides*) and ling (*Molva molva*). The samples were collected by the Portuguese onboard sampling programme (PNAB/EU DCF). The low frequency of occurrence registered by most of these species in OTB fisheries for the period 2004-2019 indicates that discards can be considered negligible for the most WGDEEP stocks, with exception of greater forkbeard for some of the years of that period. In 2020, the Portuguese onboard sampling programme was compromised by the pandemic situation due to Covid-19 and the sampling only occurred in the first quarter. For this reason, the sampling effort was not representative of the fishing effort of the bottom otter trawl fleet (OTB) and the algorithm usually used for discards estimation cannot be applied. For the species presenting low frequencies of occurrence in the discards of sampled hauls in the previous period (2004-2019), discards for 2020 were considered zero or negligible. In the case of more frequent species (e.g. greater forkbeard) a new discard estimation approach was developed and the results obtained are presented.

1. Introduction

This working document compiles the information available, from the period 2004-2019, on the discards of black scabbardfish (*Aphanopus carbo*), alfonsino nei (*Beryx spp*), roughhead grenadier (*Macrourus berglax*), blackspot(=red) seabream (*Pagellus bogaraveo*), greater forkbeard (*Phicys blennoides*) and ling (*Molva molva*) produced by the Portuguese bottom otter trawl fleet (OTB) (Table 1). The data was collected by the Portuguese onboard sampling programme and a summary of the onboard sampling and discards estimation are presented in Sections 2 and 3. The discard series obtained for the period 2004-2019 is presented in Section 3. Due to the pandemic situation in 2020, very few trips were sampled in the first quarter of the year for the bottom otter trawl targeting demersal species (OTB_DEF), and no trips were sampled in the bottom otter trawl targeting crustaceans. Since this sampling effort was not representative of the fishing effort of the fleet, the discard raising procedure previously used (Jardim and Fernandes, 2013) cannot be used to estimate discards at fleet level for 2020, and a new approach for discard estimation is presented.

Table 1 – Species composition and common names of the WGDEEP species

Species	3-alpha code	English name	Portuguese name
Aphanopus carbo	BSF	Black scabbardfish	Peixe-espada-preto
Beryx spp	ALF	Alfonsino nei	Imperadores
Macrourus berglax	RHG	Roughhead grenadier	Granadeiro
Pagellus bogaraveo	SBR	Blackspot(=red) seabream	Goraz
Molva molva	LIN	Blue ling	Maruca
Phicys blennoides	GFB	Greater forkbeard	Abrótea-do-alto

2. Onboard sampling

The Portuguese onboard sampling program, included in the EU DCF/PNAB, uses a stratified random sampling design and the vessel selection is based on an opportunistic sampling of cooperative commercial vessels between 12 and 40 meters over-all length (LOA). For sampling purposes, the bottom otter trawl fleet is split into two components: a crustacean fishery (OTB_CRU) that operates cod-end mesh sizes 55-59mm and >70mm targeting deep-water rose shrimp, Norway lobster and blue whiting and a demersal species fishery (OTB_DEF) that operates cod-end mesh size 65-69mm and >70mm and targets horse-mackerel, cephalopods and other finfish. Annual sampling targets are fixed for each fishery, namely 12 trips in the OTB_CRU fishery, 27 trips in the OTB_DEF fishery. Table 2 presents the sampling levels of the period 2004-2020.

Table 2 – Sampling levels of the Portuguese onboard sampling programme in the OTB_DEF and OTB_CRU fisheries for the period 2004-2020.

Year	Trips sampled		Hauls sampled		Hours fished	
	OTB_CRU	OTB_DEF	OTB_CRU	OTB_DEF	OTB_CRU	OTB_DEF
2004	17	24	111	125	479	315
2005	15	39	74	159	372	349
2006	7	42	30	194	133	380
2007	12	38	73	162	263	287
2008	12	34	66	128	255	254
2009	16	38	84	135	314	264
2010	16	31	103	116	375	208
2011	13	30	56	83	217	161
2012	13	31	68	60	302	130
2013	6	27	28	50	118	108
2014	10	24	42	52	167	112
2015	13	26	51	48	201	105
2016	12	29	42	61	172	143
2017	10	32	28	69	128	155
2018	11	22	40	47	174	86
2019	8	23	27	45	119	98
2020	0	4	0	6	0	11

The sampling protocol used in Portuguese sampling of the OTB fisheries is detailed in Jardim, *et al* (2012). A brief account follows. Two observers are deployed per fishing trip. Several hauls are made on each fishing trip and observers take a sample from the haul's catch, sort the specimens into retained and discarded fraction and register the weight and length composition of each species fraction. Observers collect concurrent fishing effort information (e.g. hours fished) and register environmental information (GPS coordinates, depth, bottom type, etc.). The on-board sampling protocols of the OTB_CRU, OTB_DEF fisheries have suffered only minor changes and adaptations between 2004 and 2010. In 2011 the size of catch samples taken from the OTB fishery was doubled (from 1 to 2 boxes of catch) and the within-trip selection of hauls and sets was standardized to “at least, every other haul/segment”.

3. Data analysis

The procedures used to raise discard data from samples to haul and fleet level, considering each fishery have been previously described in Jardim and Fernandes (2013) and Fernandes *et al.* (2017). A brief account follows.

3.1 Estimates of discards at haul level

In the OTB fisheries, the total volume discarded (in kg) in each haul is estimated by multiplying the ratio of discard and retained sample weights (all species combined) by the total retained weight in the haul (all species combined). The volume of discards of individual species in each haul is calculated *a posteriori* by multiplying the proportion (in weight) of species discards in the catch sample by the total catch volume estimated for each haul (total volume discarded + total volume landed) (Fernandes *et al.*, 2017).

3.2 Estimates of discards at fleet level (2004-2019)

The procedure generally used to raise discards from haul to fleet level in the Portuguese trawl fisheries is described in Jardim and Fernandes (2013). This procedure relies on haul level discard data (discards per hour) and effort data (fishing hours and fishing trips) derived from logbooks, sales slips and, for 2012-2019 periods, VMS (Vessel Monitoring System) data was also used. Using this procedure species with low frequency of occurrence or abundance in discards (i.e., a large number of zeros in the data set) cannot be reliably estimated at fleet level, because the discard estimation algorithm is sensitive to large numbers of zeros in the dataset (Fernandes *et al.*, 2021; Jardim *et al.*, 2011).
Summary discard information for the period 2004-2019 is presented in Tables 3-7. Frequencies of occurrence of the WGDEEP species in the sampled hauls are presented in Table 3 and Table 4. Discards information (mean number of individuals in the sampled hauls, standard deviation and range) are summarized in Table 5 and Table 6. Greater forkbeard (GFB) is the only species presenting discard volumes in some years of the period and the results are presented in Table 7.

Table 3 – Frequency of occurrence (%) of species in discards of hauls sampled from the OTB_DEF fishery. See Table 1 for species codes.

3-alpha code	2004	2005	2006	2007	2008	2009	2010	2011
BSF	2	1	2	--	--	--	--	--
ALF	--	--	--	--	--	--	--	--
RHG	--	--	--	--	--	--	--	--
LIN	--	--	--	--	--	--	--	--
SBR	--	--	1	1	--	--	--	--
GFB	5	--	2	1	--	4	2	--

3-alpha code	2012	2013	2014	2015	2016	2017	2018	2019
BSF	--	--	--	--	--	--	--	--
ALF	--	--	--	--	--	--	--	--
RHG	--	--	--	--	--	--	--	--
LIN	--	--	--	--	--	--	--	--
SBR	--	--	--	--	--	1	--	--
GFB	--	2	--	2	--	--	--	--

Table 4 – Frequency of occurrence (%) of species in discards of hauls sampled from the OTB_CRU fishery. See Table 1 for species codes.

3-alpha code	2004	2005	2006	2007	2008	2009	2010	2011
BSF	6	1	--	--	--	--	--	--
ALF	1	--	13	--	--	--	--	2
RHG	--	--	--	--	--	--	--	--
LIN	--	--	--	--	--	--	--	--
SBR	--	--	--	1	--	--	1	--
GFB	30	42	57	26	64	31	32	25

3-alpha code	2012	2013	2014	2015	2016	2017	2018	2019
BSF	--	--	--	4	--	7	--	7
ALF	--	--	--	--	--	--	5	--
RHG	--	--	--	--	--	--	--	--
LIN	--	--	--	--	--	--	--	--
SBR	1	--	--	--	--	--	--	--
GFB	35	29	36	51	36	54	25	41

Table 5 – Discards (in number of specimens per haul) of species in the OTB_DEF fishery (2004-2019); See Table 1 for species codes; "--" indicates no occurrence; SD – standard deviation.

	BSF			SBR			GFB		
Year	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
2004	0.4	3.6	0-37	--	--	--	2.4	12.3	0-106
2005	1.0	10.1	0-121	--	--	--	--	--	--
2006	0.9	8.3	0-109	0.5	5.3	0-72	1.6	12.7	0-140
2007	--	--	--	0.3	2.5	0-24	0.3	2.5	0-25
2008	--	--	--	--	--	--	--	--	--
2009	--	--	--	--	--	--	1.5	10.2	0-106
2010	--	--	--	--	--	--	0.5	3.9	0-36
2011	--	--	--	--	--	--	--	--	--
2012	--	--	--	--	--	--	--	--	--
2013	--	--	--	--	--	--	0.1	0.4	0-3
2014	--	--	--	--	--	--	--	--	--
2015	--	--	--	--	--	--	0.4	2.8	0-20
2016	--	--	--	--	--	--	--	--	--
2017	--	--	--	0.2	1.7	0-14	--	--	--
2018	--	--	--	--	--	--	--	--	--
2019	--	--	--	--	--	--	--	--	--

Table 6 – Discards (in number of specimens per haul) of species in the OTB_CRU fishery (2004-2019); See Table 1 for species codes; "--" indicates no occurrence; SD – standard deviation.

	BSF			ALF			SBR			GFB		
Year	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
2004	3.5	19.7	0-174	0.4	4.6	0-48	--	--	--	56.1	239.2	0-2216
2005	0.3	2.5	0-21	--	--	--	--	--	--	29.5	80	0-599
2006	--	--	--	47.3	237.2	0-1300	--	--	--	180.8	812.3	0-4550
2007	--	--	--	--	--	--	0.3	2.5	0-21	61.7	407	0-3500
2008	--	--	--	--	--	--	--	--	--	94.4	148.6	0-823
2009	--	--	--	--	--	--	--	--	--	27.9	65.8	0-421
2010	--	--	--	--	--	--	0.5	4.8	0-49	43.9	134.1	0-912
2011	--	--	--	0.4	2.8	0--21	--	--	--	13.1	33.5	0-203
2012	--	--	--	--	--	--	0.4	3.5	0-29	23.3	44.9	0-214
2013	--	--	--	--	--	--	--	--	--	13.6	30.2	0-119
2014	--	--	--	--	--	--	--	--	--	71.1	139.7	0-601
2015	0.5	4.8	0-25	--	--	--	--	--	--	107.3	488.0	0-3527
2016	--	--	--	--	--	--	--	--	--	36.2	82.1	0-360
2017	1	2.6	0-14	--	--	--	--	--	--	23.9	34.6	0-144
2018	--	--	--	--	--	--	--	--	--	44.1	125.8	0-522
2019	5	26.0	0-137	--	--	--	--	--	--	20.9	31.9	0-120

Table 7 – Greater forkbeard discarded in the Portuguese OTB_CRU fishery (2004-2019); volume (in metric tons) and CVs (% in brackets). See Table 1 for species codes; "(a)" = low frequency of occurrence (< 30%).

Year	GFB
2004	30 (33%)
2005	31 (48%)
2006	264 (5%)
2007	(a)
2008	25 (50%)
2009	33 (25%)
2010	18 (31%)
2011	(a)
2012	7 (63%)
2013	(a)
2014	31 (31%)
2015	28 (30%)
2016	64 (21%)
2017	16 (45%)
2018	(a)
2019	45 (43%)

4. Discards estimation procedure (2020)

In what concerns to 2020, discards cannot be estimated with the same raising procedure because there is no representative sampling effort in OTB fisheries. A preliminary analysis performed to investigate the OTB fleet fishing pattern (e.g. fishing days, fishing duration in hours, number of hauls per trip, landed weights) showed no significant differences between 2020 and the previous sampling period (2004-2019). For this reason, the WGDEEP species that presented frequencies of occurrence below 30% in all the previous sampling period were also considered to have no or negligible discards in 2020. The only species with discard estimates in some of the years included in the period 2004-2019 was the greater forkbeard, in OTB_CRU. For this species, a new approach for calculating discard estimates for 2020, using standardized discards-per-unit-effort (DPUE – discarded weight per hour) series, was explored and developed. The complete methodology of this approach is described in Coelho *et al.* (*in press*.). A brief account follows. Exploratory analysis of the data was first performed, using the haul level data. The generalized linear model (GLM) with log-link function as a Tweedie regression model was used to estimate the standardized DPUE year trend. The Tweedie distribution method selected is a way for dealing with a high mass of zeros and uses the statistical distribution from the Tweedie family of distributions, that allows for zero observations (Dunn and Smyth, 2008; Coelho *et al*, *in press*). In the case of greater forkbeard, the percentage of zero discards was 63.8%, for the 2004-2019 period. The GLM fitting approach included the choice of the response variable, the choice of the error distribution and link function, the selection of the explanatory variables, the extraction of the standardized series and the analysis of the performance between the alternative models. In the case of the greater forkbeard, the simple effects model including the explanatory variables ‘fishing area’ (SW and S), ‘quarter’, ‘total haul catches’ (without GFB) and ‘landings per-unit-effort of *Nephrops’* presented the best results among the different models tested. The criteria used for selecting the best model fit were the analysis of residual distribution patterns, the relationship between predicted vs. observed DPUE, the deviance explained and also the value of the Akaike Information Criterion (AIC). The mean estimates of the standardized DPUE were computed with least square means (Coelho, *et al*. *in press*).

The final step for obtaining the discard estimate of greater forkbeard for OTB_CRU in 2020, was to calculate the average of the standardized DPUEs from the period 2017-2019 and multiply it by the fishing effort (in fishing hours) of the OTB_CRU fleet. The Figure 1 presents the standardized DPUE series obtained for 2004-2019 (black line), including the estimate of 25 tonnes in 2020, and the discard estimates provided to WGDEEP in the period 2004-2019 (red dots) (Table 7).

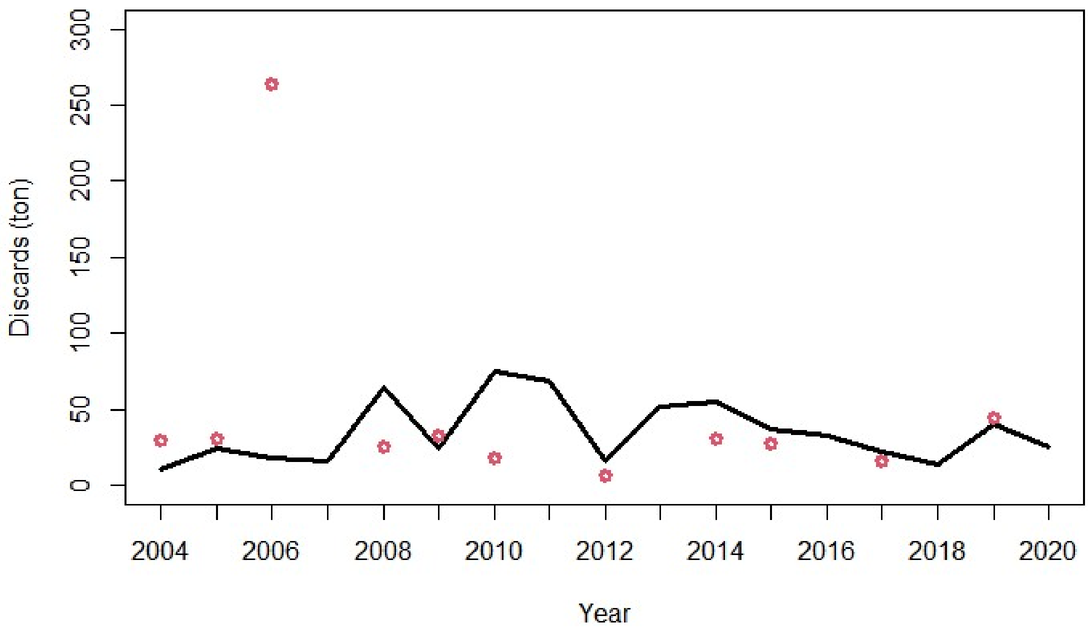

Figure 1 - Annual discard estimates obtained from the discard raising procedures using standardized DPUE (black line) and from annual fleet-based (red dots), previously reported to WGDEEP.

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The ICES Working Group on the Biology and Assessment of Deep-Sea Fisheries Resources (WGDEEP 2021).

Updating data from deep-water fishery of the Azores (ICES subdivision 27.10.a.2)

by

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Abstract

This document resumes and updates the information of the demersal/deep-water fishery from the Azores for the 2021 ICES working group WGDEEP. A general summary description of the fishery is presented including information on landings, spatial distribution of effort and catches.

1. Description of the Fishery

The Azores demersal/deep-water fisheries are a multispecies and multigear fishery with economically important and represent more than 70% of the annual total landed catch of the region (Menezes e Pinho, 2009; Santos et al., 2020). About 70 demersal species are landing in the Azores, from which around 24 are classified as deep-water representing their landings in the last three years about 2200 tons in weight and around 13 million Euros in value at the first sale on the auctions (Fig. 1). The dynamic of the fishery seems to be dominated by the main target species *Pagellus bogaraveo*. However, others commercially important species are also caught (*Beryx* spp., *Polyprion americanus* and *Helicollenus dactylopterus*) and the target species seems to change seasonally according abundance, species vulnerability and market (Pinho and Menezes, 2005; Pinho et al., 2014; Santos et al., 2019).

The fishery is clearly a typical small scale, where the small vessels (<12m; 90% of the total fleet) predominate, using mainly traditional bottom longline and several types of hand lines.

The ecosystem is a seamount type with fishing operations occurring in all available areas, from the islands coasts to the seamounts within the Azorean EEZ. Few seamounts are explored outside the EEZ, being the most frequently visited those at south on Fishery Committee for the Eastern Central Atlantic (CECAF) areas (WD Pinho, 2018). The fishery takes place at depths until 1000 m, catching species from different assemblages (shallow, intermediate and deep), with a mode on the 200-700 m strata, the intermediate strata (slope) where the most commercially important species occur (Menezes et al., 2006; Santos et al., 2019). No major changes are observed on the vessels regime of operation and spatial distribution of effort although in the recent five years more vessels change from the longline to hand lines gear.

Since the end nineties the landings of most of the commercially important species start to decrease (Table 1, Fig. 2 and 3). This was a result of intensive fishing as a consequence of the development or entry of new and more technological vessels to the fishing, expanding the fishing areas to offshore seamounts and increasing the catchability (Diogo et al, 2015). Notably, the target species of the fishery, *Pagellus bogaraveo* seems to be the more resilient species with landings starting to decrease a decade later with an important decrease on landings observed during the last four years (see Fig. 2). The fishery is currently limited by the management rules to constrain the catches (TAC/quota).

To avoid species overexploitation technical measures were introduced by the regional government since 1998 (including fishing restrictions by area, vessel type and gear, fishing licence based on landing threshold, minimum lengths and closed areas to fishing; Santos et al., 2019). Under the E. C. Common Fisheries Policy, TAC's where introduced for some species, namely blackspot seabream, black scabbardfish, alfonsinos, and deep-water sharks (Table 2). During 2017 red seabream quotas were allocated by island, vessel and access conditions regulated by quater. In 2019 some techniques measures have been changed, as for example a closed season (EC. Reg 74/2015) implemented in 2016, to reduce effort during the spawning period, was revoked and the minimum lengths were revised by EC. Reg. 63/2019.

Since 2002, the use of bottom longline in the coastal areas was significantly reduced, because the local authorities have banned the use of this gear in the coastal areas on a range of 6 miles for local vessels and coastal vessels with a length lower than 24m and 30 miles for larger vessels. As a consequence, the smaller boats that operate in this area have changed their gears to several types of handlines, which may have increased the pressure on some species included the red seabream. The deep water bottom longline is currently a seamount fishery. As a consequence, the fishery expanded to offshore seamounts areas, with high concentration on the seamounts along the Mid Atlantic Ridge, including small vessels, targeting mainly red blackspot seabream (*Pagellus bogaraveo*), bluemouth (*Helicolenus dactylopterus*), alfonsinos (Beryx spp.) and wreckfish (*Polyprion americanus)* (Fig. and 2) (see Diogo et al, 2015).
All this changes in the fishing pattern of the fleet may explain the changes in the landings of some species that were more vulnerable to the use of bottom longlines (Table 1, Fig. 3). An important issue is the effect of the management measures on the dynamic of the fishery, which may difficult the interpretation of the landings or abundance trends due to spatio-temporal target effects (Santos et al., 2019). The alfonsinos fishery for example has a fishing season shorter and shorter during each year due to quota limitation and target effect from the offshore longline fishery.

2. Landings

Total landings in weight of deep-water species increase until 1994, decreasing thereafter with an abrupt decrease in 1999 due to a general decrease observed on landings by species with a particular crash observed for the silver scabbard fish (*Lepidopus caudatus*) (Fig. 2 and 3). Landings in value increase until 2007 decreasing thereafter. The landings of the major deep-water species caught by the Azores fleet, for the period 1980 to 2020, are resumed in Table 1 and Figures 3. The fishery has expanded to more offshore areas, with high effort on the seamounts along the Mid Atlantic Ridge (WD Pinho, 2018). This area expansion is a consequence of the decrease on the abundance observed for almost all the demersal/deep water species in the coastal and nearby areas since 1994 (Fig. 2 and 3).

Disaggregated landing data by vessel is available since 1985. Information by gear type and effort data are collected by shore based samplers that inquire the fishing masters during the landings operations. The present reported annual catches in weight include only the official landings collected in the Azorean port auctions, since the discards and the frozen or transformed fish are not quantified on the landings.

The present accepted definition of "deep-water species" presents some conflicts with the case of the Azores fishery, since the local ecosystem is a natural deep-water one, the dynamics of some species covers both strata, shallow and deep, and literally all the Azorean fleet can be considered as a deep-water fishery. However, landings of some deep-water species as defined by ICES (Annex I species, EC Reg. 2347/2002) represents actually a minor fraction of total demersal landings because the exploitation of these species is not economical profitable under the actual framework of a small scale fishery (see Table 1).

3. Discards

Discards data were analysed for the period 2004-2011 for the bottom demersal/deep-water metier using DCF data. There is new information only for 2018, however, with the same level of discards for the period 2004-2011, because the exploitation pattern of the fleets is similar, particularly for the longliners. Due to the value of the species negligible discard are expected.

4. *Length compositions*

Fishery biological data were not update because the DCF data was not available.

5. Fishery abundance index

Standardized fishery abundance index was not updated for a number of species, because the DCF data was not available.

Acknowledgements

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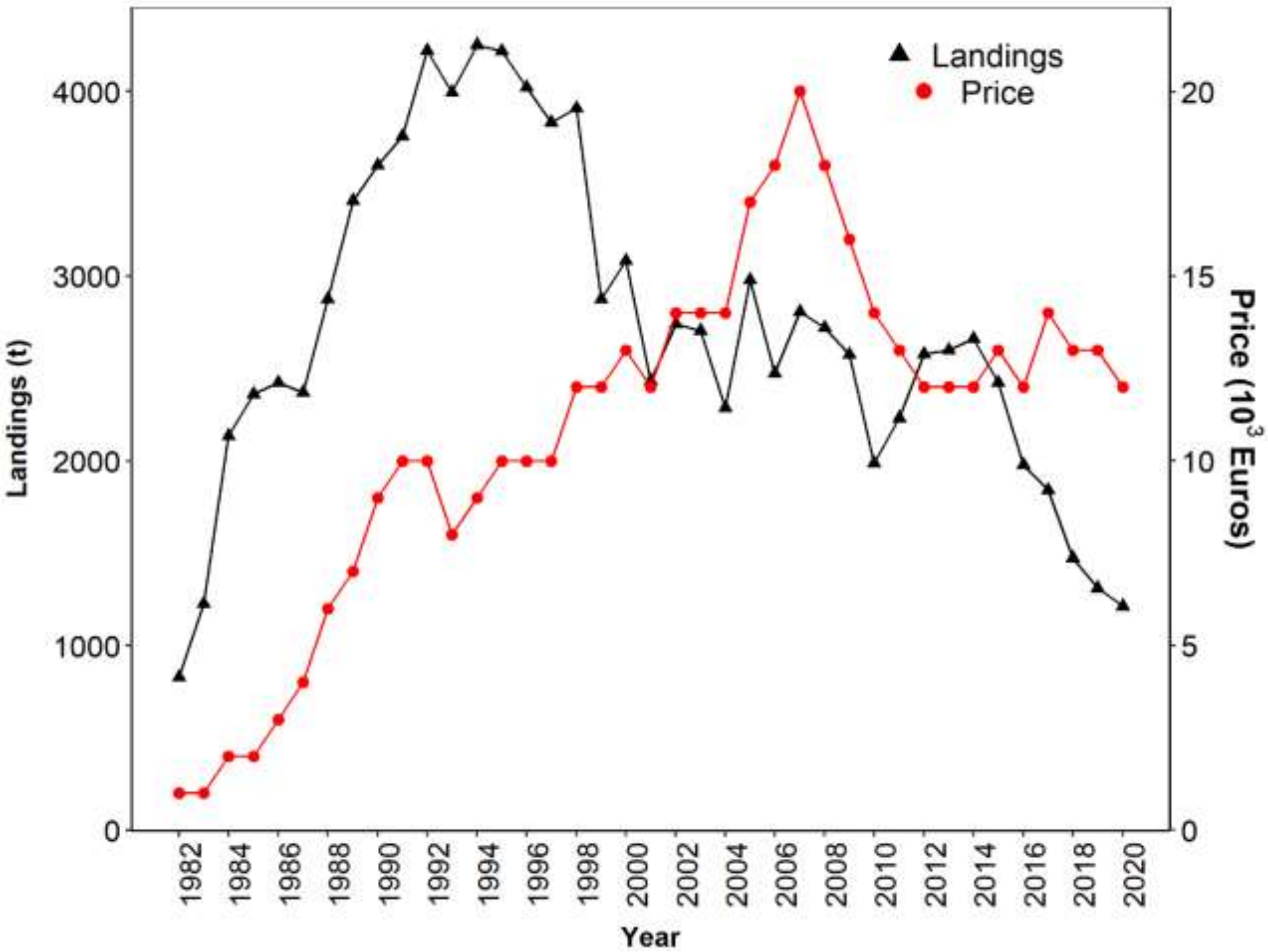

Figure 1. Total landings, in weight and value, of deep-water species from Azores (1980-2020). Important historical management events are also shown on the graph.

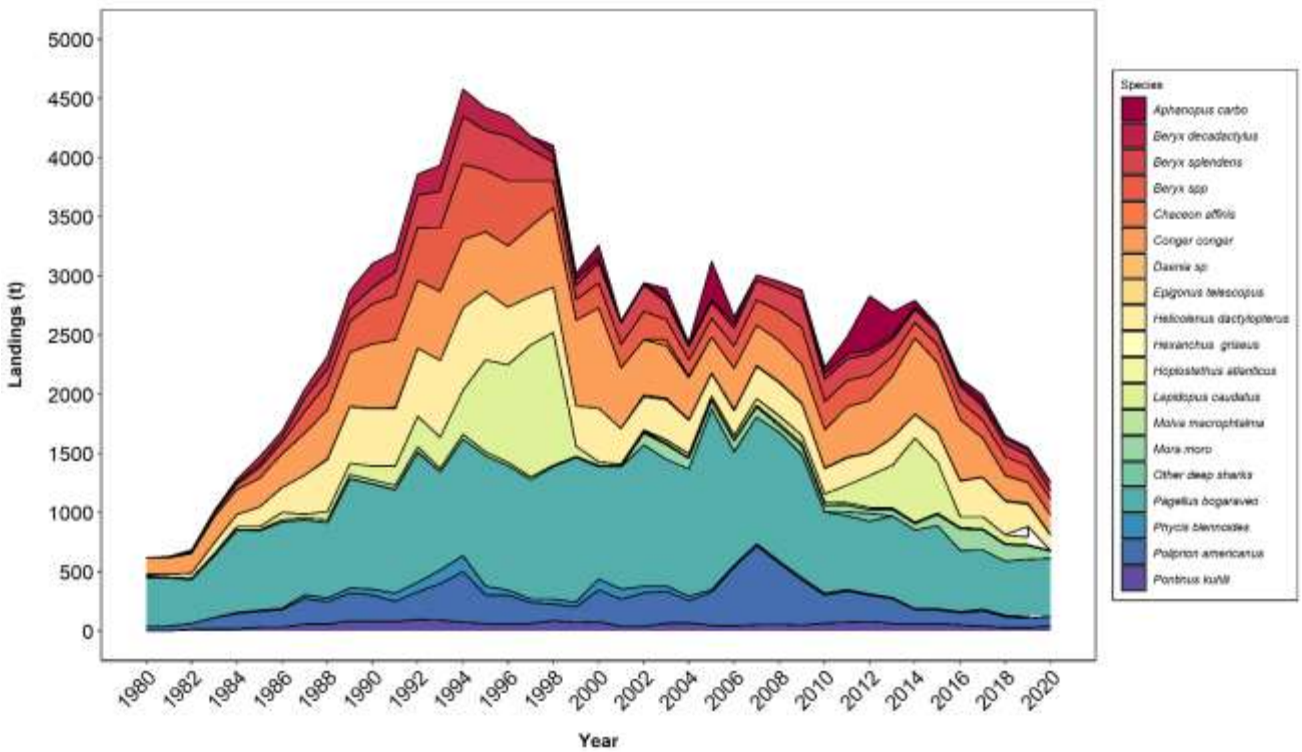

Figure 2. Overview (1980-2020) of the deep-water species landings from the Azores (ICES 10 a2).

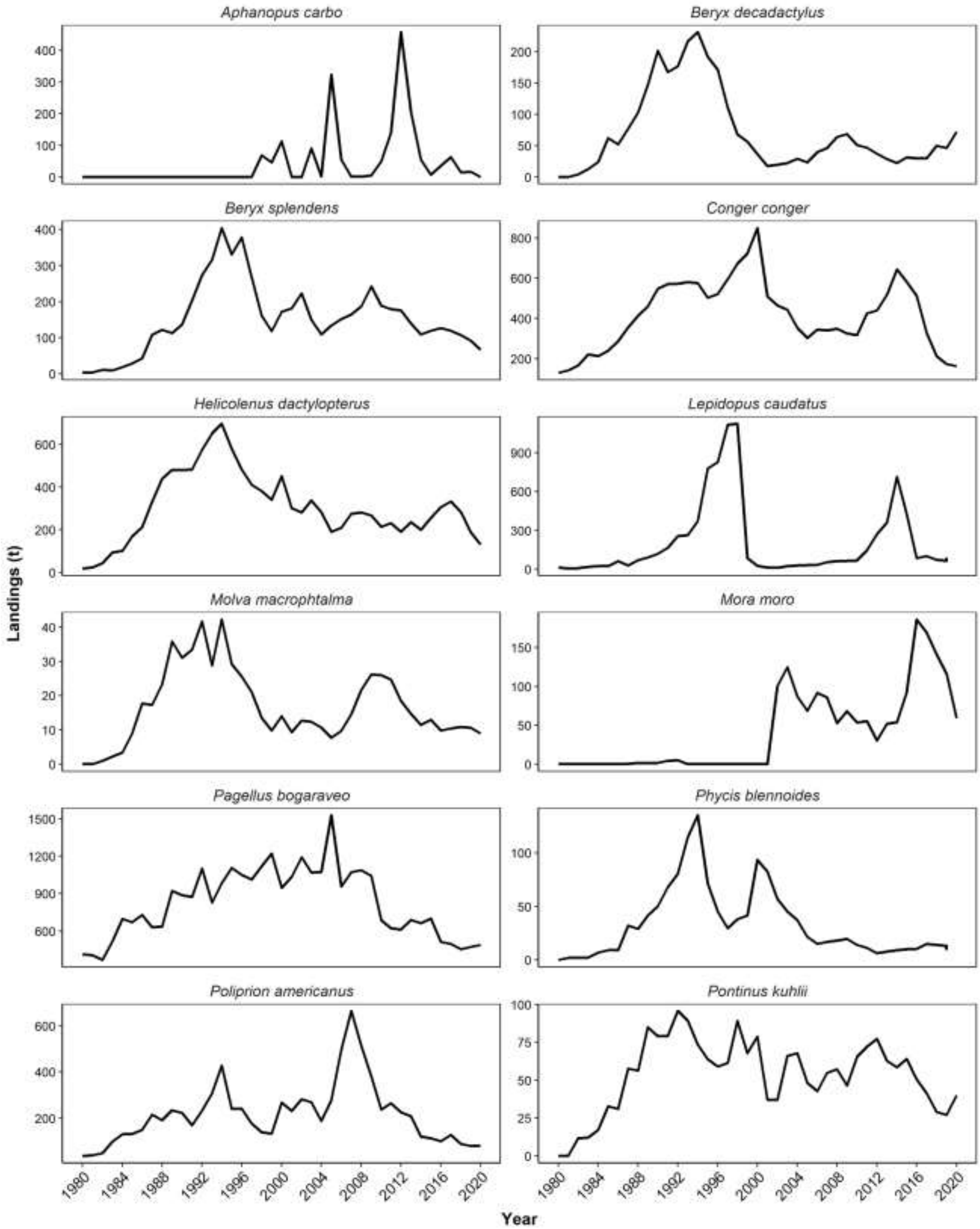

Figure 3. Annual landings of major demersal/deep-water species of the Azores (1980-2020).

Table 1. Landings (tons) of deep-water species from the Azores (ICES area X). + landed as mixed species; * Include 270t from CECAF 34.2.0.

Year	*Aphanopus carbo*	*Beryx decadactylus*	*Beryx splendens*	*Conger conger*	*Epigonus telescopus*	*Helicolenus dactylopterus*	*Hoplostetus atlanticus*	*Molva macrophalma*	*Mora moro*	*Pagellus bogaraveo*	*Phycis blenoides*	*Polyprion americanus*	*Lepidopus caudatus*	*Dalatias licha*	*Hexanchus griseus*	*Deania sp. (+)*	*Centrophorus sp. (+)*	*Other deep water sharks (+)*	*Chaceon affinis*
1980			3	131		18				415	0	38	13						
1981			4	143		22				407	2	40	6						
1982		4	11	166		42		1		369	2	50	10						
1983		13	10	222		93		1		520	2	99	18						
1984		24	19	214		101		1		700	7	131	23						
1985		62	29	241		169		2		672	9	133	25						
1986		52	42	287		212		3		730	9	151	63						
1987		77	108	356		331		9		631	32	216	30						
1988		103	122	413		439		18		637	29	191	70						
1989		147	113	459		481		17		924	42	235	91						
1990		201	137	547	3	480		23	2	889	50	224	120						
1991		168	203	570	11	483		36	4	874	68	170	166						
1992		176	274	572	+	575		35	+	1090	91	233	255						
1993		217	316	581	+	650		33	+	830	115	309	266						
1994		234	410	575	+	708		42	+	989	136	433	374						
1995		194	335	507	+	589		29	+	1115	71	244	780	321					
1996		171	379	521	+	483		26	+	1052	45	243	826	216					
1997		111	268	596	+	410		21	+	1012	30	177	1115	30					
1998	5	68	161	672	+	381		14	+	1119	38	140	1187	34					
1999	46	56	119	723	+	340		10	+	1222	41	133	86	31					
2000	112	35	168	831	+	441		13	+	947	91	263	27	31					
2001	+	17	182	509	+	301	343	9	+	1034	83	232	14	13					
2002	+	20	223	465	14	280	+	13	100	1193	57	283	10	35	7		4		
2003	91	22	150	443	15	338	+	12	125	1068	45	270	25	25	2		6		49
2004	2	29	110	354	6	282	+	11	87	1075	37	189	29	6	1	1	1		13
2005	323	23	134	304	4	190	+	8	69	1383*	22	279	31	14	1	1	1		
2006	55	40	152	346	10	209	+	10	92	958	15	497	35	10	1	1	3		
2007	0.2	46	165	340	7	274	+	14	86	1063	17	662	55	7	1	0.3	3	1	
2008	0.2	63**	187**	349	7	281	+	22	53	1089	18	513	63	10	0.4	6	3	0.1	0.1
2009	5	68**	243**	326	7	267	+	26	68	1042	20	382	64	6	0.3	0	3	0.4	
2010	49	51	189	318	5	213	+	26	54	687	14	238	68	2	1	3	1	1.8	0
2011	139	47	179	426	5	231	+	25	55	624	11	266	148	0	0	0	0	4.6	0
2012	458	37	175	441	4	190	+	19	31	613	6	226	271	0	0	0	0	31.1	0
2013	206	28	140	517	4	235	+	15	52	692	8	209	361	0	0	0	0	69.7	0
2014	54	22	109	644	2	200	+	11	54	663	9	121	713	0	0	0	0	0.0	0
2015	7	31	120	583	4	256	+	13	92	701	10	114	429	0	0	1	0	0.0	0
2016	36	29	127	513	6	306	+	10	186	515	10	101	87	0	0	1	0	0.1	0
2017	63	30	119	329	5	333	+	10	169	499	15	128	101	0	0	2	0	0.0	1
2018	14	50	107	214	4	283	+	11	140	445	14	89	73	0	0	1	0	0.0	2
2019	17	46	92	174	9	187	+	11	116	473	13	80	65	0	0	0	0	0.0	2
2020	0	72	67	164	5	130	0	9	59	491	9	81	88	0	0	0	0	0.0	2

\+ landed as mixed species
** includes 270 t from CECAF 34.2.0

Table 2. Historical quotas for deep-water species of the Azores (ICES X).

Regulation	Species	Year	ICES Area	TAC/Quota PT	Landings PT	Landing Azores
	P. bogaraveo	2003	X	1116	1068	1068
	P. bogaraveo	2004	X	1116	1075	1075
Reg 2270/2004	*P. bogaraveo*	2005	X	1116	1528	1528
	P. bogaraveo	2006	X	1116	958	958
Reg 2015/2006	*P. bogaraveo*	2007	X	1116	1071	1071
	P. bogaraveo	2008	X	1116	1089	1089
Reg 1359/2008	*P. bogaraveo*	2009	X	1116	1042	1042
	P. bogaraveo	2010	X	1116	687	687
Reg 1225/2010	*P. bogaraveo*	2011	X	1116	624	624
	P. bogaraveo	2012	X	1116	613	613
Reg 1262/2012	*P. bogaraveo*	2013	X	1004	692	692
	P. bogaraveo	2014	X	904	663	663
Reg. 1367/2014	*P. bogaraveo*	2015	X	678	701	701
	P. bogaraveo	2016	X	507	515	515
Reg 2285/2016	*P. bogaraveo*	2017	X	507	499	499
	P. bogaraveo	2018	X	507	445	445
Reg 2025/2018	*P. bogaraveo*	2019	X	566	473	473
	P. bogaraveo	2020	X	553	491	491
Reg 2270/2004	*Beryx sp*	2005	III, IV, V, VI, VII, VIII, IX, X, XII	214	202	157
	Beryx sp	2006	III, IV, V, VI, VII, VIII, IX, X, XII	214	212	192
Reg 2015/2006	*Beryx sp*	2007	III, IV, V, VI, VII, VIII, IX, X, XII	214	256	211
	Beryx sp	2008	III, IV, V, VI, VII, VIII, IX, X, XII	214	292	250
Reg 1359/2008	*Beryx sp*	2009	III, IV, V, VI, VII, VIII, IX, X, XII	214	353	311
	Beryx sp	2010	III, IV, V, VI, VII, VIII, IX, X, XII	214	267	240
Reg 1225/2010	*Beryx sp*	2011	III, IV, V, VI, VII, VIII, IX, X, XII	214	247	226
	Beryx sp	2012	III, IV, V, VI, VII, VIII, IX, X, XII	214	224	213
Reg 1262/22012	*Beryx sp*	2013	III, IV, V, VI, VII, VIII, IX, X, XII	203	185	168
	Beryx sp	2014	III, IV, V, VI, VII, VIII, IX, X, XII	193	149	131
Reg. 1367/2014	*Beryx sp*	2015	III, IV, V, VI, VII, VIII, IX, X, XII	194	151	151
	Beryx sp	2016	III, IV, V, VI, VII, VIII, IX, X, XII	195	158	156
Reg 2285/2016	*Beryx sp*	2017	III, IV, V, VI, VII, VIII, IX, X, XII	182	151	149
	Beryx sp	2018	III, IV, V, VI, VII, VIII, IX, X, XII	182	157	157
Reg 2025/2018	*Beryx sp*	2019	III, IV, V, VI, VII, VIII, IX, X, XII	164	148	138
	Beryx sp	2020	III, IV, V, VI, VII, VIII, IX, X, XII	164	150	139
	Aphanopus carbo	2003	VIII, IX, X	4000	2630	91
	Aphanopus carbo	2004	VIII, IX, X	4000	2463	2
Reg 2270/2004	Aphanopus carbo	2005	VIII, IX, X	3956	2746	323
	Aphanopus carbo	2006	VIII, IX, X	3956	2674	55
Reg 2015/2006	Aphanopus carbo	2007	VIII, IX, X	3956	3453	0
	Aphanopus carbo	2008	VIII, IX, X	3956	3602	0
Reg 1359/2008	Aphanopus carbo	2009	VIII, IX, X	3561	3601	5
	Aphanopus carbo	2010	VIII, IX, X	3561	3453	49
Reg 1225/2010	Aphanopus carbo	2011	VIII, IX, X	3561	3476	139
	Aphanopus carbo	2012	VIII, IX, X	3561	2668	458
Reg 1262/22012	Aphanopus carbo	2013	VIII, IX, X	3659	2336	206
	Aphanopus carbo	2014	VIII, IX, X	3659	2163	54
Reg. 1367/2014	Aphanopus carbo	2015	VIII, IX, X	3660	2535	7
	Aphanopus carbo	2016	VIII, IX, X	3661		36
Reg 2285/2016	Aphanopus carbo	2017	VIII, IX, X	3294		63
	Aphanopus carbo	2018	VIII, IX, X	2965		14
Reg 2025/2018	Aphanopus carbo	2019	VIII, IX, X	2801		17
	Aphanopus carbo	2020	VIII, IX, X	2801		0
Reg 2270/2004	Phycis blenoides	2005	X and XII	43	22	22
	Phycis blenoides	2006	X and XII	43	10	15
Reg 2015/2006	Phycis blenoides	2007	X and XII	43	14	17
	Phycis blenoides	2008	X and XII	43	13	18
Reg 1359/2008	Phycis blenoides	2009	X and XII	36	13	20
	Phycis blenoides	2010	X and XII	36	12	14
Reg 1225/2010	Phycis blenoides	2011	X and XII	36	13	11
	Phycis blenoides	2012	X and XII	36	5	6
Reg 1262/22012	Phycis blenoides	2013	X and XII	36	8	8
	Phycis blenoides	2014	X and XII	36	6	9
Reg. 1367/2014	Phycis blenoides	2015	X and XII	37	8	10
	Phycis blenoides	2016	X and XII	38	10	10
COM(2016) 643 fi	Phycis blenoides	2017	X and XII	40	15	15
	Phycis blenoides	2018	X and XII	36	14	14
Reg	Phycis blenoides	2019	X and XII			13
	Phycis blenoides	2020	X and XII			9
Reg 2270/2004	Deep-water sharks	2005	X	120 (1)	4	4
	Deep-water sharks	2006	X	120 (1)	4	4
Reg 2015/2006	Deep-water sharks	2007	X	20	4	4
	Deep-water sharks	2008	X	20	9	9
Reg 1359/2008	Deep-water sharks	2009	X	10	4	4
	Deep-water sharks	2010	X	0	4	4
Reg 1225/2010	Deep-water sharks	2011	X	0	0	0
	Deep-water sharks	2012	X	0	0	0
Reg 1262/2012	Deep-water sharks	2013	X	0	0	0
	Deep-water sharks	2014	X	0	0	0
Reg. 1367/2014	Deep-water sharks	2015	X	0	0	0
	Deep-water sharks	2016	X	0	0	0
Reg 2285/2016	Deep-water sharks	2017	X	10	0	0
	Deep-water sharks	2018	X	10	0	0
Reg 2025/2018	Deep-water sharks	2019	X	7	0	0
	Deep-water sharks	2020	X	7	0	0
Reg 1225/2010	Hoplostethus atlanticus	2010-12	X	0	0	0
Reg 1262/22012	Hoplostethus atlanticus	2013-14	X	0	0	0
Reg. 1367/2014	Hoplostethus atlanticus	2015-16	X	0	0	0
Reg 2285/2016	Hoplostethus atlanticus	2017-18	X	0	0	0

(1) Reg. 860/2005
(2) Em Dezembro de 2009 podem ser pescados até 10 % das quotas de 2010.
(3) Permitida tolerância de 3% do tac 2009 (PT=10t)

Working Document for the ICES Working Group on Biology and Assessment of Deep-Sea Fisheries Resources

Copenhagen, 22th April - 28th May 2021

Scabbard fish in the Madeira archipelago (CECAF 34.1.2)

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Abstract

This working document updates the information existing from the previous WGDEEP meeting of 2020 for the *Aphanopus* spp. in CECAF fishing area 34. Mainly an update on the time-series of annual Portuguese landings (by vessel segment), length distributions and unstandardized CPUE at CECAF area. A standardized biomass index series based on daily landings of commercial mid-water drifting longline fishery in Madeira was also updated with data from 2020.

1. INTRODUCTION

The fishery for deep-water species carried out in the Madeira EEZ and international adjacent waters (CECAF 34.1.2. area), dates back to the 17th century (Merrett and Haedrich, 1997) and for several decades this was the only fishery targeting scabbard fish in the Northeast Atlantic (Bordalo-Machado and Figueiredo, 2009). This fishery as an important and irreplaceable economic and social value in the Madeira fisheries sector. In Madeira, exploited deep-water fish stocks are overwhelmingly dominated by two scabbard fish species: *Aphanopus carbo* Lowe 1839 and *Aphanopus intermedius* Parin, 1983, which represent about half of the overall landings throughout the year (Delgado et al. 2013, 2018; Hermida and Delgado 2016). This deep-sea fishery targeting the black and intermediate scabbard fish, off the Madeira archipelago, is recognized as an artisanal and selective activity targeting predominantly adult individuals and presenting a low rate of bycatch (Severino et al., 2009).

Both scabbard fish species 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) for *A. carbo*, although more frequent at 800-1300 m in Madeira (Morales-Nin and Sena-Carvalho, 1996) and to 1350 m for *A. intermedius* (Delgado et al., 2013). *Aphanopus carbo* and *A. intermedius* seem to be adapted to a strong activity of migrating upwards at night to feed on crustaceans, cephalopods and fishes (Tuset et al., 2010). Furthermore, these two sympatric species move to reproduction areas off Macaronesian archipelagos (i.e., Madeira and the Canary

Islands) and the northwest coast of Africa (Figueiredo et al. 2003; Pajuelo et al. 2008; Perera 2008; Farias et al. 2013). The spawning season of both *Aphanopus* species has been reported to take place from October to December (Figueiredo et al. 2003; Delgado et al. 2013).

The black and intermediate scabbard fish fishery represents one of the most profitable commercial activities on small-scale fisheries in Madeira archipelago. In 2020, the commercial landings in weight of *Aphanopus* spp. reached annual catches of up to 2136 tonnes yielding a total first sale value of *ca* 6.5 M€.

WGDEEP does not assess fisheries in Madeira (Eastern Central Atlantic area, CECAF) or in other areas outside the ICES area. Nonetheless, it is admitted that the incorporation of reliable CECAF data could provide a wider perception of the stock dynamics of these migratory species in the northeast Atlantic.

1.1. Fishery in Madeira

In compliance with the Multiannual Union Programme for Data Collection (EU-MAP), the Madeira fishing fleet targeting the deep water species, *A. carbo* and *A. intermedius*, uses a specialized fishing gear with longlines (LLD_DWF_0_0_0). The fishing gear is a mid-water horizontal drifting longline, set in the water column usually at depths of between 800 and 1300 m (**Figure 1**).

This fishery is known by its highly selective nature, concerning the bycatches of non-target species and the length structure of the catches of the targeted species – constituted almost exclusively by adult specimens over 90 cm total length. The catches of sub adult individuals scarcely achieve around 0.5% of the total number of individuals captured.

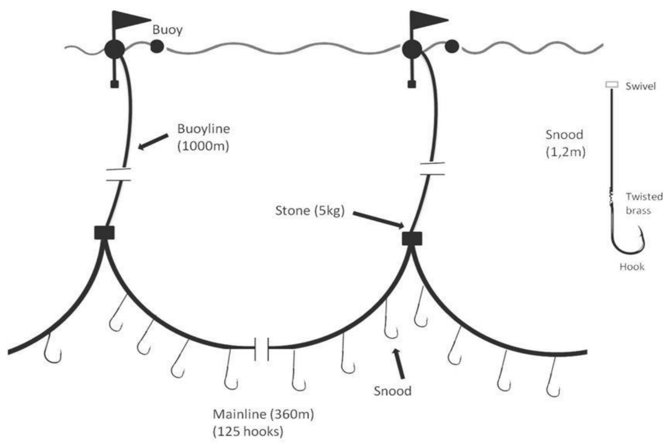

Figure 1 – Mid-water horizontal drifting longline used by the Madeira fishing fleet.

There is a combination of prevailing factors that result in a fishery with such unique features. Such factors are the geographical area of the fishery, where, according to the migratory model proposed by Farias et al. (2013), only adult specimens are available to this type of fishery and the highly selective nature of the fishing methodology itself, namely the fact that the passive fishing gear is operated strictly within a depth layer of the water column, between 1000 and 1200 meters deep, without being anchored, and always well above the seafloor. The gear aims to catch the black scabbard fish in its daily vertical migration to feed, thus minimizing the probability of capture of benthic by-catch species.

This fishery, carried out by the fishing vessels targeting the black and intermediate scabbard fish registered in Madeira, which was traditionally performed mostly around the islands of Madeira and Porto Santo and the seamounts inside the Madeira EEZ, has undergone considerable geographic expansion in recent decades in the Northeast Atlantic, mostly from 2005 onwards, and initiated a process of expansion looking for new fishing areas (**Figure 2**). Progressively, new fishing grounds located in international waters SE of the Azores, off the Canaries and the "rediscovery" of the seamounts within the Madeira EEZ became indispensable for this fishery and bilateral agreements with the Azores and the Canaries were made to allow the fleet access to those areas.

In 2015, 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. 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 2).

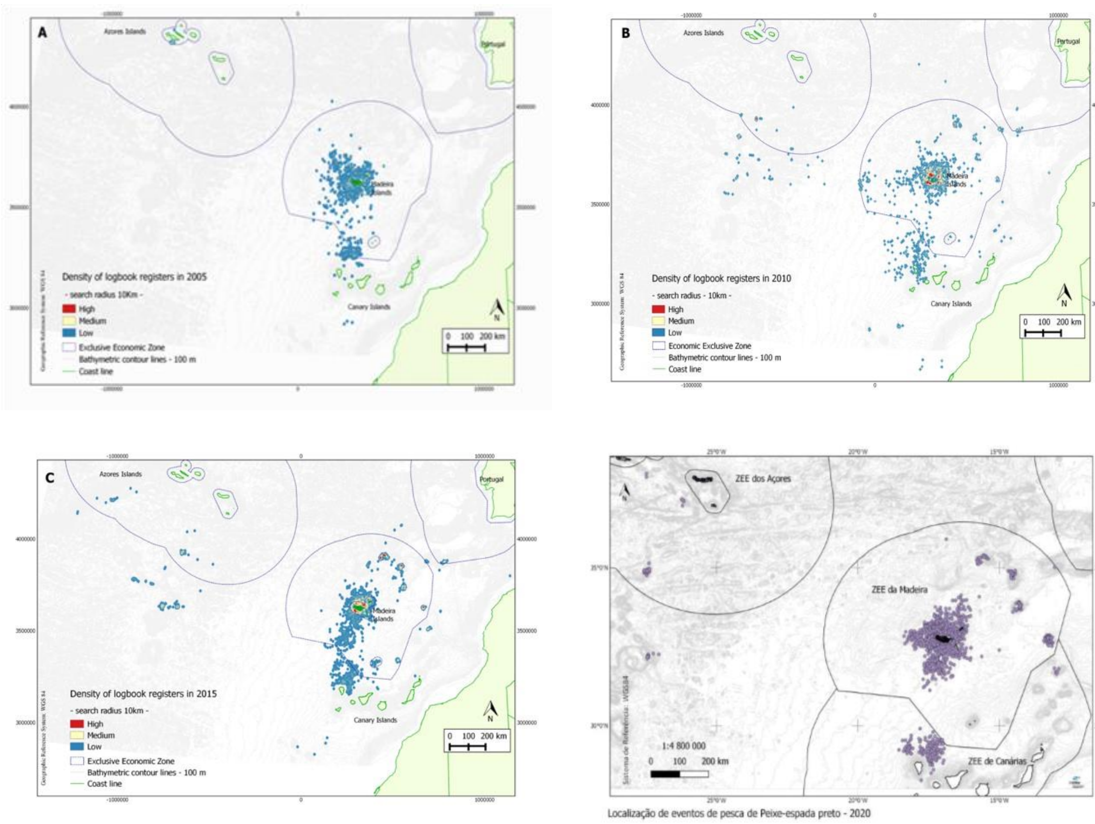

Figure 2 - Density plots illustrating the geographical distribution of the fishing sets with catches in 2005 (A), 2010 (B), 2015 (C) (Delgado *et al*., 2018) and 2020 (D): density maps estimated with the software Quantum GIS 2.2, module "heatmap" covering a search radius of 10 Km (Regional Directorate of the Sea - Madeira).

From 2019 to the present, most of fishery targeting the black and intermediate scabbard fish 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 black and intermediate scabbard fish and the lack of interest in these species by the Canary fishing fleet, which makes profitability 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 distance between Madeira and Azores.

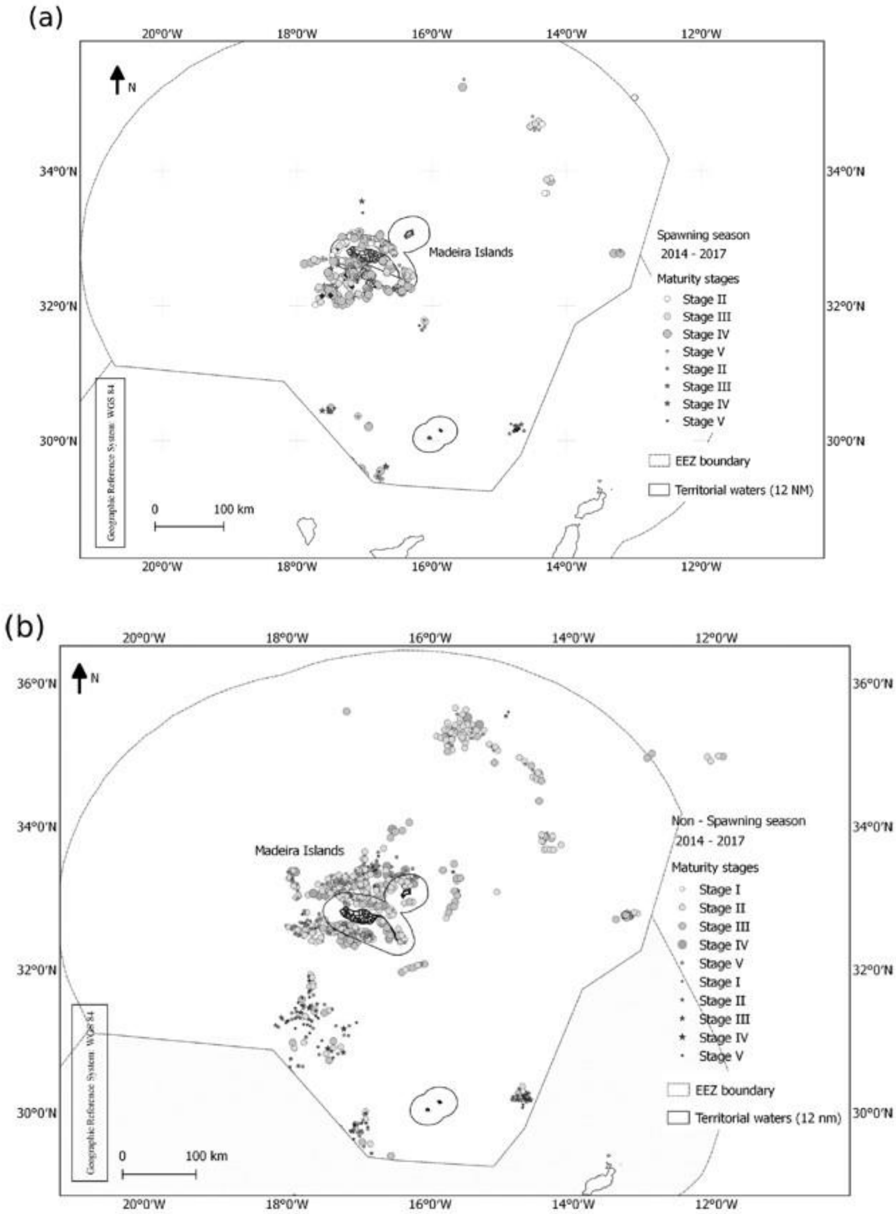

Figure 3 - Map showing both *Aphanopus* species distribution, *A. carbo* (grey circles) and *A. intermedius* (grey stars), during spawning (a) and non-spawning (b) seasons according to the distance from the coast (<12 and >12 nautical miles; 1 n.m. = 1.852 km) (Vasconcelos et al., 2020).

The enlargement of the maritime area covered by the fishing operations was prompted by the decrease of the abundance of the resource in the traditional fishing grounds, near the islands of Madeira and Porto Santo. And also due to the improvement of the fishing fleet of Madeira verified in the last years. This search for new fishing grounds was driven by the need to stabilise catches that suffered a severe decline from 2000 onwards. A relative stabilisation of the fishery was achieved in the last years but the enormous increase in the costs led several vessels to leave the activity.

Though, most of the *Aphanopus* spp. fishery still remains concentrated off the islands of Madeira and Porto Santo, especially during the spawning season from October to December, mainly the fishery operated by the small vessels (< 12 m). Migrations to areas less than 12 n.m. from the coast, were observed for *A. carbo* throughout the spawning season (**Figure 3**) (interannual database from 2014-2017; Vasconcelos et al., 2000). The mature stages IV and V were the ones that overwhelmingly dominated this migration pattern to shallower areas. This migration of mature adults towards areas near the coast, especially during spawning, occurs simultaneously with a noticeable increase of the proportion of fishing events inside the EEZ (<12 n.m.), making them more susceptible to mid-water drifting longline fishery (Vasconcelos et al., 2000).

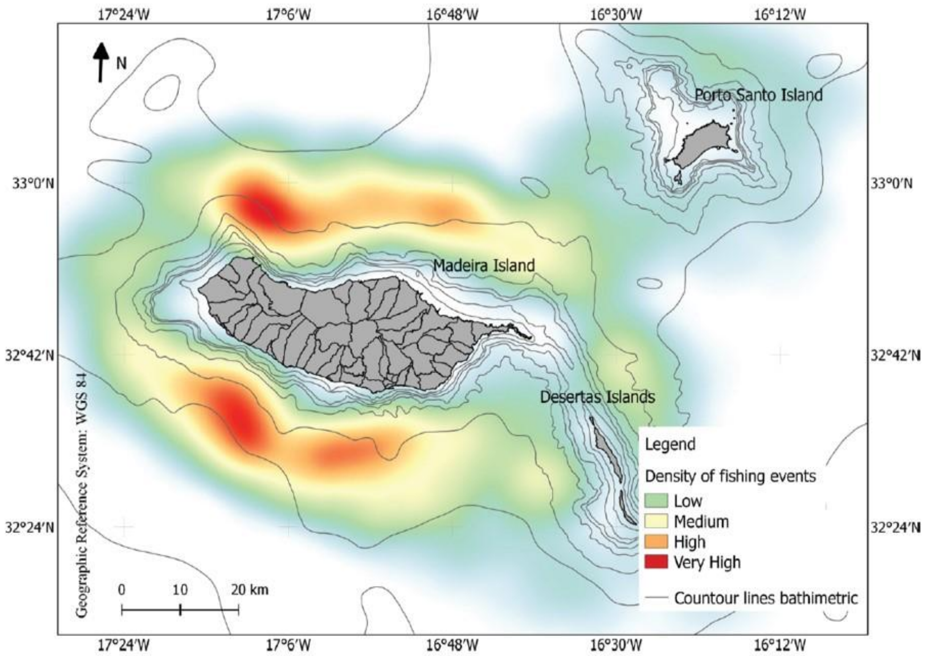

Figure 4 - Kernel density estimation plot showing the mean density values of the fishing events during the spawning season per compartment of 10 km × 10 km generated for the study area and for the period 2014–2017. Low: 1–10; Medium: 11–20; High: 21–30; and Very High: >31 fishing events (Vasconcelos et al., 2020).

There are three main aggregation areas identified off Madeira (**Figure 4**), where fishing events occurs during spawning, mainly the fishing grounds from Câmara de Lobos and Ribeira Brava at the south coast of Madeira and Porto do Moniz-Seixal at the north coast (Vasconcelos et al., 2000). The fishing grounds are located at an average distance of 2 to 4 n.m. offshore, although the same depths are found over a wider range of 3 to 6 n.m. offshore (Vasconcelos et al., 2000). Most likely, these areas correspond to areas with environmental and sea bottom topography that favour reproduction, as these areas generally correspond to canyons where there are prominent folds in the bathymetry towards the coast and its nearby steep slopes. These represent very closed geological formations with the dimension of extensive canyons, probably protected from strong currents and where high densities of spawning individuals aggregate, facilitating high probability of successful external fertilization (Vasconcelos et al., 2000).

2. METHODS

2.1. Fishery dependent data

<u>2.1.1. Landings and mean price in Madeira archipelago</u>

Portuguese 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 for the period between 1990 and 2020.

<u>2.1.2. Landings and mean price in Madeira archipelago by vessel length category</u>

Portuguese landings of *Aphanopus* spp. in CECAF area 34 (in weight, tonnes, and value, euro) were analysed by year and by fishing vessel segment (vessel length category). Fishery dependent data were collected from commercial landings for the period between 2008 and 2020. 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 2009 and 2020. Numbers-at-length were raised to the total landings.

2.3. CPUE

All landings from the commercial mid-water drifting longline fishery at all the fishing ports of Madeira (mainly port of Funchal), in the Northeast Atlantic (32°00'–33°30'N, 15°30'–18°00'W) were considered for this analysis, during the period between 2008 and 2020. 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.

The standardized CPUE model based on daily landings of commercial mid-water horizontal drifting longline fishery in Madeira was updated with data from 2020.

3. RESULTS AND DISCUSSION

3.1. Fishery dependent data

3.1.1. Landings and mean price in Madeira archipelago

The annual landings of black and intermediate scabbard fish derived from Madeiran mid-water longliners for the period between 1990 and 2020 are presented in **Figure 5**.

Catches in CECAF 34 area were updated with fishery data from Madeiran mid-water longliners landings from 1990 to 2020. These catches are recorded by the Regional Fisheries Department of Madeira (**Figure 5**). CECAF catches have been decreasing after the 1998 peak, but a slight increase was observed since 2012 (landings in 2020 were around 2136 tons).

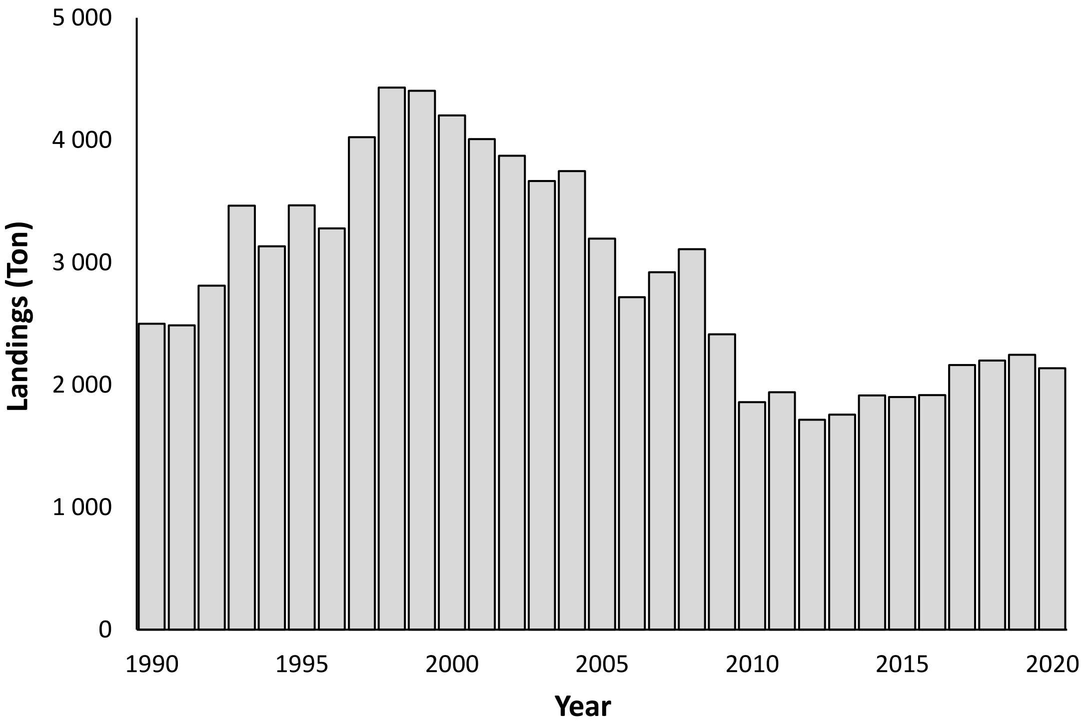

Figure 5 - Time-series of annual Portuguese landings of *Aphanopus* spp. at CECAF area (1990-2020).

The EU TAC and total catches for CECAF 34 area from 2005 to 2020 are presented in **Table 1.** It was observed a relevant decrease in the EU TAC for the *Aphanopus* spp. fishery in CECAF 3.3.1.2, from 4285 tons in 2005 to 2189 tons in 2020.

Table 1 - Black scabbard fish TACs and total landings in CECAF 34 area between 2005 and 2020.

Year	EU TAC CECAF 34.1.2 area	Landings CECAF 34.1.2. Area
2005	4 285	3 195
2006	4 285	2 717
2007	4 285	2 922
2008	4 285	3 109
2009	4 285	2 413
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

Following the methodology adopted at WGDEEP 2016 (ICES, 2016), standardised annual catch estimates for the period from 1990 to 2020 of the nineteen resources (ordered in terms of total weight catch) and grouped into four groups (1, large pelagics; 2, elasmobranchs; 3, small pelagics; and 4, demersals) were determined based on data extracted from DSEIMar/DRM database (**Figure 6**).

The results do not support that, given the diversity of species, which includes different taxonomic groups, lifestyles and both short- and long-lived organisms, the declining trends are reflecting changes on resources abundance, which would imply that Madeiran waters are subject to severe over-exploitation. Further studies and a careful interpretation of trend variations of some resources are still required. It may happen that in some cases landing trends are not only related to the resources' abundance in Madeiran waters, but subject to other factors like variations on the market regulation (e.g. small pelagic fishery), environmental, application of TAC's and quotas, among others.

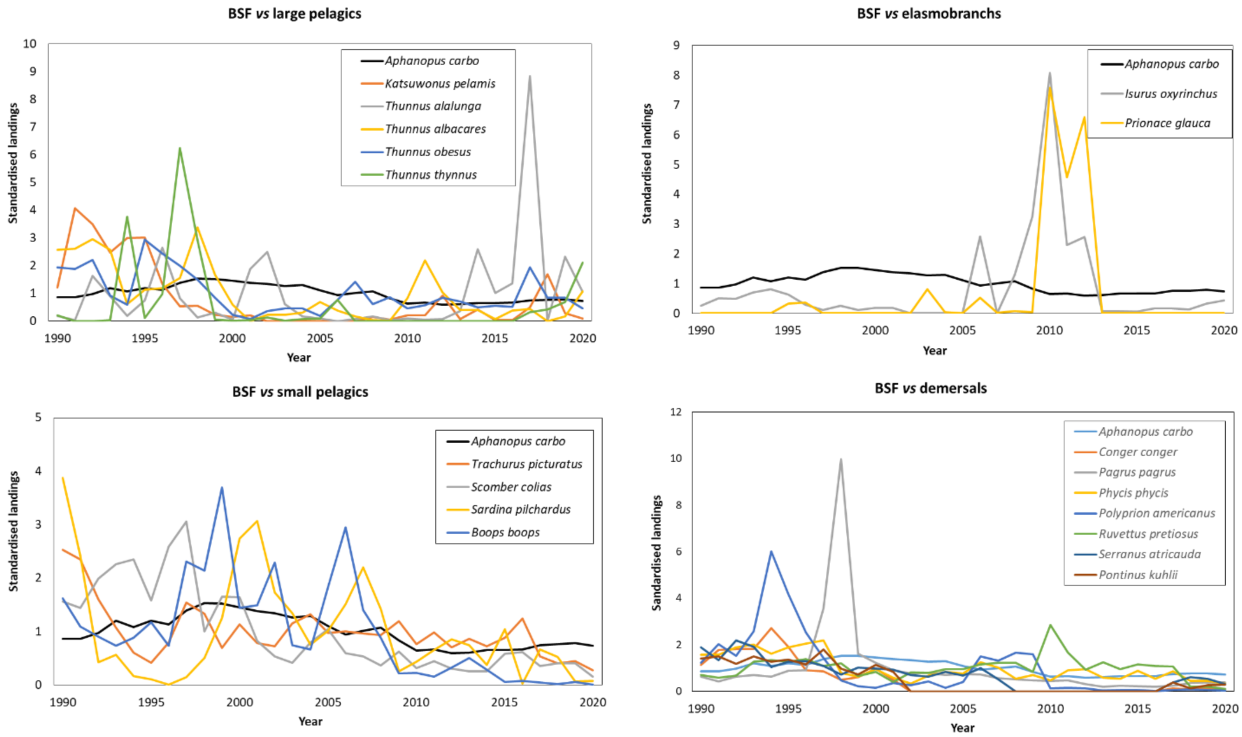

Figure 6 - Trends in standardised landings of black scabbard fish and the 19 other top ranked species in Madeiran landings.

The first sale value of *Aphanopus* spp., in millions of euros, for the period between 2008 and 2020 is presented in **Figure 7**. This value followed the same trend observed in the annual landings in terms of weight. A slight decrease was observed in 2020 yielding a total first sale value of *ca.* 6.5 M€.

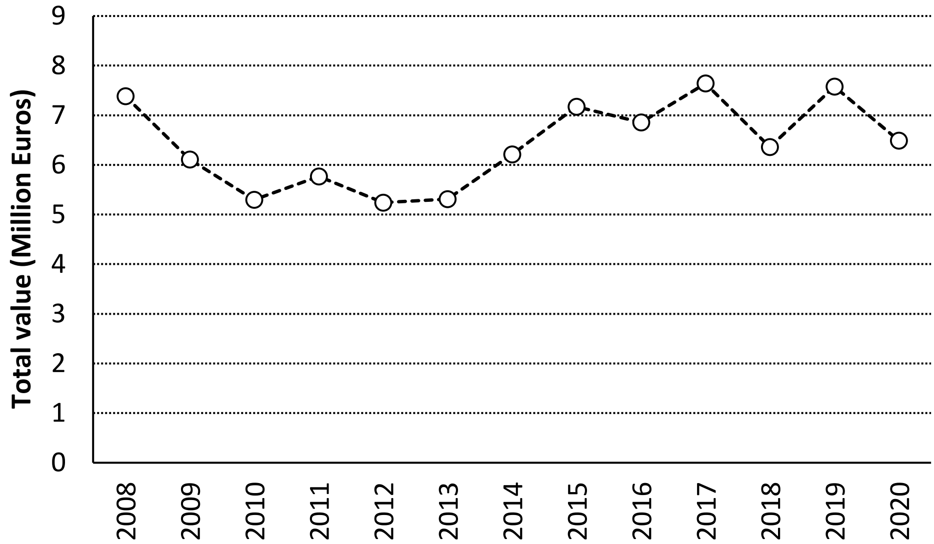

Figure 7 – Economic value of the catches of *Aphanopus* spp., in millions of euros, for CECAF 32.1.2., between 2008 and 2020.

3.1.2. Landings and mean price in Madeira archipelago by vessel length category

The number of vessels in activity in Madeiran longline fleet has steadily decreased during the last two decades (**Figure 8**).

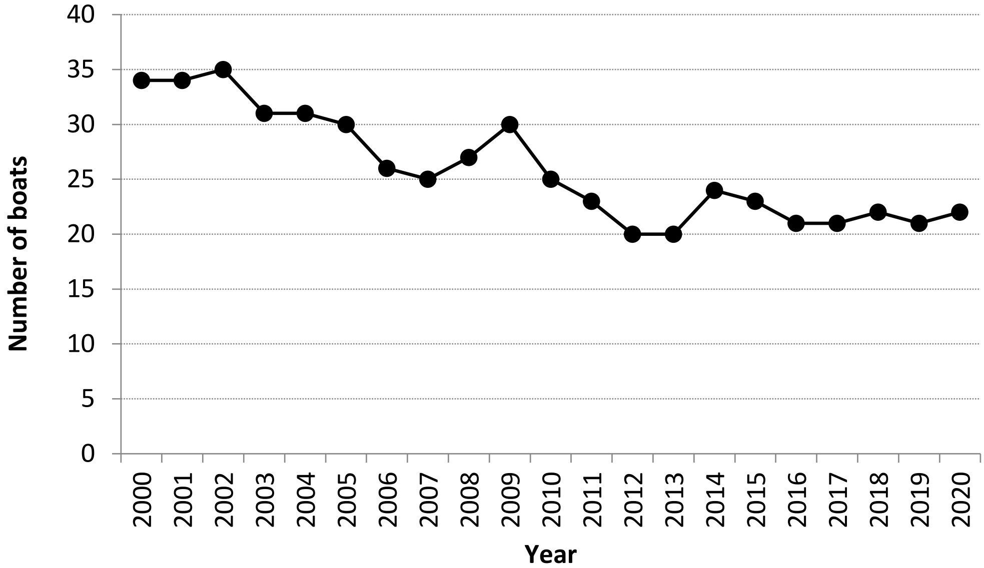

Figure 8 - Number of vessels active in the fishery of *Aphanopus* spp. at CECAF area between 2000 and 2020.

Though, in the last years, the fishery as achieved a certain stability in the number of active vessels, as the small number of vessels remaining in the fishery are small artisanal vessels (**Figure 9**). In 2020, 50% of the active vessels were grouped between 12 and 18 m of overall length, thus hardly having operational conditions to make any significant increase in the present total number of hooks used in each fishing set.

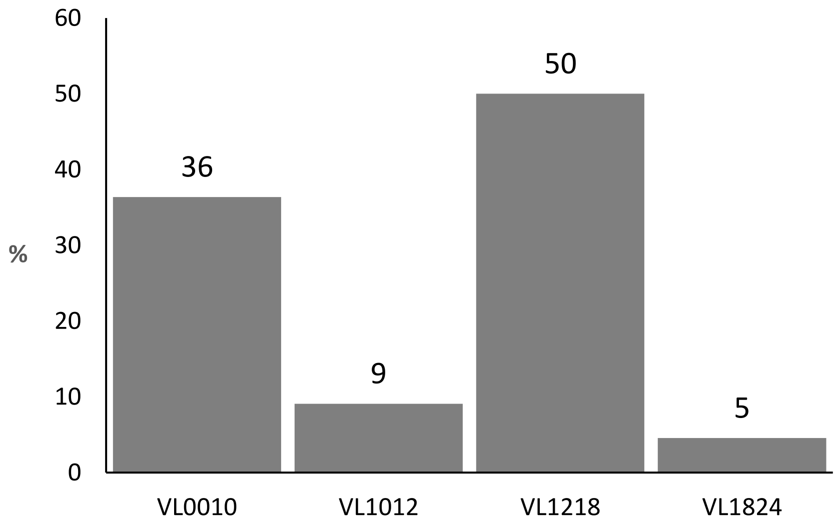

Figure 9 - Composition of the active fleet in the fishery of *Aphanopus* spp. at CECAF area in 2020 per vessel length category (n=22 vessels).

A time-series of annual Portuguese landings at CECAF area per vessel length is represented in **Figure 10**. The majority of the annual landings in Madeira are made by vessels of the length segments VL1218 and VL1824, wherein 79% of the total landings in 2020 were captured by VL1218.

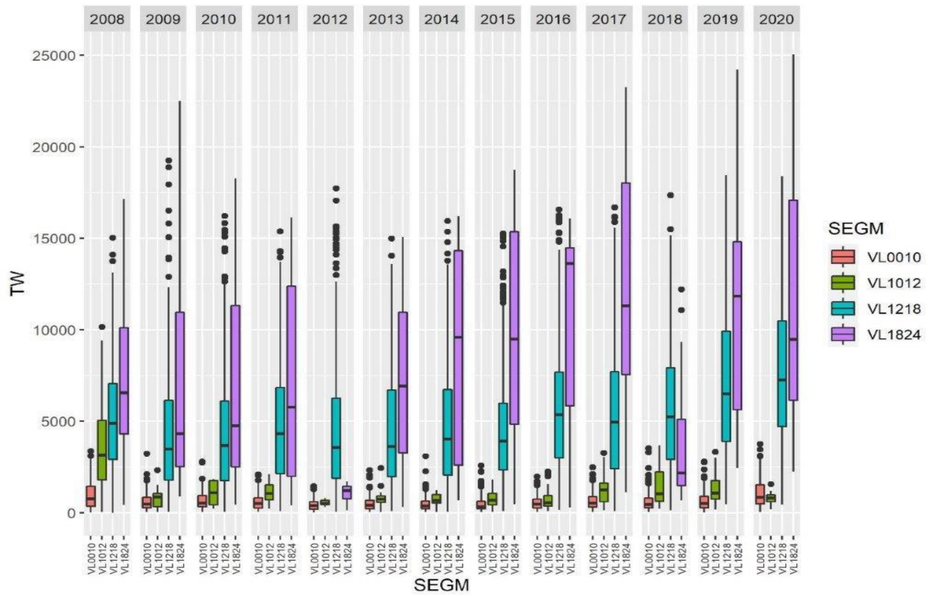

Figure 10 - Time-series of annual Portuguese landings of *Aphanopus* spp. at CECAF area per vessel length category (2008-2020).

The vessel length category VL1218 presented the highest landing values, followed by the vessel segment VL1824 (**Figure 11**). Though the number of vessels in the segment VL1824 represents only 5% of the total active fleet in Madeira, their contribution is higher than both vessel segments VL0010 and VL1012 together. The decrease observed in the economic value for the vessel segment VL1218 in 2020 is related to the decrease in effort performed by the vessels in this length category.

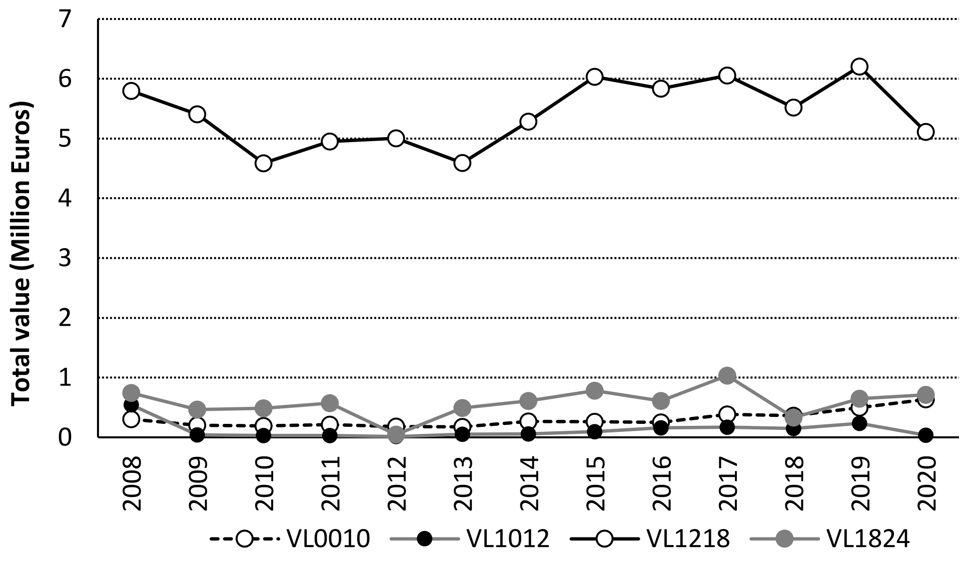

Figure 11 – Economic value of the catches of *Aphanopus* spp., in millions of euros per vessel category between 2008 and 2020.

3.2. Length distribution

Annual total length–frequency distributions of the exploited population caught by the Madeiran longline fleet in CECAF area for the period 2009-2020 are presented in **Figure 12**. The analysis of this figure indicates neither great changes on the length range between years nor on the mean length (around 114-118 cm total length, TL). From 2011 to 2017 the mean length was constant at 118 cm TL, occurring a slight decrease in 2019 and 2020 (114 cm TL). The smaller number of vessels sampled in 2020 for length frequency distribution analysis, may have influenced the decrease in the estimated mean value.

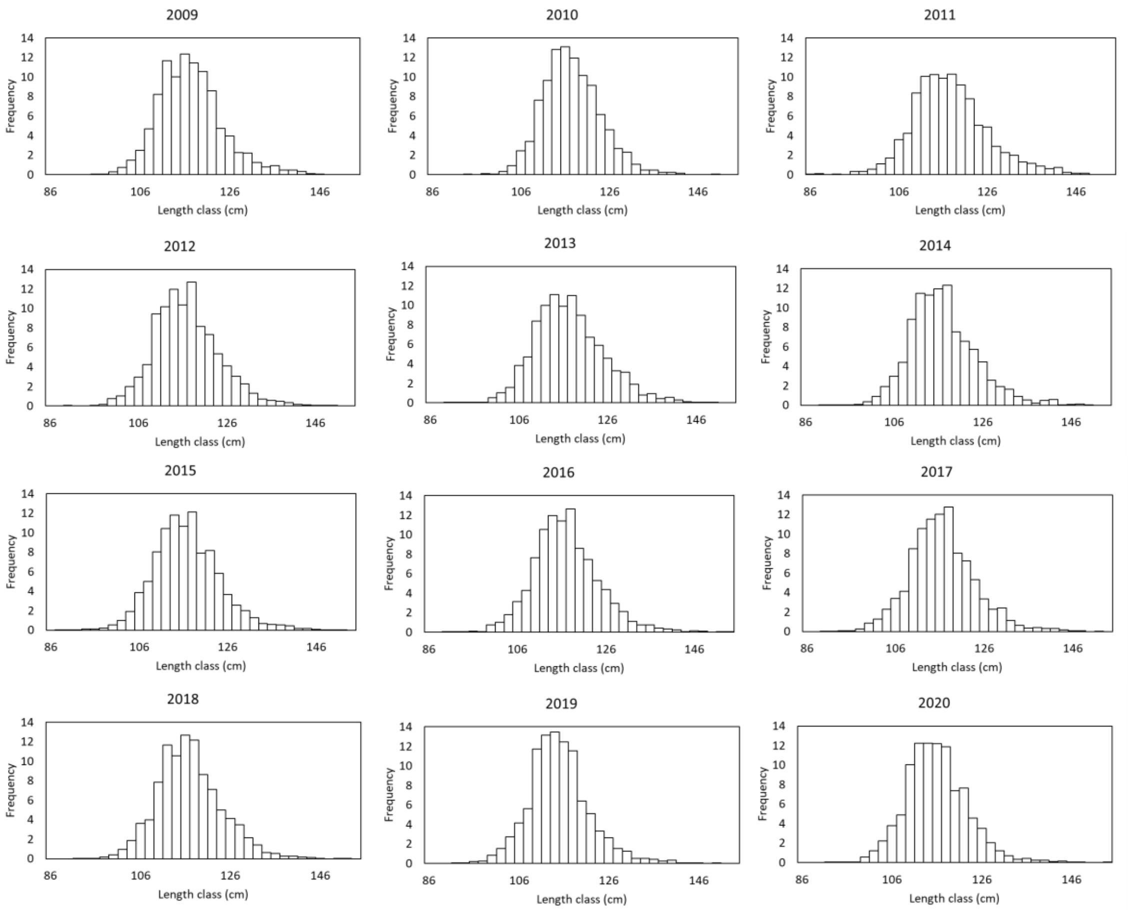

Figure 12 - Annual length–frequency distribution of specimens of *Aphanopus* spp. landed by the Portuguese mid-water longliners operating along CECAF area.

3.3. CPUE

Regarding the fishing effort in total number of hooks accumulated per year (**Figure 13**), there was an overall decrease in the available period, reflecting the decline of the number of vessels. The year of 2004 stands for the highest (22 M) total number of hooks 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 year 2018 and 2020 (*ca.* 12 M). From 2019 to 2020, it was also observed a decrease of *ca.* 2.2 M hooks.

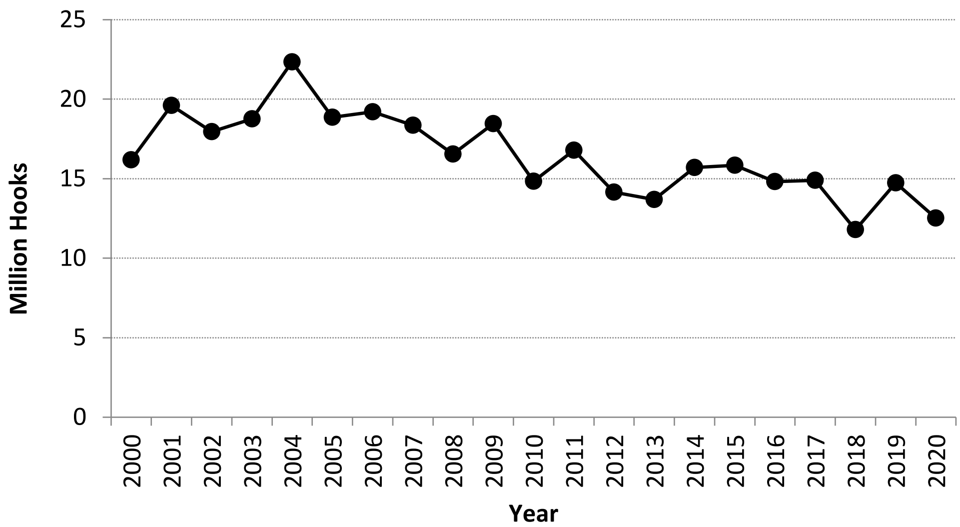

Figure 13 - Time-series of the total annual effort estimated for the CECAF area (million hooks) for the *Aphanopus* spp. fishery.

In CECAF 34 area, the fishing effort that corresponds to the total number of hooks per year shows a trend of a continuous decrease from 2000 to 2020. Such decreasing trend is in line with the reduction of the number of active vessels (**Figure 14**).

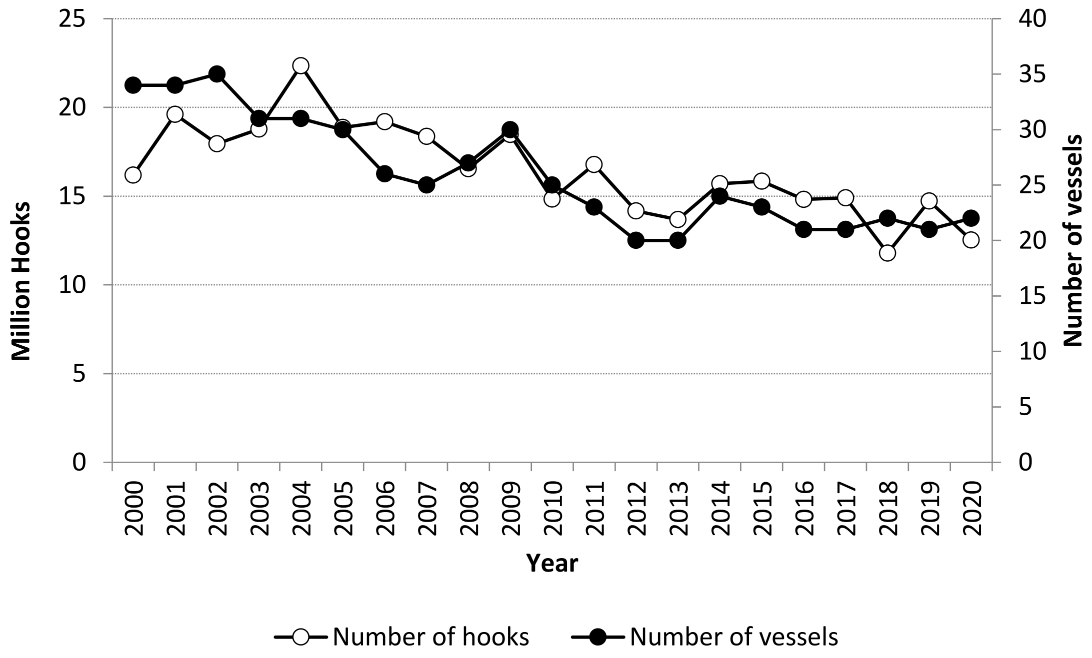

Figure 14 - Time-series of the total annual effort estimated for the CECAF area (million hooks and vessels) for the *Aphanopus* spp. fishery.

The unstandardized CPUE had an overall decline along the analysed period (**Figure 15**). The variation observed in the years 2000-2006 was about -45% in CPUE, corresponding to an increase of 16% in the fishing effort. From 2006 to 2008 there was a slight recovery of the landings and of the unstandardized CPUE. The decreasing trend of landings restarted in 2008, but all indicators analysed reached a certain level of stability between 2010 and 2016, and even a slight recovery was observed in 2020.

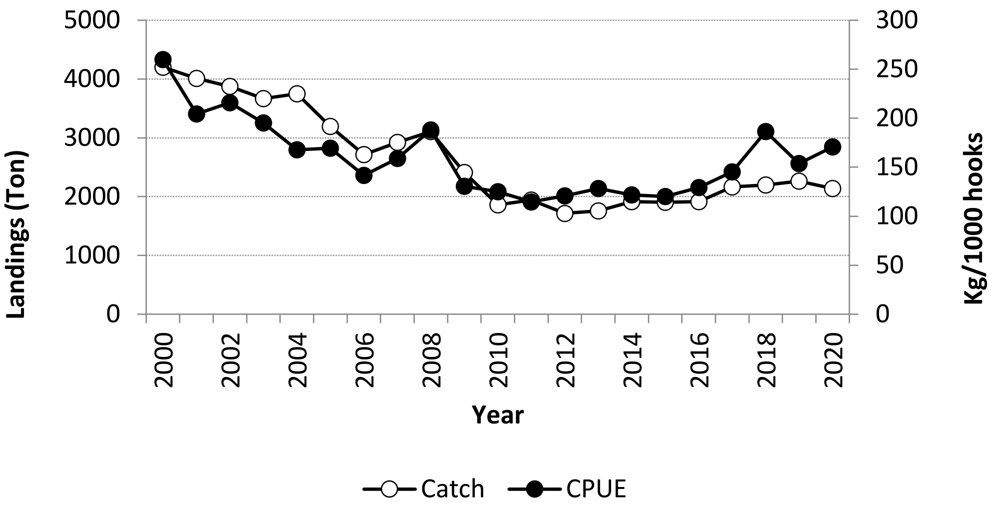

Figure 15 - Time-series of Landings per unit effort, CPUE unstandardized (kg / thousand hooks) of *Aphanopus* spp. in CECAF area.

A standardized CPUE model based on daily landings of commercial drifting longline fishery in CECAF 34 area is being developed for the period of 2008-2020. An exploratory data analysis showed a high correlation between the number of hooks per haul and the number of hauls (**Figure 16**), but no other variable showed highly correlation with the number hooks per haul.

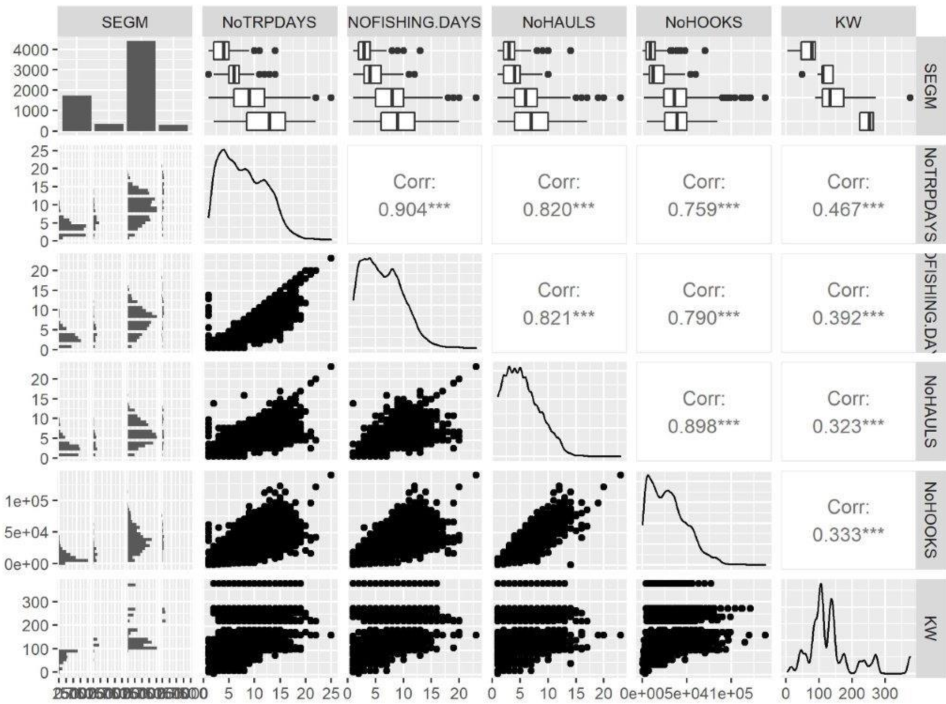

Figure 16 - Exploratory data analysis showing the correlation between the potential variables for the CPUE standardised model of *Aphanopus* spp.

For the period from 2008 to 2020, a standardised CPUE was obtained by adjusting a GLM model based on daily landings of commercial mid-water horizontal drifting longline fishery in CECAF 34 (**Figure 17**). The response variable (LPUE) was black and intermediate scabbard fish landings in weight per fishing haul (kg/haul).

The exploratory standardised CPUE data analysis per year and by vessel segment showed a recovery in the last five years, especially in the vessel segments smaller than 18 meters from 2016 to 2019 (which represents 95% of the Madeira mid-water drifting longline fleet) and in the vessel segment bigger than 18 meters in 2020 (which represents 5%). However, these are just preliminary results and further analyses need to be performed.

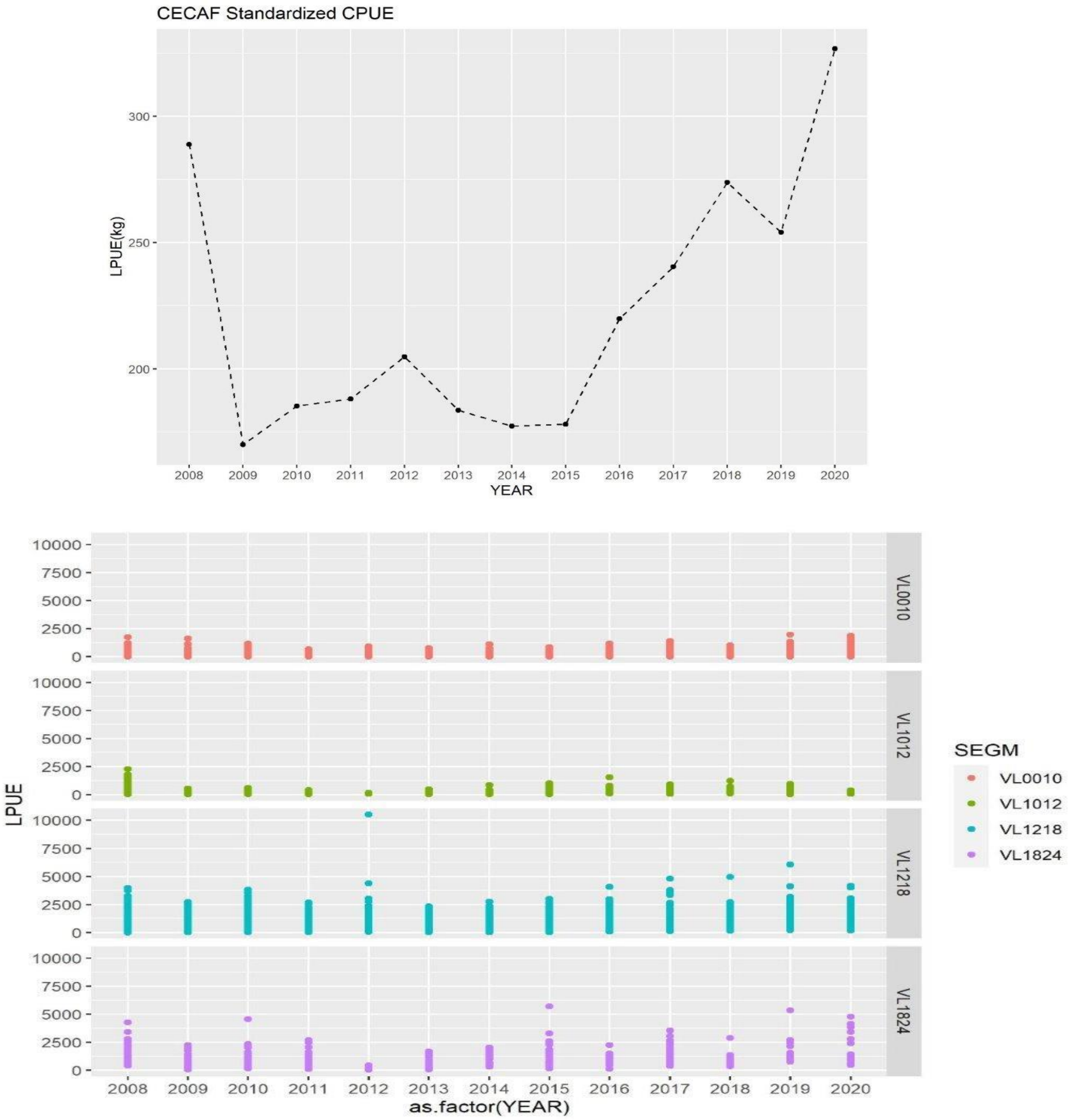

Figure 17 - Time-series of the standardized CPUE (kg/haul) of *Aphanopus* spp., all segments combined (upper) and by vessel segment (lower).

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