WORKING GROUP ON CEPHALOPOD FISHERIES AND LIFE HISTORY (WGCEPH; Outputs from 2022 meeting)

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Contents

i Executive summary

WGCEPH worked on six Terms of Reference. These involved reporting on the status of stocks; reviewing advances in stock identification, assessment for fisheries management and for the Marine Strategy Framework Directive (MSFD), including some exploratory stock assessments; reviewing impacts of human activities on cephalopods; developing identification guides and recommendations for fishery data collection; describing the value chain and evaluating market drivers; and reviewing advances in research on environmental tolerance of cephalopods.

ToR A is supported by an annual data call for fishery and survey data. During 2019–2021, compared to 1990–2020, cuttlefish remained the most important cephalopod group in terms of weight landed along the European North Atlantic coast, while loliginid squid overtook octopus as the second most important group. Short-finned squid remained the least important group in landings although their relative importance was almost double in 2019–2022 compared to 1992–2020. Total cephalopod landings have been fairly stable since 1992.

Cuttlefish landings are towards the low end of the recent range, part of a general downward trend since 2004. Loliginid squid landings in 2019 were close to the maximum seen during the last 20 years but totals for 2020 and 2021 were lower. Annual ommastrephid squid landings are more variable than those of the other two groups and close to the maximum seen during 1992–2021. Octopod landings have generally declined since 2002 but the amount landed in 2021 was higher than in the previous four years.

Under ToR B we illustrate that the combination of genetic analysis and statolith shape analysis is a promising method to provide some stock structure information for *L. forbsii*. With the summary of cephalopod assessments, we could illustrate that many cephalopod species could already be included into the MSFD. We further provide material from two reviews in preparation, covering stock assessment methods and challenges faced for cephalopod fisheries management. Finally, we summarise trends in abundance indices, noting evidence of recent declines in cuttlefish and some octopuses of the genus *Eledone*.

Under ToR C, we describe progress on the reviews of (i) anthropogenic impacts on cephalopods and (ii) life history and ecology. In relation to life history, new information on *Eledone cirrhosa* from Portugal is included.

Under ToR D we provide an update on identification guides, discuss best practice in fishery data collection in relation to maturity determination and sampling intensity for fishery monitoring. Among others, we recommend i) to include the sampling of cephalopods in any fishery that (a) targets cephalopods, (b) targets both cephalopods and demersal fishes or (c) takes cephalopods as an important bycatch, ii) Size-distribution sampling, iii) the use of standardized sampling protocols, iv) an increased sampling effort in cephalopod.

Work under ToR E on value chains and market drivers, in conjunction with the Cephs & Chefs INTERREG project, has resulted in two papers being submitted. Abstracts of these are in the report.

Finally, progress under ToR F on environmental tolerance limits of cephalopods and climate envelope models is discussed, noting the need to continue this work during the next cycle.

ii Expert group information

Expert group name	Working Group on Cephalopod Fisheries and Life History (WGCEPH)
Expert group cycle	Multiannual fixed term
Year cycle started	2020
Reporting year in cycle	3/3
Chairs	Ana Moreno, Portugal
	Daniel Oesterwind, Germany
	Graham Pierce, Spain
Meeting venue and dates	2 - 5 June 2020, online meeting via WebEx
	8 - 11 June 2021, online meeting via WebEx
	13 - 16 June 2022, Santa Cruz de Tenerife, hybrid meeting

1 ToR A – Cephalopod fishery status and trends

ToR a: Report on cephalopod stock status and trends: Update, quality check and analyse relevant data on European fishery statistics (landings, directed effort, discards and survey catches) across the ICES area.

1.1 Introduction

Updated data on Northeast Atlantic fishery statistics and survey catches for cephalopods were obtained via the "Fisheries Data calls" issued by ICES for all working groups in 2020, 2021, and 2022.

Among other data analysis (which varies from year-to-year according to the ToRs), WGCEPH produces annual updates of landings per ICES division (or group of divisions) and per country divided into four cephalopod groups: Cuttlefish, Loliginids (otherwise known as common or long–finned squid), Ommastrephids (short–finned squid), and Octopods (Annex 3, an Excel workbook version is available on request). At present, family is generally the lowest taxonomic level available for most commercial fishery datasets.

During the period 1992–2021, cephalopod landings varied between 35 and 55 thousand tonnes (mean= 46*103 tonnes). Important peaks occurred in 1999, 2012, and 2016, and the lowest landings occurred in 1994, 2009, 2018, and 2020 (2020 probably due to the pandemic lockdown). Cuttlefish contribute most to the cephalopod landings in Northeast Atlantic waters, 40% of average annual landings vs. 31% for Octopods, 22% for Loliginids and 8% for Ommastrephids (Figure 1.1 and 1.2).

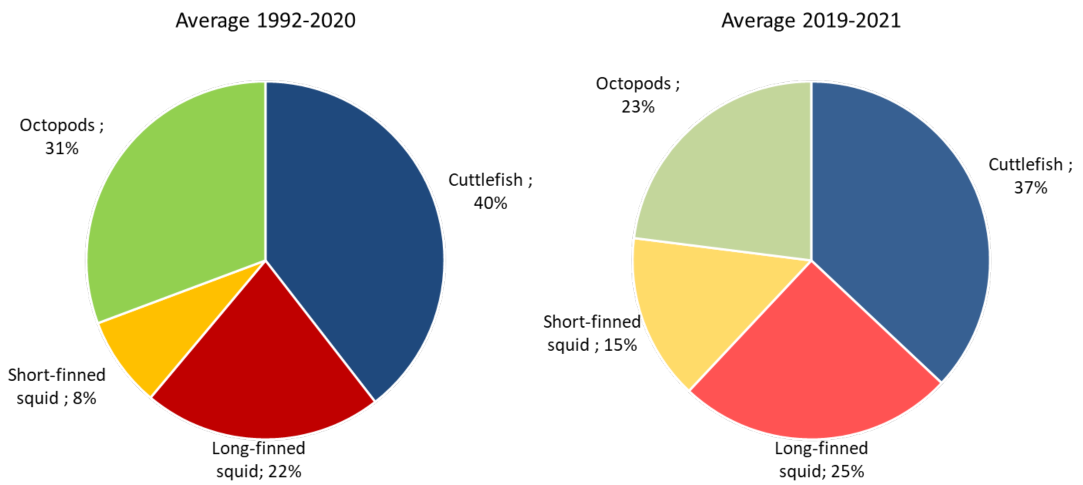


Figure 1.1 Relative importance of cephalopod resources in Northeast Atlantic waters. Percentage in relation to 1992 to 2021 average and 2019 to 2021 average.

This ranking has changed in 2017 with a decrease of octopods landings and an increase of long–finned squid landings. In the present reporting period (2019–2021), a decrease in landing proportions of cuttlefish (37%) and octopods (23%) is observable, while landing proportions of loliginids (25%) and ommstrephids (15%) increased. Noticeable is the large increase of short–finned squids in 2021 (Figure 1.1 and 1.2). Nevertheless, the cuttlefishes and octopods (most of it the common cuttlefish, *Sepia officinalis*) still account for the majority of landings in the European ICES area.

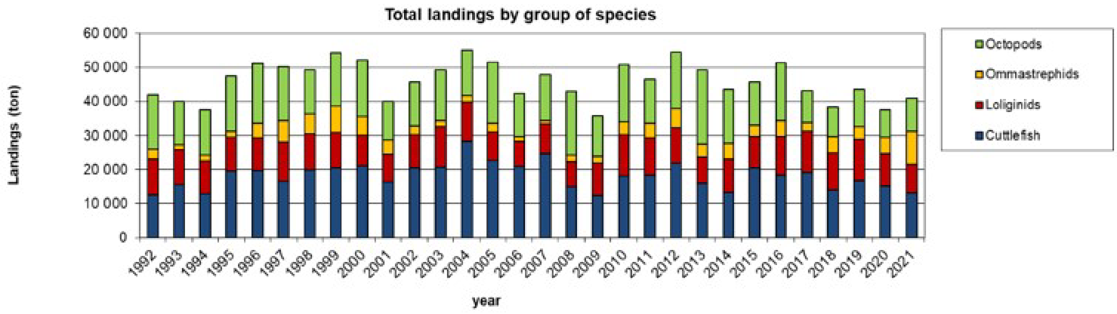


Figure 1.2 Total landings from Northeast Atlantic waters by groups of species (in tonnes).

1.2 Data quality and data call

There were some issues with the data received and it was necessary to make re–extractions of data from the intercatch database before the analysis was possible. Portugal and UK Scotland did not provide effort data in intercatch but provided trawl catch and effort. In 2020, there was a problem with Scottish data due to the way Scotland had coded squids, but an e-mail exchange between WGCEPH and the Scottish data provider solved the problem. Similar code problems occurred with Portuguese data provider, as Portugal reported most ommastrephid squid under OFJ (*Ommastrephes bartrami*), a species that is not common in Portuguese waters. In 2020, some research survey data were not available in the accession at the beginning of the meeting. Data files were requested and received by the WGCEPH members, e.g. from German, French, and English surveys. The FR–CGFS survey data for the reporting period (2020–2022) were not submitted to the group and are not available from DATRAS.

As mentioned before, landings and discards of cephalopods are most often recorded by family or order rather than by species. For example, common squid landings are still reported mainly at the family (Loliginidae) level by most countries. Fisheries research surveys are usually not dedicated to cephalopods and not all species will be taken in proportion to their abundance in all gears.

Table 1.1. Research surveys with relevant data for the assessment of cephalopod distribution and status.

Survey	Divisions and subdivisions	Acronym	Years submitted
German Surveys			
North Sea International Bottom Trawl Survey	4.a, b, c	GER–IBTS 1Q GER–IBTS 3Q	2019, 2020, 2021
Scottish Surveys			
Northern Ireland Surveys			
Northern Ireland Groundfish Survey in the Irish Sea	7.a	NIGFS	2019, 2020, 2021
English Surveys			
North Sea Beam Trawl Survey	7.d + 4.c	UK–BTS7D 3Q	2019,2020, 2021
Irish Surveys			

Survey	Divisions and subdivisions	Acronym	Years submitted
Irish Groundfish Survey	6.a + 7.abcgjk	IE–IGFS	2019, 2020, 2021
French Surveys			
French Channel Groundfish Survey	7.d + 4.c	FR–CGFS	Not submitted and not available in DATRAS
French southern Atlantic Bottom Trawl Survey	7.fghj + 8.ab	EVHOE	2019, 2020, 2021
Spanish Surveys			
Spanish Porcupine Bottom Trawl Survey	7.c.2 + 7.k.2	SP–PORC	2019, 2020, 2021
Spanish North Coast Bottom Trawl Survey	8.c, 9.a.n	SP–NORTH	2019, 2020, 2021
Spanish Gulf of Cadiz Bottom Trawl Survey	9.a.s.c	SP–ARSA Q1 SP–ARSA Q3	2019, 2020 Note: not undertaken in 2021
Portuguese Surveys			
Portuguese Crustaceans survey	9.a.c.s + 9.a.s.a	PT–UWTV	2021 Note: not undertaken in 2019 and 2020
Portuguese International Bottom Trawl Survey	9.a.c.n + 9.a.c.s + 9.a.s.a	PT–IBTS	2021 Note: not undertaken in 2019 and 2020

1.3 Status and trends of the cuttlefish stocks

1.3.1 Data quality and data call

Cuttlefish landings, discards and effort data (kWd) were uploaded to Intercatch by Belgium, Denmark, Germany, Ireland, France, Netherlands, Portugal, Spain and the UK. Uploaded data represents all main areas where the species occurs (in decreasing order of importance these are: English Channel, Bay of Biscay and Western Iberia and Gulf of Cadiz). LPUE (Landing per Unit Effort) data were submitted by Portugal, Germany, France, Ireland and UK

Survey data were presented by France (EVHOE), Ireland (IE–IGFS), Portugal (PCRUS–UWTV, PT_IBTS), Spain (SP–PORC, SP–ARSA and SP–NORTH), and UK (BTS7D).

1.3.2 Cuttlefish fisheries overview

Weight (tonnes) of cuttlefish landed between 2000 and 2021, by ICES Subarea/Division and country are presented in Supplementary Information, Table 1. General pattern of cuttlefish landings was consistent with the situation observed in previous years.

Most of catches in 2019–2021 (52.5–63.6%) as in the past were coming from the English Channel (ICES divisions 27. 7d,e). In this area of the biggest cuttlefish fishery in Europe (and indeed any cephalopod fishery there) after a period of high catches (2002–2007) and following decline no trend was obvious during the recent decade. In both Bay of Biscay and in Atlantic waters off Portugal and Spain (ICES divisions 27.8 and 27.9) cuttlefish landings were either declining in the recent decade (27.8) or relatively stable (27.9) (Figure 1.3).

The major cephalopod fishing countries in 2019–2021 was France that accounted for 46.9–53.3% of landings followed by the UK (19.9–27.9% of landings) (Figure 1.4). InterCatch extractions show that some cuttlefish catches might be reported as *Sepia officinalis* – CTC (Belgium, France, Portugal, Spain) and some Sepiidae + Sepiolidae, CTL (Denmark, France, Netherlands, Spain, Sweden, UK). Some small amounts of *S.elegans* (EJE) and *S.orbygniana* (IAR) were reported by France, Spain and N.Ireland (UK). A sepiolid *Rossia macrosoma* (ROA) occurred in catches and was discarded by fishers of Spain. Discards of unidentified CTL by Sweden also likely refers to this species or some other sepiolids.

Across the entire ICES area, in 2019–2021, the most important gear for catching cuttlefish were diverse otter trawls (41.7–45.7%), followed by beam trawls (21.7–26.9%), and traps (6.1–9.8%), diverse seines (3.3–6.7%), trammel, gill and driftnets (5.6–8.0%) and other gears of minor importance, including dredges, longlines, and handlines (Figure 1.5).

Average landings in the last three years were less than the long–term average and mostly lower than those in three preceding years (Figure 1.6). It might be an indication of the simultaneous decrease of all stocks in recent years. The only exclusion was the minor fishery in the southern North Sea, where recent catches increased, possibly because of the range shift northward due to climate changes. Generally, landings in every ICES Division showed high interannual fluctuations (Figure 1.3.).

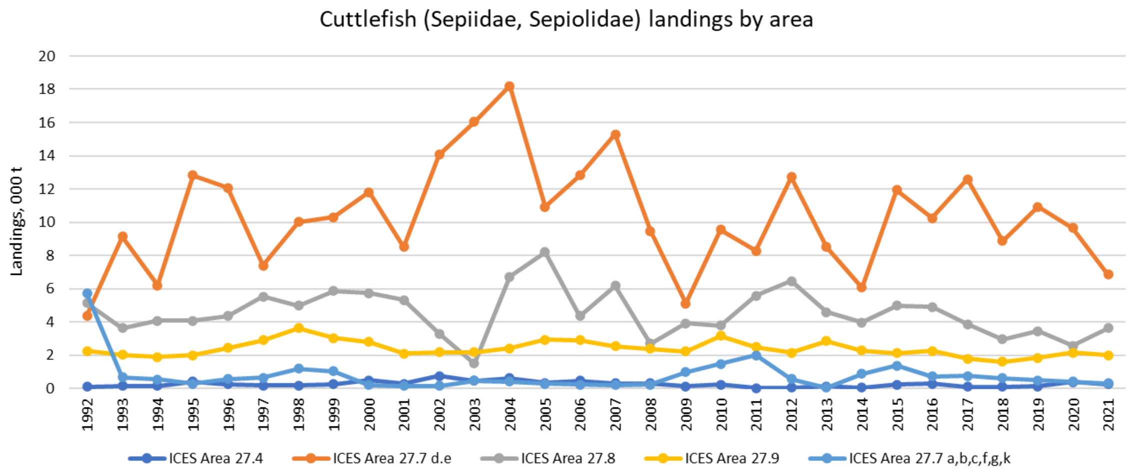


Figure 1.3 Proportion of landings of cuttlefish by area between 2000 and 2020.

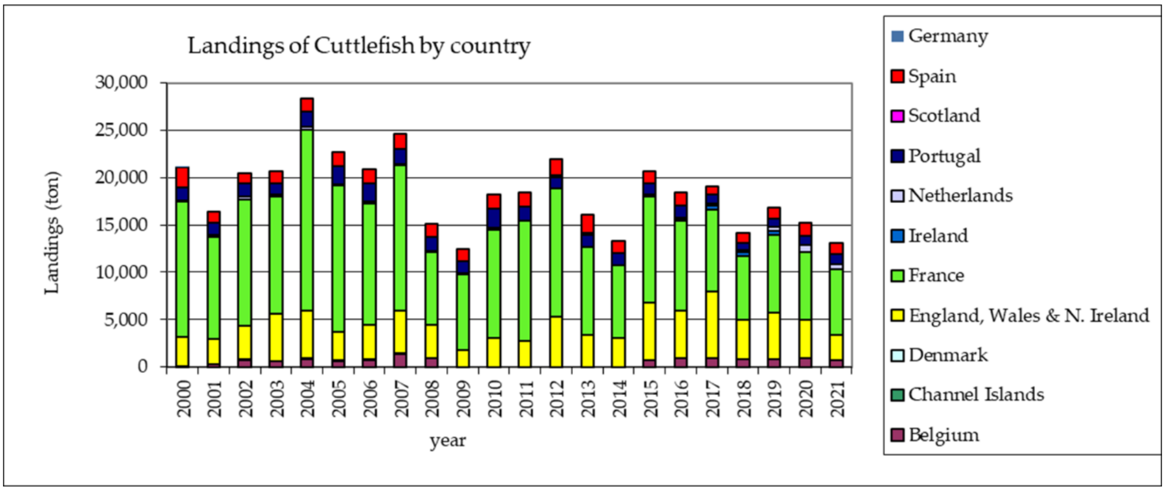


Figure 1.4 Proportion of landings of cuttlefish by country between 2000 and 2021.

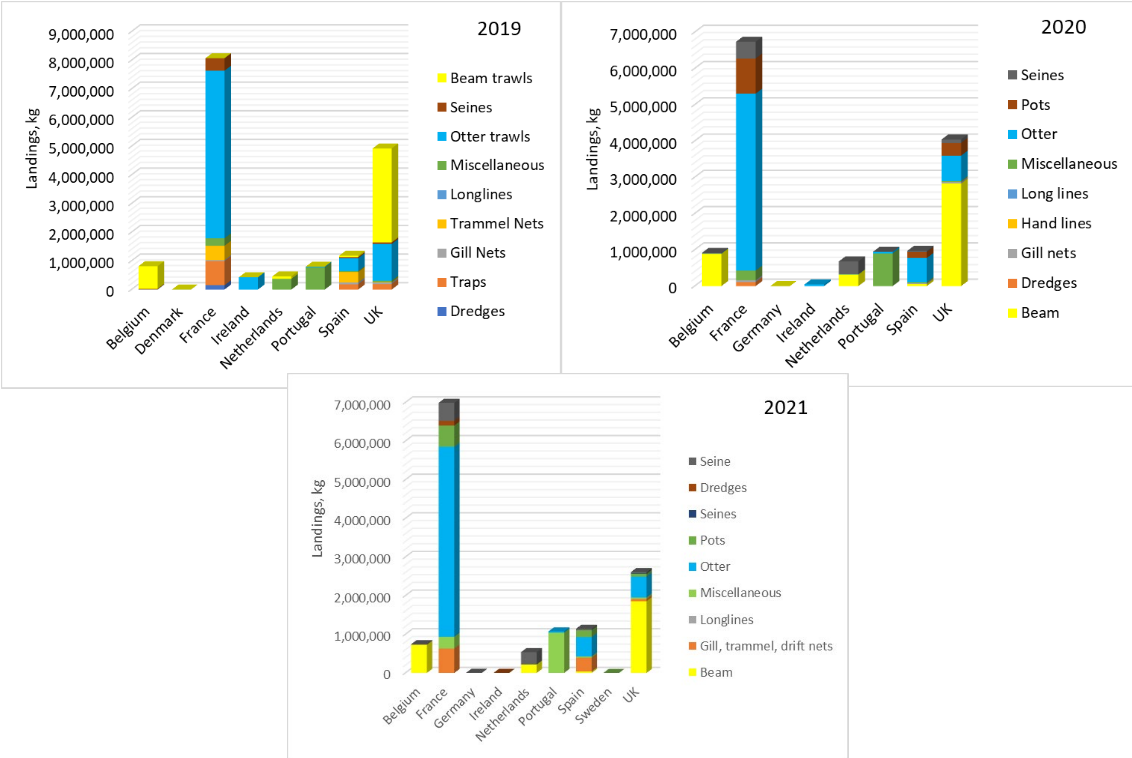


Figure 1.5 Proportion of landings of cuttlefish by country and by different gears 2019–2021.

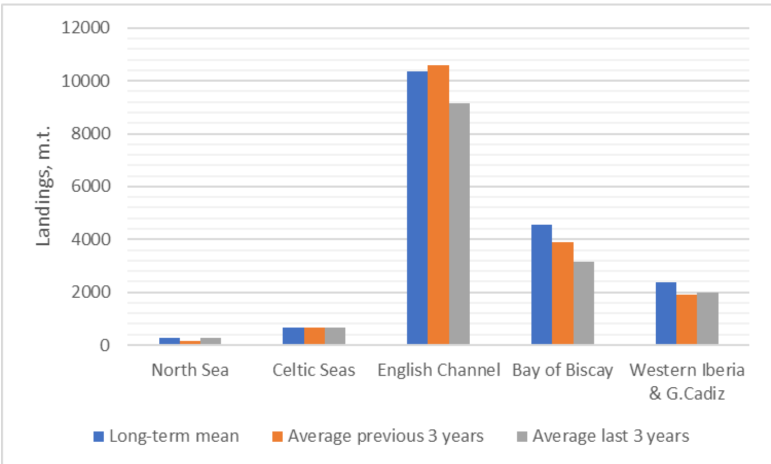


Figure 1.6 Recent mean landings (last 3 years) and landings in the previous three-year period, by subarea/division, compared with long term mean (1992–2021).

Available discard data for 2019–2021 are presented in Table 1.2. In all metiérs the discard rates were estimated to be very low, being highest in beam trawls and lowest in static gears. The discarding of cuttlefish was generally negligible (Table 1.2). Nearly half of all cuttlefish discards (43.6%) were estimated to come from ICES Area 27.7.e, with areas 27.8.a and 27.7.d being also important and accounting for 18.8 and 11.1% respectively.

Table 1.2 Discarding practices of the different mètiers in respect to cuttlefish catch.

	2019			2020			2021		
	Disc	Land	% Disc	Disc	Land	% Disc	Disc	Land	% Disc
Beam	114,505	4,205,246	2.65	67,959	4,091,796	1.63	1,373	2,837,391	0.05
Dredge		150,549	0.00		109,040	0.00		121,620	0.00
Gillnets	65	155,077	0.04	0	125,613	0.00	0	119,243	0.00
Lines		153	0.00		823	0.00		398	0.00
Misc.	4,143	1,491,371	0.28	0	1,221,871	0.00		1,418,277	0.00
Otter	151,019	8,036,138	1.84	35,518	6,344,975	0.56	37,192	5,957,832	0.62
Pots		1,213,580	0.00	0	1,486,149	0.00	0	801,324	0.00
Seines	14,241	547,941	2.53	0	956,856	0.00		880,907	0.00
Trammel	740	877,938	0.08	908	855,027	0.11	5,253	924,836	0.56

1.3.3 Fishery in the North Sea

In the ICES area 27.4 catches of cuttlefish have been highest between 2002 and 2008 (300–760 tonnes) and in recent years ranged 30–270 tonnes without an obvious trend but attaining 397 tonnes in 2020 (Figure 1.7). They were taken mostly by France and Netherlands, and to some extent by the UK in the southwestern part of the sea. The most important gear for catching cuttlefish there are beam trawls accounting for 80% of the catch, in which cuttlefish was taken as bycatch.

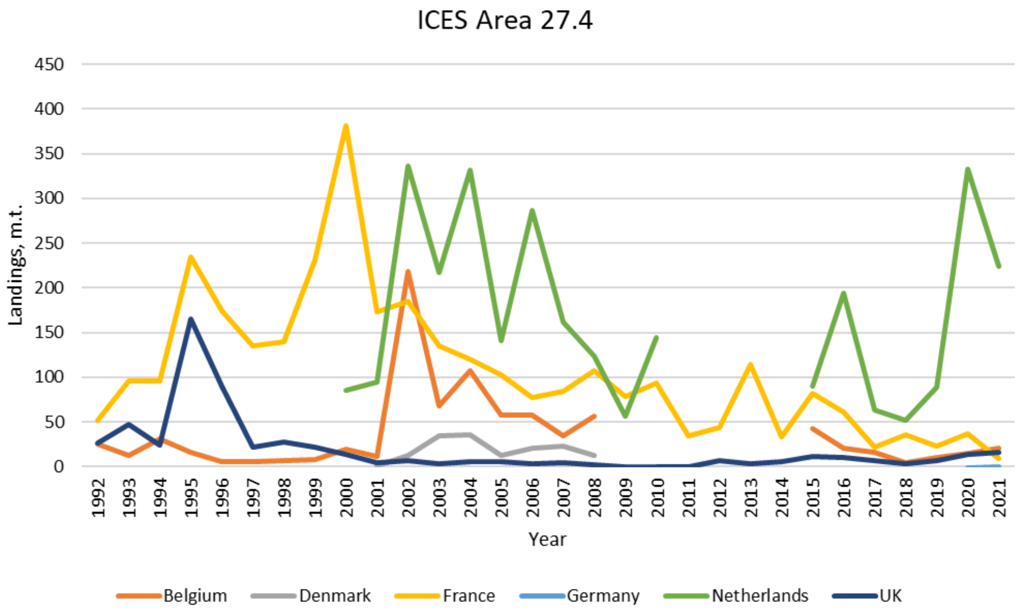


Figure 1.7 Trends in cuttlefish landings in the North Sea (27.4a,b,c).

1.3.4 Fisheries in Celtic Seas

Celtic Seas (ICES Area 27.7 a,b,c,f,g,h,j,k) followed the same pattern as other areas with landings in the last three years being lower than in three previous years. The period of highest abundance was in 2009–2011. Most of the catches were taken by the French fleet (Figure 1.8). Landings in the area were characterized by high interannual variability and generally did show a declining trend from the peak of 2009–2011.

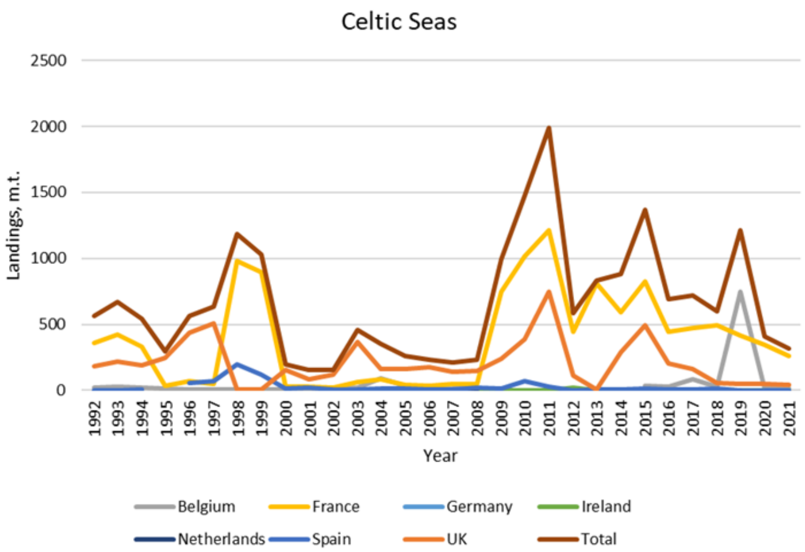


Figure 1.8 Trends in cuttlefish landings in Celtic Sea for the years 2000 to 2021 by national fleet.

1.3.5 Fishery in the English Channel

The English Channel is the most important fishing ground for cuttlefish in the Northeast Atlantic. Most of the catch was taken in the western part of the area closer to northern shores (Figure 1.9).

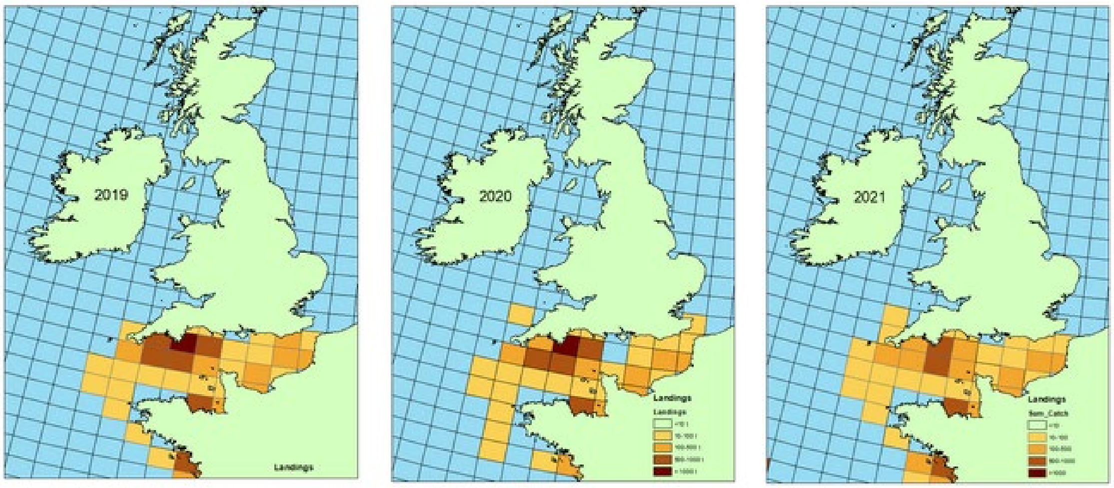


Figure 1.9 Spatial distribution of French and UK landings (combined) of cuttlefish in 2019–2021.

Landings in 2021 (6,856 tonnes) were below the historical average (10,359 tonnes), as well as catches in three recent years were below those in the three preceding years (Figure 1.10). The most important fishing gears are beam trawls mostly used by the UK and otter trawls preferred by French fishers.

Historically, landings increased from 1992 to the period of high catches in 2003–2007, which was followed by years of randomly fluctuating catches. During this period landings of the French fleet gradually decreased whereas the UK fleet increased until 2019. In the two most recent years, landings of both countries were at a low level.

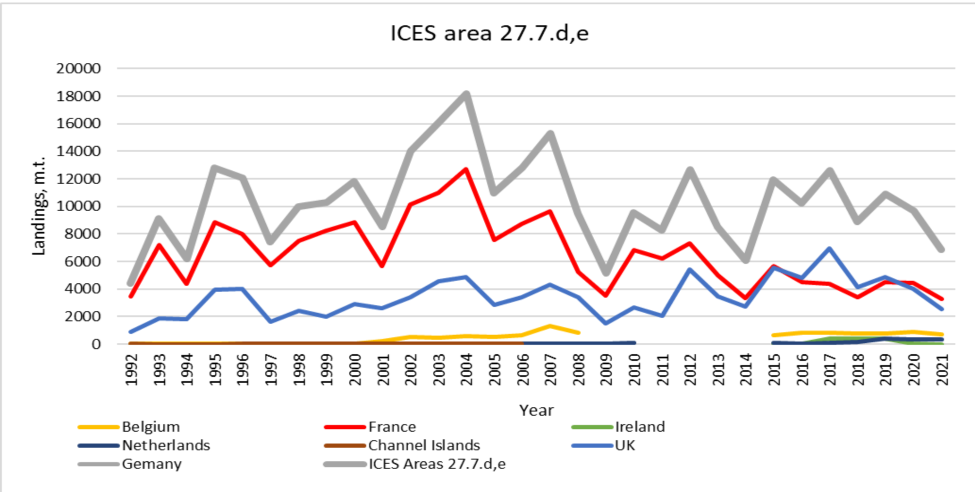


Figure 1.10 Trends in cuttlefish landings in the English Channel (27.7.d,e) for the years 2000 to 2021 by national fleet.

1.3.6 Fishery in the Bay of Biscay

In the Bay of Biscay, cuttlefish is almost exclusively exploited by the French fishing fleet (Figure 1.11).

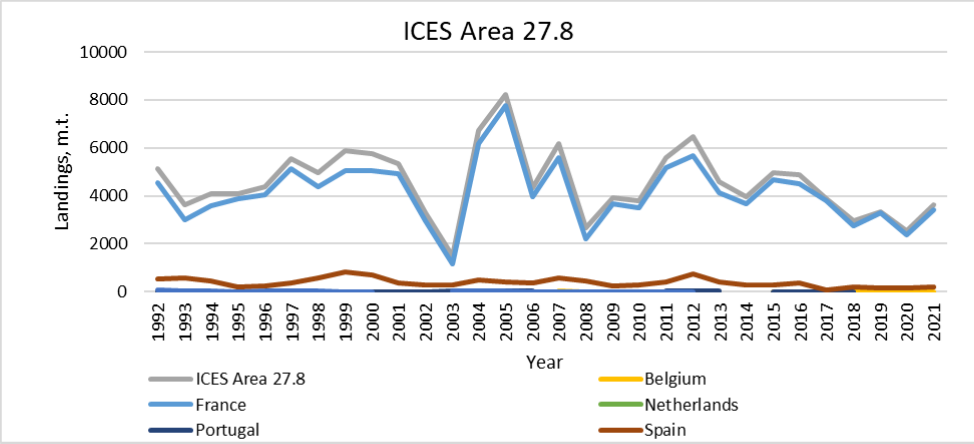


Figure 1.11. Trends in cuttlefish landings in the Bay of Biscay (27.8.a,b,c,d).

Landings peaked in 2004–2007 and have decreased since 2012, in recent years being below the historical average. Cuttlefish landed in 2019–2021 were mainly fished by otter trawls 70.9–73.4%), followed by trammelnets (15.2–17.9%).

1.3.7 Fisheries in Western Iberia and Gulf of Cadiz

In ICES division 27.9.a, cuttlefish is the second most important cephalopod resource (after Octopods) fished more or less equally by Portugal and Spain. Landings were declining from the peak of late 1990-ies, particularly from 2014 onwards, though were at the reasonably high level in 2004–2007, 2011 and 2013 (Figure 1.12). InterCatch extractions show that the most important gear type in 2019–2020 was "miscellaneous" gears (MIS = 42.7 -43.8%), which makes it difficult to judge the relative importance of the different gears. Data from 2021 show that the most important fishing gear were otter trawls (59.2% of landings) followed by pots (16.2%) and trammelnets (15.7%).

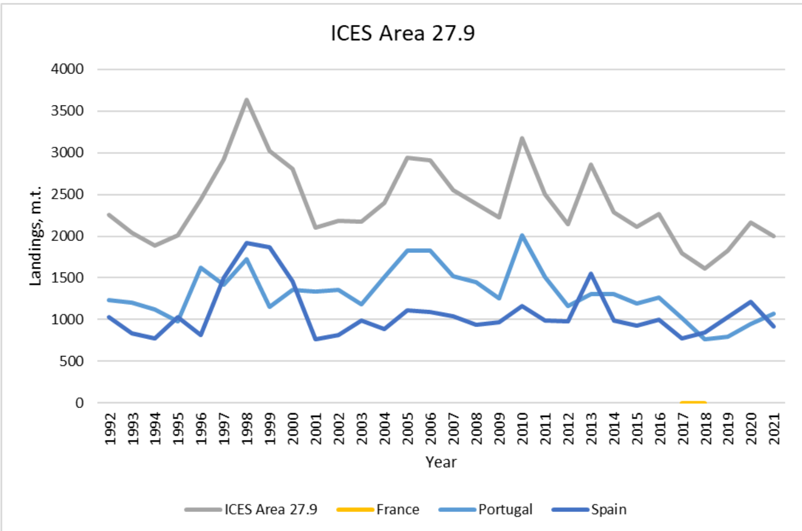


Figure 1.12 Trends in cuttlefish landings in Western Iberia and Gulf of Cadiz (ICES division 27.9.a) for the years 2000 to 2021 by national fleet.

1.3.8 Research Surveys in the English Channel

Cuttlefish data from the UKBTS 7D (up to 2021), UK Q1SWBEAM (up to 2021) and FR–CGFS (up to 2017) were available. The survey EVHOE was also available but was not found to be useful as few cuttlefish were captured. Comparative analysis of the data suggested wide random fluctuation of the stock with some declining trend from a period of the maximum abundance in 1998–2007 (Figure 1.13), which is consistent with respective decline in landings (Figure 2.8).

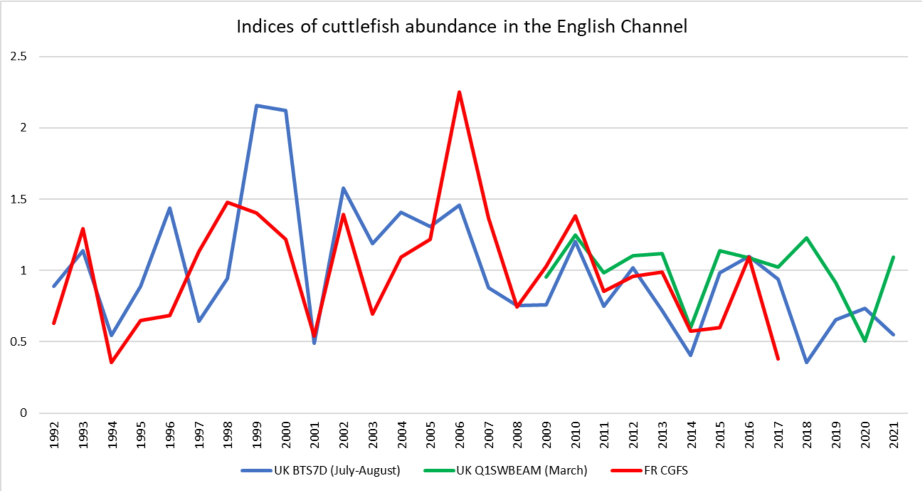


Figure 1.13 Trends in cuttlefish biomass survey indices in the English Channel (ICES divisions 27.7.d,e) – absolute values divided by the average value of time-series.

1.3.9 Research Surveys in the Gulf of Cadiz

Catches of cuttlefish by Spanish research surveys during the last 20 years fluctuated above and below average without any regularity or obvious trend (Figure 1.14). No data were available for the year 2021. To some extent their fluctuations were consistent with those of catches, particularly in autumn survey, which demonstrated relatively high cuttlefish biomass in 1998, 2005–2006, 2013, 2015 and 2019 that is similar to years of high landings (Figure 2.10).

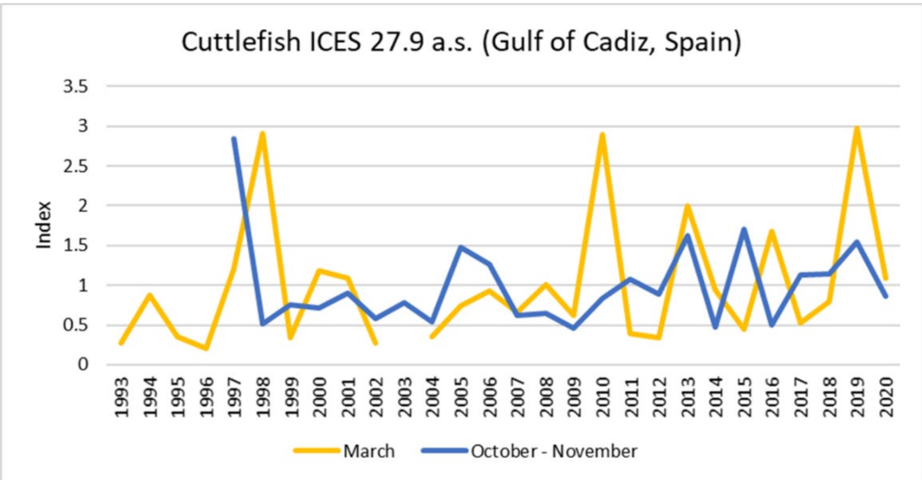


Figure 1.14 Trends in cuttlefish biomass survey indices in the Gulf of Cadiz (ICES Subdivisions 27.9.a.s.a and 27.9.a.s.c) - absolute values divided by the average value of time-series.

1.3.10 Summary of trends and status

Table 1.3 summarises the trends of cuttlefish using landings as surveillance indicators of GES, considering that the mean of the most recent 3 years should be above the long-term historic average (ICES, 2014). High landings of cuttlefish were observed in years when survey data show relative high abundance of the species, at least in the English Channel and west Iberian waters.

On another hand, in all main areas the period of 2004–2007 was a period of high abundance followed by some decline that demonstrates that cuttlefish stock dynamics is generally driven by environmental factors that might be common across wide geographic areas.

Table 1.3 Summary of cuttlefish fishery trends.

Cuttlefishes	Landings historical 1992–2021 (mean tonnes)	Landings 2016–2018 (mean tonnes)	Landings 2019–2021 (mean tonnes)	Recent mean vs. historical mean	Recent tendency 2019–2021*vs.* 2016–2018
North Sea	263	165	265	1.0	→
Celtic Seas	637	673	406	0.64	↘
English Channel	10 360	10 581	9 151	0.88	↘
Bay of Biscay	4 543	3 904	3 211	0.71	↘
Western Iberia and G. Cadiz	2 388	1 891	1 997	0.84	↘

1.4 Status and trends for loliginid squid (Loliginidae or long-finned squid) stocks

Commercial landings and discards of loliginids, and abundance/biomass derived from surveys in the period 2019–2021 are presented by ICES area and Member State. Trends in landings and abundance/biomass between 2000 and 2021 are presented for five of the most important fishing areas. Information on the data call and data quality may be found in section 1.2.

1.4.1 Loliginid fisheries overview

Weight (tonnes) of loliginids landed between 2000 and 2021, by ICES Division/SubArea and country are presented in Annex 3, Table 2. Catches of loliginid squid may include *Loligo forbesii*, *Loligo vulgaris*, *Alloteuthis media* and *Alloteuthis subulata*, with the latter two species being of lower commercial interest. Landings are reported under several species codes that are variously used by different countries. All species codes were extracted and included in this report, i.e. sqr = *Loligo vulgaris*, sqf = *L. forbesii*, sqc = *Loligo* spp., sqz = Loliginidae, oum = *Alloteuthis media*, oul = *A. subulata*, ouw = *Alloteuthis* spp. The highest landings were from France and the UK, both of which reported using sqz or sqc (Loliginidae / *Loligo* spp.). Therefore, the species identity in the landings was not precise for the countries with the highest landings (Figure 1.15).

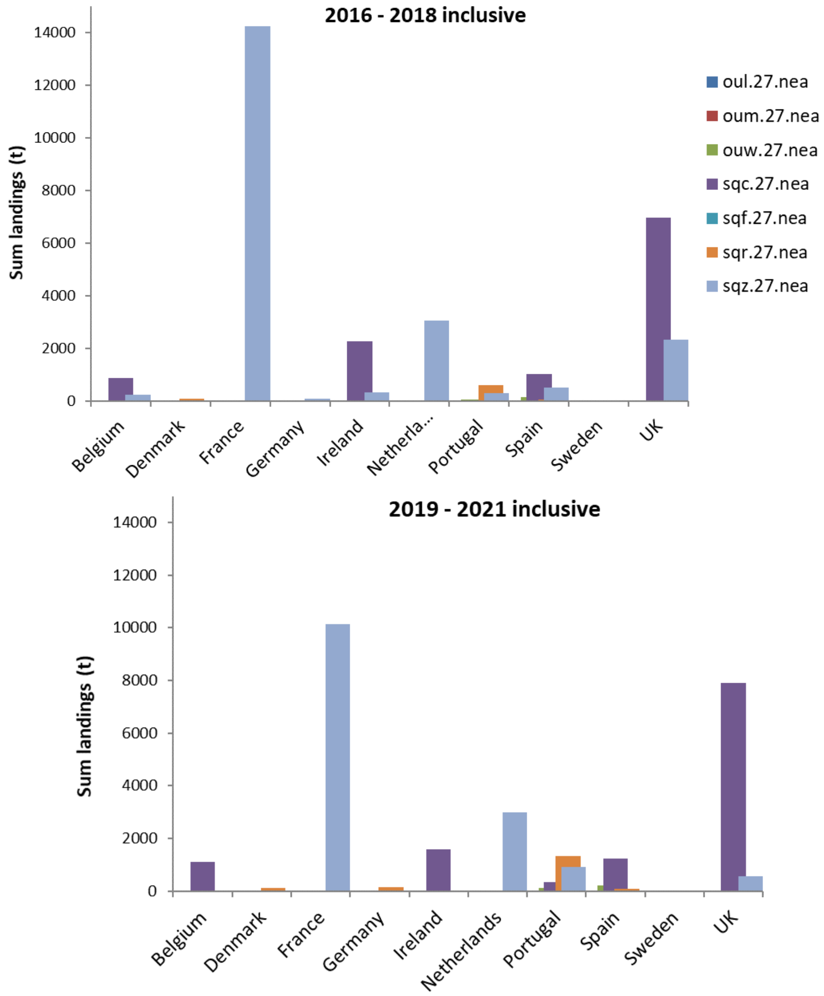


Figure 1.15 Sum of landings (tonnes) by country / stock 2016—2018 (up) and 2019–2021 (bottom).

A breakdown of the loliginid landings by the main fishing areas from 2000–2021 is shown in Figure 1.16. Six regions were important, accounting for around 99% of the reported loliginid catches (landings + discards). Most landings (36%) came from the English Channel, which includes ICES divisions 27.7.d,e. The next highest landings (19%) came from the North Sea in ICES divisions 27.4.a–c. Closely following was the Bay of Biscay (18% of landings) in ICES divisions 27.8.a–d. The Celtic Seas reported 14% of landings (ICES divisions 27.6.a,b and 27.7.a–c,f–k). Landings from Western Iberia and Gulf of Cadiz (ICES division 27.9.a) were about 9%, on average, in the period, while those on the Azores grounds (ICES Subarea 27.10) were 4%.

The change in the landings in each of these six regions across the time-series can be seen in Figure 1.17. An upward trend in overall landings between 2013 and 2019 was reversed in 2020 and 2021. In the overall 2000–2021 time-series, there has been a weak upward trend with important peaks, in 2003, 2010 and 2017, and also 2019 (Figure 1.18).

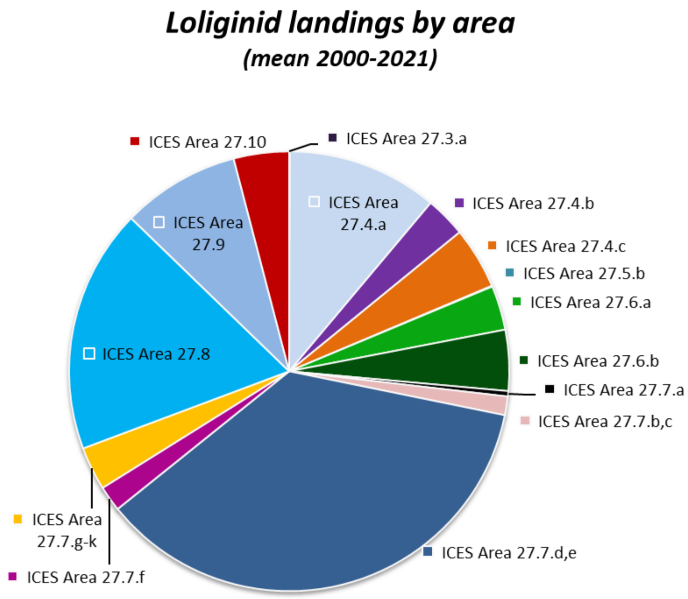


Figure 1.16 Percentage of loliginid landings by ICES divisions between 2000 and 2021 (mean values across the time period).

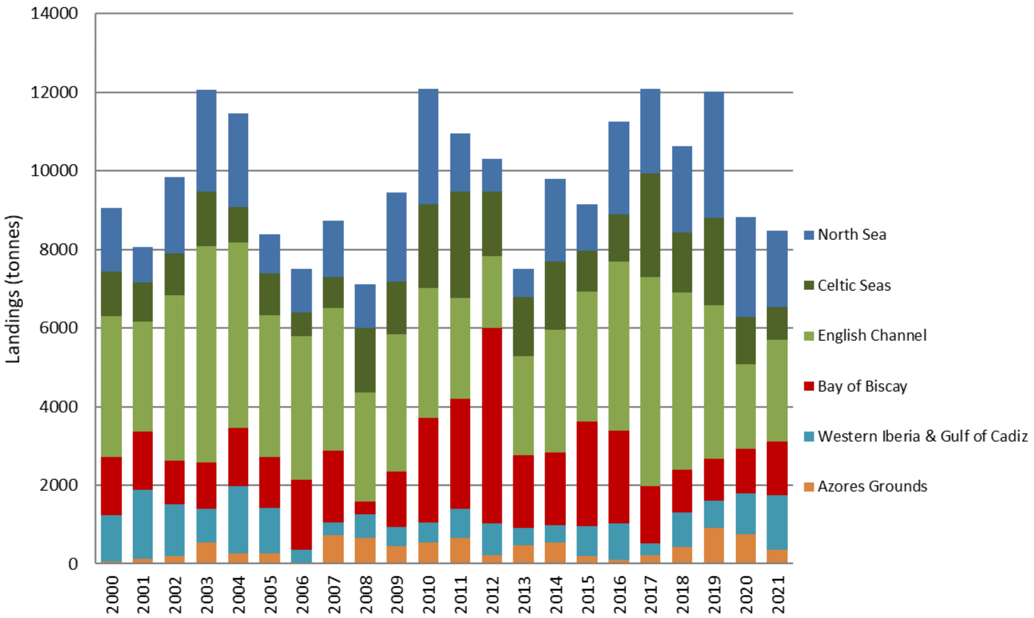


Figure 1.17 Change in the landings of loliginids in the six main fishing regions between 2000 and 2021.

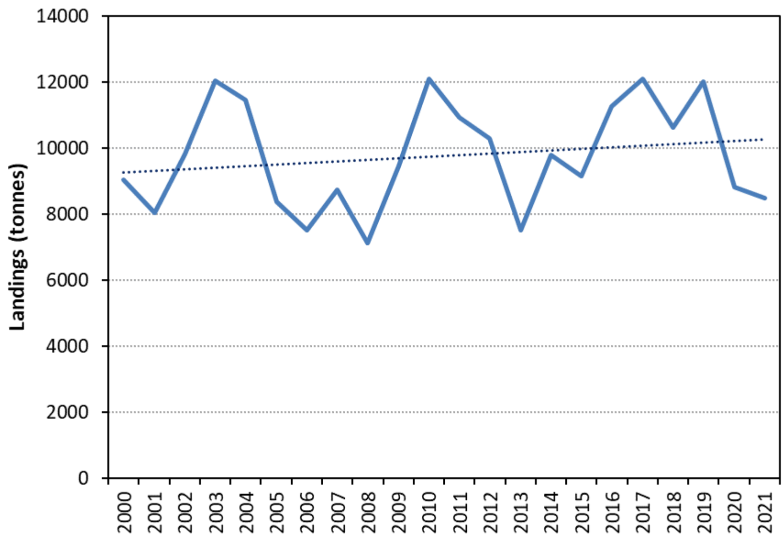


Figure 1.18 Trends in total loliginid landings across the ICES areas.

The recent trend in mean landings (2019–2021) has been equal to or below the historical mean in three regions: Celtic Seas, English Channel and Bay of Biscay, and slightly above the historical trend in the North Sea, Western Iberia and Gulf of Cadiz and Azores grounds (Figure 1.19). Similarly, compared to the recent past (2016–2018), the loliginid landings have been higher in 2019–2021 in the North Sea, Western Iberia and Gulf of Cadiz and Azores Grounds. In the NE Atlantic, loliginids are exploited mainly by the trawl fleet (77%, in 2019–2021 period), with the exception of Belgium, Denmark, Germany, the Netherlands and Portugal where a reasonably large proportion of other metiers are also used (Figure 1.20).

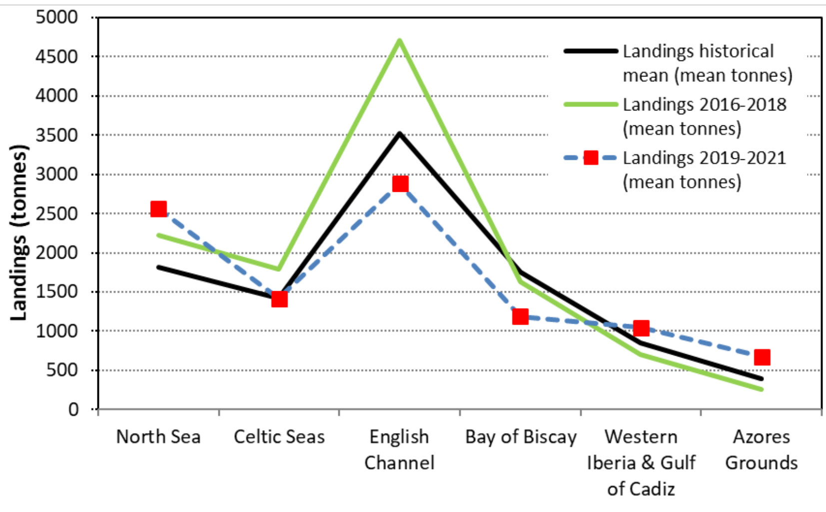


Figure 1.19 Trends in total loliginid landings in the recent mean landings (2019–2021) and the previous three years (2016–2018) by region, compared with the historical 2000–2021 mean.

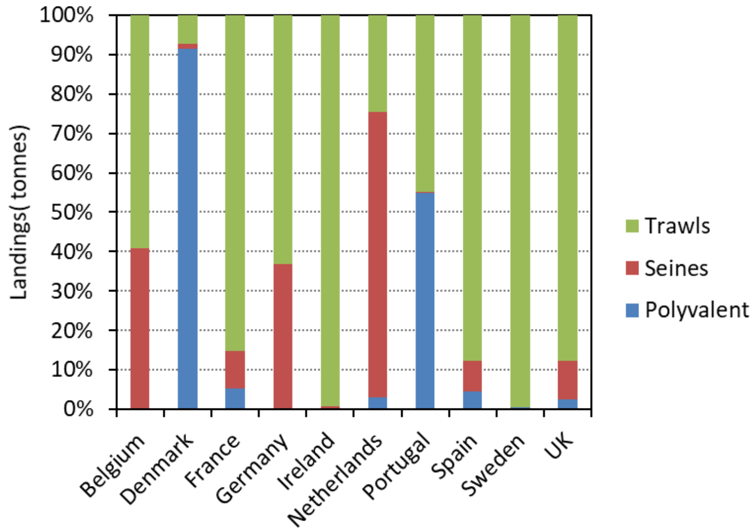


Figure 1.20 Loliginid landing proportions by fleet for each country for the years 2019 to 2021.

Discards are reported mainly at the family level (Loliginidae) by most countries. Some countries report zero loliginid discards, or do not report at all, particularly in recent years. Where discards are reported these are generally negligible, comprising <1% of overall catches on average across ICES divisions (Table 1.4).

Table 1.4. Percentage of the loliginid catch that is discarded (% Discards) and relative percentage of catches by sub-area (% Catches) in the period 2018–2021.

	2018		2019		2020		2021	
Division	% Discards	% Catch	% Discards	% Catch	% Discards	% Catch	% Discards	% Catch
27.3.a	21	0	22	0	3	0	2,5	0
27.4.a	0	14		16		16		13
27.4.b	1	1	0	3	0	4		2
27.4.c	0	7	0	8	0	16		8
27.5.b		0		0		0		0
27.6.a	0	6		6		7		7
27.6.b	0	5	0	10	0	4	0	1
27.7.a	0	0	0	0	0	0	0	0
27.7.b	0	0	0	0	0	0	0	0
27.7.c	4	0	0	0	0	0	0	0
27.7.d	0	34	0	27	0	19		24
27.7.e	5	9	0	6	0	5	0	7
27.7.f	0	1	0	0	0	1		0
27.7.g	4	0	0	0	0	0	0	0
27.7.h	10	1	0	1	0	1	0	1
27.7.j	1	1	0	1	0	2	0	1
27.7.k	0	0	0	0		0	0	0
27.8.a	2	8	0	6	0	10	0	14
27.8.b	1	3	0	2	0	2	0	2
27.8.c	0	0	0	0	0	0	0	1
27.8.d	1	0		0		0		0
27.9.a	0	9	1	6	0	12	0,3	17
mean	2		1		0		0,2	

The largest proportion of the catch was discarded at ICES division 27.3.a (2.5–22% of the catch), where overall loliginid landings were also very low. ICES divisions 27.7.h, e, g and c had discards of up to 10% of the catch in 2018, but these figures have declined more recently (2019–2021). The trawl fleet is associated with almost all of the loliginid discards, with much fewer coming from seines (this was seen only in Belgium, France and Spain) and none reported from polyvalent (MIS) fleet, although here were few data available from this fleet.

Fishing effort for loliginids is shown in Figure 1.21. As these are generally not targeted fisheries, the link between catch and effort is not straightforward. Effort in France reduced from 2016 to 2017 / 2018, while effort increased in 2018 in Portugal. Effort reduced again in France from 2019 to 2020 / 2021, whereas it increased in this period in Spain and in 2021 in the UK.

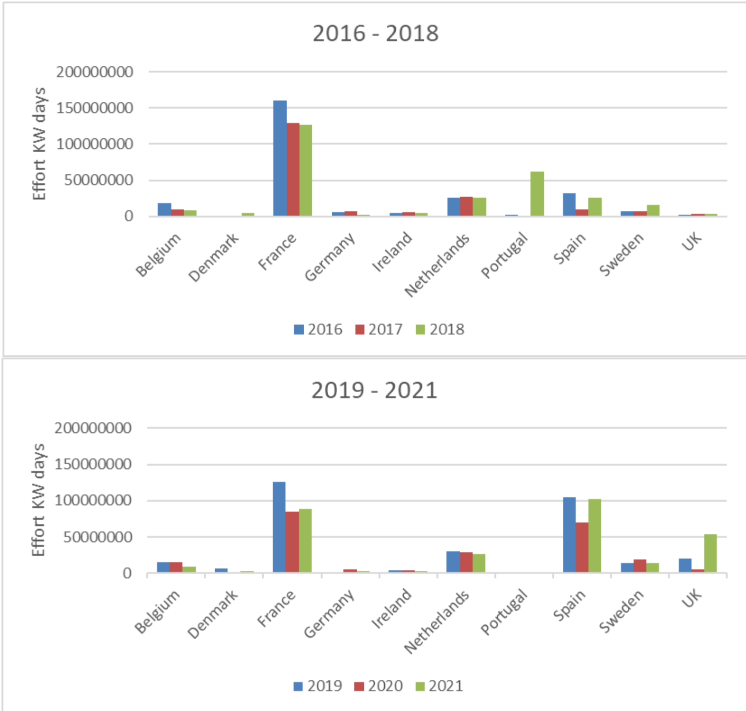


Figure 1.21 Fishing effort (KW days) for loliginids.

1.4.2 Fisheries in the North Sea

Loliginid fisheries landing statistics for the North Sea (27.4) indicate that summed landings were 1932 tonnes in 2021, which is a reduction on 2020 and 2019 (Figure 1.22).

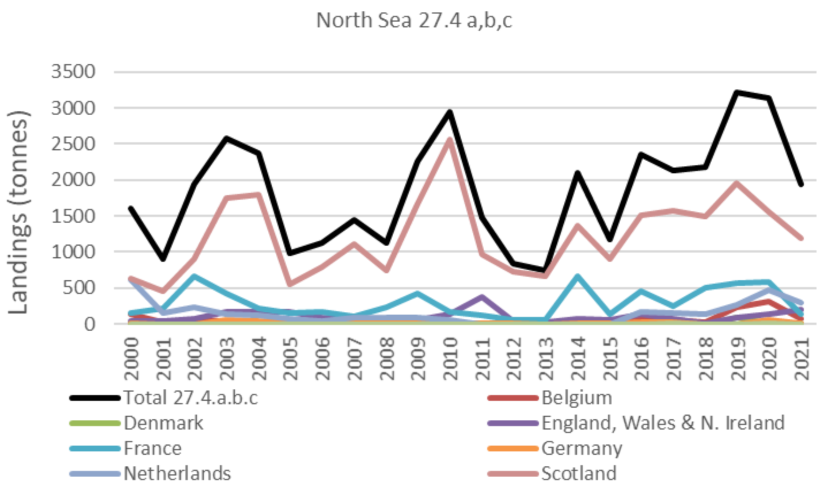


Figure 1.22 Trends in loliginid landings in the North Sea (Divisions 27.4.a–c) for the years 2000 to 2021, by national fleet.

Scotland remains the main fishing fleet exploiting North Sea loliginids, especially in the northern North Sea (27.4.a), while in the southern North Sea (27.4.c), France produced most of the landings. Several countries (mainly the UK) exploited the central North Sea (27.4.b). Some of the highest landings in the entire time-series were reported by Scotland, France and the Netherlands in 2019 and 2020 but this was reduced in 2021. Landings in the North Sea have exceeded the long term mean for five out of the last six years. The main fleet operating in the North Sea is the trawl fleet, which was responsible for 85% of landings during 2018–2021.

1.4.3 Fisheries in the Celtic Seas

Overall loliginid squid production in the Celtic Seas (ICES area 27.6.a,b, 27.7.a–c, f–k) in 2021 was 842 tonnes, which was a decrease on the peaks reached in 2017 (2637 tonnes) and 2019 (2211 tonnes) (Figure 1.23). The main fleets fishing in this area are UK/Scotland in the northern part, and France, England and Ireland in the southern part, though this is highly variable across years.

ICES division 27.6.a had sharp increases in reported landings to 753 tonnes in 2019 (mainly reported by Scotland) and in 2020 (609 tonnes, mainly by Spain). The landings in this area reduced somewhat in 2021 (530 tonnes). Area 27.6.b (Rockall) also had a reduction in 2020 (320 tonnes) and 2021 (64 tonnes) after recent peaks in 2019 and 2017. It was notable that Ireland and Scotland landings were much reduced in 2021 and there were no landings reported in the case of Scotland in 2020 at Rockall. Loliginid landings have decreased very much in the last 7–10 years in other subareas, notably in 27.7.a-c, 27.7.f. and to a lesser extent in 27.7 g-k. In the 2018–2021 period, a large majority (97%) of landings in the Celtic Seas were made by the trawl fleet.

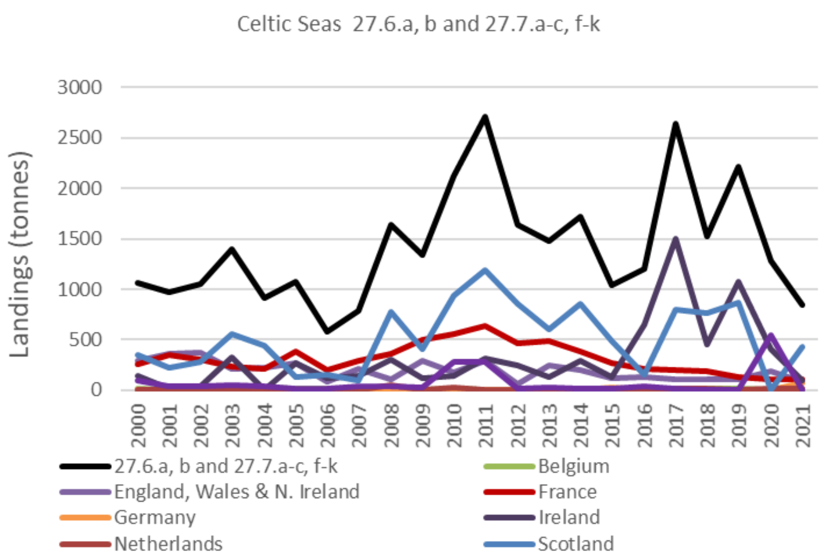


Figure 1.23 Trends in loliginid landings in the Celtic Seas (Divisions 27.6.a,b and 27.7.a–c, f–k) for the years 2000 to 2021 by national fleet.

1.4.4 Fisheries in the English Channel

English Channel (ICES divisions 27.7.d.e) landings increased slightly in 2021 to 2572 tonnes after showing a declining trend since peak landings of 5311 tonnes in 2017. The main fleet targeting this area is French, along with steady levels of exploitation from the UK and some recent increases from the Netherlands (Figure 1.24). Only two of the last six years (i.e. 2020 and 2021) have been below the long-term average for English Channel loliginid landings. 30% of landings are made by seines in the English Channel with the remainder mostly made up from the trawling fleet.

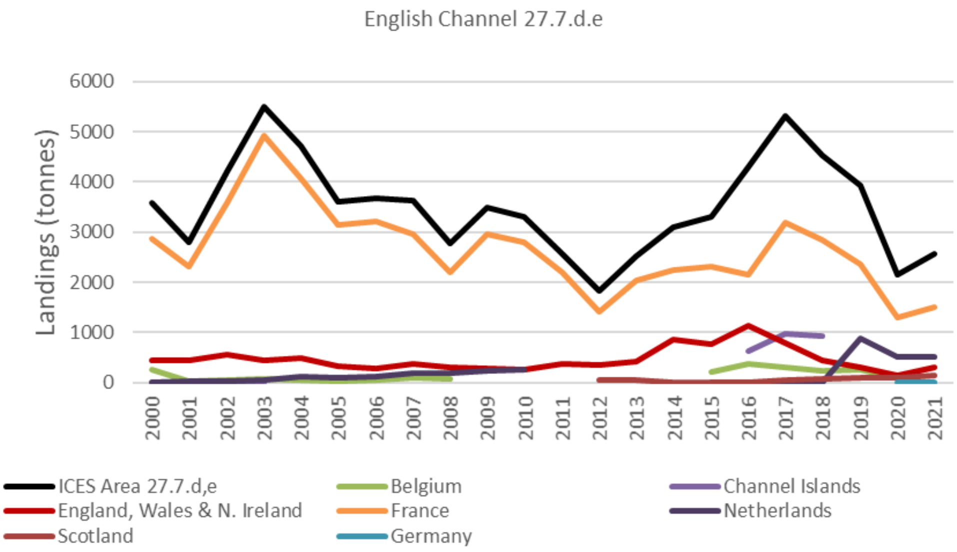


Figure 1.24 Trends in loliginid landings in the English Channel (Divisions 27.7.d,e) for the years 2000 to 2021 by national fleet.

1.4.5 Fisheries in the Bay of Biscay

Landings in the Bay of Biscay have held steady at ~1000 tonnes for the past 4 years (ICES divisions 27.8.a–d) (Figure 1.25). France dominates catches in divisions 27.8.a,b,d and Spain dominates catches in division 27.8.c. Landings from the Bay of Biscay have been almost exclusively from the French fleet in recent years. 82% of these landings are from the trawl fleet and 11% from seines.

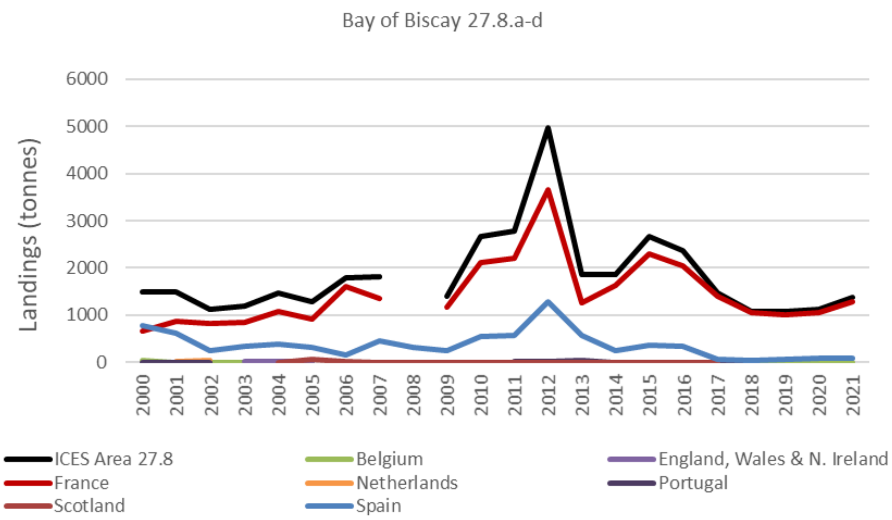


Figure 1.25 Trends in loliginid landings in the Bay of Biscay (Divisions 27.8.a–d) for the years 2000 to 2021, by national fleet. Note that there are no French data for 2008, hence no total.

1.4.6 Fisheries in Western Iberia and the Gulf of Cadiz

Landings are on an increasing trend in Western Iberia and Gulf of Cadiz, reaching 1405 tonnes in 2021. (ICES division 27.9.a) (Figure 1.26). Landings in both 2020 and 2021 have been above the long-term average for this region with loliginids almost exclusively being fished by Portugal and Spain. 80% of landings are taken by the trawling fleet, with 16% being taken from the polyvalent fleet and only 4% from seines.

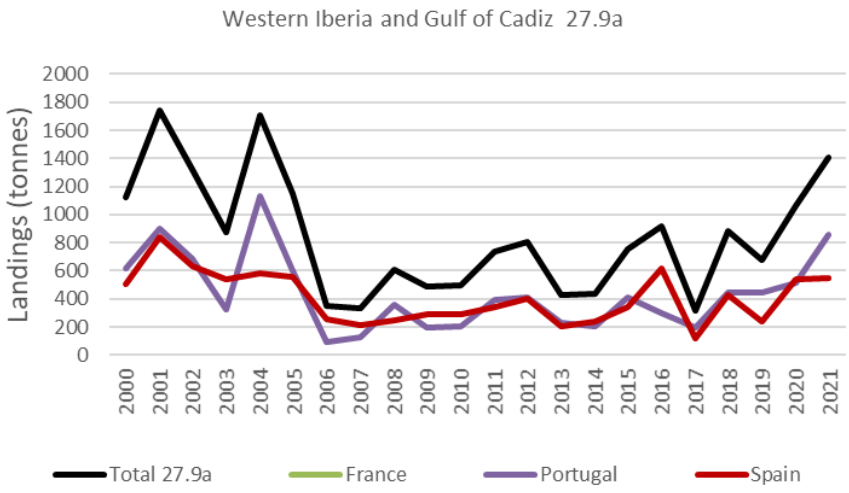


Figure 1.26 Trends in loliginid landings in Western Iberia and Gulf of Cadiz (ICES division 27.9.a) for the years 2000 to 2021, by national fleet.

Landings of *Alloteuthis* spp., reported as '*A. subulata*', '*A. media*' or '*Alloteuthis* spp.' mainly come from this region, whereas all other regions mainly landed *Loligo* species. Given known identification issues in this group (Anderson *et al*., 2008), for the purposes of this report these will be regarded as '*Alloteuthis'* spp. Between 2019–2021, 85% of *Alloteuthis* landings were from Western Iberia and the Gulf of Cadiz. These came from Spain (~223 tonnes) and Portugal (~129 tonnes). The remainder (3 tonnes) were fished from the Bay of Biscay and were landed by France.

1.4.7 Relative biomass indices for loliginids: overview

Regional fishery CPUEs datasets by species or groups of species need further improvement to be used as a proxy of biomass. The following bottom trawl research cruises, including those with data submitted in DATRAS, were analysed as possible proxies of biomass of loliginid species: PT-IBTS, GER-IBTS, SP-NGFS, SP-GCGFS, SP-PorcGFS, IE-IGFS, FR-EVHOE and UK-SWCGFS. Data from the French survey FR–CGFS is not available to the group since 2017.

1.4.8 Research surveys in the North Sea

The trends from various fisheries surveys in the North Seas (ICES area 27.4.a-c) is shown in Figure 1.27 (top), where we can see a fluctuation in *Loligo forbesii* since the beginning of the series, and an increasing trend since 2019 (surveys in both quarters show this). *Loligo vulgaris*, on the other hand, has been little in evidence, apart from 2015, 2017 and 2018 and then only in the first quarter. *Alloteuthis* spp. are holding steady abundance in the first quarter and showing an increasing trend in the third quarter. Overall, the loliginids trend in the recent (2019–2021) vs. previous three years (2016–2018) was mixed; there was a steady or increasing trend in *L. forbesii* / *Alloteuthis* and a slightly decreasing one in *L. vulgaris* (Figure 1.27 (bottom)). These observations complement a slightly increasing trend in fisheries landings of loliginids in the North Sea (Table 1.5).

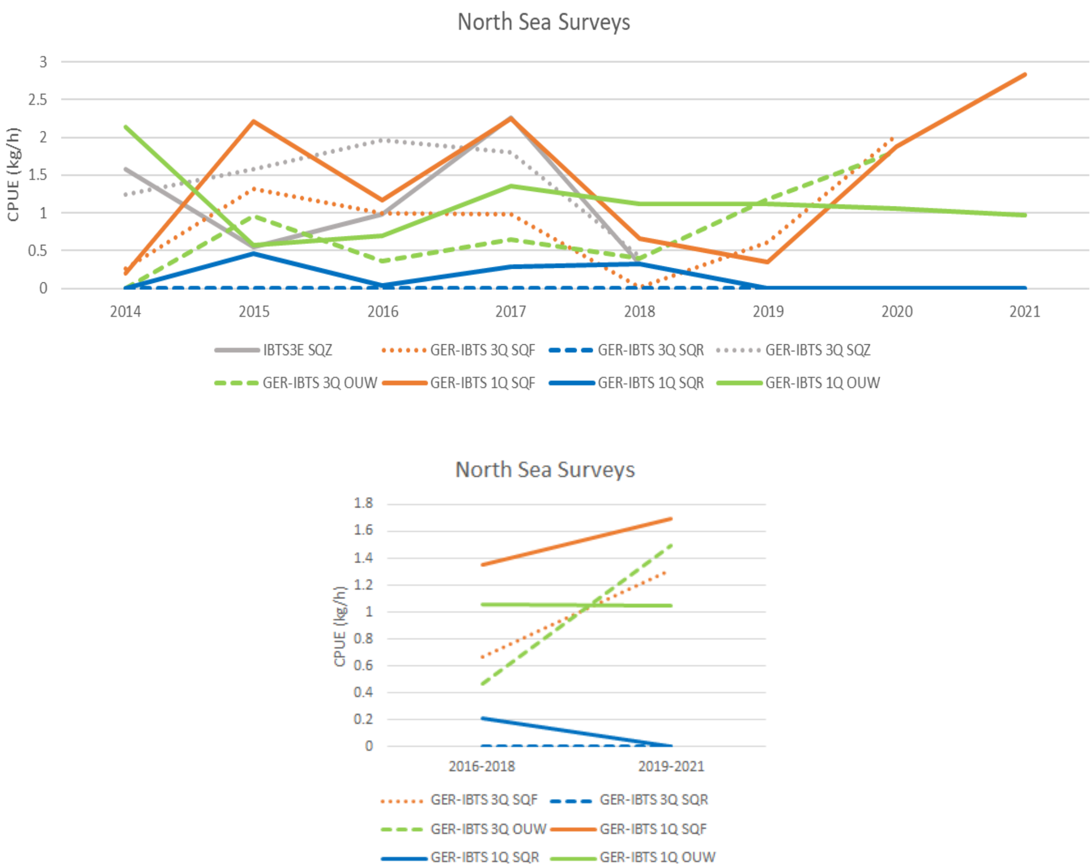


Figure 1.27 CPUE (kg/h) from research surveys in the North Sea (top) and recent trends in surveys (bottom).

1.4.9 Research surveys in the Celtic Seas

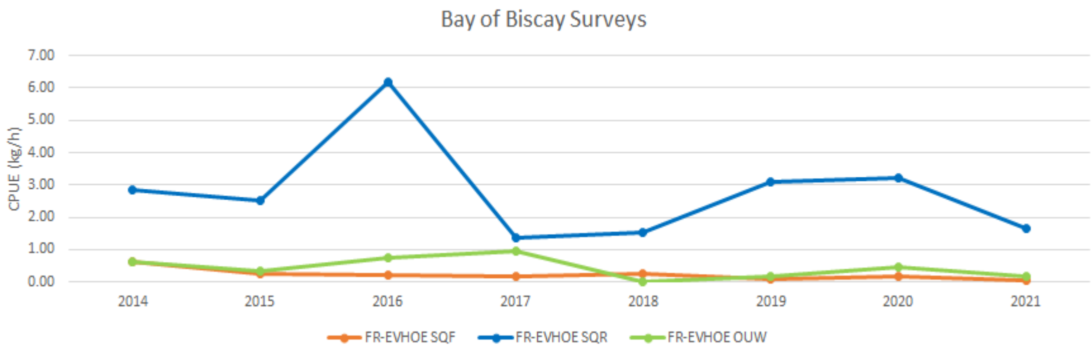
The trends from various fisheries surveys in the Celtic Seas (ICES divisions 27.6.a,b, 27.7.a–c, f–k) are shown in Figure 1.28 (top). There has been a degree of fluctuation in *L. forbesii* on the Irish shelf and a decrease in *L. forbesii* on the Porcupine Bank in 2018–2019, but this has increased slightly in 2020/2021. *Alloteuthis* spp. on the Irish Shelf also showed a large decrease in 2018 and has remained at a lesser abundance since then. The loliginids trend in the recent (2019–2021) vs. previous three years (2016–2018) was generally decreasing, which agrees with what has been observed recently in the fisheries landings in the Celtic Seas (Figure 1.28, bottom; Table 1.5). An exception was *L. forbesii* on the Irish shelf, which increased in the most recent three years.

Figure 1.28 CPUE (kg/h) from research surveys in the Celtic Seas (top) and recent trends in surveys (bottom).

1.4.10 Research surveys in the Bay of Biscay

The trends from the French survey (EVHOE) in the Bay of Biscay (ICES divisions 27.8.a,b,d) are shown in Figure 1.29 (top). *L. vulgaris*, which is the most abundant loliginid in this area, showed a steady trend since 2014, except for an important peak in 2016.

L. forbesii abundance is generally very low and was the lowest of the time-series in 2021. *Alloteuthis* spp. appears in this area also in reduced abundance. The loliginids trend in the recent (2019–2021) vs. previous three years (2016–2018) was generally decreasing, which agrees with what has been observed recently in the fisheries landings in the Bay of Biscay (Figure 1.29, bottom; Table 1.5).



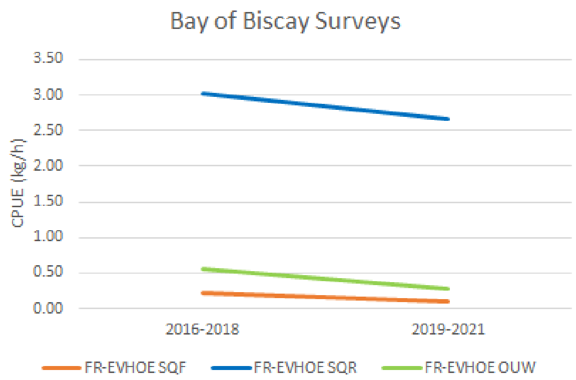
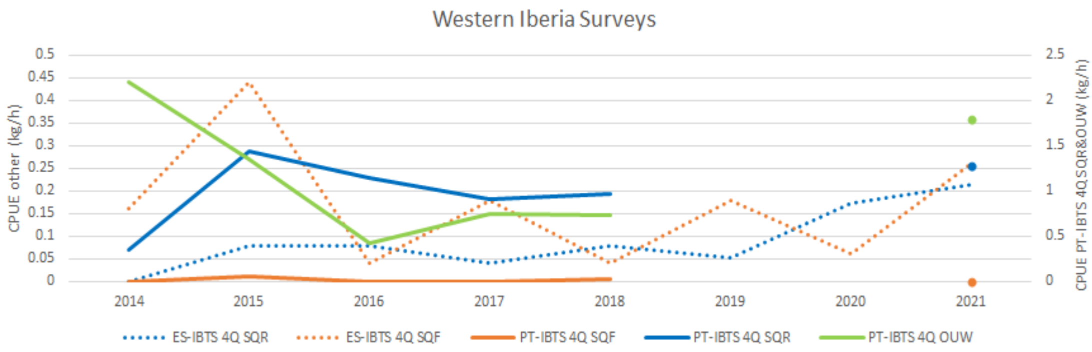


Figure 1.29 CPUE (kg/h) from research surveys in the Bay of Biscay (top) and recent trends in surveys (bottom).

1.4.11 Research surveys in Western Iberia

The trend from various fisheries surveys in Western Iberia (ICES division 27.8.c and subdivision 27.9a.n.c) is shown in Figure 1.30 (top), where we can notice that *Loligo forbesii* for the northern (Spanish) surveys begins the series at high abundance in 2015 and fluctuates thereafter; the abundance in Portuguese waters is very low and no catches of this species were recorded in the PT–IBTS.

Meanwhile, *Loligo vulgaris* is generally at higher abundance towards the central / south (Portuguese surveys) than in the north (Spanish surveys), although the latter has also increased in 2021. *Alloteuthis* spp. was at high abundance at the beginning of the time-series (2014) and declined thereafter to a steady abundance. There were no Portuguese surveys in 2019 and 2020. In 2021, the survey series restarted with a new research vessel. The overall trend recently (2019–2021) vs. previous three years (2016–2018) given by the ES–IBTS was upwards for all the loliginids (Figure 1.30, bottom), mirroring the recent trends in the fisheries landings for Western Iberia (Table 1.5).



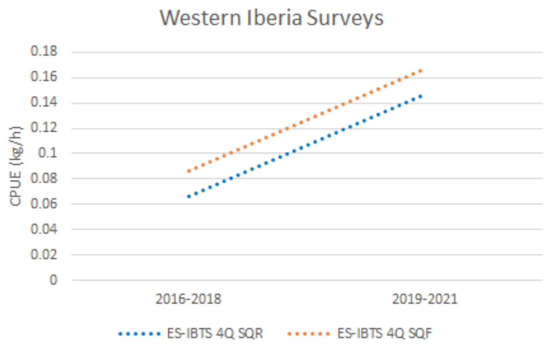
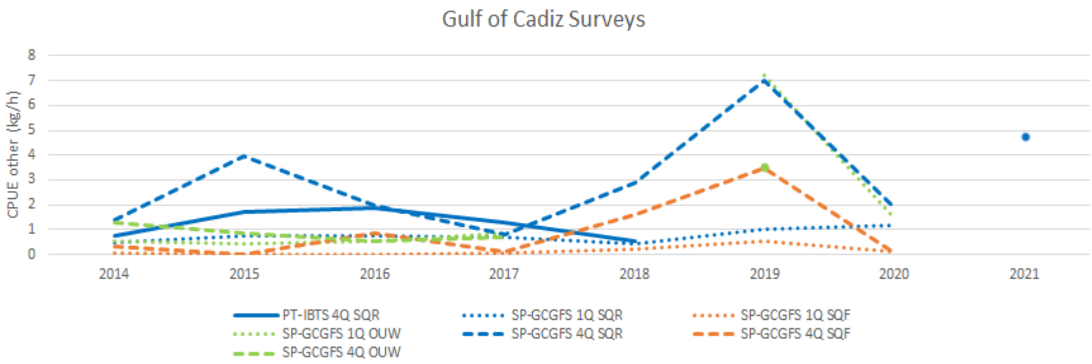


Figure 1.30 CPUE (kg/h) from research surveys in Western Iberia (top) and recent trends in surveys (bottom).

1.4.12 Research surveys in the Gulf of Cadiz

The trend from various fisheries surveys in Gulf of Cadiz (ICES Subdivision 27.9.a.s) is shown in Figure 1.31 (top), where we can observe a recent (2019) increase in *Loligo vulgaris* abundance in the eastern Gulf of Cadiz, in particular in the 4th quarter surveys. Abundance has since dropped again in 2020 and no relevant surveys were carried out in the region in 2021. In the western Gulf of Cadiz (Portuguese waters) abundance of *L. vulgaris* has been steady and low since 2014, but a significant increase was observed in 2021 (no surveys in 2019 and 2020). *Loligo forbesii* abundance also increased in 2019 (Spanish surveys - 4th quarter only) and dropped lower again in 2020. *Alloteuthis* spp. abundance was also elevated in 2019 and dropped back to its base-level abundance in 2020 (Figure 1.31 top). The overall trend recently (2019–2021) vs. previous three years (2016–2018) was an increasing one, due to the high abundances observed in 2019 for all loliginid species and this mirrored the recent positive trend in the fisheries landings (Figure 1.31, bottom, Table 1.5).



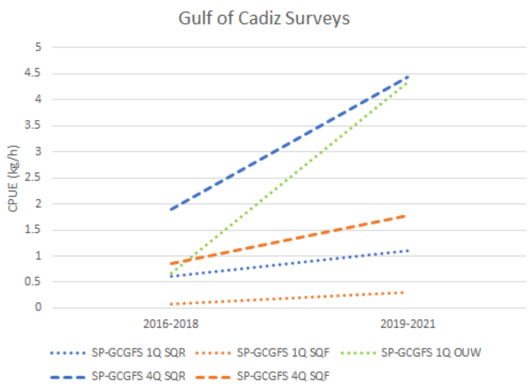


Figure 1.31 CPUE (kg/h) from research surveys in the Gulf of Cadiz (top) and recent trends in surveys (bottom). Only surveys with at least two data points in each three-year period are shown.

1.4.13 Summary of trends and status

In 2019–2021, loliginid landings were above both the historical mean (2000–2021) and recent past (2016–2018) in the North Sea, Western Iberia and Gulf of Cadiz, and the Azores, while landings were below these means in Celtic Seas, English Channel and Bay of Biscay (Table 1.5). Based on landings, we could conclude that the status of loliginid populations may not be good in the Bay of Biscay or English Channel, since landings from both regions were also below both the historical mean and recent analysis periods (e.g. 2015–2017 vs. 2018–2020). In 2019–2021, the recent mean landings trend in the Celtic Seas switched from positive to negative, relative to the previous analysis periods (2015–2017 vs. 2018–2020).

Trends in the recent tendency of abundance relative to the past was also examined using fishery surveys, by comparing average CPUE from the 2019–2021 period vs. 2016–2018 (Table 1.6). North Sea surveys in the third quarter are increasing (*L. forbesii* and *Alloteuthis* sp.) or stable (*L. vulgaris*), while those in the first quarter are increasing in the case of *L. forbesii*, but decreasing in *L. vulgaris* and *Alloteuthis* spp. In the Celtic Seas, there was a decreasing trend in *L. forbesii* in the Porcupine survey (7.c.2 and 7.k.2), but an increasing trend in this species on the Irish Shelf (6.a + 7.abcgjk). *Alloteuthis* spp. showed a decreasing trend on the Irish Shelf (Table 1.6). In the Bay of Biscay, a decreasing trend was observed in *L. forbesii*, *L. vulgaris* and *Alloteuthis* spp. In North-Western Iberia, there was an increasing trend in both *L. forbesii* and *L. vulgaris* (fourth quarter). In the Gulf of Cadiz, there was an increasing trend in *L. forbesii*, *L. vulgaris* and *Alloteuthis* spp. in the first and fourth quarters.

Table 1.5 Summary of trends and status in loliginid fishery landings per region.

Region	Historical mean landings (2000-2021)	Landings 2016-2018 (mean tonnes)	Landings 2019-2021 (mean tonnes)	Trend 2019-2021 vs 2016-2018	Trend 2019-2021 vs 2016-2018
North Sea	1816	2226	2560	335	Positive ↗
Celtic Seas	1423	1794	1418	-377	Negative ↘
English Channel	3518	4710	2880	-1830	Negative ↘
Bay of Biscay	1755	1635	1188	-446	Negative ↘
Western Iberia & Gulf of Cadiz	848	703	1047	344	Positive ↗
Azores Grounds	397	252	671	419	Positive ↗

Table 1.6 Summary of trends in loliginid CPUE per fishery survey.

	Surveys	Recent tendency 2019-2021 vs 2016-2018		
		L. forbesii	*L. vulgaris*	*Alloteuthis sp.*
North Sea	GER-IBTS 3Q	↗	—	↗
	GER-IBTS 1Q	↗	↘	↘
Celtic Seas	UK-NWGFS	NA	NA	NA
	UK-SWBEAM	NA	NA	NA
	ES-PorcGFS	↘	NA	NA
	IR-GFS	↗	NA	↘
Bay of Biscay	FR-EVHOE	↘	↘	↘
North-Western Iberia	ES-IBTS 4Q	↗	↗	NA
	PT-IBTS 4Q	NA	NA	NA
Gulf of Cadiz	PT-IBTS 4Q	NA	NA	NA
	SP-GCGFS 1Q	↗	↗	↗
	SP-GCGFS 4Q	↗	↗	NA

1.5 Ommastrephidae stocks status and trends

1.5.1 Data quality and data call

Ommastrephid commercial landings and discards were provided by ICES division and metier via InterCatch by the following Member States: Belgium, Denmark, France, Ireland, Netherlands, Poland, Portugal, Spain, Sweden and UK. In general, data were uploaded to Intercatch in time.

Abundance/biomass indices derived from research surveys and commercial catch data, and effort of the main trawler fleets were sent to Accessions section in the WGCEPH sharepoint. In addition, several requests for data were made to persons responsible for surveys and data collection.

1.5.2 Ommastrephid fisheries overview

The short-finned squids of the family Ommastrephidae (broadtail shortfin squid: *Illex coindetii*, lesser flying squid: *Todaropsis eblanae*, European flying squid: *Todarodes sagittatus* and neon flying squid: *Ommastrephes bartramii*) and other less frequently captured families are included in this section. All these taxa occur within the area that includes ICES Subarea 3 to Div. 9a, Mediterranean waters and North African coast. In the figures below proportion of landings by division (Figure 1.32), by country (Figure 1.33) and by gear (Figure 1.34).

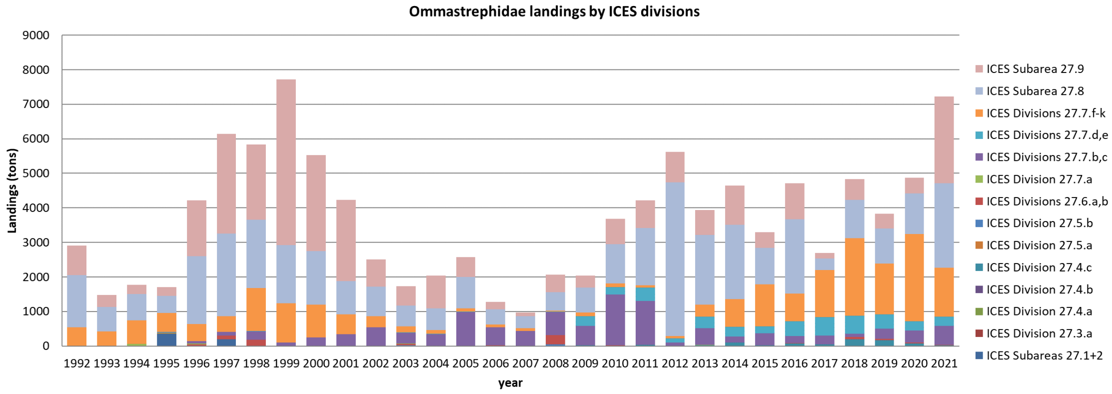


Figure 1.32 Landings of Ommastrephidae (short-finned squid) by area between 1992 and 2021.

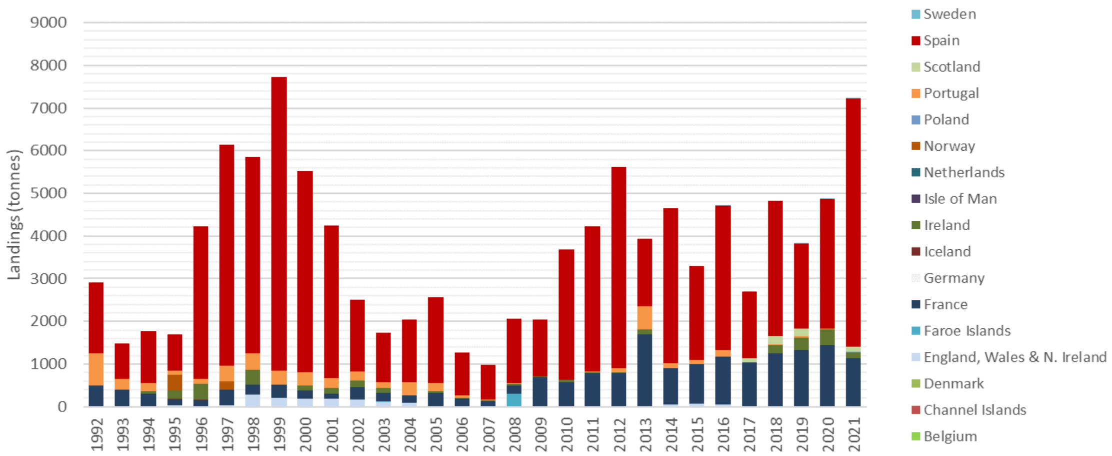


Figure 1.33 Landings of Ommastrephidae (short-finned squid) by country, 1992–2021.

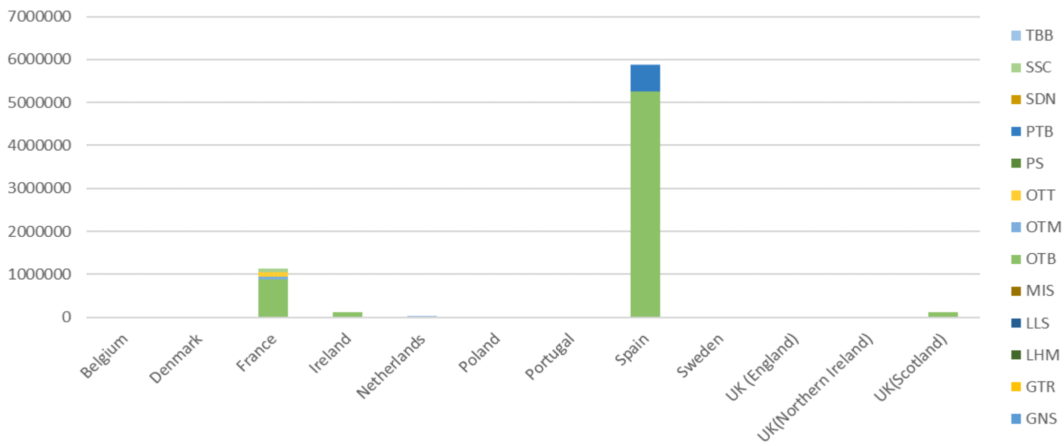


Figure 1.34 Catches of Ommastrephidae by country and gear for year 2021.

The map of spatial distribution of landings of Ommastrephidae from 2018 to 2021 (Figure 1.35) shows that the fishing pattern by fishing area remains stable during years with a slight increase of landings in ICES Subareas 8 and 9.

Discard information by country was provided in the data call for 2021. Discard percentage in relation to total catch is estimated to be around 1% of total catches. Analysing data by ICES division, the discard percentage is higher for areas with small catches and however, areas with higher catches have smaller discards (Table 1.7).

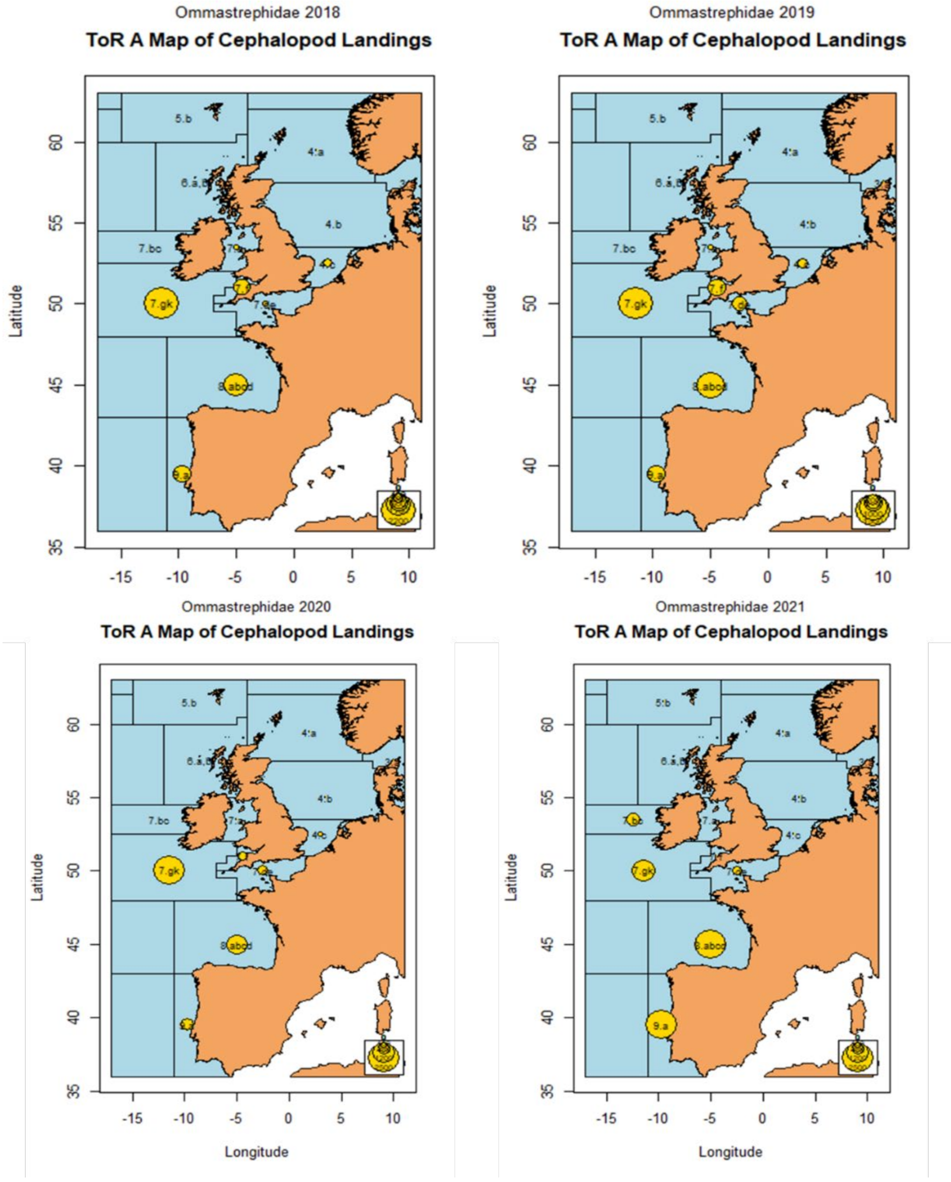


Figure 1.35 Spatial distribution of landings of Ommastrephidae from 2018 to 2021.

Table 1.7 Percentage of Ommastrephidae discards in relation to total catches (% Discards) and relative percentage of catches by subarea (% Catches) in 2021.

ICES division/subdivision	% Discards	%Catches by area
27.3.a	0%	0%
27.3.a.20	2%	0%
27.4.a	0%	0%
27.4.b	0%	0%
27.4.c	0%	0%
27.5.b	0%	0%
27.5.b.2	0%	0%
27.6.a	0%	0%
27.6.b.2	100%	0%
27.7.b	1%	2%
27.7.c	0%	3%
27.7.c.2	1%	3%
27.7.d	0%	3%
27.7.e	0%	1%
27.7.f	0%	0%
27.7.g	9%	0%
27.7.h	2%	1%
27.7.j	0%	7%
27.7.j.2	1%	11%
27.7.k	0%	1%
27.7.k.2	0%	0%
27.8.a	0%	3%
27.8.b	6%	4%
27.8.c	0%	27%
27.8.d	0%	0%
27.8.d.2	0%	0%
27.9.a	0%	0%
27.9.a.c	0%	9%
27.9.a.n	0%	25%
27.9.a.s.a	0%	0%
27.9.a.s.c	8%	1%
Total general	1%	100%

(dark grey)	areas with higher discards have small catches
(light grey)	areas with higher catches have small discards

Trends in landings and abundance/biomass until 2021 are presented for the five most important fishing areas.

1.5.3 Fisheries in the North Sea

Commercial landings of Ommastrephidae are mainly in Division 4c. France is the main contributor with 13 tonnes in 2021 (Figure 1.36).

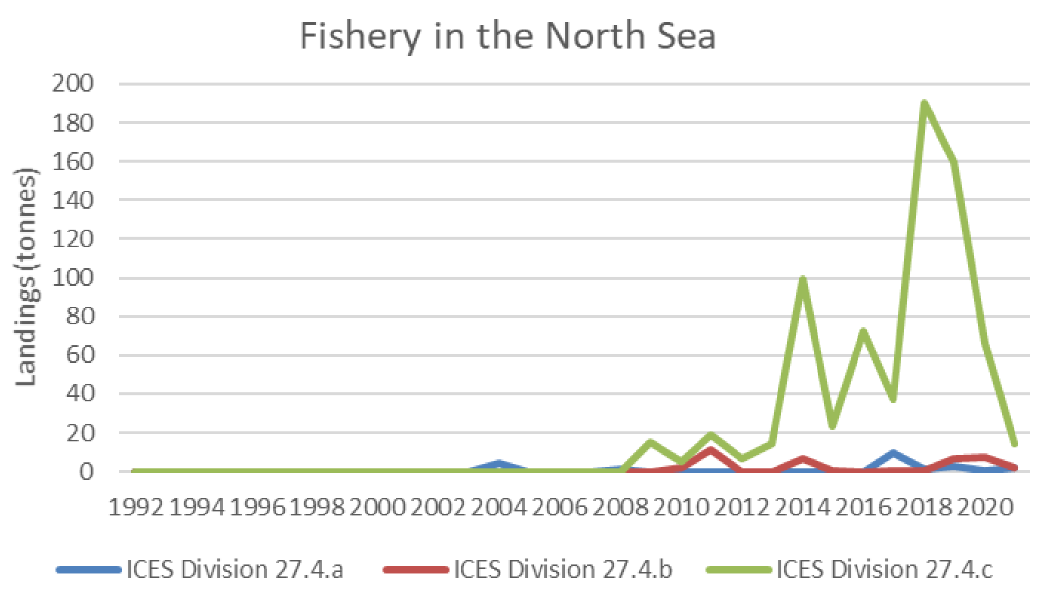


Figure 1.36 Trends in Ommastrephidae landings in the North Sea (27.4a,b,c).

1.5.4 Fisheries in the Celtic Seas

Available commercial landings data indicate that between 300 and 2000 tonnes are landed per year in Subarea 7 (Figure 1.37). Most of these landings were reported by France in Divisions 7f–k.

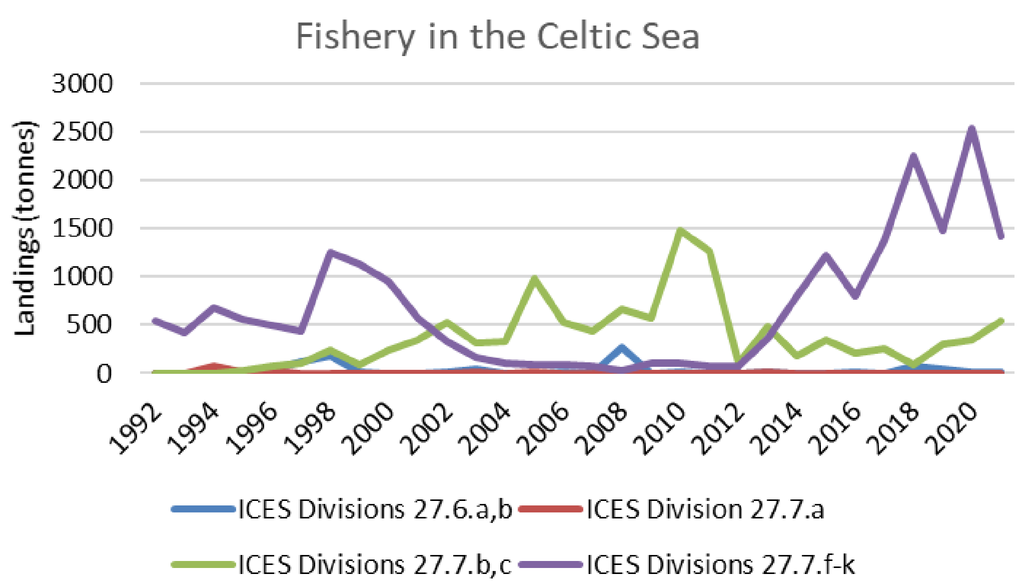


Figure 1.37 Trends in Ommastrephidae landings in the Celtic Seas (27.6.a,b and 27.7.a–c,f–k).

1.5.5 Fisheries in the English Channel

In the English Channel the landings have decreased in the last years and France is the main contributor to the landings with almost 100% of landings in 2021 (Figure 1.38).

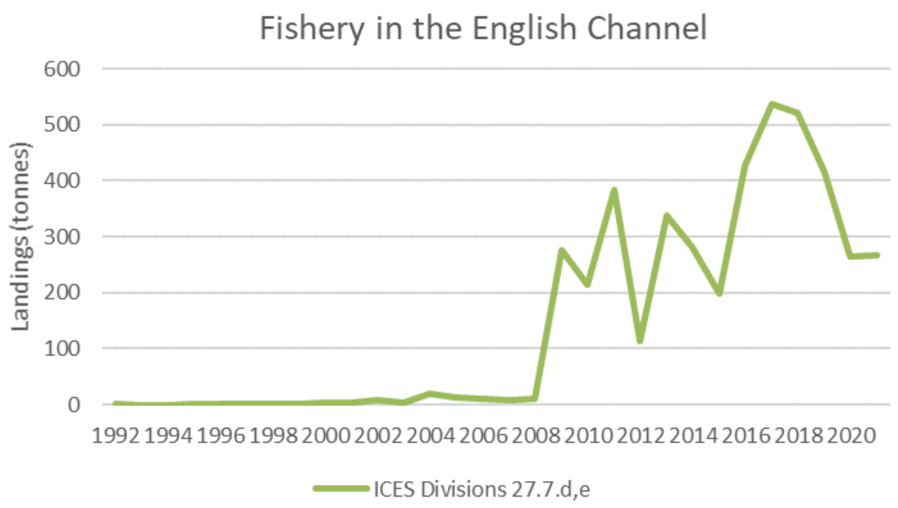


Figure 1.38 Trends in Ommastrephidae landings in the English Channel (27.7.d,e) for the years 1992 to 2021.

1.5.6 Fisheries in the Bay of Biscay

The countries contributing to Ommastrephidae catches in Division 8abd were France and Spain (Figure 1.39). In 2021, France landed 220 tonnes of Ommastrephids from divisions 8abd, while Spanish landings amounted for 243 tonnes. Spain landed around 1980 tonnes from division 8c.

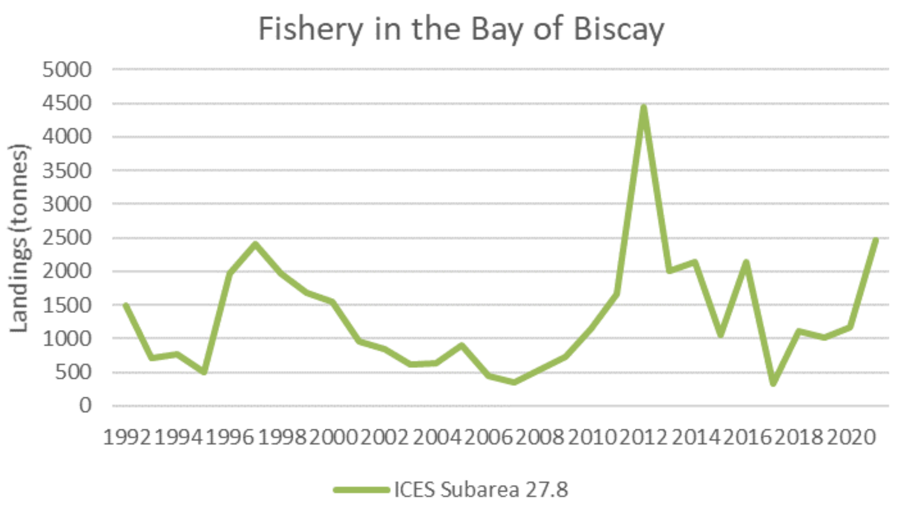


Figure 1.39 Trends in Ommastrephidae landings in the Bay of Biscay (27.8.a,b,c,d) for the years 1992 to 2021 by national fleet.

1.5.7 Fisheries in Western Iberia and Gulf of Cadiz

The landings in the last years of the time-series show a sharp increase (Figure 1.40). Portugal and Spain are the main contributors with 3% and 97% of total landings respectively.

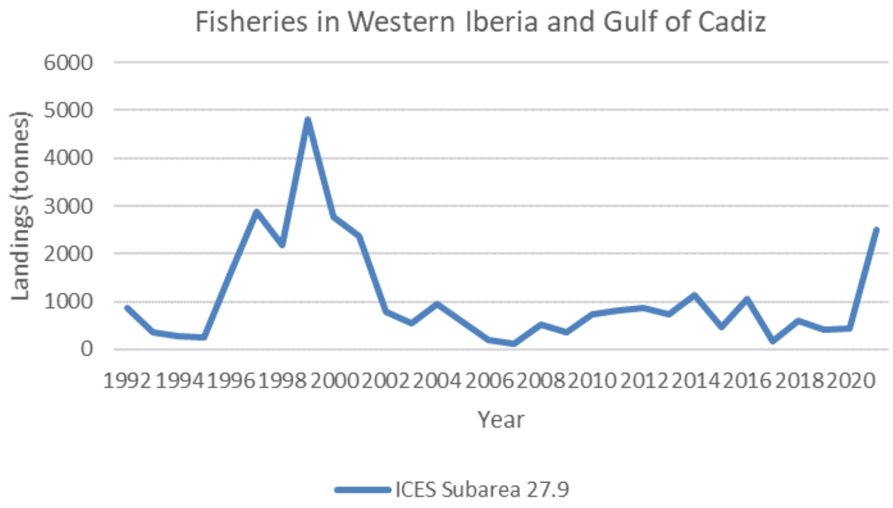


Figure 1.40 Trends in Ommastrephidae landings in Western Iberia and Gulf of Cadiz (ICES division 27.9.a) for the years 1992 to 2021.

1.5.8 Relative biomass indices for Ommastrephids

Bottom trawl research cruises, including those with data submitted in DATRAS, were analysed as possible proxies of biomass of Ommastrephidae species.

1.5.9 Research Surveys in the North Sea

The file 'CPUE per length per haul per hour' from the IBTS quarter 1 and 3 (2012–2022) was downloaded on 12/07/2022 from ICES DATRAS. Data were provided by DE, DEK, FR, GB, GB–SCT, NL, NO and SE and filtered for ommastrephids (incl. the following classifications: *Illex*, *Illex coindetii*, *Illex illecebrosus*, Ommastrephidae, *Todarodes*, *Todarodes sagittatus*, *Todaropsis*, *Todadropsis eblanae*) and RFA 1,2,3,4,5,6,7. First, we summarized the CPUE per length class per haul, afterwards the mean and standard deviation of the CPUE per length class per haul was estimated for each year and quarter.

In quarter 1, the trend analysis shows a strong increase in Ommastrephids CPUE since 2014 until 2019 with a maximum CPUE in 2019 (Figure 1.41). Afterwards the CPUE value decreased constantly until 2022. Most common species are *I. coindetii* followed by *T. eblanae* and *T. sagittatus*. Due to the relatively high CPUE values of *I. coindetii*, the family trend is mainly driven by this species, while *T. eblanae* and *T. sagitattus* CPUE values are stable.

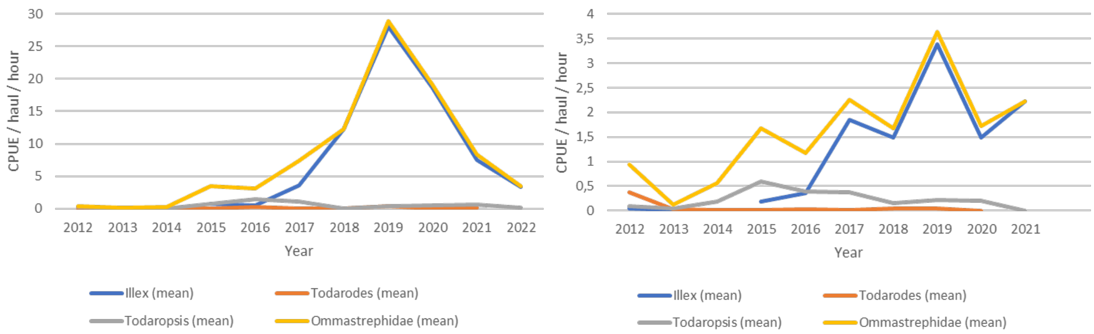


Figure 1.41 Catch per unit effort in numbers per haul per hour for North Sea ommastrephids based on North Sea International Bottom Trawl survey. Left: Quarter 1; right quarter 3. Illex (incl. *Illex*, *I. coindetii*, *I. illecebrosus*), *Todaropsis* (incl. *Todaropsis, T. eblanae*), Todarodes (incl. *Todarodes, T. sagittatus*), Ommastrephids (incl. Ommastrephids, *Illex, I. coindetii, I. illecebrosus, Todaropsis, T. eblanae, Todarodes, T. sagittatus*).

In general, CPUE values for ommastrephids are lower in quarter 3 compared to quarter 1 but increase with high fluctuations. Again, this trend is mainly driven by *I. coindetii*, while *T. eblanae* and *T. sagittatus* are less abundant and show a stable trend.

1.5.10 Research surveys in the Celtic Sea

Porcupine bank (27. 7c, k)

Results on main cephalopods species captured in the bottom trawl surveys in the Porcupine Bank (Divisions 7c and 7k).

European flying squid (*Todarodes sagittatus*): In 2021, the biomass of *T. sagittatus* was 21% of the cephalopods mean stratified biomass. After three years of decreasing in biomass it shows a slight increase in the last two years. Regarding abundance the values increased quadrupling the abundance of the previous year (Figure 1.42).

Lesser flying squid (*Todaropsis eblanae*): The biomass of *T. eblanae* was 22% of the mean stratified biomass of the cephalopods caught in this last survey. Both the biomass and the abundance of this species decreased after the peak reached in 2019, especially in abundance, which was reduced to less than half (Figure 1.43).

Broadtail shortfin squid (*Illex coindetii*): *I. coindetii* (only 16% of the cephalopods mean stratified biomass caught) increased strongly in 2020 reaching the second highest value of the time-series (Figure 1.44) and decreased again in 2021 to previous years values. This last survey, the species was mainly caught in the Irish shelf and southeast of the bank.

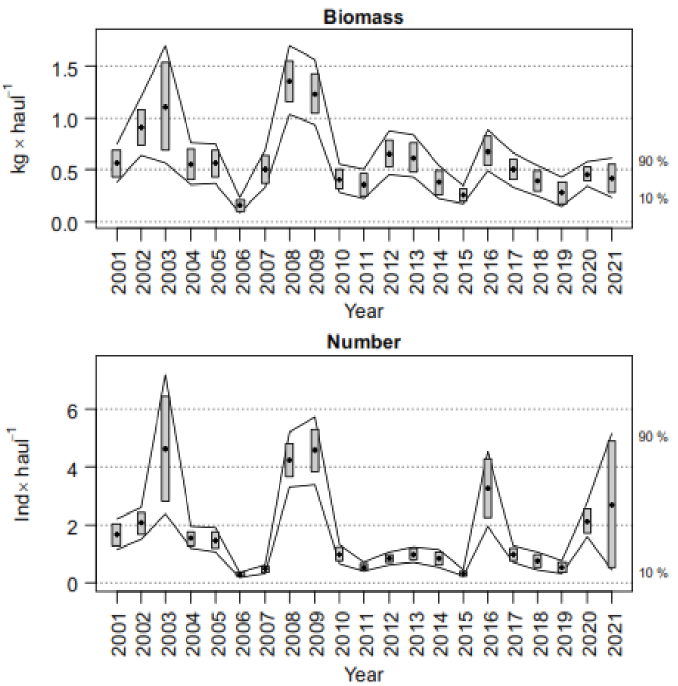


Figure 1.42 ***Todarodes sagitattus*** **biomass index and abundance during the Porcupine bank bottom trawl survey time-series (2001–2021). Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (a= 0.80, bootstrap iterations = 1000).**

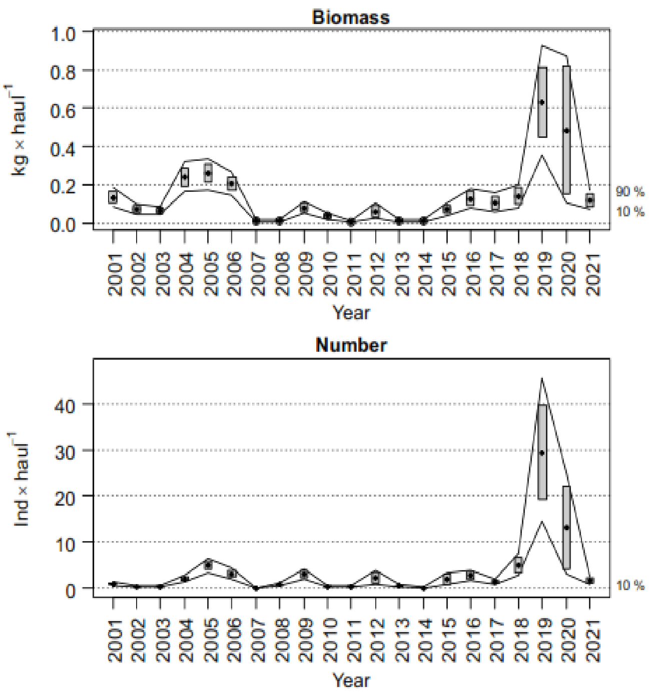


Figure 1.43 ***Todaropsis eblanae*** **biomass index and abundance during the Porcupine bank bottom trawl survey time-series (2001–2021). Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (a= 0.80, bootstrap iterations = 1000).**

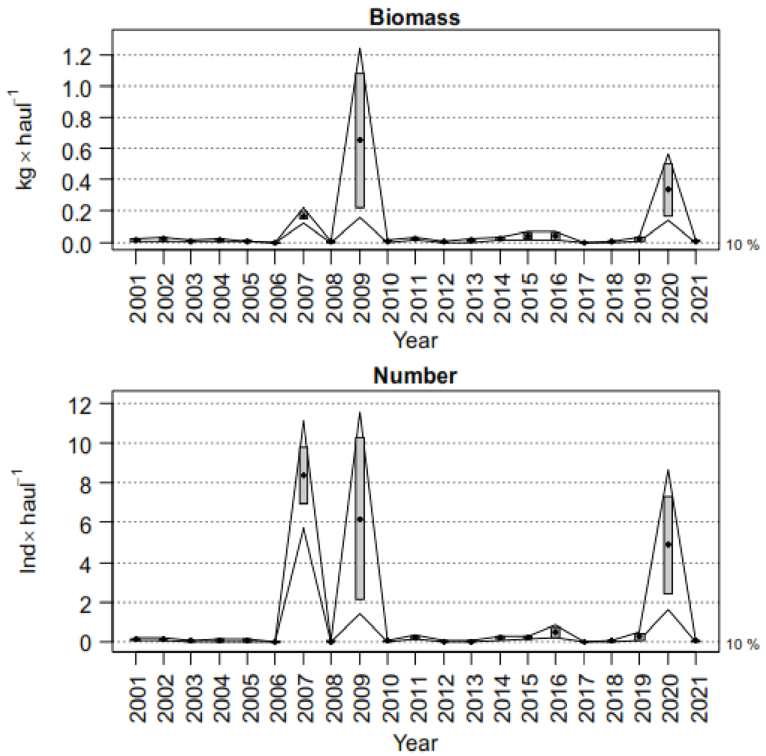


Figure 1.44 *Illex coindetii* biomass index and abundance during the Porcupine bank bottom trawl survey time-series (2001–2021). Boxes mark parametric standard error of the stratified biomass index. Lines mark bootstrap confidence intervals (a= 0.80, bootstrap iterations = 1000).

1.5.11 Research surveys in subarea 7

Cefas survey data trends in subarea 7 are shown in figure 1.45. The 7d beam trawl survey (BTS7D) and the northwest groundfish survey NWGFS caught too few ommastrephids to examine trends. Trends extracted from other survey programmes look rather different and in all cases confidence limits are wide (Figure 14b). Catch rates were low in Q1SWBEAM (quarter 1) as a beam trawl probably is not an appropriate gear to catch ommastrephids. Catch rates in Q4WIBTS (quarter 4) were also low, rising from 2003 to a peak in 2008 and then falling again to 2011. Catch rates in WCGFS (quarter 1–2) were higher than in the other two survey series and suggested a general increase from 1982 to 1993 followed by a decline to 2004. For the year 2020, due to some problems with surveys due to coronavirus, only IBTS 3E is updated. The resulting value is very high due to two high catches, even if they are deleted, the mean value still would be higher than in 2003–2019 so it is the real trend.

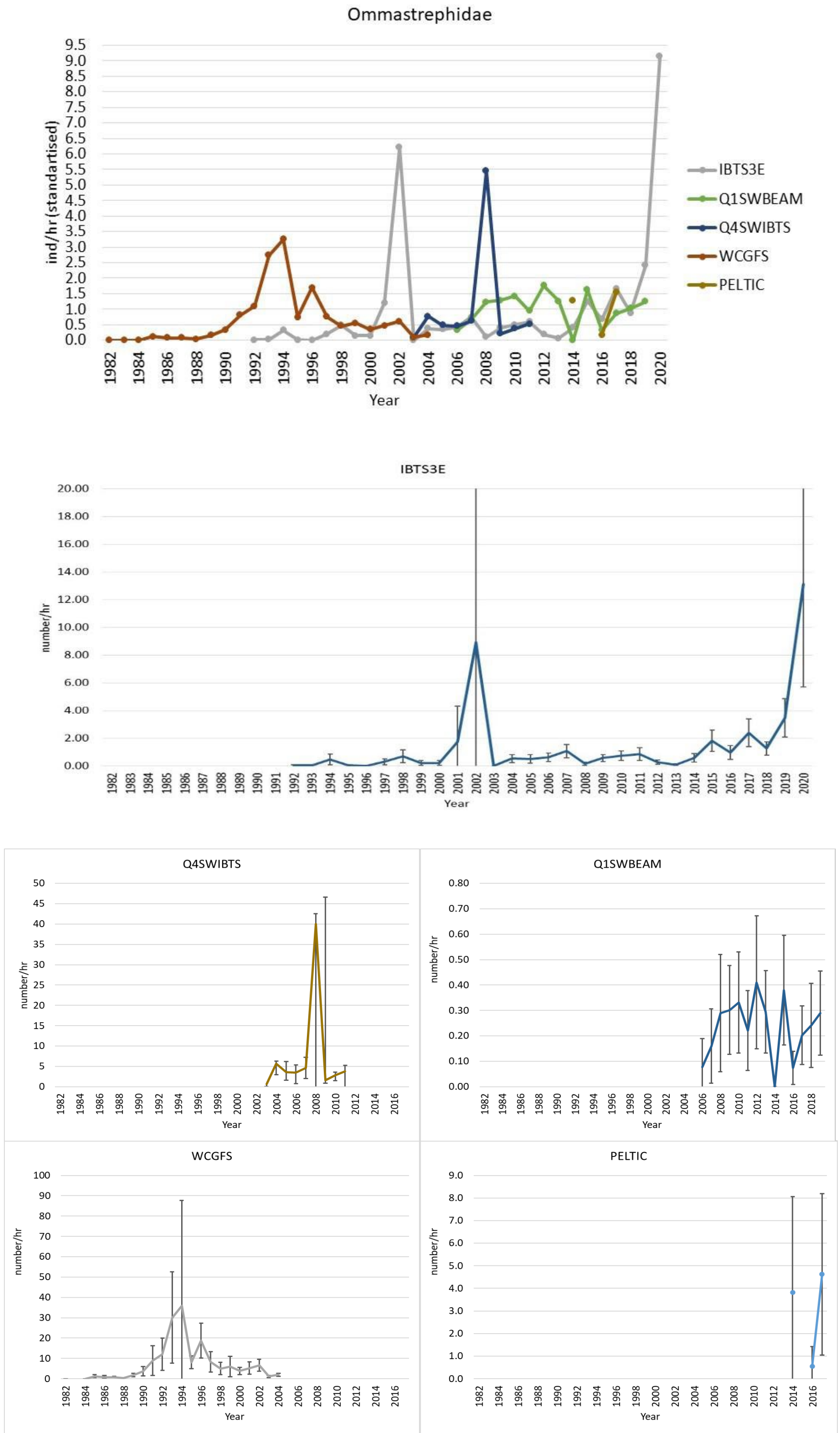


Figure 1.45 Trends in Ommastrephidae catch rates (numbers per hour of towing) in area 7 from Cefas surveys: (top) all available data combined (bottom) selected surveys with error bars showing confidence intervals.

From 2016 onwards, the taxonomic resolution in the data does not cause any concerns, although the suitability of some of the trawl gears used (like a beam trawl) is doubtful for these species.

1.5.12 Research surveys in the Bay of Biscay

EVHOE survey data were updated in 2021. Based on this survey, abundance indices for three species of Ommastrephidae have been extracted: *I. coindetii*, *T. eblanae* and *Todarodes sagittatus*. The time-series is from 1987 to 2021 and the area covered are Divisions 8ab. The abundance indices show fluctuating trends with peaks for *I. coindetii* species in 2012 and 2015 and a peak for *T. eblanae* in 2018 (Figure 1.46) with a significant decrease in the year 2021.

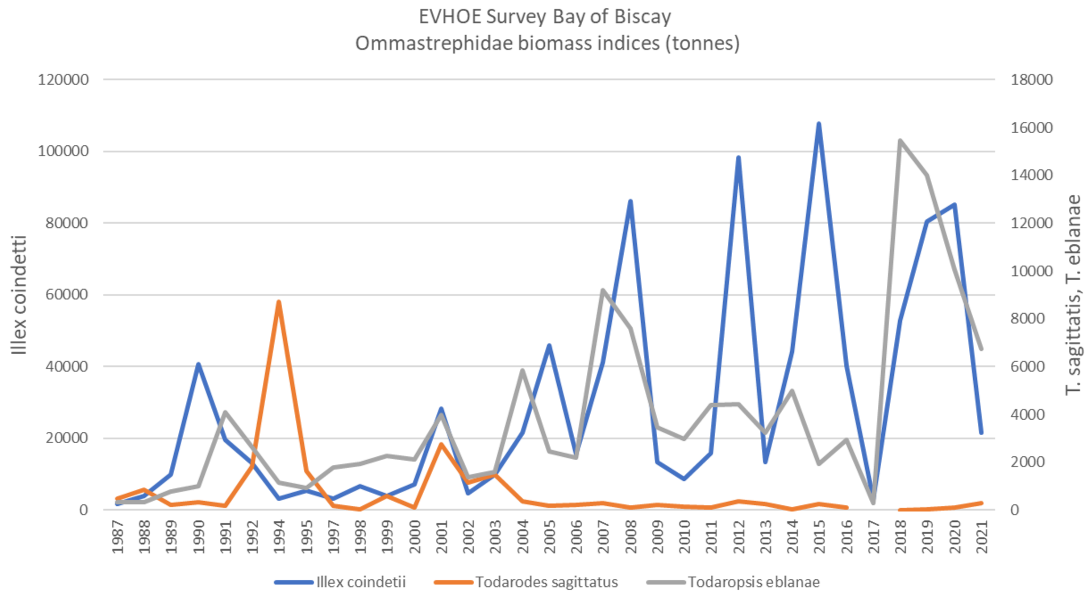


Figure 1.46 EVHOE survey biomass (t) for Ommastrephidae selected species in Divisions 8abd.

1.5.13 Research Surveys in Western Iberia

Spanish Northern Shelf groundfish survey

The SPNSGFS (Spanish Northern Shelf groundfish survey) covers ICES Div. 8.c and the Northern part of 9.a corresponding to the Cantabrian Sea and Galician waters. The main ommastrephid species caught in the survey are *I. coindetti*, *T. sagittatus* and *T. eblanae*. Abundances of Ommastrephids in this survey are low and variable, although *T. sagittatus* is generally least abundant (Figure 1.47). In the year 2016 both *I. coindetti* and *T. eblanae* showed peaks in abundance (Figure 1.48, Figure 1.49).

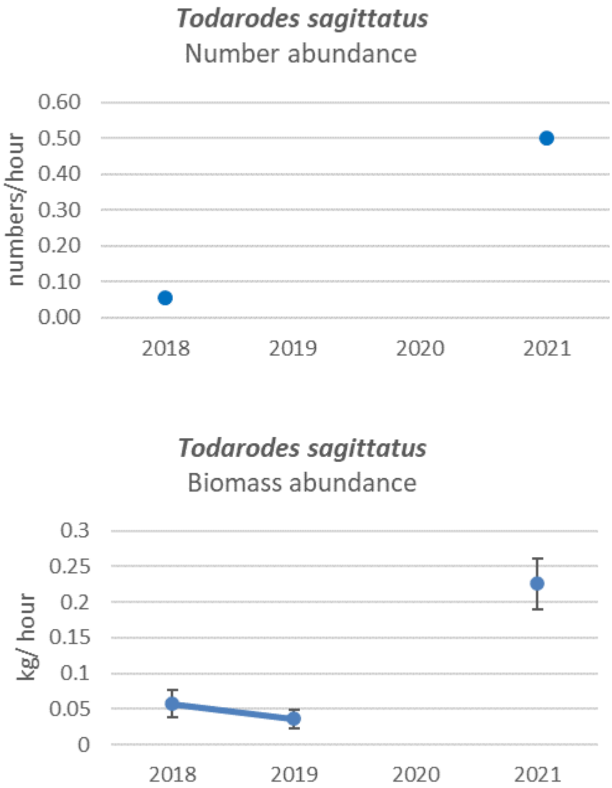


Figure 1.47. *Todarodes sagittatus* biomass index and numerical abundance during the Spanish Northern Shelf groundfish survey time-series (2018–2021) with standard error of the stratified biomass index.

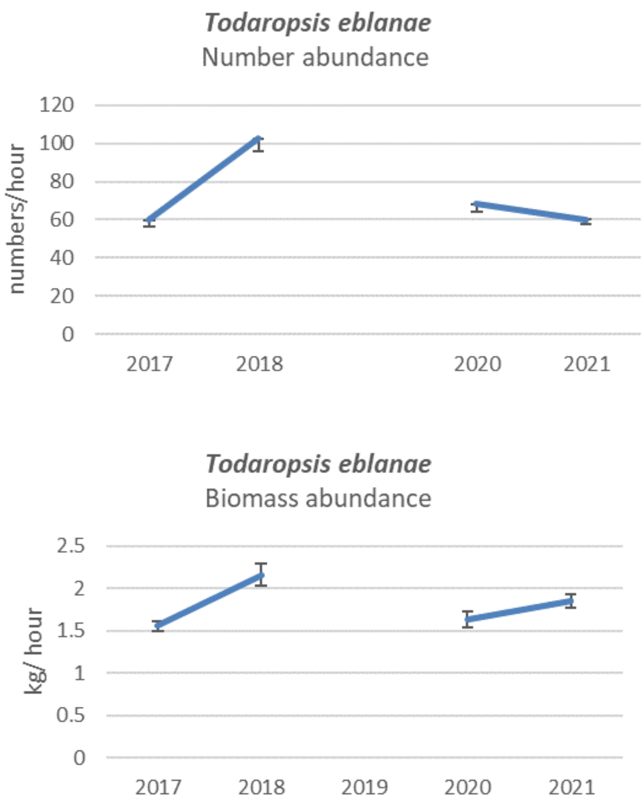


Figure 1.48 ***Todaropsis eblanae*** **biomass index and numerical abundance during the Spanish Northern Shelf groundfish survey time-series (2017–2021) with standard error of the stratified biomass index.**

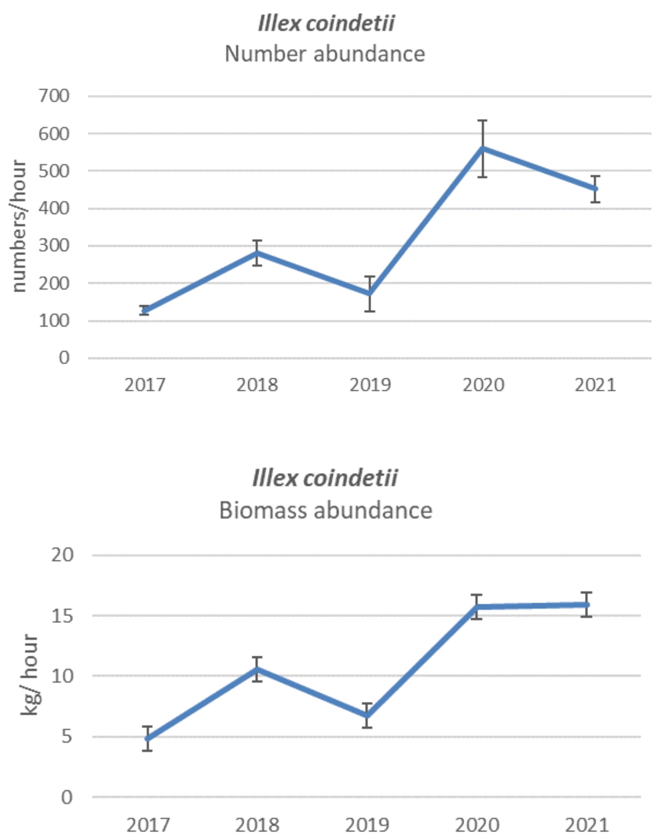


Figure 1.49 *Illex coindetii* biomass index and numerical abundance during the Spanish Northern Shelf groundfish survey time-series (2017–2021) with standard error of the stratified biomass index.

1.5.14 Portuguese Groundfish Survey in Div. 9a of Portuguese continental waters

There were no Portuguese surveys in 2019 and 2020. In 2021, the survey series restarted with a new research vessel. *Illex coindetii, Todaropsis eblanae* and *Todarodes sagittatus* abundance indices for 1981–2021 are presented. Abundance varies widely with isolated peaks, e.g. for *I. coindetii* in 1986 and 2021, for *T. sagittatus* in 1994 and for and *T. eblanae* in 1996, 1999 and 2003 (Figure 1.50).

1.5.15 Research Surveys in the Gulf of Cadiz (27.9a. south)

The South Spanish Groundfish Survey (ARSA/SPGFS) is conducted in the southern part of ICES Div. 9.a, the Gulf of Cadiz. No survey was conducted in 2021, so the data presented are until 2020. SPGFS aims to collect data on the distribution and relative abundance, and biological information of commercial fish and it is carried out in November and March each year. Some species of ommastrephids are recorded, including *Illex coindetii* and *Todaropsis eblanae*. For *I. coindetii* abundance there was a peak of abundance in 2001 (10 kg per hour in March survey) and abundance was higher in 2018 than in any year since 2001. For *T. eblanae*, catch rates were lower, with peaks in abundance seen in 2001, 2005 and 2010 in the November survey and no catches in 2020. (Figure 1.51).

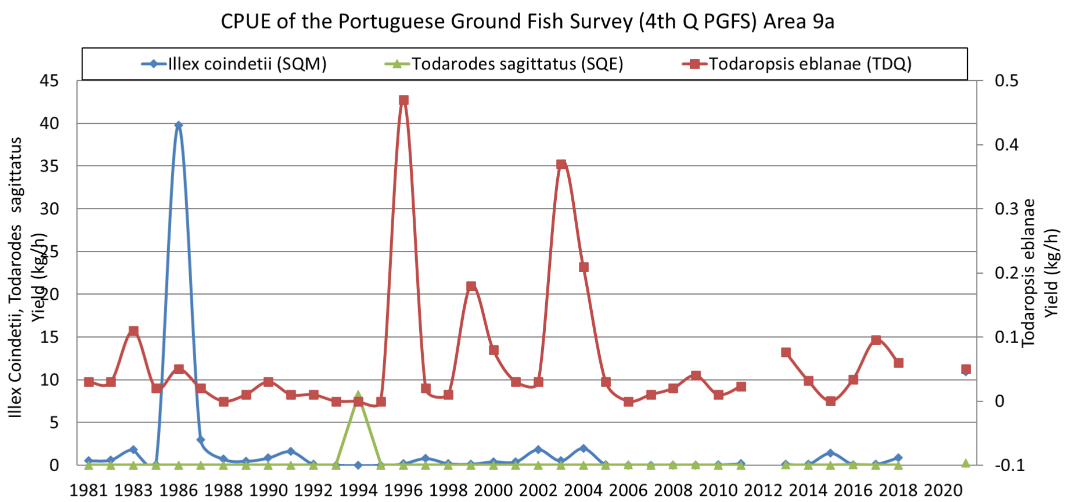


Figure 1.50 CPUE of the main Ommastrephidae species in the Portuguese Ground Fish Survey, 1981–2021. This survey was not undertaken in 2012, 2019 or 2020.

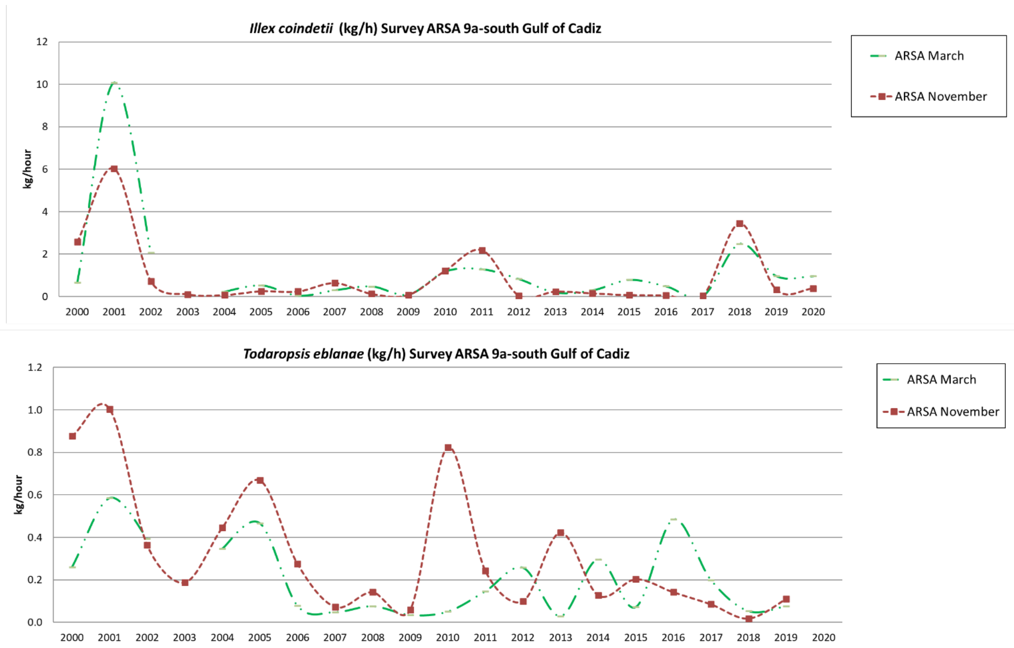


Figure 1.51 Abundance Indices of Ommastrephids, *Illex coindetii* (top) and *Todaropsis eblanae* (bottom) in (kg/h) of the Spanish Scientific Surveys in subdivision 9a South (Gulf of Cadiz).

1.5.16 Summary of trends and status for Ommastrephids

Table 1.8 and Table 1.9 summarizes the trends of Ommastrephidae using landing comparison, considering that the mean of the most recent three years should be above the long-term historic average (ICES, 2014); and survey biomass indices comparing the mean for the most recent three years (2019–2021) with the previous three years period (2016–2018).

Table 1.8 Summary of Ommastrephidae trends based on landings.

Region	landings historical mean (tons)	landings 2016-2018 (tons)	Landings 2019-2021 (tons)	recent mean vs. historical mean	recent tendency 2019-2021 vs. 2016-2018
North Sea	9	35	29	20	↘
Celtic Seas	271	420	557	286	↗
English Channel	144	495	315	171	↘
Bay of Biscay	1325	1198	1549	224	↗
Western Iberia & G. Cadiz	1079	604	1126	47	↗

Table 1.9 Summary of Ommastrephidae trends based on surveys.

Region	Description	Surveys	Recent tendency 2019-2021 vs. 2016-2018		
			Illex coindetii	Todaropsis eblanae	Todarodes sagittatus
North Sea	North Sea international Bottom Trawl Survey Q1	IBTS Quarter 1	↑	↓	↑
Celtic Sea	Spanish Porcupine Bottom Trawl Survey	ES-PorcGFS	↑	↑	↑
	Beam trawl survey - Western Channel Beam Trawl Survey (SWECOS_GBE)	UK-SWBEAM	NA	NA	NA
English Channel	UK-SBTS (SBTS_Q3_GBE)	UK-BTS7D	NA	NA	NA
Bay of Biscay	French Southern Atlantic Bottom trawl survey	FR-EVHOE	↑	↑	↑
North-Western Iberia	Spanish North Coast Bottom Trawl Survey	ES-IBTS 4Q	NA	NA	NA
	Portuguese International Bottom Trawl Survey	PT-IBTS 4Q	NA	NA	NA
Gulf of Cadiz	Spanish Gulf of Cadiz Bottom Trawl Survey (1quarter)	SP-GCGFS 1Q	NA	NA	NA
	Spanish Gulf of Cadiz Bottom Trawl Survey (4 quarter)	SP-GCGFS 4Q	NA	NA	NA

Conclusions

In some survey series, Ommastrephidae are occasionally identified to species and it is possible that ratios of the species could be estimated. More promisingly, landings of Ommastrephidae in Galicia (Spain) have been identified to species during market sampling. However, despite some improvements being done, in general the identification of species in both survey and commercial data needs to be improved.

In relation to trends, analysing trends based on landings, there is an increase of Ommastrephidae in the southern regions and a decrease in the northern regions.

When analysing trends based on surveys species compositions, *Illex coindetii* trends increase in the last years for all regions. For *Todaropsis eblanae* there is an increasing trend in the northern regions and for *Todarodes sagittatus* no clear trend could be observed.

Ommastrephidae discards are estimated to be around 1% of total catches.

1.6 Trends and status of the Octopod stocks (O. vulgaris and Eledone spp.)

1.6.1 Data quality and data call

Octopod commercial landings and discards were provided (ICES division and metier) via InterCatch by the following Member States: Belgium, France, Ireland, Netherlands, Portugal, Spain, Sweden and UK. Some data delays occurred but finally all data were uploaded to Intercatch.

Abundance/biomass indices derived from research surveys and CPUE for the main trawler fleets were sent to Accessions section in the WGCEPH sharepoint, and several requests were made to responsible people of surveys and data collection to receive the data.

The most important fishing nations for Octopods report Octopus catches at species level (OCC-*O. vulgaris*) and Eledone at least at genus level (EOI-*E. cirrhosa*, OCM-*Eledone* sp.).

Abundance/biomass indices derived from surveys were sent to the Accessions section in the WGCEPH sharepoint. Survey data were presented by Ireland (IE–IGFS), and Spain (SP–GCGFS 1st and 4th quarter, SP–NORTH, SP_PORC), and Portugal (PT–IBTS, PCRUS–UWTV). SP_GCGFS, IE–IGFS, PT–IBTS, and PCRUS–UWTV included data by haul. There were no Portuguese surveys in 2019 and 2020. None of the Portuguese surveys are considered to provide good estimates for *Octopus vulgaris*.

1.6.2 Octopod fisheries: overview

Trends in commercial landings for the three species of Octopods (common octopus *Octopus vulgaris*, horned octopus *Eledone cirrhosa*, and musky octopus *Eledone moschata*) are analysed in the period 2000–2021 in this section. The first two species are distributed from ICES Subarea 27.3 to ICES division 27.9.a, Mediterranean waters and North African coast. *E. moschata* inhabits southern waters from ICES division 27.9.a towards the south.

Catches of this species group averaged around 13946 tonnes annually (s.d. 3428 tonnes) along the dataseries and 10574 tonnes in the last three years. There was a peak in 2013, mainly due to the Spanish catches in Division 9.a. (western area and gulf of Cadiz). In 2019, after 2 years decreasing, there was a slight increase in landings. This increase was mainly due to Spanish catches from division 9.a. In 2020, there was the lower landings value of the historical series (7865 tonnes). The landings increased to 12912 tonnes in 2021.

Most of the catches recorded from ICES Subareas 27.3 to 27.7 were taken by trawlers and are expected to comprise mainly of *E. cirrhosa* although catches are usually not identified to species level. Only a small proportion of reported catches of Octopods derive from ICES Subareas 27.3, 27.4, 27.5 and 27.6. Anecdotal evidence from Scotland indicates that *E. cirrhosa* is usually discarded, although its presence is confirmed by regular occurrence in small numbers in survey trawls (see MacLeod *et al.*, 2014).

Octopod landings are higher in ICES Subarea 27.9 (mainly 27.9.a) followed by ICES Subarea 27.8 (Fig 1.52). For more southern ICES divisions (27.8.abd, 27.8.c and 27.9.a), the main countries exploiting these species are Spain, Portugal and France (Figure 1.53). These countries provide the greatest catches of octopods mainly in ICES divisions 27.8.c and 27.9.a. During the last twenty–two years, on average 95% of all octopus landings into European ICES countries were caught in divisions 27.8c and 27.9 a. Since Spain and Portugal identify the landings to species, it can be added that the bulk of the catch in division 27.9.a consists of *Octopus vulgaris*.

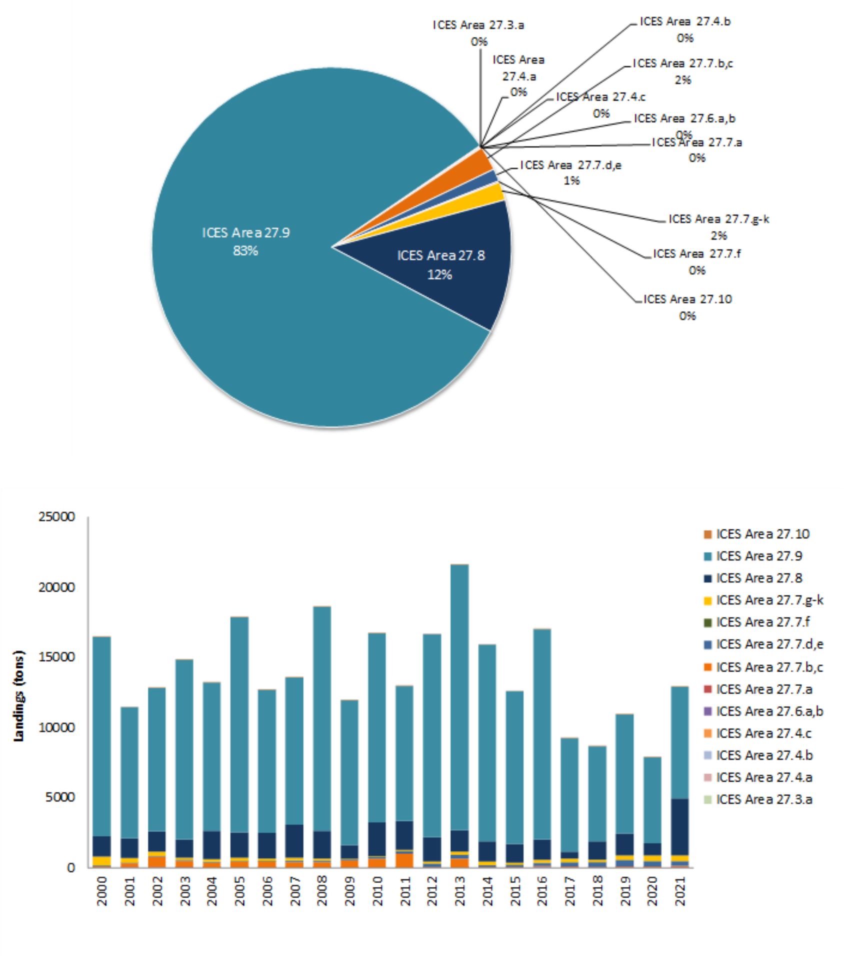


Figure 1.52 Octopods: mean and annual landing proportions by area for the period 2000–2021.

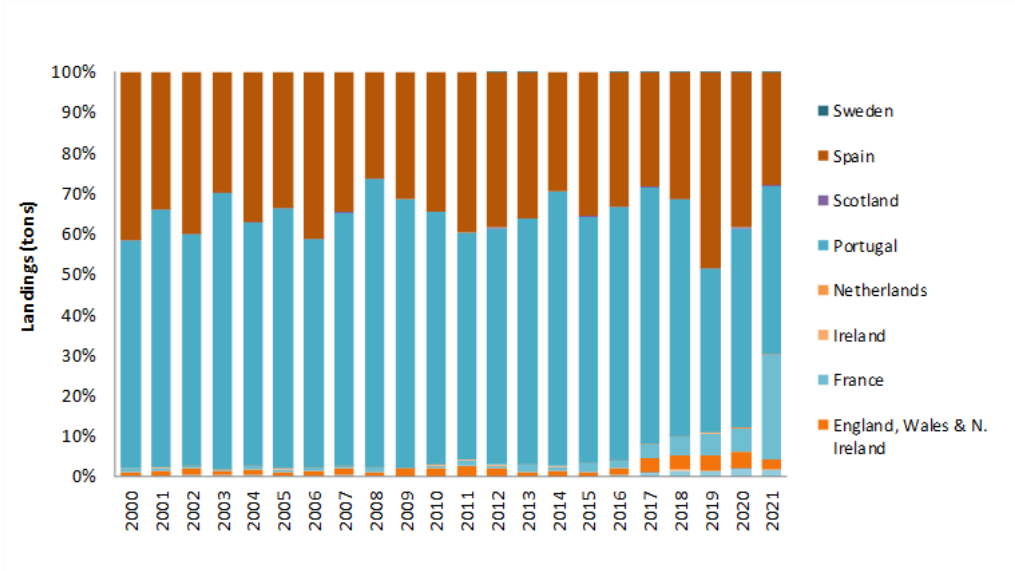


Figure 1.53 Proportion of landings of Octopods by country between 2000 and 2021.

The evolution of total catches of Octopods by year depends on the evolution of landings of these countries (Figure 1.54). There was a peak of landings in 2013, mainly due to the Spanish catches in division 9.a. (Western area and Gulf of Cadiz). In 2021, after 4 years of low total landings, there was a slight increase of landings. The landings trend is mainly driven by Spanish and Portuguese catches from division 9.a (Figure 1.55). The average landings in the most recent years show an important decrease in the most important divisions for these fisheries (27.8 and mainly 27.9), compared both with the recent mean (2016–2018) and the long-term mean (2000–2021).

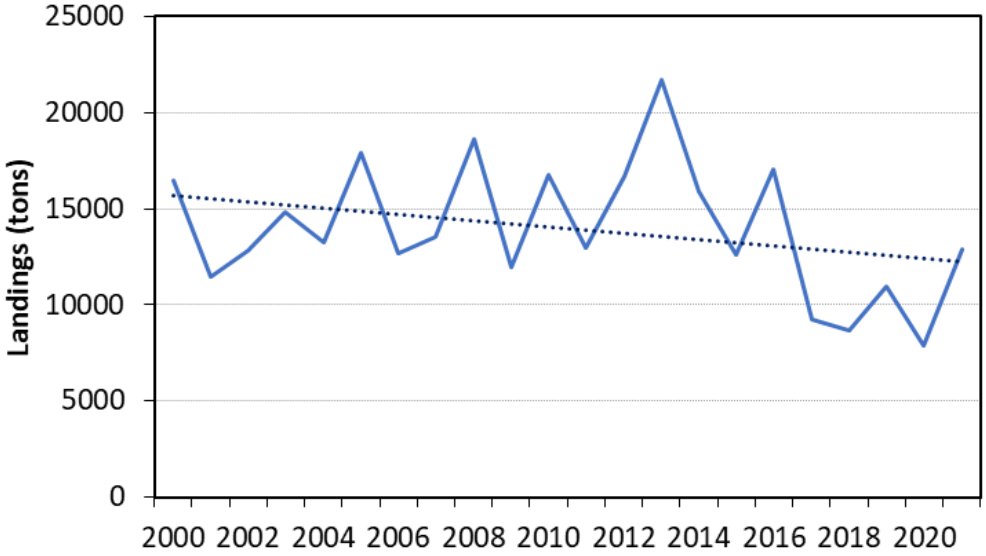


Figure 1.54 Trends in total Octopod landings for the years 2000 to 2021.

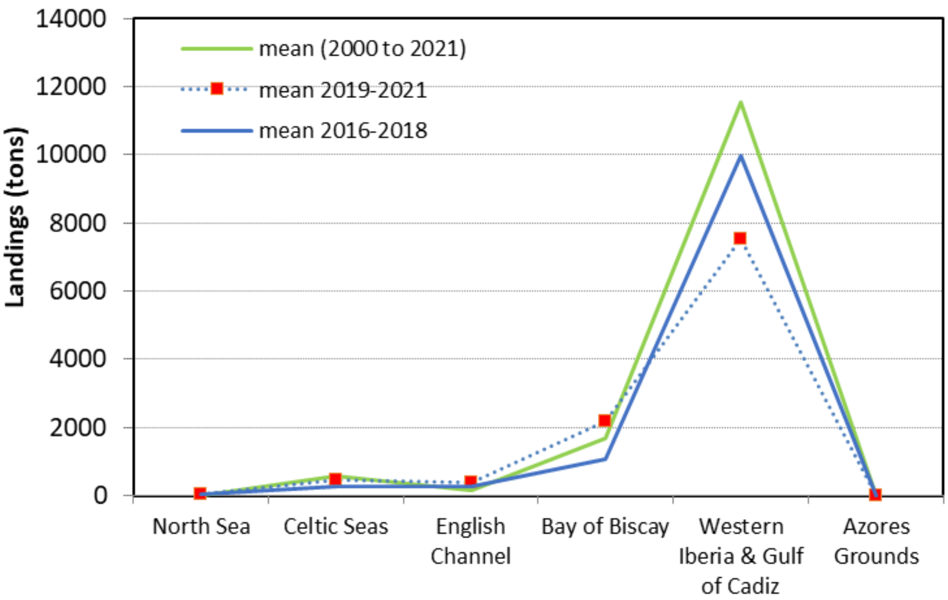


Figure 1.55 Recent mean Octopod landings (last 3 years) and the mean of the previous three years, by region, compared with long-term mean (2000–2021).

Figure 1.56 shows the Octopod landings by metier in 2021 and figure 1.57 shows Octopod landings proportion by fleet for each country in 2020 across the entire ICES area. The most important reported metiers for catching Octopods in 2020 were MIS_MIS_0_0_0 (42.2%) and FPO_MOL_0_0_0_all (52.4%), which is similarly to previous years. Landings by MIS_MIS_0_0_0 were mainly reported by Portugal and FPO_MOL_0_0_0_all by Spain and correspond largely to the trap fishery for *O. vulgaris* in these countries in 27.8.c, 27.9.a, and 27.10. In total, the artisanal metiers (pots, traps, gillnets and lines) represent around 70.8% of octopodid landings and trawl metiers around 28.9%. Most of the catches recorded from ICES divisions 27.3 to 27.7 are taken by the trawl fleets from Belgium, Denmark, France, Ireland, Netherlands, the UK and Sweden. Most of the Spanish catches from the Gulf of Cadiz come from the trawl fleet. The artisanal metiers represent 95%, 64%, 26% and 2% for Portugal, Spain, France, and the Netherlands, respectively. The fishery for octopods with artisanal metiers in other countries represents less than 2%.

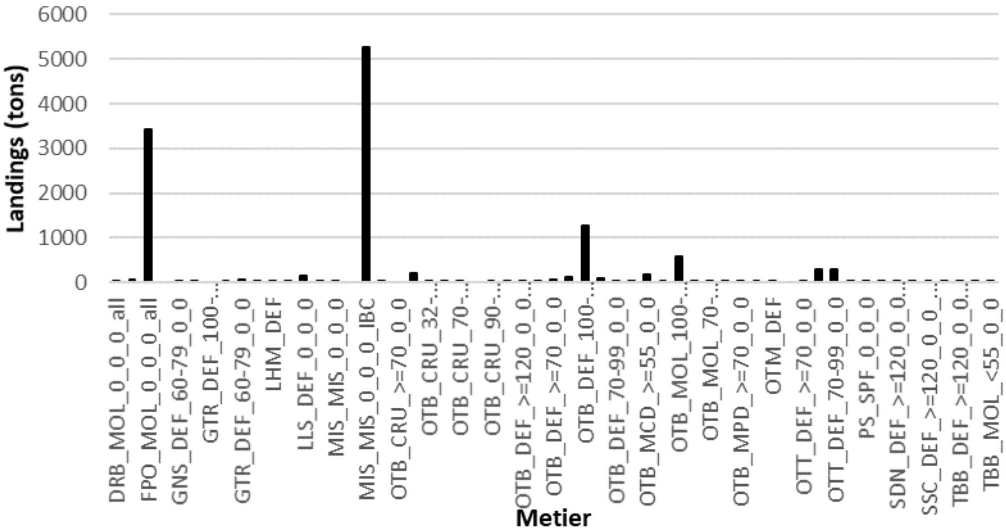


Figure 1.56 Octopod landings by metier in 2021.

In general, mapping the spatial distribution of landings of Octopods in 2019 and in 2021 (Figure 1.58), most of the catch in the area was taken in 27.9.a, particularly in western Iberian and Gulf of Cadiz waters.

Identifying the most important areas for Octopods is interesting. In fact, trends in total Octopod landings in the ICES area for the years 2000 to 2021 was a decrease (Figure 1.58). Analysing by area, the average landings (last three years) in the most important areas for these fisheries (27.8 and mainly 27.9) had a decrease compared with long-term mean (2000–2021).

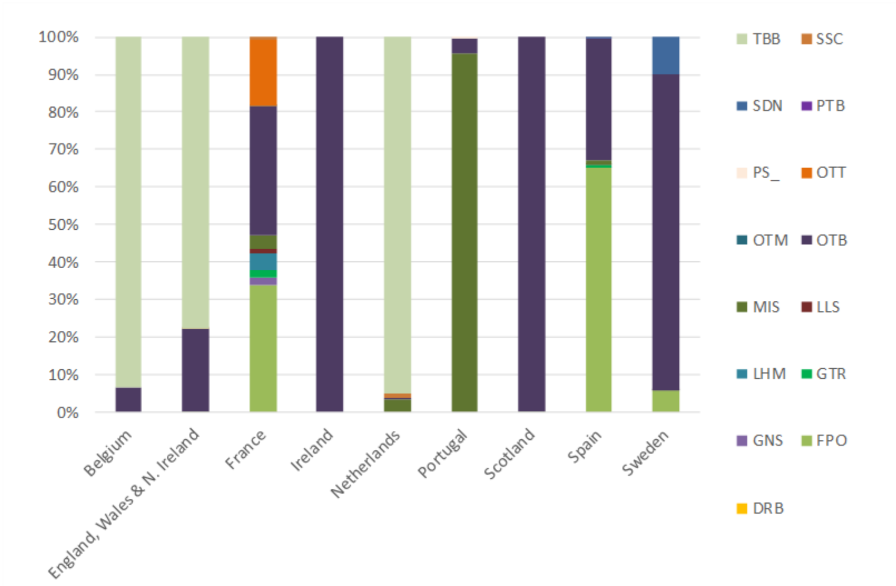


Figure 1.57 Octopod landing proportions by fleet for each country in 2021.

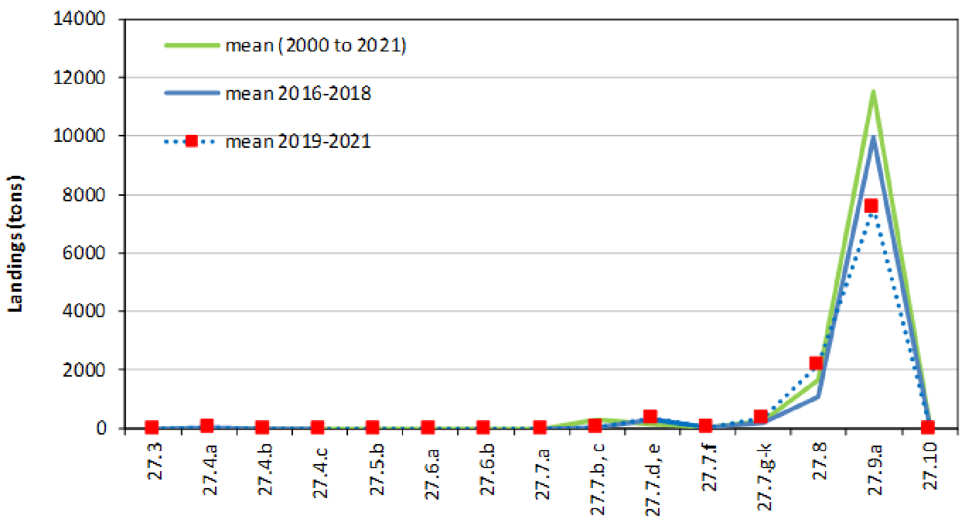


Figure 1.58 Trends in total Octopod landings in the ICES area for the years 2000 to 2021 and recent mean landings (last three years) and the previous three years by subarea/division compared with long-term mean (2000–2021).

Similarly, to previous years, discarding of octopods was negligible, below 1% of catches, especially in relation to the high valued *O. vulgaris*. When summarizing data across metiers that submitted both landings and discards information, the highest discard rate occurred in the trawl fishery. Most of the discards were reported from divisions 27.8 and 27.9, where most of the fishery occurs. However, the discard percentage is generally higher for areas with small catches, although some areas that contribute less than 1% of total octopus catches also show a low discard rate (Table 1.10). The only area with high catches (27.9.a) has a very low percentage of discards.

Table 1.10 Percentage of Octopod discards in relation to total catches (% Discards) and relative percentage of catches by subarea/division (% Catches) in 2018–2020.

	2019		2020		2021	
	% Discards	% catches by area	% Discards	% catches by area	% Discards	% catches by area
27.3.a	3.26	0.03	0.00	0.03	6.64	0.04
27.4.a	0.00	0.00	0.00	0.00	0.00	0.22
27.4.b	40.49	0.09	0.14	0.09	0.00	0.05
27.4.c	0.00	0.21	0.57	0.21	0.00	0.00
27.6.a	12.70	0.01	0.00	0.01	0.00	0.01
27.6.b	65.42	0.00	74.80	0.00	0.00	0.00
27.7.a	2.00	0.05	4.76	0.05	0.00	0.03
27.7.b	0.53	0.11	4.93	0.11	0.00	0.20
27.7.c	2.31	0.20	3.34	0.20	0.00	0.28
27.7.d	0.50	0.02	4.68	0.02	0.00	0.04
27.7.e	12.17	4.48	8.35	4.48	10.50	2.65

	2019		2020		2021	
	% Discards	% catches by area	% Discards	% catches by area	% Discards	% catches by area
27.7.f	5.15	0.28	4.23	0.28	1.54	0.44
27.7.g	1.48	0.33	4.11	0.33	0.10	0.47
27.7.h	1.68	0.47	1.97	0.47	1.97	0.58
27.7.j	1.44	2.25	1.81	2.25	0.00	1.89
27.7.k	0.23	0.03	0.00	0.03	0.00	0.03
27.8.a	0.03	3.22	0.11	3.22	0.00	23.86
27.8.b	0.87	3.12	3.27	3.12	0.00	3.30
27.8.c	1.77	7.93	0.00	7.93	0.00	4.13
27.8.d	0.00	0.02	0.00	0.02	0.00	0.17
27.9.a	0.14	77.09	0.25	77.09	0.21	61.52
27.10	0.00	0.06	0.00	0.06	0.00	0.09

1.6.3 Fisheries in the North Sea

Commercial landings of octopods in ICES Area 27.4.abc have a low contribution of total landing in ICES areas. England, Wales and Northern Ireland were the main contributors in 2016 and 2019 with landings between 20 and 50 tonnes (Figure 1.59), all of them of *E. cirrhosa*. In the rest of the years, Ireland had the highest landings, although always below 20 tonnes.

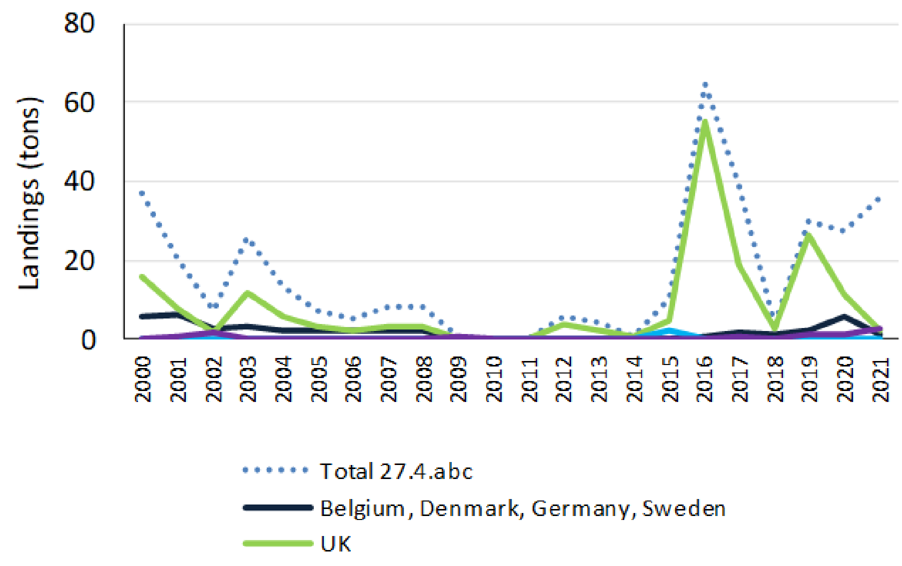


Figure 1.59 Trends in Octopod landings in the North Sea (27.4 abc).

1.6.4 Fisheries in the Celtic Seas

Octopod landings from the Celtic Sea varied between 505 and 701 tonnes between 2000 and 2021. Most of these landings correspond to *E. cirrhosa*. A main peak was observed in the year 2000, mainly derived from landings by Spain. Between 2002 and 2012, octopods in this area were mainly exploited by the UK fleets, but since then octopods were landed in similar quantities also by France and Spain. More recently (since 2017), Belgium also contributed to the Celtic Sea landings. The contribution from Ireland was generally low.

Most of these landings were reported by Spain in ICES Area 27.7 a–c, f–k followed by England, Wales and Northern Ireland in ICES Area 27.7 a–c, f–k. Spanish, Belgium and French landings were 145 tonnes, 115 and 154 tonnes, respectively in 2021. Landings from Ireland in these ICES Area are minimal although France increased the landings in Celtic sea from 60 tonnes in 2018 (less in previous years) to 154 tonnes in 2021 (Figure 1.60).

Spain reported substantial landings of Octopods in the first years of the dataseries, but since 2014 catches decreased and no data were provided for 2012. In 2015, only Spain and France reported landings.

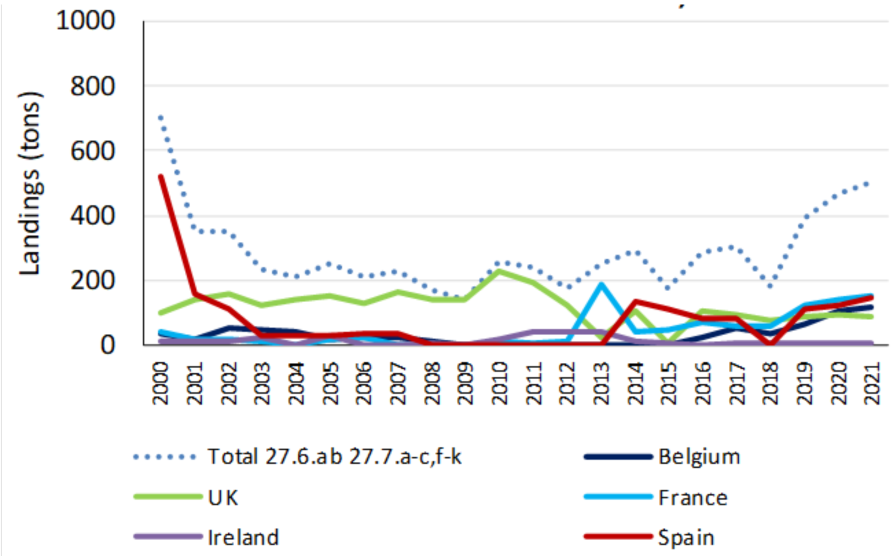


Figure 1.60 Trends in Octopod landings in the Celtic Seas (27.6.a,b and 27.7.a–c,f–k).

1.6.5 Fisheries in the English Channel

Landings in the English Channel have increased in the last few years and England, Wales and Northern Ireland are the main contributors with more than 80% of total landings from 2007 to 2017. This percentage decreased to 60–68% in 2018–2019 because France and Belgium reported more landings in this area (39 tonnes and 93 tonnes in 2019 respectively). Reported English landings of this group averaged around 19 tonnes from 2000 to 2006 although they have subsequently increased, to a maximum of 248 tonnes in 2012 with a similar amount in 2013 (Figure 1.61). In the three last years, the English average landings were around 242 tonnes.

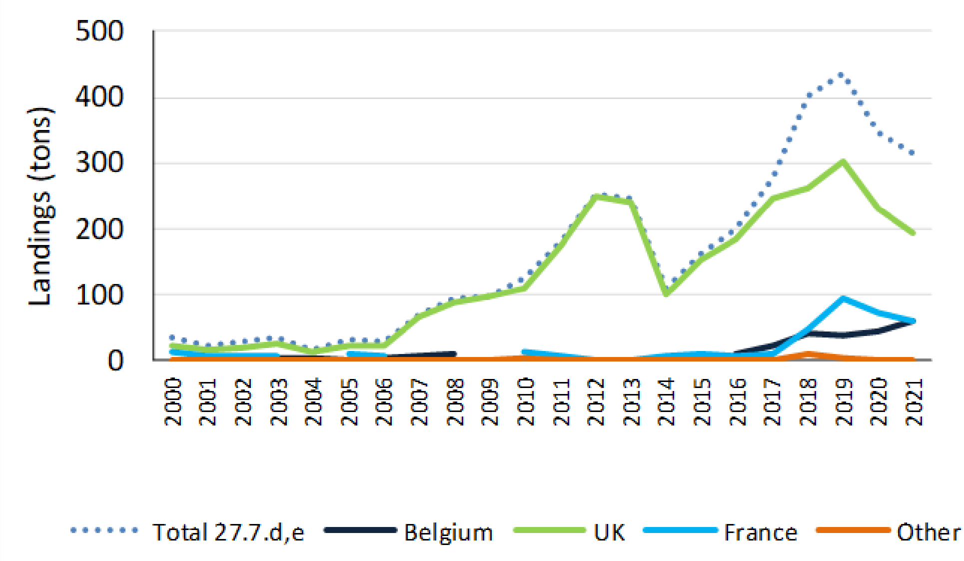


Figure 1.61 Trends in Octopod landings in the English Channel (27.7.d,e).

1.6.6 Fisheries in the Bay of Biscay

The countries contributing to Octopod landings in ICES divisions 8abcd were France and Spain although the landings of France in 27.8.c were low before 2021. Belgium contributed in 27.8.abd and Portugal in 27.8.c with reduced landings. In 2021, France landed 381 tonnes of Octopods from ICES Area 8abd. Spanish landings amounted for 3162 tonnes in ICES divisions 27.8.abd.

In ICES divisions 27.8.abd, logbook data suggest that *Eledone* spp. account for more than 80% of the total landings of Octopods in this area and for last years derived mainly from OTB_DEF_70–99_0_0.

The Spanish commercial fleet operating in divisions 27.8.abd is mostly composed of vessels with base ports in the Basque country (Spain). Landings varied from 2260 tonnes in 2010 to 850 tonnes in 2021 (Figure 1.62).

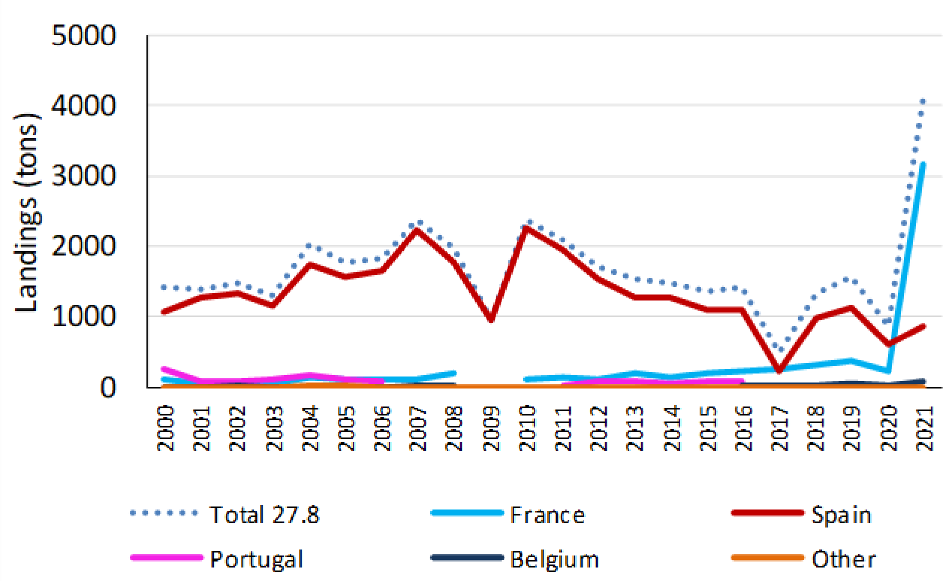


Figure 1.62 Trends in Octopod landings in the Bay of Biscay (27.8.abcd).

The recent higher landings of Octopods reported by the Basque trawlers may reflect increased targeting of cephalopods. In 2009–2012, the metier targeting cephalopods (OTB_MCF) showed an increased number of trips and increased cephalopod catches. The increase in the OTB_MCF *metier* in 2013–2014 seems to be related to a decrease in the metier targeting demersal species such as hake, megrim or anglerfish (OTB_DEF). On the other hand, in the Cantabrian Sea (area 27.8.c), most of Octopod catches are *O. vulgaris* landed by the Spanish fleet using mainly traps (98–99%). There was a decrease of *O. vulgaris* in the last 10 years, the maximum value was reached in 2010–2011. Later, both *O. vulgaris* and *E. cirrhosa* landings decreased slowly.

In ICES division 27.8.c, most of Octopod catches were *O. vulgaris*. This species was landed by the Spanish fleet using traps as the main gear for catching *O. vulgaris*. In the Cantabrian Sea, this artisanal fleet accounts for more than 98–99% of *O. vulgaris* landings in ICES division 27.8.c.

Despite *O. vulgaris* being the most important catches in this area, there has been a decrease for the last 10 years. The maximum was reached in 2010–2011. After this year, *O. vulgaris* and *E. cirrhosa* have decreased somewhat.

1.6.7 Fisheries in Western Iberia and Gulf of Cadiz

In the ICES division 27.9.a, the Octopod group is the most important cephalopod resource. The Octopod landings in ICES Area 27.9.a account for 84%, on average (mean 2000–2021) of total landings for all Subareas/Divisions. The countries contributing to Octopod catches in this area were (in order) Portugal and Spain (Figure 1.63). Artisanal fleets are responsible for a substantial proportion of Octopod landings in this area although an important part of the Portuguese artisanal fleet was included as "miscellaneous" gears in InterCatch data. Artisanal fleets are responsible for a substantial proportion of Octopod landings in this area. Portugal reports artisanal landings to the Inter–Catch as metier MIS ("miscellaneous" gears), representing more than 90% of Octopod landings. The most important Portuguese fleet landing Octopods is the small-scale fleet that targets *O. vulgaris* using mainly traps and pots. These vessels own several gear licences and landings are in most cases associated to the MIS metier and not to a more discriminated level. The next important gear is the trawl.

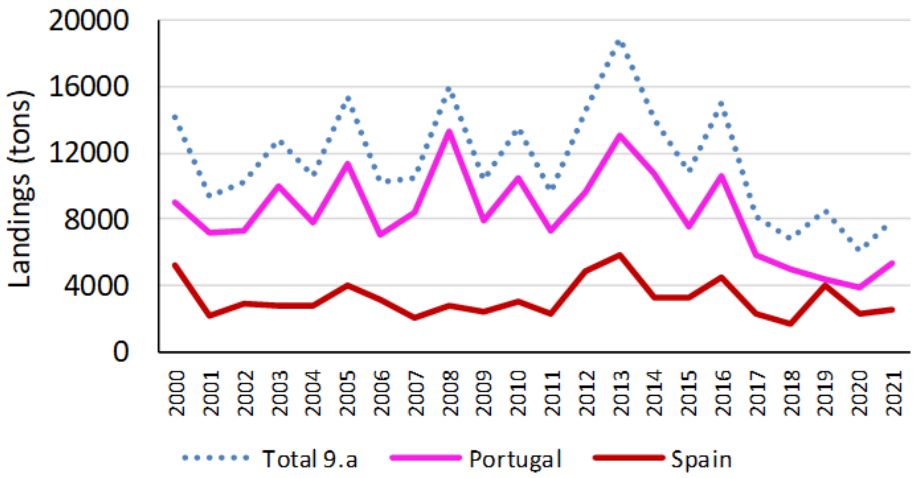


Figure 1.63 Trends in Octopod landings in ICES division 27.9.a.

Octopus vulgaris

The Portuguese landings are the most important for *O. vulgaris* in 27.9.a, in particular from subdivision 27.9.a.s.a (above 3000 tonnes for most of the historical series). A decreasing trend in total landings of *O. vulgaris* in division 27.9.a was observed since 2013, and a similar trend was noticed in all the five subareas until 2018 (Figure 1.64). In 2019, an increase in landings from the southern areas was observed, contrasting a further decrease in landings from the western areas. In 2021, 7345 tonnes of *O. vulgaris* were landed from 27.9.a, below the 2000–2021 mean (10531 tonnes). A slight increase was observed in subdivisions 27.9.a.c.s and 27.9.a.s. following the sharp decrease that occurred in the Spanish waters of the Gulf of Cadiz. Both the northern Portuguese (27.9.a.c.n) and Galician subdivisions maintained the decreasing trend in 2020. The large year-to-year variation in landings is thought to be related to large recruitment variation due to environmental changes such as variations in rainfall and discharges of rivers, as demonstrated in Sobrino *et al.* (2002, 2020).

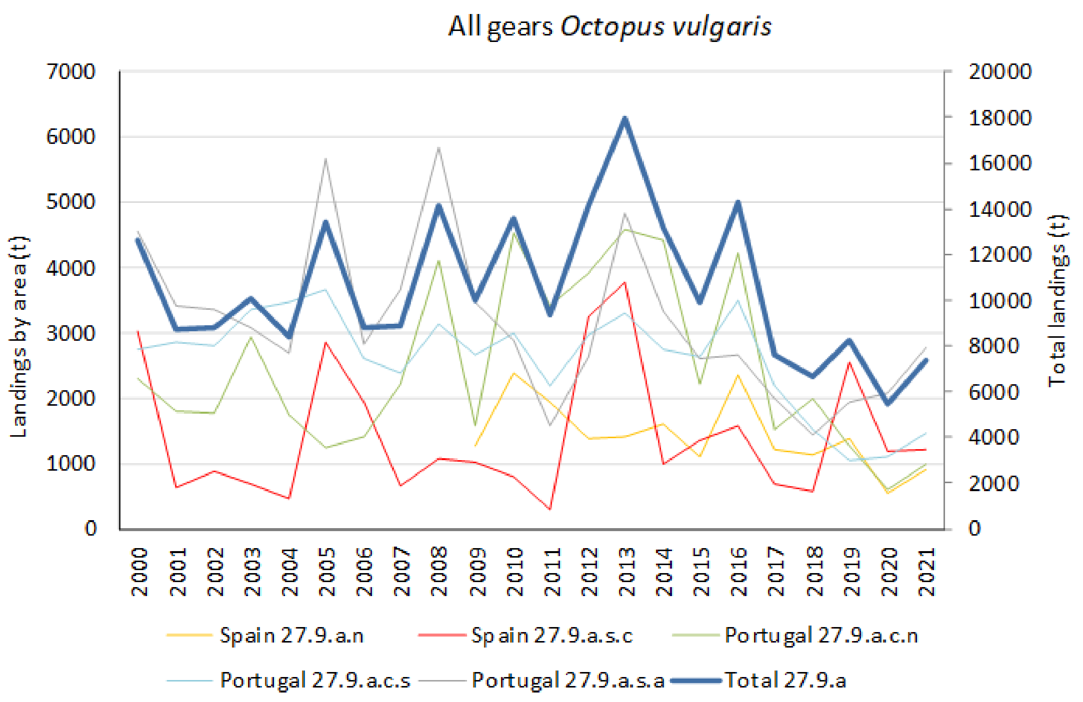


Figure 1.64 Trends in *Octopus vulgaris* landings (all gears) in every subdivision of ICES division 27.9.a.

In Galician (subarea 27.9.a.n) and Portuguese waters, the artisanal fleet accounts for more than 95% of *O. vulgaris* landings, mostly from the artisanal trap fishery (Table 1.11). In the Gulf of Cadiz (subdivision 27.9.a.s.c) the trawl fishery was more relevant. From 2000 to 2009, the Spanish bottom-trawl fleet accounted for around 60% of the *O. vulgaris* catch the Gulf of Cadiz and the artisanal fleet, using mainly clay pots and hand-jigs, landed the remaining 40%. However, since 2010 the contribution of the artisanal fleet for *O. vulgaris* landings has increased substantially, reaching 85% in 2021.

Table 1.11. *Octopus vulgaris* landings in subdivisions of ICES division 27.9.a.

	OTB					Artisanal / MIS				
	Spain	Portugal				Spain	Portugal			
Year	27.9.a.n	27.9.a.s.c	27.9.a.c.n	27.9.a.c.s	27.9.a.s.a	27.9.a.n	27.9.a.s.c	27.9.a.c.n	27.9.a.c.s	27.9.a.s.a
2000	NA	63	27	4	5	NA	37	73	96	94
2001	NA	78	26	3	4	NA	22	74	97	95
2002	NA	73	18	3	4	NA	27	82	97	96
2003	NA	73	17	2	3	NA	27	83	98	96
2004	NA	75	13	1	3	NA	25	87	99	96
2005	NA	52	8	1	3	NA	48	92	99	97
2006	NA	44	6	1	3	NA	56	94	99	97
2007	NA	77	14	1	1	NA	23	86	99	99
2008	NA	62	19	5	4	NA	38	81	95	96
2009	1	42	10	1	2	99	58	90	99	98
2010	2	50	7	2	2	98	50	93	98	98

2011	2	51	5	1	2	98	49	95	99	98
2012	1	29	6	5	2	99	71	94	95	98
2013	1	35	5	4	2	99	65	95	96	98
2014	1	19	4	3	2	99	80	96	97	97
2015	0.27	26	2	2	2	99.73	72	98	98	97
2016	0.34	20	5	3	2	99.66	75	95	97	98
2017	0.17	14	2	1	3	99.83	80	98	99	96
2018	0.47	16	4	4	2	99.53	83	96	96	97
2019	0.02	16	4	1	3	99.98	84	96	99	97
2020	1.19	14	2	0	2	98.81	85	98	100	98
	Mean (%)									
	1	***28***	***5***	***2***	***2***	***99***	***71***	***95***	***98***	***98***

Total landings in ICES division 27.9.a were rather stable from 2000 to 2012 although a decreasing trend is apparent in Portuguese landings since 2016 (Figure 1.64). *Octopus vulgaris* was the main species caught with landing between 14330 tonnes in 2016 and 1458 tonnes in 2018.

In Spain, the artisanal and trawler fleets catch *O. vulgaris*. In Galician waters (ICES Subdivision 27.9.a.n), the artisanal fleet accounts for more than 98–99% of *O. vulgaris* landings, mostly from traps. In Portuguese waters subdivision 27.9.a.c), a large percentage of *O. vulgaris* comes from the polyvalent (artisanal) fleet, using a range of gears which includes gillnets, trammelnets, traps, pots and hooks lines. In the Gulf of Cadiz (subdivision 27.9.a.s), from 2000 to 2009 the bottom–trawl fleet accounted for around 60% of the *O. vulgaris* catch on average in the time-series (Table 1.11). The artisanal fleet using mainly clay pots and hand-jigs took the remaining 40%. However, from 2010 to 2019 the contribution of artisanal fleet has been increasing until 50% to 84% in 2019.

Eledone spp.

The two *Eledone* species, *E. cirrhosa* and *E. moschata* are often not separated in landings statistics with the exception for the Spanish landings from the Gulf of Cadiz (subdivision 27.9.a.s.c). Nevertheless, landings of *Eledone* spp. are almost all *E. cirrhosa*. This species is caught by trawlers mainly as bycatch due to its low commercial value. *Eledone* spp. trawl landings in 27.9.a reached a peak in 2015 (953 tonnes) mainly because of high landings in subdivision 27.9.a.n (Figure 1.65). The trend in this area is quite the opposite to the trend in the other southern subdivisions. The subdivisions 27.9.a.c.s and 27.9.a.s.a have very low landings. In 2020, landings from the Spanish Gulf of Cadiz had a sharp increase along with a significant decrease in the two northern subdivisions.

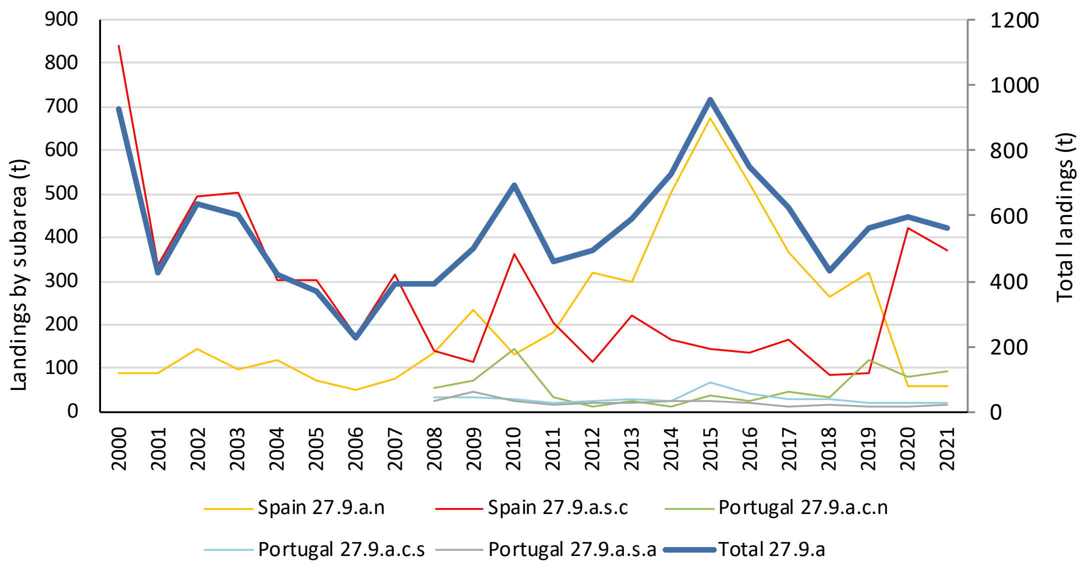


Figure 1.65 Trends in *Eledone* species, *E. cirrhosa* and *E. moschata*, in every subdivision of ICES division 27.9.a.

1.6.8 Relative Octopod biomass indices: overview

Fishery-independent information for Octopods was supplied for different surveys (bottom trawl research cruises) carried out annually in Iberian waters by Portugal and Spain: SP–NGPS "DEMERSALES" carried out in 27.8.c and 27.9.a.n by Spain, PT-IBTS in 27.9.a.c and 27.9.a.s by Portugal and SP-GCGFS "ARSA" in 27.9.a.s.c by Spain. The ARSA survey is carried out twice a year, in spring and in autumn.

1.6.9 Research surveys in Western Iberia (27.8.c and 27.9.a west) and in the Gulf of Cadiz (27.9.a.s)

Catches of *O. vulgaris* by Spanish research surveys during the last 20 years fluctuated above and below average without any regularity. *Eledone* spp. had more stability in its survey indices.

The estimated yields (kg/h) of *O. vulgaris* in Spanish DEMERSALES survey in the north during 2000–2021 fluctuated widely, reaching a maximum value in 2012 (2.5 kg/h) but dropping to a minimum (0.15 kg/h) in 2015. In the ARSA survey in the south, again strong fluctuations are evident, with a peak in 2013 (6.9 kg/h) and a minimum of around 1 kg/h seen in six years during the series, most recently in 2014. In both series, an increase was detected in 2019, in relation to the previous year (Figure 1.66). Data from the Portuguese survey were not very informative, with biomass survey indices less than 0.5 kg/h. Only 2003–2004 showed higher values, of around 2 kg/h. In 2021, the PT-IBTS started to be carried out with a new vessel and estimated CPUE was comparable to the SP-NGPS.

The estimated yields (kg/h) of *E. cirrhosa* in the DEMERSALES survey also fluctuated over the time-series with a sharp increase in 2013, tending to be slightly higher than values for *O. vulgaris* (Figure 1.67). In the ARSA survey, CPUE of *Eledone* spp. (*E. cirrhosa* and *E. moschata*) reached its highest value in 2015 with around 3–4 kg/h, as compared to the peak of 8 kg/h seen in the DEMERSALES series in 2013. Generally, yields in both series (ARSA and DEMERSALES) ranged from 1–3 kg/h, with a decreasing trend in ARSA survey from 2015 to 2019.

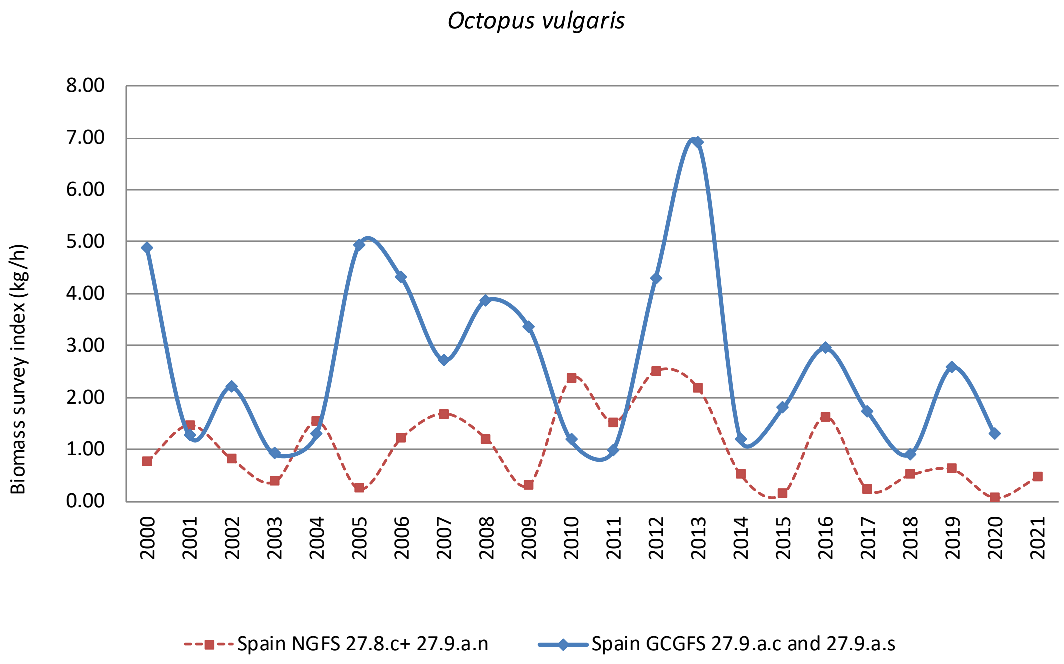


Figure 1.66 Trends in *Octopus vulgaris* biomass survey indices in the Western Iberia (ICES division 27.8.c and subdivision 27.9.a west) and in the Gulf of Cadiz (27.9.a.s).

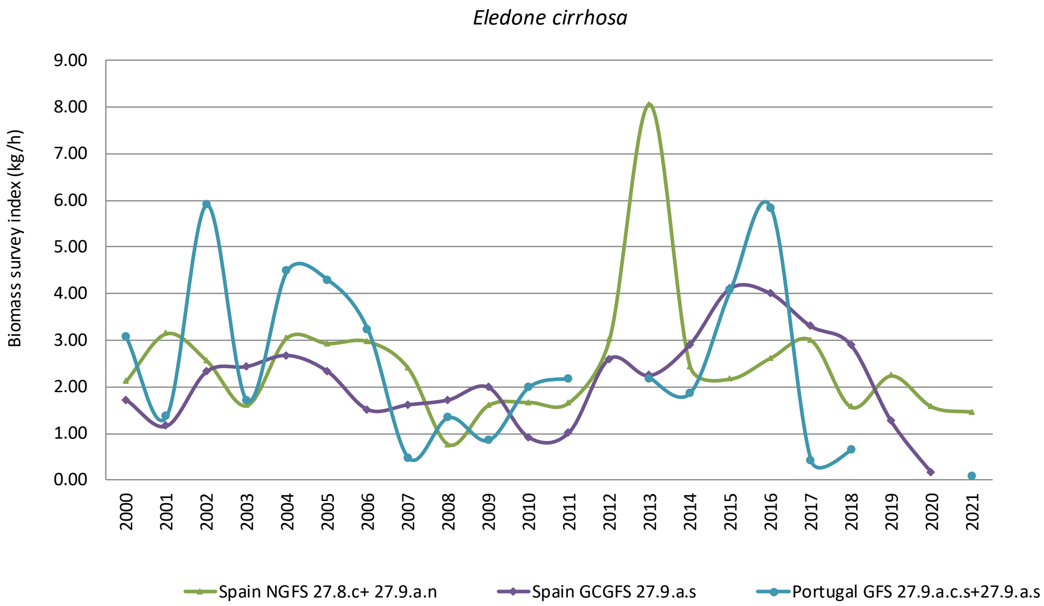


Figure 1.67 Trends in *Eledone cirrhosa* biomass survey indices in the Western Iberia (ICES division 27.8.c and subdivision 27.9.a west) and in the Gulf of Cadiz (27.9.a.s).

1.6.10 Summary of trends and status of Octopods

Table 1.12 summarizes the Octopod trends using landings as surveillance indicators of GES, considering that the mean of the most recent three years should be above the long-term historical average (ICES, 2014) and also the recent tendency by comparing the mean for the most recent three years (2019–2021) with the previous three years period (2016–2018). Table 1.13 and table

1.14 summarizes the trends for *O. vulgaris* and *E. cirrhosa*, respectively, using survey biomass indices. Based on landings, Octopods seems to be in good environmental status in the North Sea and in the Celtic Sea and still in poor state but recovering with recent increasing trend in the Celtic Seas and the Bay of Biscay. *E. cirrhosa* is the most abundant octopod in these four areas and survey biomass trends of this species in these areas reveal the same as landings. Based on landings, Octopods are in poor state in the Western Iberia, the Gulf of Cadiz and in Azores grounds. The recent trend is still decreasing. In these areas the main commercial Octopod is *O. vulgaris*. Survey biomass trends of this species in the Western Iberia and the Gulf of Cadiz reveal the same poor state as landings trends.

Table 1.12 Summary of trends in Octopod landings.

Octopods	Landings historical mean (mean tonnes)	Landings 2016–2018 (mean tonnes)	Landings 2019–2021 (mean tonnes)	Recent mean vs. historical mean	Recent tendency 2019–2021 *vs.* 2016–2018
North Sea	12	27	28	+	↗
Celtic Seas	555	276	466	–	↘
English Channel	157	277	366	+	↗
Bay of Biscay	1676	1076	2168	–	↘
Western Iberia and Gulf of Cadiz	11533	9978	7534	–	↘
Azores Grounds	12	10	7	–	↘

Table 1.13 Summary of *Octopus vulgaris* trends (surveys).

Octopus vulgaris		Survey historical mean (kg/h)	Survey 2016–2018 (kg/h)	Survey 2019–2021 (kg/h)	Recent mean vs. historical mean	Recent tendency 2019–2021 vs. 2017–2018
Western Iberia	SP–NGFS	1.02	0.79	0.39	–	↘
Gulf of Cadiz	SP–GCGFS	2.65	2.16	1.60	–	↘

Table 1.14 Summary of *Eledone cirrhosa and Octopus vulgaris* trends in survey biomass. EVHOE biomass in kg/0.02 nm²

Eledone cirrhosa	Survey historical mean (kg/h)	Survey 2016–2018 (kg/h)	Survey 2019–2021 (kg/h)	Recent mean vs. historical mean	Recent tendency 2019–2021 vs. 2017–2018
North Sea GER – NSIBTS 1Q	0.03	0.07	0.11	+	↗
English Channel FR – EVHOE 27.7.de	0.60	0.67	–	+	↗

Eledone cirrhosa	**Survey historical mean (kg/h)**	**Survey 2016–2018 (kg/h)**	**Survey 2019–2021 (kg/h)**	**Recent mean vs. historical mean**	**Recent tendency 2019–2021 vs. 2017–2018**
Bay of Biscay					
FR – EVHOE 27.8abd*	0.29	0.49	–	+	↗
Western Iberia					
SP–NGFS	2.49	2.40	1.76	–	↘
PT – IBTS	2.42	2.30	0.09	–	↘
Gulf of Cadiz					
SP – GCGFS	2.14	3.40	0.72	–	↘

2 ToR B

This ToR aimed to review relevant advances in stock identification, stock assessment methods and fishery management measures and conduct preliminary assessments of the main cephalopod stocks in the ICES area, based on trends and/or analytical methods, thus also supporting the needs of the MSFD reporting. The various sections of this text are based on forthcoming or recently published papers and there is some overlap in the introductory material of the different sections because they were written as stand-alone documents.

2.1 Stock identification

Because populations can share spawning grounds but can be found in discrete units outside the spawning period, genetic characteristics do not give a full picture regarding the 'stock concept' and important information can be gained by considering non–genetic markers (Begg *et al*., 1999), particularly if ecological groups are associated with biological differences, such as growth rate. In addition, although no single unit may be able to guarantee the long–term survival of a fishery, the combined effect of many populations – so-called 'metapopulations' (possibly occupying habitats of variable quality), may be able to do this, assuming that there is an 'intermediate' level of exchange of individuals between them (Levins, 1970).

In a recent study, 'ecological' stocks were identified using statolith shape markers at regional scales in *Loligo forbesii*. Four distinct groups were identified on the Irish Shelf and north of Scotland, with the north of Ireland being particularly distinct, and only stocks in the north of Scotland and Rockall being undifferentiated, though Rockall was ecologically distinct from all other shelf locations sampled (Figure 2.1). The results demonstrated that *L. forbesii* forms distinguishable groups (based on shape statistics), maintaining these groups over sufficiently long periods for local conditions to affect the shape of the statolith. Genetic microsatellite (9 loci) analysis revealed no statistically significant differences at broader scales in the North Atlantic shelf. However, there was a non-significant trend in genetic variability (pairwise F_{ST}) involving Rockall, which was highly non-random and judged to be indicative of a semi-isolated breeding group at Rockall, particularly considering past genetic analysis involving this area (Brierley *et al*., 1995; Shaw *et al.*, 1999). Some biological (length) differences were also seen at Rockall. Thus, Rockall was semi–isolated genetically and also distinct from most shelf locations on the basis of statolith shape.

Management implications:

This stock identification study demonstrated that *L. forbesii* formed separable (ecological) groups over short time-scales with a semi–isolated breeding group at Rockall. The genetic distinctiveness of the Rockall stock varies over time. Rockall also supports a targeted fishery which operates without any catch limits and is located inside a small spatial area that is separated from shelf populations by an expanse of deep water. We consider Rockall to potentially be vulnerable to being overexploited from targeted fishing and poorly replenished from shelf stocks due to its isolation. There are also potential biological (length) differences at Rockall, which require further investigation given the known tendency for polymodal size structure and length microcohorts in this species. Future research into seasonal stock movements in *L. forbesii*, particularly at Rockall, as well as presence/absence of spawning locally within Rockall, would be useful.

The above study was published in the *ICES Journal of Marine Science* (Sheerin *et al*., 2022); see also Göpel *et al*., 2022.

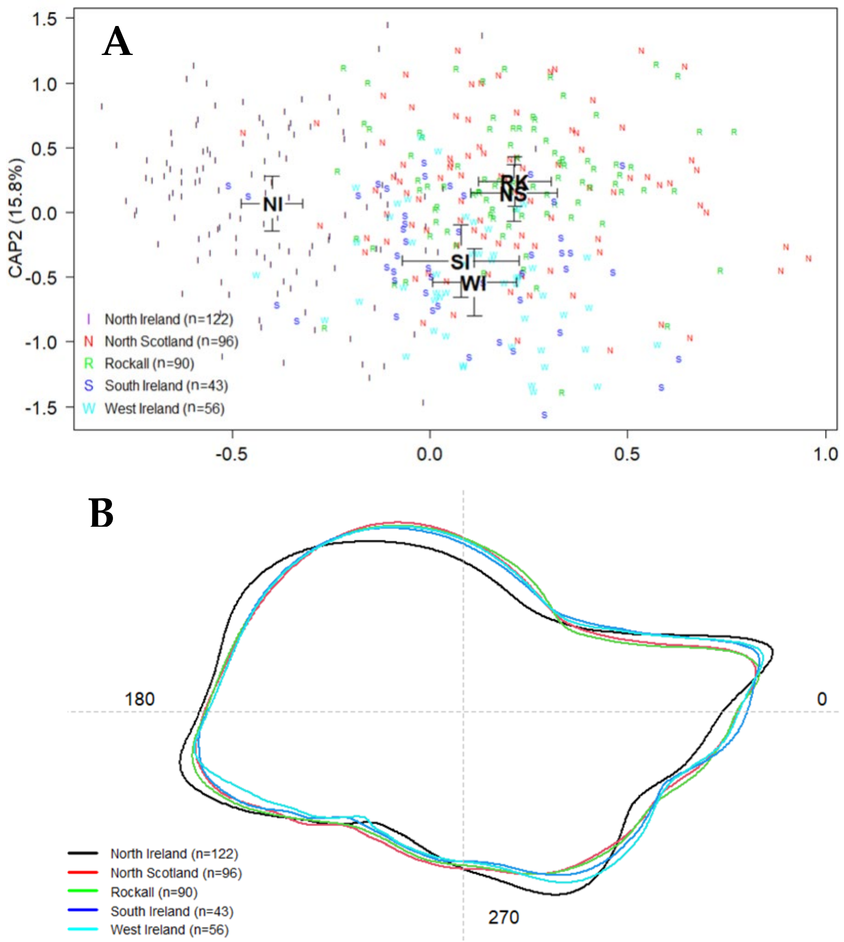


Figure 2.1 A) Canonical scores on discriminating axes CAP1 and CAP2 for each *L. forbesii* location: north Ireland (I, black), north Scotland (N, red), Rockall (R, green), south Ireland (S, blue) and west Ireland (W, cyan). Large black letters represent the mean canonical value (with 95% confidence intervals) for each location and smaller coloured letters represent individual squid (SI = south Ireland, NS = north Scotland, NI = north Ireland, WI = west Ireland, RK = Rockall). B) Mean statolith shape of *L. forbesii* (males and females) in north Ireland (black), north Scotland (red), Rockall (green), south Ireland (blue) and west Ireland (cyan) under discrete wavelet reconstruction. The numbers show angle in degrees (°) based on polar coordinates where the centroid of the statolith is the centre point of the polar coordinates (Sheerin *et al.*, 2022).

2.2 Stock assessment methodology

The present review is based on a forthcoming paper by Gleadall *et al*. (in prep.). Several of the papers cited were co-authored by WGCEPH members and were presented to and/or developed in conjunction with WGCEPH (e.g. Sobrino *et al*., 2020; Arkhipkin *et al*., 2021; Moustahfid *et al.*, 2021; Roa–Ureta *et al.*, 2021). Previous reviews which cover the topic of cephalopod stock assessment include Caddy (1983 a,b), Pierce and Guerra (1994), Rodhouse *et al*., (2014), Arkhipkin *et al.* (2015) and Sauer *et al*. (2019).

Doubleday *et al.* (2016) proposed that cephalopods were generally proliferating globally, consistent with the idea that cephalopods were ecologically replacing overfished finfish (Rodhouse and Caddy 1998; Hunsicker *et al*., 2010; Doubleday and Connell, 2018). The combination of general rise in global commercial importance of cephalopods over the last few decades, alongside clear evidence of large and apparently unpredictable fluctuations in abundance (despite the general upward trend globally), and the suspicion that overfishing could be playing a role, all increase the importance of stock assessment and appropriate fishery management.

In the context of fisheries, many authors have emphasized the differences between fish and cephalopods, although Pauly (1998) argued for thinking of cephalopods as though they were fish, an argument relating to the constraints imposed on gill–breathing animals in relation to body size. The most notable and relevant aspects of cephalopod biology, most of which were highlighted by Caddy (1983b) both contribute to their suitability as a resource (e.g. rapid individual growth and high population productivity, plus their ecological opportunism and apparent resilience to high fishing pressure) but also contribute to the difficulties associated with applying traditional stock assessment and fishery management approaches. Thus, aside from the fact that we often fail to identify them correctly (or at least not to species) and often have not defined populations or stocks, they are short–lived, age determination is difficult, and they are notoriously variable in relation to individual growth rate, life cycle phenology, and population abundance, reflecting both high sensitivity to environmental conditions and high phenotypic plasticity. The life cycle is typically seasonal, with one or two annual pulses of recruitment and spawning seasons (i.e. one or two cohorts per year), implying a generation time of 12 or 24 months (equivalent to the lifespan, including the egg phase, if the is post-spawning mortality). However, the seasonal timing of the peaks of recruitment and spawning can apparently vary over the years (e.g. Pierce *et al.*, 2005), and both recruitment and spawning may be spread out over and extended period, sometimes with several "pulses" or microcohorts detectable (i.e. the extended spawning period likely often reflects between individual differences in phenology and not extended periods of spawning by individuals). Seasonal peaks may be more or less prominent, with recruitment and/or breeding occurring all year-round in some species in some regions. Additional complications include small and large size modes at maturity (notably in male loliginid squid) and one- or two-year life cycles (as confirmed in the cuttlefish *Sepia officinalis*).

As indicated by Caddy (1983b), the challenges posed by cephalopods in relation to stock assessment have at least two distinct implications. First, many assessment methods work poorly with cephalopods because the model assumptions are not met. Examples include length–based assessments that assume the peaks in length–frequency distributions of cephalopods represent annual cohorts, also the application of simple production models that rely on the assumption of a fixed carrying capacity. Second, those approaches that do work well may provide results that are of little or no utility for managers. Retrospective assessments offer very little in terms of predictive power in short-lived, environmentally sensitive, species with non-overlapping generations and weak to non-existent stock recruitment relationships.

Several recent publications point towards particular solutions for, respectively, assessment (Arkhipkin *et al*., 2021; Roa–Ureta *et al*., 2021) and forecasting (Moustahfid *et al.*, 2021; Sobrino *et al.*, 2020) of cephalopod abundance. The former papers follow Caddy (1983b) and Boyle and Rodhouse (2005) in highlighting the importance of real time assessment and the utility of depletion models, while the latter focus on the relationships between cephalopod abundance and oceanographic conditions and possible ways to operationalise them. Despite such advances, in some parts of the world, cephalopod stock assessment and cephalopod fishery management are largely notable by their absence, including in large-scale fisheries of northern Europe and high seas fisheries in the southwest Atlantic (see Arkhipkin *et al*., 2022 in relation to the latter.

Depletion models

Depletion models are based on the idea that, following recruitment, stock abundance will gradually decline through a combination of fishing and natural mortality. By monitoring the rate of decline, the originl abundance can be estimated. For many years the management of fishing for squid (Illex argentinus and Doryteuthis gahi) within the Falkland Islands Conservation Zone has been by real–time on–board monitoring of catch and effort coupled with the application of depletion models to follow the decline of the incoming recruits over time and thus help ensure that sufficient numbers remained to give rise to the next generation of squid. Depletion models were first developed by Leslie and Davis (1939) (to estimate the numbers of rats) and De Lury (1947) and were further developed for application in this fishery, with increasing sophistication over the years (Beddington *et al*., 1990; Rosenberg *et al*., 1990; Basson *et al*., 1996; Agnew *et al*., 1998, 2005; Hatfield and Des Clers 1998; McAllister *et al*., 2004; Roa–Ureta and Arkhipkin 2004; Roa–Ureta 2012; Winter and Arkhipkin 2015). Winter and Arkhipkin (2015) suggested that assessment of Doryteuthis gahi could be improved by accounting for all in-season recruitment pulses.

The present day small–scale fishery for common octopus *Octopus vulgaris* in Western Asturias (northern Spain) is assessed using a generalised depletion model fitted to weekly fishery data. Harvest control rules further take into account results from application of a Pella–Tomlinson production model and a Shepherd stock-recruitment model, which revealed inherently cyclic population abundance fluctuations. Roa–Ureta *et al.,* (2021) concluded that there was no fixed maximum sustainable yield (MSY) and proposed the use of average "latent productivity" minus two times the standard error of the estimate as a precautionary and sustainable annual harvest rate. It should be noted that this fishery holds Marine Stewardship Council (MSC) certification, which places a number of requirements on the fishery, not least the need for effective management; in this case achieved through co-management.

Depletion models have also been applied retrospectively to model abundance trends in various cephalopod stocks, including jumbo squid *Dosidicus gigas* in the Gulf of Mexico (Morales-Bojórquez 2002), slender inshore squid Doryteuthis plei (Perez 2002), veined squid *Loligo forbesii* in the English Channel (Royer *et al*., 2002) and in Scotland (Young *et al*., 2004), *Ommastrephes bartramii* in the Northwest Pacific (Chen *et al*., 2008; Cao *et al*., 2015; Ding *et al*., 2019), *Octopus vulgaris* in Morocco (Robert *et al*., 2010), *Octopus cyanea* in the western Indian Ocean (Sauer *et al*., 2011) and squid and cuttlefish in the Mediterranean (Keller *et al*., 2015; Maynou 2015). Keller *et al*. (2015) noted that current fishery monitoring under the EU Data Collection Framework (which involves collecting biological samples three times a year) was inadequate to allow use of depletion models, recommending sampling every week or every two weeks during the depletion period.

The application of depletion models in real time assessment is demanding. In the Falkland Islands it arguably worked well because the life cycle and migrations of the species were well–known, the fishery operated in a well–defined area, and the licence to fish required acceptance of with both ongoing data collection and (if deemed necessary) early closure of the fishery to ensure sufficient escapement. The approach was undoubtedly expensive and could not protect the fishery from years of poor recruitment whether resulting from environmental variation or from overfishing in the high seas. The alternative of using retrospective depletion assessments is problematic. In the Western Asturias octopus fishery, the dynamics of the stock are well-understood and, importantly, fishing effort is strictly controlled, and fluctuations in abundance seem to be both moderate in extent and reasonably predictable. It is less clear that this approach could be successfully applied to squid fisheries, especially if fishing effort is not regulated, because squid abundance is almost certainly intrinsically more variable. Based on stock size estimates for *Illex argentinus* in the southwest Atlantic by Csirke (1987), Beddington *et al.* (1990) suggested that recruitment varied between years by a factor of ten.

Cohort analysis and yield-per-recruit models

Virtual population analysis (VPA) or cohort analysis (which deal with population abundance) and yield-per-recruit (YPR) models (which numbers to biomass) use catch-at-age data. They assume the existence of discrete age cohorts in the fished population, which are followed from their recruitment to their disappearance, and depend on the existence of a straightforward method of age determination (e.g. age may be derived from established age-length relationships). In cephalopods there are usually no more than two annual cohorts alive at any one time (ignoring the issue of microcohorts) so the structure of such models reduces to a simple description of population dynamics, describing the change in population size as a function of recruitment plus natural and fishing mortality (also accounting for initial body weights and the growth rate for YPR models) and readily rearranged to generate the so-called catch equation of Gulland (1965).

Because contact between a cephalopod population and a fishery may occur over only a few months of the year, following a cohort through its life requires focusing on a much shorter timescale than is needed for longer lived species (Pierce and Guerra 1994).

As Henderson and Hart (2006) pointed out, YPR, Egg–Per–Recruit and similar models are frequently required for cephalopod stocks because management commonly aims to ensure sufficient escapement to support the next generation. The depletion approach may permit estimation of the original stock size and the rate at which it is being depleted but a different approach is needed to define the threshold minimum spawning-stock biomass (SSBmin) below which the stock should not be allowed to pass.

A VPA approach was used in the *Illex argentinus* fishery (Csirke 1987; Rosenberg *et al*., 1990) while a YPR approach was developed for the Northwest Atlantic fisheries for *Illex illecebrosus* and *Doryteuthis* (formerly *Loligo*) *pealeii* (Lange and Sissenwine 1983), incorporating a Von Bertalanffy (asymptotic) growth model, nowadays considered to be unsuitable for cephalopods. Roel and Butterworth (2000) fitted a simple population dynamics model to data from jig and trawl fisheries for *Loligo reynaudii*, in South Africa, showing that the then current level of fishing effort would almost certainly lead to severe decline in stock biomass. Although there is no routine assessment of stocks in the English Channel, several publications present cohort analysis and similar approaches for squid and cuttlefish stocks in this area (e.g. Royer *et al*., 2002, 2006; Gras *et al*., 2014).

Henderson and Hart (2006) developed an approach to modelling post-spawning mortality as a function of age, thus offering a way to avoid the unrealistic assumption in cohort models that the probability of natural mortality is constant over the life of the animal. They also demonstrated the importance of accounting for uncertainty in age estimates.

In the Mediterranean, there have been various recent attempts to assess octopus stocks using length-based cohort analysis or YPR models, in which cohort identify and relative abundance was derived from length–frequency data from trawling surveys (Agnesi *et al*., 1998; Orsi Relini *et al*., 2006; Giordiano *et al*., 2010). Cohorts were identified in the length-frequency distributions using Bhattacharya analysis (which attempts to decompose a distribution into a series of normally distributed components). In the case of curled octopus *Eledone cirrhosa*, most studies suggested the existence of two or three annual cohorts. Age data from the Atlantic, based on counting increments in stylets indicated a maximum post-hatching age only 17 months in this species (Regueira *et al*., 2015). The total lifespan could thus be around two years. However, it should also be noted that female octopuses guard the hatched eggs and the lifespan of an individual female may exceed the generation time. Ideally, “cohorts” identified from length-frequency data should be verified by age determination studies.

Data-poor methods

Survey catch rate is used as an abundance index in various cephalopod fisheries. Kidokoro and Mori (2004) described the annual jigging surveys carried out for Todarodes pacificus in the Sea of Japan. The stock abundance indices thus derived were also used to estimate absolute abundance based on a previously calculated coefficient. Hendrickson and Showell (2016) derived numerical and biomass indices of abundance for Illex illecebrosus using trawl surveys. The utility of trawl survey data has also been explored in regions where there is no current cephalopod stock assessment. WGCEPH regularly describes survey abundance trends as well as trends in fishery catches for cephalopods in European Atlantic waters (see ToR A). An important consideration in relation to survey catch data are that cephalopod distribution (notably squid distribution) may be rather patchy. This issue can be accounted for using a geostatistical approach as proposed by Roa-Ureta and Niklitschek (2007), who used data for Doryteuthis gahi in the Falkland Islands as one of their case studies.

Length-frequency data can be used to construct "catch curves", which estimate total mortality by generating a plot of log frequency against log age. Fishing mortality can be estimated by subtracting natural mortality, for example derived from Pauly's (1980) empirical relationship between natural mortality, body weight, growth rate and seawater temperature. The more obvious issues for using length–frequency data in cephalopods to identify cohorts are that age is usually unknown, size modes are not always annual cohorts (they may be within-year microcohorts) and von Bertalanffy growth curves, as used for fish, may be inappropriate for cephalopods.

Production models have been applied to various cephalopod stocks, both for assessment and research purposes. These models depend on the idea that "surplus production" (i.e. the part of the population that can be removed annually without resulting in a decline in abundance) is maximal when a population is at intermediate abundance relative to environmental carrying capacity. In the CECAF area (Saharan Bank) in the 1970s there were several attempts to apply production models to fishery catch and effort data for *Octopus vulgaris*, the last of which concluded that fishing effort was close to that needed for Maximum Sustainable Yield (MSY), although previous applications had suggested a less optimistic picture (Sato and Hakanaka 1983).

Cephalopod stocks are unlikely to have a fixed MSY. Indeed, Caddy (1983b) pointed out that MSY would depend on recruitment strength. Environmental variation will result in year-to-year variation recruitment strength and/or carrying capacity and, at least in *Octopus vulgaris*, intrinsically cyclic population dynamics prevent an equilibrium being reached (see Roa-Ureta *et al*. (2021).

ICES WGCEPH has explored various variants of production models (ICES 2016, 2017, 2019, 2020), including A Stock Production Model Incorporating (environmental) Covariates (ASPIC) and, most recently, Surplus Production in Continuous Time (SPiCT), with moderate success. In some cases, confidence limits were too wide to draw any conclusions about stock status. Preliminary assessments for North Atlantic cephalopod stocks based on SPiCT were summarized in a Working Document included in the 2019 WGCEPH report.

Abella *et al.* (2010) applied an ASPIC model to various fished stocks in the Ligurian Sea (Mediterranean), including common cuttlefish *Sepia officinalis* and the curled octopus *Eledone cirrhosa*. Froese *et al*. (2018) applied a CMSY approach (essentially a simplified variant of a production model using catch time-series) to landings and survey data (1970–2014) from 397 European stocks of fish and invertebrates, including several squid, cuttlefish and octopus stocks. For example, in the case of *E. cirrhosa* in the Ionian Sea. They found that stock biomass B was around 43% of BMSY and that current fishing effort F was around 4.5 times higher than FMSY, suggesting overexploitation. Tsikliras *et al*. (2021) applied the related AMSY method (which uses and abundance time-series) to 74 unassessed stocks in the Aegean Sea, again including several cephalopod stocks. Geraci *et al.* (2021) applied a SPiCT model to data for *Eledone cirrhosa* and *Eledone moschata* in the Strait of Sicily, finding evidence of severe overexploitation.

Forecasting

The existence of relationships between ocean temperature and squid catches was reported in the 1970s and 1980s (e.g. Dow 1976; Coelho and Rosenberg 1985). In the early 1980s, Japan was using a combination of recruitment surveys and empirical models based on oceanographic conditions to predict the abundance of Todarodes pacificus, although this was not linked to any specific management of Japanese squid fisheries (Osako and Murata, 1983). Fogarty (1989) reviewed empirical models for predicting yield or abundance of exploited marine invertebrates (including some cephalopods), generally based on relationships between catch or catch per unit effort (CPUE) and environmental variables.

Numerous subsequent studies have identified apparent links between abundance and oceanographic conditions (see Pierce *et al*., 2008 for a review) in all the main groups of fished cephalopods, for example in *Illex argentinus* (Waluda *et al*., 1999a,b; Chemishirova *et al*., 2021), neon flying squid *Ommastrephes bartramii* and jumbo flying squid *Dosidicus gigas* (Chen *et al.,* 2021), chokka squid *Loligo reynaudii* (Roberts and Sauer 1994), *Octopus vulgaris* (Sobrino *et al*., 2002, 2020; Otero *et al*., 2008), giant Pacific octopus *Enteroctopus dofleini* (Scheel 2015; Scheel and Johnson 2021), *Sepia officinalis* (Guerra and Sanchez 1985; Guerra 2006) and southern cuttlefish *Sepia australis* (Mqoqi *et al*., 2007).

Sea surface temperature frequently figures in such studies, even for demersal species, in part because such data are readily obtainable but also reflecting the fundamental importance of temperature in controlling the rate of biological process and its correlation with other relevant variables for which it may act as a proxy. Thus, lower temperatures may be associated with stronger upwelling and hence higher productivity (positively associated with *Octopus vulgaris* abundance; (Otero *et al*., 2008). High nutrient concentrations can lead to eutrophication, hence reduced oxygen concentrations and, as a consequence, lower cuttlefish abundance (Guerra 2006).

The relevant environmental variables, and hence presumably the mechanisms involved, may differ between areas for the same species. Thus Sobrino *et al*., (2002) highlighted the importance of rainfall (and hence river discharges and salinity) as well as sea temperature in determining abundance of *Octopus vulgaris* in the Gulf of Cadiz, while Otero *et al*. (2008) pointed to the importance of wind structure (and hence the strength of seasonal upwelling, linked to productivity) for the same species in Galicia; see Moustahfid *et al*. (2021) for further discussion of the influence of eastern and western boundary currents on squid.

The general rationale for using empirical models to forecast abundance as a function of environmental conditions is clear: recruitment is affected by oceanographic parameters such as temperature, nutrient concentrations and primary production (Cushing 1975; Fogarty 1989), and in annual species (including many cephalopods) the fished stock consists entirely of new recruits of the year. However, such models can be (and often are) constructed with no detailed understanding of the underlying mechanisms, and several authors have urged caution because of the risk of spurious correlations (e.g. Walters and Collie 1988; Solow 2002; Caputi *et al*., 2014).

A possible route forward is via the use of hybrid models, which incorporate some combination of environmental variables, direct estimates of abundance and the output from assessment models. Thus Sobrino *et al.*, (2020) proposed the use of a combination of rainfall (which affects salinity) and recruitment surveys to forecast the abundance of *Octopus vulgaris* in the Gulf of Cadiz. Moustahfid *et al*., (2021) observed that although substantial progress had been made in relating squid population dynamics to environmental variability and change, several challenges remained before forecast products could be developed to support squid fisheries management.

Other approaches

Morales-Bojórquez *et al*. (2012) used a mark-recapture method to estimate population size in the jumbo squid *Dosidicus gigas* in the Gulf of California. The squid were captured with jigs, tagged and released. The squid were apparently unharmed by the process. Tags were recovered from landing ports (facilitated by a reward for each tag returned). In two trials, in different seasons, approximately 1000 squid were marked each time. Resulting population estimates were 20.2 million squid (95% CI 16–26.5 million) in October 2001 and 132.6 million (85.5–222 million) in April 2002. Such an approach is most likely to be successful in highly mobile species with large and robust individuals caught with non-destructive gear, as such, it is doubtful that it could be usefully applied in most cephalopod fisheries.

Cephalopods are recognised as ecologically important as both predators and prey, and at least some squids appear to be keystone species (e.g. Gasalla *et al.*, 2010; Rodhouse *et al.*, 2014). Whole ecosystem models such as Ecopath with Ecosim thus arguably represent the ultimate solution in terms of ecosystem–based stock assessment. Although their application to stock assessment is currently limited, not least due to the enormous associated data demands, they are already used for management strategy evaluation in fisheries and could be used to help set reference points for harvest control (Bentley *et al.*, 2021). Simpler ecosystem models, e.g. GADGET (Bartolino *et al.*, 2011) and multispecies assessment models are used more routinely in fisheries but we are not aware of applications that include cephalopods.

2.3 New assessment work: trend analysis

During the 2020–2022, work continued on evaluation of trends in cephalopod stocks using a time–series approach (started during 2017–2019) and various new assessment results were reported (mentioned in the review in the previous section). The present section provides extracts from the trend analysis undertaken during the current and previous cycles. The full version of this analysis will be written up as a paper.

2.3.1 Objectives

This analysis aimed to determine whether common trends could be detected in year-to-year trends in cephalopod abundance indices across different areas, within species or family groups and, if so, to quantify the trends. Additional questions which were examined for one or more species groups and/or subsets of data included:

- Are results obtained using fishery and survey series similar?
- Are results obtained for different fishing gears similar?
- Are the observed trends linked to environmental factors and/or past fishing mortality (using effort and/or landings as a proxy)?
- Are the cephalopod-environment relationships time-lagged?
- Can we identify particular months or seasons (e.g. linked to particular life-cycle events) in which cephalopod abundance and environmental factors should be measured in order to capture environmental relationships?
- Are there common trends across different cephalopod groups?

2.3.2 Methodology

Time-series of annual “abundance indices” were compiled from data previously supplied to WGCEPH as well as data supplied by WGCEPH members and national fishery research institutes. The longest time-series started in 1980 and series generally extended to 2018.

Fishery series included both landings and landings per unit effort (LPUE) series, based on single gear types or multiple gears, and on single countries or all countries combined. Where possible, series were assigned to an ICES fishery subarea (e.g. 4, 7, 8) or division(s) (e.g. 4a, 7de). Each annual survey in the survey series includes data from multiple hauls and for each series, average abundances per year (as number/hour or kilogramme/hour) were calculated, usually as a simple arithmetic mean.

All datasets were standardised by dividing by the highest value (i.e. all index values were finally in the range 0 to 1 and the maximum was always 1.

Exploratory analysis included construction of dotplots and histograms to check distributions and identify outliers / errors.

Transformation of datasets to improve normality was considered and rejected because no single transformation would have worked for all series. Autocorrelation and partial autocorrelation were computed for all series. Generally, strong autocorrelation was evident, if at all, only for a lag of one year.

Very short time-series and series with several years of missing data were discarded as were any series containing obvious errors. For cuttlefish, the initial dataset comprised 60 different series. Subsets of comparable series (e.g. landings series for different ICES areas) were selected for further analysis to answer the main question and subsidiary questions.

Preliminary analyses of different series from the same area allowed exploration of relationships between landings and landings-per-unit effort series (if both were available), between numbers-based and weight-based survey abundance estimates, between indices arising from catches of different fishing gears, and between fishery-derived and survey abundance index series.

To answer both the main question and the subsidiary questions, two main approaches were used:

- Simple correlation analysis. It should be noted that this will overestimate the significance of correlations if there is significant autocorrelation within time-series.
- Dynamic Factor Analysis (DFA), an approach designed for time-series. The analysis was run for 1, 2 and 3 common trends to identify which of these models had the lowest AIC. Normally the best models had only 1 or 2 common trends. Factor loadings were calculated to quantify the contribution of each series to the identified common trend(s).
- Where important common trends were detected, further DFAs were run including one or more environmental explanatory variables.
- Where DFA showed a significant environmental effect, the environmental effects were further explored using simple Gaussian GAMMs for the response variable-explanatory variable combinations where the significant effects were seen. An AR1 variance structure (i.e. autocorrelation between adjacent years) was assumed for the response series.

All DFA analyses were run in BRODGAR (https://www.brodgar.com/) (Highland Statistics Ltd). This package provides a menu–driven interface to R but certain routines, including the one for DFA, are written in FORTRAN.

2.3.3 Results for cuttlefish

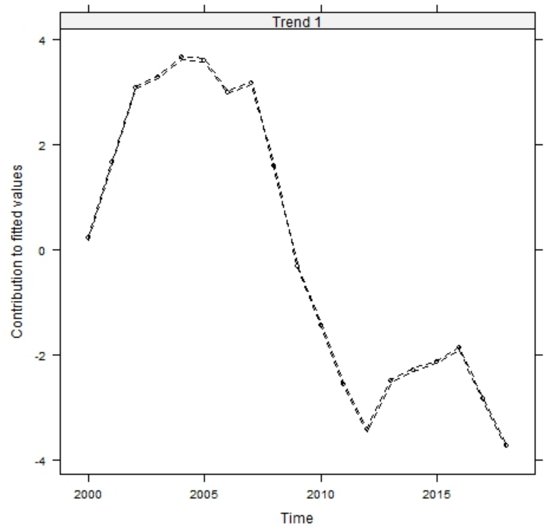
Common trends across areas for cuttlefish landings data

Using fishery data on total cuttlefish landings provided to ICES for the years 2000–2018, summed across all contributing countries and assigned to ICES divisions within the Northeast Atlantic, positive correlations were seen between various northeastern divisions (North Sea, English Channel, Skagerrak and Kattegat) and between some of the Celtic Sea divisions, as well as negative correlations between the North Sea and Celtic Sea also a tendency for North Sea and Celtic Sea to be negatively correlated (Table 2.1). None of these series was significantly correlated with a series of landings data from the Canary Islands (area 34 1 2) during 2007–2017.

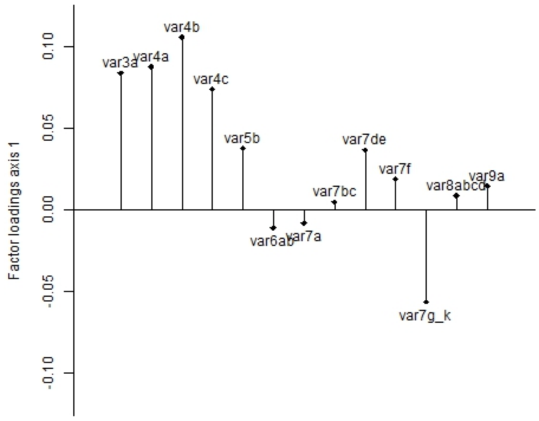
Table 2.1 Pearson correlations between standardised annual cuttlefish landings series 2000–2018 for different ICES fishery divisions in the Northeast Atlantic (FAO area 27) plus a series for the Canaries (area 34.1.2) during 2007–2017. Significance is indicated by * P<0.05, ** P<0.01, *** P<0.001. Colours indicate groups of divisions showing positive or negative correlations.

	4a	4b	4c	5b	6ab	7a	7bc	7de	7f	7g–k	8abcd	9a	34 1 2
3a	0.924 ***	0.572 *	0.361	0.199	–0.184	–0.201	–0.017	0.436	0.153	–0.448	0.115	0.354	0.178
4a		0.723 ****	0.476 *	0.418	–0.247	–0.208	0.129	0.622 **	0.412	–0.426	0.075	0.292	–0.018
4b			0.777 ***	0.515 *	–0.169	–0.058	0.055	0.780 ***	0.450	–0.500 *	–0.060	0.074	0.016
4c				0.368	–0.295	–0.075	–0.015	0.643 **	0.193	–0.516 *	–0.013	0.211	–0.249
5b					–0.118	–0.060	0.111	0.479 *	0.461 *	–0.208	0.495 *	0.130	0.000
6ab						–0.111	–0.144	–0.451	–0.271	0.138	–0.167	–0–109	0.246
7a							0.222	–0.107	–0.176	0.547 *	0.105	0.048	–0.312
7bc								–0.059	–0.148	0.467 *	–0.073	0.450	–0.283
7de									0.681 ***	–0.402	0.155	0.002	–0–145
7f										–0–290	0.014	–0.417	–0.176
7g–k											–0.064	–0.033	–0.343
8abcd												0.352	0.133
9a													–0.223

DFA results for the Northeast Atlantic areas indicated a single common trend, with an initial increase to a peak around 2004–2005 and a sharp decline from 2007 to 2012, followed by a slight recovery to 2016 and a further decline to 2018 (Figure 2.2a.) Factor loadings (Figure 2.2b.) indicated that the trend is strongly positively related to series from the North Sea (4a, 4b, 4c), Skagerrak and Kattegat (3a), more weakly to the English Channel (7de and Faroe (5b), and negatively related to the Celtic Sea (7ghjk), essentially consistent with the correlation analysis. This is thus a localised common trend, strongest in subareas 3 and 4.



(a)



(b)

Figure 2.2 DFA results for Northeast Atlantic fishery landings series for cuttlefish: (a) the fitted common trend and (b) factor loadings.

The DFA analyses were repeated including environmental explanatory variables. Annual NAO and annual NAO two years previously (i.e. lag 2) were included. Only the former had a significant effect and only for landings from divisions 7bc (which, according to its factor loading, contributed very little to the common trend). A GAMM for landings from subdivisions 7bc vs. annual NAO indicated a significant effect of NAO (P<0.001) (see Figure 2.3).

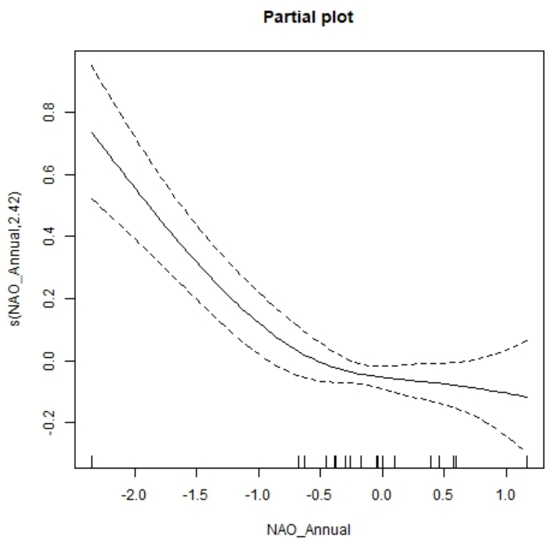


Figure 2.3 Smoother plot for the effect of annual NAO on standardised annual cuttlefish landings from divisions 7bc.

Common trends across areas for cuttlefish survey series

Six survey series provided sufficient years (we used a cut-off of 10 years of data) with abundance in kg/h (except for the French series from 7d which had units of kg/0.0686 km^2) to run correlations and DFA. None of the correlations was statistically significant, although negative correlations between surveys from division 7d and these from divisions 7g and 8abd approached significance (Table 2.2). There was a single common trend, a weak upward trend, positively related to subarea 4 and division 7g, and negatively related to 7d (Figure 2.4). At first sight this appears to contradict the fishery data analysis, but fewer subareas were represented, only for specific months, and generally and with shorter time-series.

Comparison of trends in cuttlefish landings for different fishing gears and fishery divisions/subdivisions in the Iberian Peninsula

Nine time-series of landings data from the Iberian Peninsula (division 8c and subdivisions of 9a) were available for analysis, with results from bottom trawl, purse-seine, traps, gillnets and mixed artisanal gears, from Portugal and Spain (Table 2.3). While some positive correlations were seen across different gears within subdivisions, and across different subdivisions in Portuguese waters, there were also some (generally weaker) negative correlations. None of the Spanish series was significantly correlated with any of other Spanish and Portuguese series, although Spanish series from 8c and 9aN were considerably shorter than the Portuguese series (2009–2018 vs. 1997–2018), while the series for combined trawl and artisanal gear landings from 9aS was longer (1993–2018).

Table 2.2 Pearson correlations between standardised annual cuttlefish survey catch rate (km/h) series 1990–2018 for different ICES fishery divisions in the Northeast Atlantic (FAO area 27). None of the correlations was statistically significant. N values (years with data) are indicated. Survey short names indicate the fishery subarea or division, the gear (Tr = bottom trawl (unspecified), GOV = GOV trawl) and the month(s) in which the survey occurred.

	7d Tr Jul–Aug	7g GOV Nov–Dec	8abd Tr Jul–Aug	9aS Tr Mar	9aS Tr Nov
4 Tr Jan–Feb (N=13)	–0.402	0.276	0.427	–0.188	0.079
7d Tr Jul–Aug (N=28)		–0.595	–0.409	0.185	–0.232
7g GOV Nov–Dec (N=10)			0.100	–0.190	0.013
8abd Tr Jul–Aug (N=24)				0.018	0.164
9aS Tr Mar (N=25)					0.031
9aS Tr Nov (N=23)					

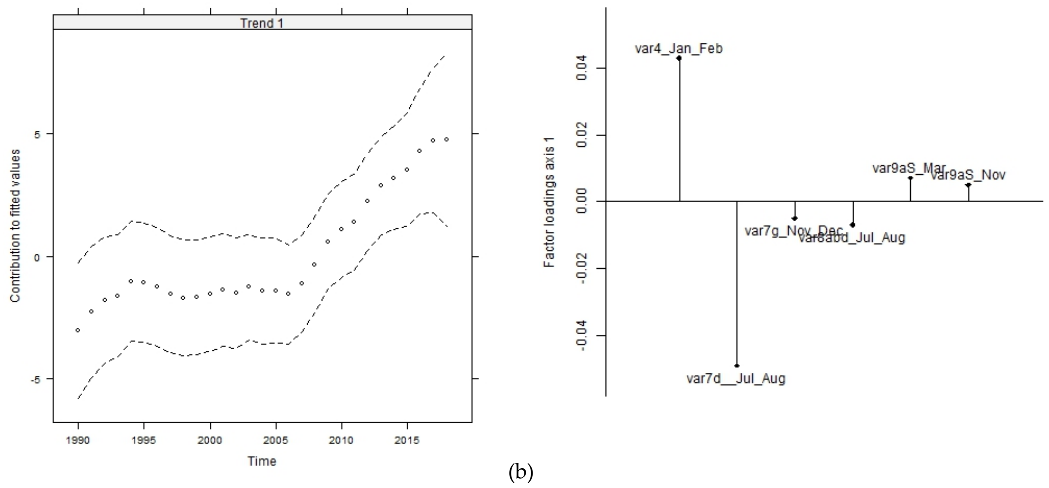


Figure 2.4 DFA results for Northeast Atlantic survey CPUE (kg/effort) series for cuttlefish: (a) the fitted common trend and (b) factor loadings.

Table 2.3 Pearson correlations between standardised annual cuttlefish fishery landings series for different combinations of fishing gear and ICES fishery divisions/subdivisions around the Iberian Peninsula. Data from Portugal (2009–2018) and Spain (2009–2018 for 8c and 9aN and 1993–2018 for 9aS). Significance is indicated by * P<0.05, ** P<0.01, *** P<0.001. Shading indicates significant positive (yellow) or negative (orange) correlations. (OTB= bottom otter trawl, PS = purse-seine, MIS = mixed artisanal gears).

	Portugal								Spain				
	9aCN. MIS	9aCN. PS	9aCS. OTB	9aCS. MIS	9aCS. PS	9aSA. OTB	9aSA. MIS	9aSA. PS	8c. Traps	9aN. Traps	8c. Gill-nets	9aN. Gillnets	9aS. Traps +MIS
9aCN.OTB	–0.190	–0.093	0.106	–0.195	0.356	–0.097	–0.058	–0.462 *	–0.159	0.099	0.424	0.170	0.036
9aCN.MIS		–0.174	0.418	0.570 **	0.550 **	0.269	0.603 **	0.625 **	0.064	–0.303	–0.206	0.385	–0.041
9aCN.PS			–0.126	0.161	–0.468 *	–0.280	–0.505 *	0.023	0.286	0.426	–0.097	–0.338	0.266
9aCS.OTB				0.144	0.716 ***	0.642 **	0.585 **	0.370	0.538	0.527	0.496	–0.237	–0.050
9aCS.MIS					–0.051	–0.160	–0.052	0.463 *	0.261	–0.205	–0.350	0.236	0.275

9aCS.PS						0.645 **	0.761 ***	0.185	−0.475	−0.228	0.256	0.126	−0.033
9aSA.OTB							0.837 ***	0.361	−0.230	0.123	0.107	−0.390	0.203
9aSA.MIS								0.566 **	−0.465	−0.147	0.225	−0.091	0.167
9aSA.PS									0.564	0.459	−0.072	−0.332	0.136
8c.Traps										0.451	0.039	−0.180	−0.257
9aN.Traps											0.576	−0.603	0.453
8c.Gillnets												0.101	0.606
9aN.Gillnets													−0.281

Comparison of trends in cuttlefish landings per unit effort for different fishing gears and fishery divisions/subdivisions in Iberian and English Channel waters

Landings per unit effort (LPUE) series were available for divisions 8c and for trawls in the various subdivisions of 9a, as in the previously described analysis but excluding the Portuguese data from purse-seines and mixed artisanal gears. The series from 7de is an abundance index provided by Cefas, based on combined monthly trawl LPUE values running from July of the previous year to June (Table 2.4). The only significant correlations were between the trawl LPUE values for the Portuguese subdivisions of division 9a.

Table 2.4 Pearson correlations between standardised annual cuttlefish fishery LPUE series for different combinations of fishing gear and ICES fishery divisions/subdivisions around the Iberian Peninsula and the English Channel. Data from Portugal (2009–2018), Spain (2009–2018 for 8c and 9aN and 1993–2018 for 9aS) and the UK (annual abundance index (AI) from 7de derived from monthly trawl LPUEs from the previous July through to June). Significance is indicated by * P<0.05, ** P<0.01, *** P<0.001. Shading indicates significant positive (yellow) or negative (orange) correlations. (OTB= bottom otter trawl).

	9aCS_OTB	9aSA_OTB	8c_Traps	9aN_Traps	8c_Gillnets	9aN_Gillnets	9aS_Trawls	7de_AI_Trawls
9aCN_OTB	0.309	0.385 *	0.440	0.131	−0.121	−0.023	0.226	0.115
9aCS_OTB		0.549 **	0.539	−0.115	0.205	0.493	0.061	−0.092
9aSA_OTB			−0.120	0.002	−0.268	−0.452	0.352	0.080
8c_Traps				0.342	0.123	−0.152	−0.366	−0.318
9aN_Traps					0.573	−0.479	0.449	0.115
8c_Gillnets						0.253	0.500	0.216
9aN_Gillnets							0.051	0.346
9aS_Trawls								0.154

2.3.4 Results for loliginid squid

Common trends across areas for loliginid landings data

As for cuttlefish, we first analysed the fishery landings data by division, as supplied to WGCEPH (N=19 years of data). Results of correlation analysis of the (Table 2.5) indicate some strong correlations between divisions that are adjacent to each other, which is the case for divisions 4a with 4b, 4c with 7de, 6a with 7a and 7bc and 7a with 7f and 7ghjk (those marked in red in the table). In addition, there were some positive correlations between northern areas (4a, 5b, 6b), and negative relationships between trends in the North Sea (4a, 4b, 4c) and those in divisions 7a, 7f, 7ghj and 8abcd. The caveat that some series are autocorrelated should be borne in mind when interpreting the significance of these correlations.

In the DFA of standardised series of Loliginidae landings for all areas, the best model (with the lowest AIC) contained three common trends. Trend 1 shows an increase in Loliginidae landings over time and factor loading indicate that this was strongly (positively) influenced strongly by the series for division 6b (Rockall) Loliginidae landings, which are known to be almost exclusively *Loligo forbesii*. This increase also likely reflects a surge in fishing activity by the Irish fleet at Rockall in recent years. Trend 2 shows an increase from around 1999 to 2007, followed by a slight decrease to 2010. This trend is mainly influenced by series from division 4b (positive relationship) and 7a (negative relationship). Trend 3 shows two peaks around 1996 and 2011 which is followed by a downward trend towards present day. The factor loadings show that this trend is largely driven by series from divisions 5b and 7bc (positive relationships), as well as 4c (negative relationship) (Figure 2.5). The first common trend clearly differs to that for cuttlefish but is strongly related to the loliginid series for division 6b, a division which probably has a negligible cuttlefish catch (amalgated wih 6a in the cuttlefish data).

Table 2.5 Pearson correlations between standardised annual long-finned (loliginid) squid landings series 2000–2018 for different ICES fishery divisions in the northeast Atlantic (FAO area 27). Significant correlations are shown in bold. The correlations marked in red reflect strong correlations between adjacent divisions.

	SQZ_3a	SQZ_4a	SQZ_4b	SQZ_4c	SQZ_5b	SQZ_6a	SQZ_6b	SQZ_7a	SQZ_7bc	SQZ_7de	SQZ_7f	SQZ_7ghjk	SQZ_8abcd	SQZ_9a	SQZ_10a
SQZ_3a	**1.00**	0.15	0.06	**-0.48**	0.16	0.25	0.03	0.00	-0.12	0.05	-0.07	0.28	0.27	0.34	-0.40
SQZ_4a	0.15	**1.00**	**0.65**	0.11	**0.41**	-0.22	**0.46**	**-0.57**	0.01	0.22	**-0.52**	**-0.53**	0.01	-0.13	0.25
SQZ_4b	0.06	**0.65**	**1.00**	0.01	0.02	-0.19	0.08	**-0.43**	-0.18	0.35	-0.24	**-0.71**	-0.06	0.01	0.12
SQZ_4c	**-0.48**	0.11	0.01	**1.00**	0.04	-0.04	-0.26	0.05	-0.04	**0.62**	-0.16	-0.19	**-0.43**	0.12	-0.03
SQZ_5b	0.16	**0.41**	0.02	0.04	**1.00**	0.19	0.29	-0.21	0.25	0.07	-0.39	0.20	-0.06	-0.01	0.15
SQZ_6a	0.25	-0.22	-0.19	-0.04	0.19	**1.00**	-0.25	**0.73**	**0.63**	0.23	**0.43**	**0.68**	0.02	**0.45**	0.00
SQZ_6b	0.03	**0.46**	0.08	-0.26	0.29	-0.25	**1.00**	**-0.44**	0.06	**-0.49**	-0.27	-0.12	0.14	-0.28	**0.47**
SQZ_7a	0.00	**-0.57**	**-0.43**	0.05	-0.21	**0.73**	**-0.44**	**1.00**	0.32	0.09	**0.67**	**0.61**	-0.12	**0.49**	-0.11
SQZ_7bc	-0.12	0.01	-0.18	-0.04	0.25	**0.63**	0.06	0.32	**1.00**	-0.06	0.12	0.35	-0.07	0.05	0.17
SQZ_7de	0.05	0.22	0.35	**0.62**	0.07	0.23	**-0.49**	0.09	-0.06	**1.00**	-0.04	-0.17	-0.31	0.15	-0.19
SQZ_7f	-0.07	**-0.52**	-0.24	-0.16	-0.39	**0.43**	-0.27	**0.67**	0.12	-0.04	**1.00**	0.31	0.01	0.05	0.13
SQZ_7ghj	0.28	**-0.53**	**-0.71**	-0.19	0.20	**0.68**	-0.12	**0.61**	0.35	-0.17	0.31	**1.00**	0.28	0.31	-0.10
SQZ_8ab	0.27	0.01	-0.06	**-0.43**	-0.06	0.02	0.14	-0.12	-0.07	-0.31	0.01	0.28	**1.00**	-0.09	-0.12
SQZ_9a	0.34	-0.13	0.01	0.12	-0.01	**0.45**	-0.28	**0.49**	0.05	0.15	0.05	0.31	-0.09	**1.00**	-0.12
SQZ_10a	-0.40	0.25	0.12	-0.03	0.15	0.00	**0.47**	-0.11	0.17	-0.19	0.13	-0.10	-0.12	-0.12	**1.00**

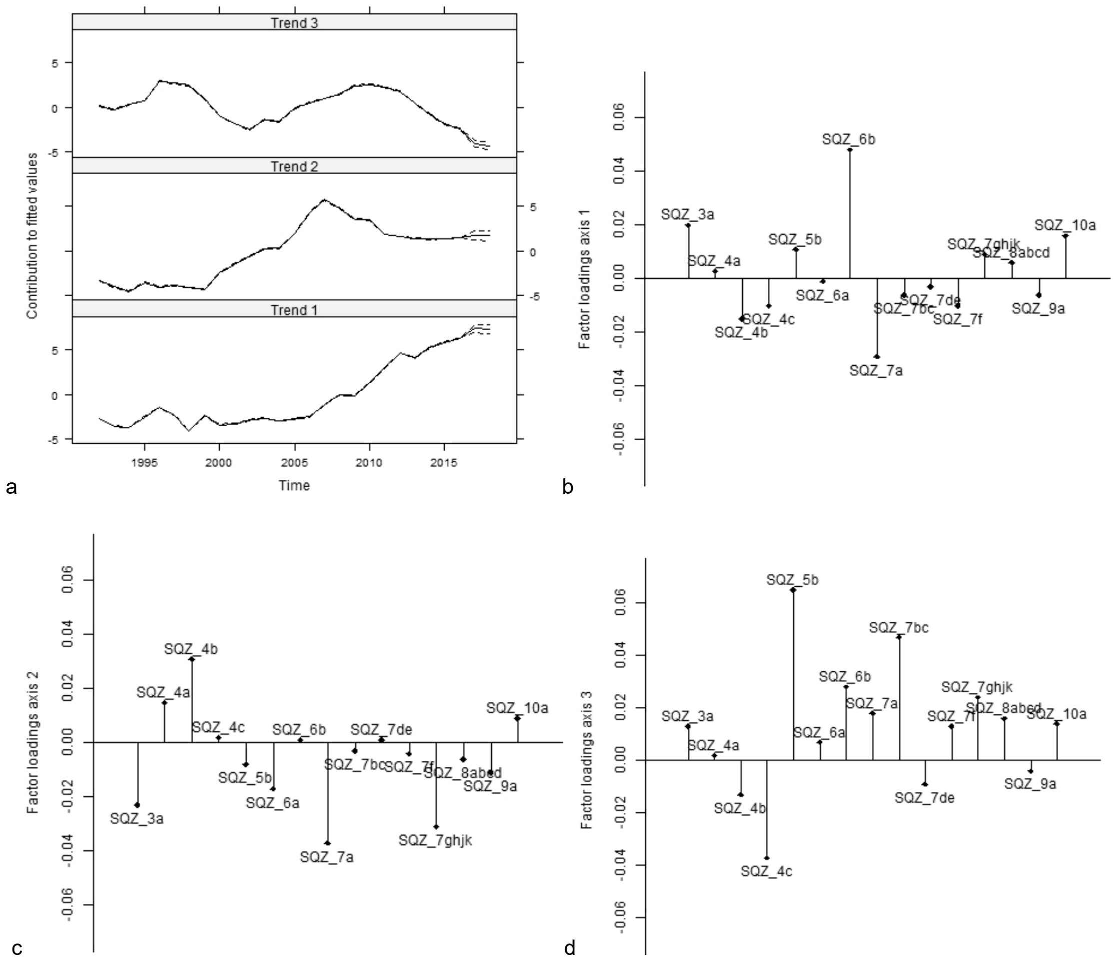


Figure 2.5 DFA results for Northeast Atlantic fishery landings series for loliginid squid: (a) the fitted common trends, (b) factor loadings for trend 1, (c) factor loadings for trend 2 and (d) factor loadings for trend 3.

Adding environmental explanatory variables resulted in a better fit (lower AIC) and resulted in a single trend, strongly positively influenced by division 6a but also negatively influenced by divisions 7a and 10a (Figure 2.6.).

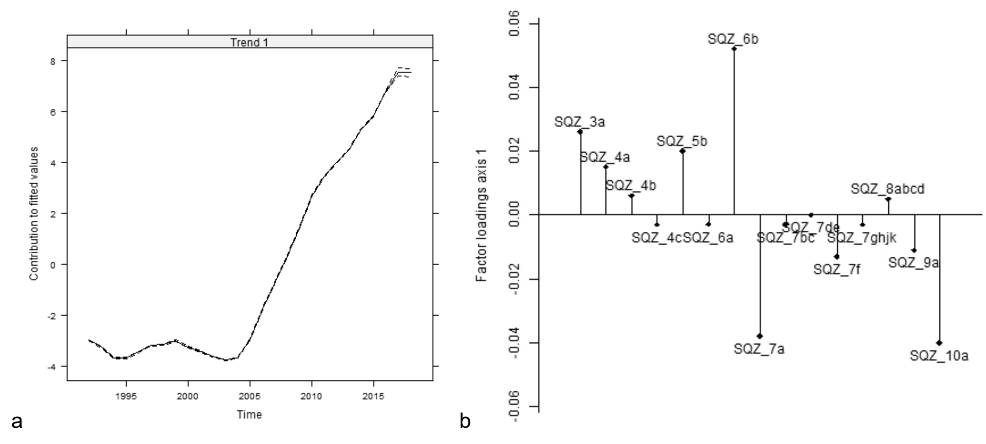


Figure 2.6 DFA results for Northeast Atlantic fishery landings series for loliginid squid with added environmental explanatory variables: (a) the fitted common trend, (b) factor loadings for the common trend.

Of the environmental variables included (North Atlantic (NA) SST, Global SST, North Sea (NS) SST and Northeast Atlantic (NEA) SSS, SBT, Chl-a and dissolved oxygen (DOx) (annual mean of subareas 6, 7 and 8), plus annual NOA and NOA (t-2)), all had significant effects except global SST and NAO (t-2). Specifically, NA SST has an effect on Loliginidae landings in divisions 7a and

7ghjk, NS SST has an effect on division 4c, annual NAO has an effect on 7bc, NEA Chl-a has an effect on 7f and 10a, DOx has an effect on 9a, NEA SSS has an effect on 3a, 4a, 4c, 5b, 6a, 6b, 7bc, 7ghjk and 10a and NEA SBT has an effect on 8abcd. However, further exploration using GAMM for landings series and the environmental series affecting them revealed few strong relationships. The following GAMMs included significant terms (n.s. = 0 non-significant) (see also Figure 2.7):

- Landings 7avs.NA SST (negative, P<0.0001)
- Landings 7bsvs.NAO (positive, P=0.0004) and NEA SSS (negative, P<0.0001)
- Landings 7ghjk *vs.* NA SST (negative, P=0.0010) and NEA SSS (n.s.)

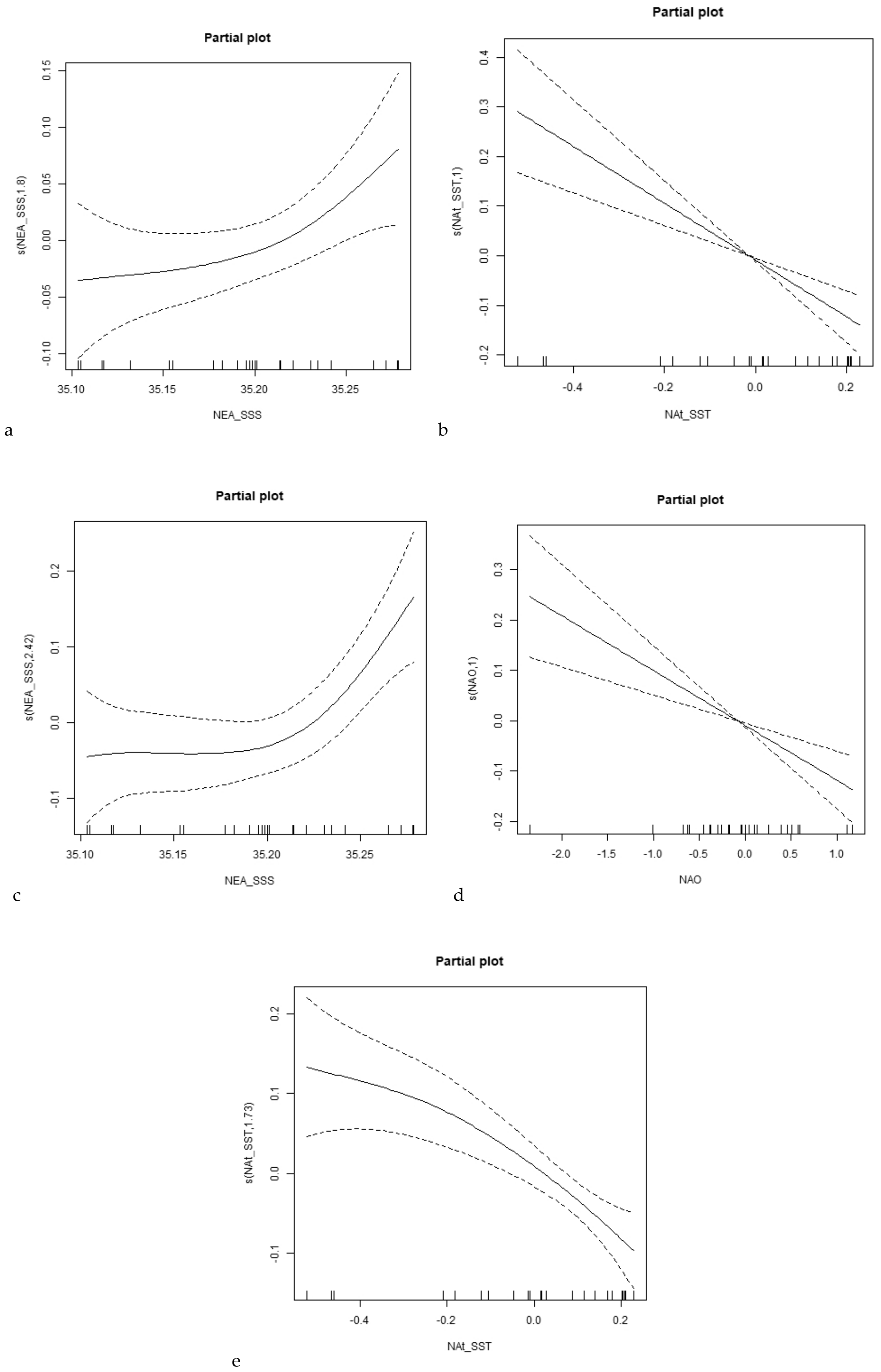


Figure 2.7 Smoother plots for the effect of environmental variables on standardised annual loliginid landings series: (a) 6a *vs.* NEA SSS, (b) 7a *vs.* NA SST, (c) 7bc *vs.* NEA SSS, (d) 7bc *vs.* NAO, (e) 7ghjk *vs.* NA SST.

2.3.5 Results for ommastrephid squid

Common trends across areas for ommastrephid landings data

As for cuttlefish and loliginid squid, we first analysed the fishery landings data by division, as supplied to WGCEPH (N=19 years of data) and standardised by dividing by the maximum value. Eight of these series included ommastrephid landings data for at least 5 years and the other (shorter) series were dropped from the analysis. DFA indicated that a model with two common trends provided the best fit. Trend 1 was generally upwards while trend 2 showed a decrease until around 2006 and a subsequent increase after 2011. Trend 1 was strongly positively related to landings from divisions 7de and to a lesser extent divisions 4c and 7f–k. Trend 2 was positively related to landings from divisions 7f–k and 9a and negatively relate to divisions 7bc (Figure 2.8).

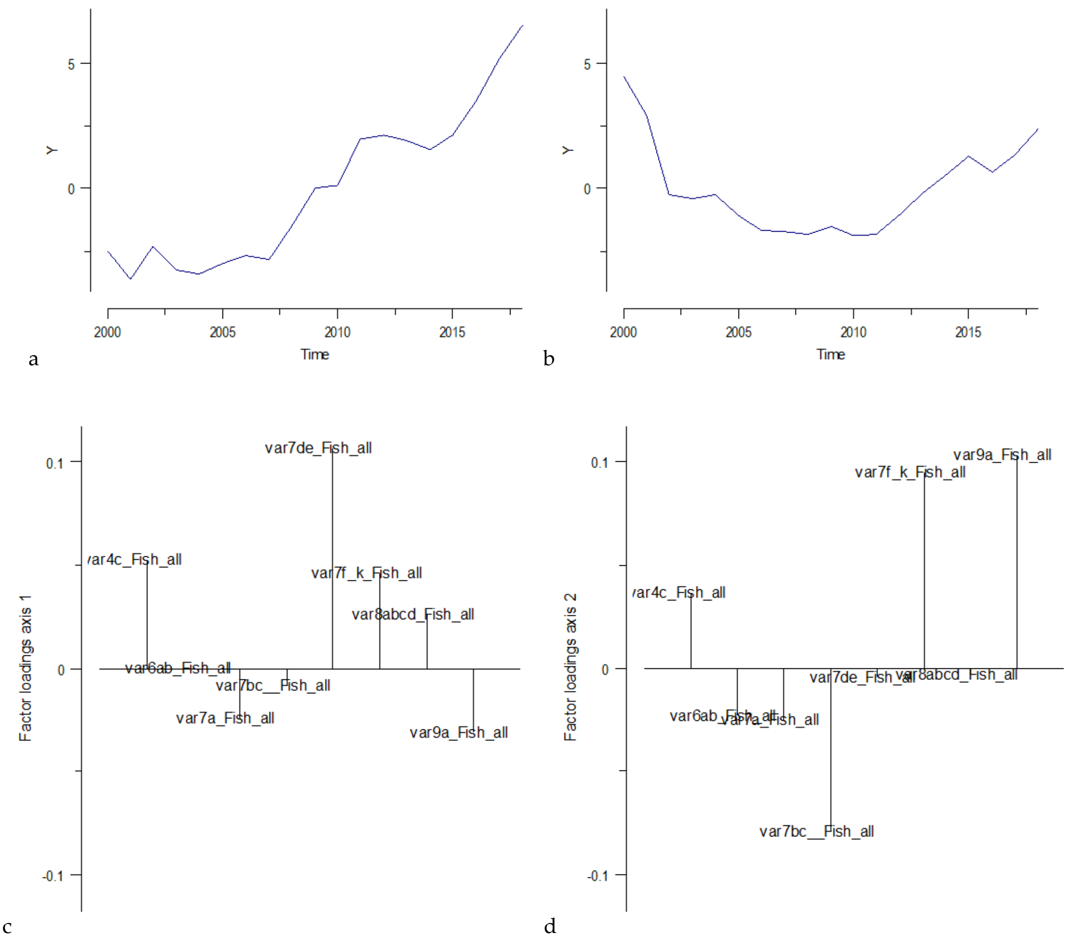


Figure 2.8 DFA results for Northeast Atlantic fishery landings series for ommastrephid squid: (a) common trend 1, (b) common trend 2, (c) factor loadings for trend 1, (d) factor loadings for trend 2.

Further exploration showed that landings from subarea 8 were related to NAO_{t-2} (i.e. the annual NAO, lagged by two years. A GAMM confirmed this relationship was significant (P<0.0001) and that landings declined at hight NAO_{t-2} values (Figure 2.9).

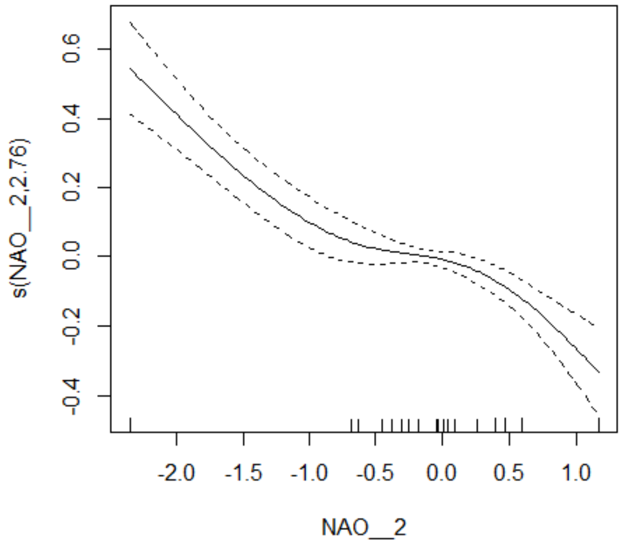


Figure 2.9 Smoother plot for the effect annual NAO (lagged by two years) on ommastrephid landings from subarea 8.

2.3.6 Results for octopus

Common trends across areas for octopod landings data

For Octopods we have the WCEPH landings series by subarea and division (2000–2018) as well as some landings series from Portugal (1992–2019). For comparability with the other groups, the DFA presented here is based on the former. Based on survey catches in each area OCT landings data may include almost exclusively *E. cirrhosa* (subareas 4, 6 and 7); mainly *O. vulgaris* with a mixture of *Eledone* spp (subareas 8 and 9) and exclusively *O. vulgaris* (subarea 10).

Correlation analysis (Table 2.6) resulted in a few significant correlations. Landings from North Sea divisions 4a, b and c were positively correlated with landings from divisions 6ab, 7g–k and 7a, respectively, while landings from divisions 6ab were negatively correlated with those from 7bc

Although the DFA with two common trends had the lowest AIC value, the difference from the AIC for the one trend model was less than 2 and we therefore retain the simpler model. The trend is mainly downwards until 2012, slightly recovering to 2015 and then declining again. The factor loadings show that this is positively related to landings from divisions 4b, 7a, 7f and 7g–k, and negatively related to divisions 7de. Subareas 8, 9 and 10 contribute little to the trends (Figure 2.10). Thus, the overall trend, rather similar to that seen in cuttlefish, if probably related mainly to *E. cirrhosa* landings. Had we not standardised the series the result may well have been different, given the high amount of *O. vulgaris* landed from subareas 8 and 9, both in absolute terms and relative to landings of *Eledone* generally.

Table 2.6 Pearson correlations between standardised annual octopod landings series 2000–2018 for different ICES fishery divisions in the northeast Atlantic (FAO area 27). Significant correlations are shown in bold.

	4b	4c	6a,b	7a	7b,c	7d,e	7f	7g–k	8	9	10
4a	0.331	–0.118	**0.831** ***	–0.023	–0.363	0.153	0.224	0.260	–0.322	0.182	–0.344
4b		0.012	0.062	0.254	–0.360	–0.325	0.381	**0.660** **	–0.261	–0.120	–0.174
4c			–0.080	**0.569** *	–0.086	–0.069	0.202	0.185	–0.208	–0.364	0.007
6a,b				–0.169	**–0.475** *	0.431	–0.061	–0.043	–0.247	–0.258	–0.322
7a					0.261	–0.429	0.297	0.253	–0.177	–0.136	0.219
7b,c						–0.289	–0.140	–0.327	0.443	0.025	0.214
7d,e							–0.310	–0.263	–0.322	0.019	–0.289
7f								0.355	–0.068	–0.330	–0.077
7g–k									–0.217	0.197	0.090
8										0.183	0.428
9											0.397

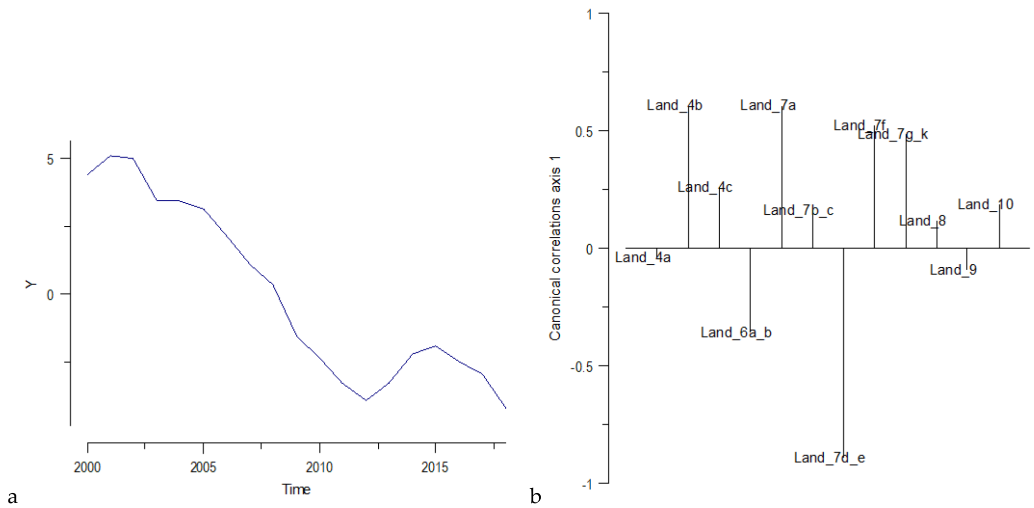


Figure 2.10 DFA results for Northeast Atlantic fishery landings series for octopods: (a) the fitted common trend, (b) factor loadings for the common trend.

2.3.7 Discussion

The results presented here are a subset of the analyses carried out but illustrate several relevant findings. Generally speaking, for each family of cephalopods, the combination of correlation analysis and DFA provides is some evidence of similar trends in landings over the last two decades across adjacent fishery divisions and both cuttlefish and octopod landings showed a general decline while trends in the two squid families were more complex. However, several caveats apply. First, fishery landings are likely to offer a valid abundance index only if there are no catch limits (which is the case) and effort is reasonably consistent. Second, by standardising, we have down-weighted the contribution to the analysis of those areas with very high abundance or landings. Furthermore, each of the families contains several species which are often not distinguished in the landings data. At least in the case of octopods, common trends seem to be driven by results from areas where *Eledone spp*. dominate landings, even if *Octopus vulgaris* is more important in terms of total amount landed. It should also be borne in mind that common trends are supported both by landings series which match them in terms of directionality and by those series which show an inverse trend. Despite all these caveats we think this is a potentially useful approach to summarize variation in abundance.

Both survey and fishery data can provide useful input to such analysis but results are likely to vary across different metiers (gear types) and, for surveys, according to the time of year when they took place and whether catch rates are expressed in termds of numbers o individuals or biomass.

DFA permits inclusion of explanatory variables, e.g. environmental variables. Where we have explored this while several environmental variables had significant effects they tended to be restricted to one of a few divisions/subdivisions, and often not those which contributed more strongly to the common trends. Evidently, some relationships will tend to be significant by chance alone: given data from ten subareas/divisions and six environmental variables and using $P<0.05$ to indicate significance, we might expect at least three combinations (i.e. 1 in 20) to show a significant relationship. Nevertheless, this again offers a useful exploratory approach.

2.4 A review of management approaches

The text in this section was written in conjunction with the Cephs and Chefs project (cephsand-chefs website) and revolves around various challenges faced in relation to introducing appropriate management for cephalopod stocks and fisheries in Europe. The original version (Pierce *et al.*, 2021) is available from the project website. The text was revised during and after the 2022 WGCEPH Meeting. It is intended that a final version will be published as a stand-alone paper.

2.4.1 Introduction

Octopus, squid, and cuttlefish are marine molluscs of the class Cephalopoda. In Europe, the most important cephalopod species for fisheries are the common octopus (*Octopus vulgaris*) in the south, and the common cuttlefish (*Sepia officinalis*) in the north. Several species of squid, as well as other cuttlefish and octopus species are also landed in significant quantities.

Global cephalopod landings have steadily increased since the 1950s and the abundance of most cephalopods also seems to be generally increasing (Doubleday *et al*, 2016). Currently, cephalopods account for around 2.5% of combined global fish and shellfish production, having increased in relative terms by 416% since 1961 to reach almost 4 million tonnes in 2013. Since then, production seems to have stabilised or fallen somewhat. East Asia and South America, led by China and Peru, respectively, have increased production the most, while production of cephalopods in Japan has halved over the last 50 years (FAO, 2020)

In Europe, cephalopods have long been considered as minor resource species. Although southern Europe has a long history of cephalopod fishing and consumption, it has been mainly through small-scale coastal fisheries under national or regional jurisdiction. Historically, cephalopod catches in large-scale commercial fisheries were sufficiently unimportant to exclude them from the European catch quota system and from the Common Fisheries Policy. Small-scale cephalopod fisheries are heavily regulated in southern Europe but the absence of stock assessment means measures could be inappropriate.

Cephalopod stocks in Europe are coming under increasing pressure from both small-scale and large-scale fisheries. Overexploitation of many commercially important finfish may have allowed "pioneer" species like cephalopods to replace them ecologically (Rodhouse and Caddy 1998; Hunsicker *et al*., 2010; Doubleday and Connell, 2018) In addition, warmer water species, including cephalopods, are shifting their ranges northwards as a consequence of climate change.

Consequently, more fishers have turned their attention towards catching cephalopods, such that previously discarded species are now landed and those previously landed as a valuable bycatch are now increasingly targeted. These trends increase the risk that, in the absence of management interventions, cephalopod fishing in Europe will become unsustainable.

This is not simply a problem for the cephalopod stocks themselves. In marine ecosystems cephalopods, especially squid, may often be keystone species, important as both prey and as predators (e.g. Gasalla *et al*., 2010, Coll *et al*., 2013, Rodhouse *et al*., 2014). In southern Europe, it is economically essential to coastal communities that these resources are not overfished. Increasing interest in cephalopod products in northern Europe offers new opportunities for fishing but hence also creates new risks for sustainability. These are all good reasons to ensure that cephalopod fishing is adequately managed.

Despite recent developments, the perception of cephalopods as minor resources persists among fisheries scientists and policy-makers, as well as northern European consumers and, to a lesser extent, northern European fishers. Another reason why the need for better management of cephalopod fisheries is not more widely recognised is the apparent resilience of these species to fishing pressure. However, although short life cycle coupled with rapid growth means that very rapid increases in stock biomass can be seen, and variable size and phenology may tend to keep some parts of the population out of harm's way, intense fishing could still overwhelm a stock's ability to replace itself (Caddy *et al*., 1983b).

Catching cephalopods in large-scale fisheries in Europe is subject to few specific restrictions. Indeed, if cephalopods are the target, certain controls (e.g. on mesh size) may be relaxed. Small–scale fisheries are, in contrast, subject to a wide array of management controls but often these are unrelated to stock status. Indeed, to the best of our knowledge, only one European cephalopod fishery is currently routinely assessed using analytical methods. Monitoring of cephalopod stocks (fishery data collection, fishery surveys) tends to be too patchy both spatially and temporally and lacks the intensity needed to support routine assessment.

The concept "sustainable fishing" has evolved in recent years to move beyond "Maximum Sustainable Yield" (MSY), with increasing focus on implementing a so-called ecosystem-based approach to monitoring assessment and management of fisheries. This encompasses the environmental impacts of fishing and the consequences of other anthropogenic stressors, the social and economic dimensions of fishing and, at least in principle, it extends through the entire seafood value chain, from net to plate. There is no "one size fits all" solution, not even at the basic level of estimating MSY because not all fish and shellfish are the same and, indeed not all cephalopods are the same. Most cephalopods taken by European fisheries are short lived and grow rapidly but deep–water cephalopods are often slow growing (e.g. the octopus *Opisthoteuthis*, which is considered vulnerable due to bycatch in deep-water trawls). In addition, species that are less mobile and/or lay their eggs on the seabed (loliginid squid, cuttlefish and octopus) are probably more vulnerable to various anthropogenic stressors than more mobile species with pelagic eggs (e.g. ommastrephid squid). In any case, emerging seafood resources present novel challenges that require novel solutions.

Cephalopods represent an essential fishery resource in Europe that is both under threat due to inaction (an absence of adequate management, reflecting both knowledge gaps and an absence of relevant policy) and at the same time, at least in some parts of Europe, has the potential to expand to help meet Europe's requirements for seafood.

This report describes a series of challenges, which need to be overcome to achieve sustainable fishing of cephalopods in European seas and, where possible, we propose solutions. For each challenge, we consider the urgency of its solution, the available and plausible solution and measures, including those already in place (drawing on examples from both within and outside Europe where appropriate), knowledge gaps and research needs, data gaps and monitoring requirements, and implementation issues and policy implications. Overall, we aim to provide a concise summary of scientific information that can help readers make informed decisions about the sustainability of cephalopod fisheries. An overview appears in Table 2.7.

Table 2.7: Challenges of managing cephalopod fishing

Problem	Urgency and relevance	Global and European examples	Measures available / in use	Research needs	Monitoring, policy, knowledge gaps
(1) High variability year-to-year in abundance	Market volatility, Need for adaptation	*Dosidicus gigas,* *Illex argentinus,* *Doryteuthis opalescens,* *Todarodes pacificus, Todarodes sagittatus*	Forecasting, recruit surveys, real time assessment and management; Diversification of fishing activity, Limit fishing effort	Tools to model variation in relation to environment (and human pressure and internal dynamics), Market studies	Better landings data; Alterative abundance indices; Better seasonal spatial monitoring of cephalopods and human pressures
(2) Stock collapses due to overfishing	Large economic consequences if it happens. Fishing pressure is increasing making it more likely, especially in short–lived species with non–overlapping generations and slow–growing species	Nautilus, probably several ommastrephid squids and *Loligo forbesii* at Rockall Bank.	Stop unregulated fishing in international waters; Better monitoring, assessment and management; Protection of spawning areas	Better understanding of stock dynamics – tease out the contributions of environmental, fishing and intrinsic drivers of abundance	Data often inadequate to judge what is happening to stock status and why; Legislative controls may be lacking in international waters
(3) Market shocks	Wide fluctuation in supply and revenue, linked to consequences of challenges 1 and 2, also Covid–19 and Brexit	50% plus drop in landings and revenues from Octopus in Galicia (Spain) between 2019 and 2020	Better forecasting and fishery management; diversification in the value chain; Improved trade statistics and traceability	Improved methods to identify the nature and origin of cephalopod products (e.g. DNA–based identification)	Need for better product labelling system and trade statistics, and enforcement thereof
(4) Varying market demand	Wide variation in consumer demand limits markets in areas of low demand and may encourage overfishing in areas of high demand	Low consumer demand in the north of Europe, high consumer demand in the south	Education of chefs, consumers and value chain actors; Development of new products to add value; Events to promote sustainable consumption		

Problem	Urgency and relevance	Global and European examples	Measures available / in use	Research needs	Monitoring, policy, knowledge gaps
(5) Lack of species ID	Errors in identification of landings Aggregation of landings into broad categories limits the value of the data	Most European cephalopod landings are identified only to family	Identification guides for fishers, fish market personnel and fishery observers; DNA barcoding	Use of imaging and AI for real–time on–board and at–market identification; Determination of most useful discriminating characteristics at family and species level, also dealing with damaged and less fresh material, investigate use of 3–d images;	Implement routine use of DNA barcoding; Training data to feed ID algorithms (multiple pictures needed per species) (plus eDNA plus habitat information); Communication and training for end–users, implementation of tools
6. Lack of stock ID including spatial structure, monitoring and assessment	Increased importance of cephalopods demands informed management	Almost all fished cephalopod stocks in Europe are not assessed and their stock structure (which may be variable) is unknown	Landings and survey catch data are available. Western Asturias octopus fishery is assessed; Many different approaches are used globally which could also be adopted in Europe	Define appropriate assessment units (pragmatic and genetic); Develop/adapt assessment methods; Define reference points	Review metiers involved in cephalopod fishing; Optimize monitoring and introduce assessment in SSF and LSF; ; Determine reference points Include cephalopods in Common Fisheries Policy
7. Absence of an ecosystem approach	As important (sometimes keystone) species in ecosystems, the wider implications of cephalopod fishing need to be assessed	This essentially applies to almost all fished stocks	Squid are included in some ecosystem models	Update information on trophic relationships including use of DNA metabarcoding; Inclusion of all cephalopod groups in ecosystem models	
8. Environmental impact of cephalopod fishing	All fishing has an environmental footprint and may cause habitat damage/loss; Some cephalopod fishing gear (e.g. cuttlefish traps) causes high egg mortality	Globally, issues include seabed damage caused by bottom trawling, discarded fishing gear, whale entanglement, dolphin bycatch, use of protected species as bait and carbon emissions. In Europe, cuttlefish traps and gillnets cause egg mortality in cuttlefish and squid	Use of more selective gears (e.g. jigs and pots); use of ceramic pots not plastic ones, avoid use of bleach, etc., to extract octopus from pots (use salt); Close cuttlefish trap mouths	Studies of habitat loss, less harmful alternatives to bleach etc. in SSF; Development of more selective gears	Need for co–management / co–creation approach; Improve bycatch reporting

Problem	Urgency and relevance	Global and European examples	Measures available / in use	Research needs	Monitoring, policy, knowledge gaps
		respectively, pots destroy *Posedonia* habitat			
9. Health risks from cephalopod consumption	Metals (cadmium) , especially in oceanic squid; Allergies, bacteria and parasites	Digestive gland and ink contain relatively high metal levels; Digestive gland is eaten in Japan; Ink is eaten in Spain	Improved traceability, Removal of more contaminated parts (digestive gland, ink)	Studies of allergens	Better monitoring of contaminants in cephalopods Improve traceability and enforcement
10. Fraud	Adding water to cephalopods is common, as are mislabelling and sales outside official channels; Sale of oceanic squid as octopus increases consumer exposure to contaminants	Squid are sold as octopus in New York. Ommastrephid squid are sold as cuttlefish in Portugal	Traceability		Better traceability, monitoring and enforcement along the value chain including improved identification of species on processed products; A legal framework that regulates the practices aimed at the incorporation of water in cephalopods should be enforced
11. Conflicts between different maritime sectors	All fisheries may be adversely impacted by other human activities, e.g. coastal SSF may be impacted by eutrophication, aquaculture, and renewable energy development.		Spatial planning and an ecosystem–based approach to fishery management EBFM; Protection of sensitive habitats (e.g. VMEs)	Deep sea and high seas cephalopod resources (e.g. ommastrephids)	Monitoring of spatial distribution of fishing activity Deep sea monitoring
12. IUU fishing	There is widespread illegal fishing globally. Fishing for cephalopods in international waters is unregulated and may have caused or contributed to recent collapses in squid fisheries.	IUU fishing is widespread in Mediterranean, Galician and Portuguese octopus. In European large–scale fisheries, there are almost no legal restrictions on cephalopod catching.	Improved traceability and enforcement. International agreements in international waters.	Traceability studies	Improved traceability and enforcement; Increase co–management especially in SSF; Implement agreements in international waters.

Problem	Urgency and relevance	Global and European examples	Measures available / in use	Research needs	Monitoring, policy, knowledge gaps
		Unregulated squid fishing takes place in the SW Atlantic; SSFs are difficult to monitor			
13. Lack of suitable management measures	Increased cephalopod catching combined with limited or unsuitable fishery management is not sustainable; There is no one–size fits all solution	Absence of specific measures in European LSF; Many measures in SSF unresponsive to stock status and difficult to monitor/enforce	Precautionary approach; Many options used globally, e.g. closed areas, protect spawners, in season controls based on on catchabiilty and depletion models; Co–management	Innovative management systems; Incorporating fisher knowledge	Need to bring cephalopods under the CFP (or equivalent). Increased co–management

2.4.2 Challenge 1. Natural highs and lows in abundance

THE PROBLEM: One of the biggest challenges to sustainable cephalopod fisheries is the high natural variability of the abundance of these resources, including the most important squid stocks in the world (Figure 2.11), reflecting their short life cycle (often only one year) and sensitivity to environmental conditions. The former explains the seasonality of abundance while the latter leads to both some variation in phenology and large year-to-year differences in abundance, with years of plenty followed by very poor years. Caddy and Gulland (1983) proposed that fisheries could be classified as steady-state, cyclical, irregular or occasional. Cephalopod stock dynamics probably span the last three categories. Roa-Ureta *et al*. (2021) argued that *Octopus vulgaris* dynamics are intrinsically cyclic while it may suggest that the dynamics of fisheries for many ommastrephid squid tend towards the irregular or even occasional, with the abundance of *Todarodes sagittatus* off Norway a possible example for the latter (Wiborg and Gjøsæter 1981). Some part of this variability is likely to be environmentally driven.

Environmental variation affects cephalopods at a range of spatial and temporal scales. Short-term variability of local abundance most likely indicates shifts in distribution, both horizontally and in terms of daily vertical migrations in some species. Over the course of a year, the life cycle is seasonal and its precise timing (the phenology) may vary between individuals (in part at due to phenotypic plasticity) as well as between years (e.g. Pierce *et al*., 2005). Year-to-year variation is likely to be a combination of changes in stock abundance and/or biomass (reflecting variation in spawning success, recruitment and growth), and the afore–mentioned shifts in distribution and phenology. Key environmental variables include temperature, and (where relevant) upwelling strength. It should be clear that some of the variation is unlikely to be predictable.

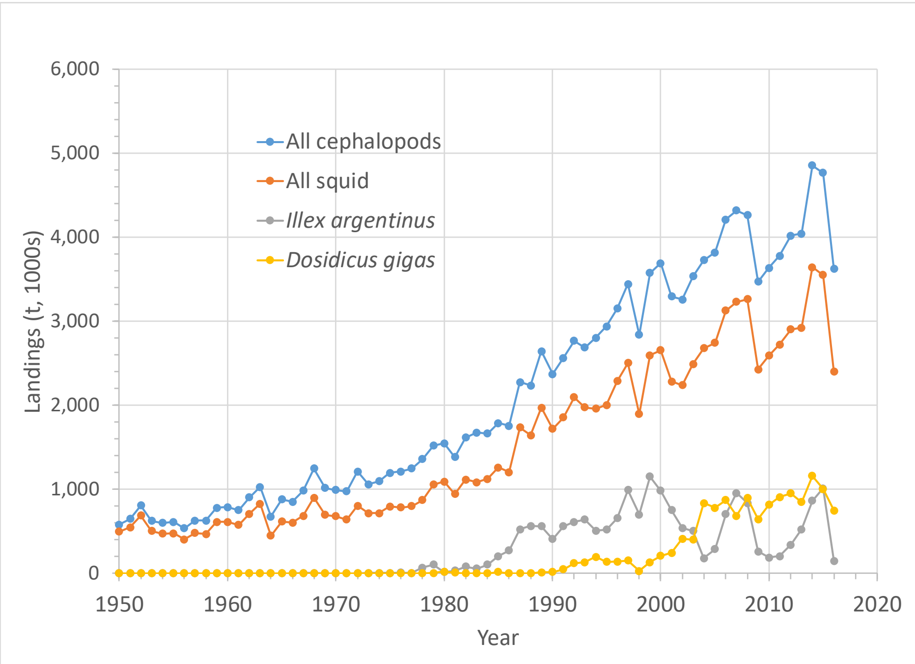


Figure 2.11 Natural variability of cephalopod abundance and evidence of stock collapse. FAO data on global landings of all cephalopods, all squid and two key squid stocks showing the marked falls in landings in 2008 and 2016.

SOLUTIONS: Fishery forecasting tools are needed to provide advance notice of changes in cephalopod abundance. This is feasible given adequate monitoring, appropriate stock assessment and a good ecological understanding of how environmental change impacts on stock dynamics (e.g. Sobrino *et al*., 2002, 2020), plus expertise in statistical and mathematical modelling. In the absence of forecasting (and recognising that it may be less than 100% successful), recruit surveys can provide an early warning of low abundance, and real-time monitoring of stock status, which has the added advantage of integrating effects of fishing mortality, can help managers decide how much effort should be deployed to catch cephalopods.

Risk-awareness, adaptability and diversification, including alternative options for fishers and other value chain actors during periods of low abundance, is needed to cope both with seasonal variation in catches and the less predictable ,and unavoidable, year-to-year volatility in supply. Control of fishing effort could avoid overfishing, which otherwise could exacerbate the natural fluctuations in cephalopod abundance. This could include both precautionary restrictions on licences to catch cephalopods and within-season real time assessment and management, as previously used in the *Illex argentinus* fishery in the Falklands and somewhat similar to the current regime in the western Asturias (Spain) octopus fishery (Arkhipkin *et al*., 2021, Roa-Ureta *et al.*, 2021).

FUTURE RESEARCH: Better forecasting models are needed (Moustahfid *et al*., 2021), also market studies on the best means to adapt to fluctuating supplies.

2.4.3 **Challenge 2. Stock collapse due to overfishing**

THE PROBLEM: European cephalopod stocks seem to be resilient to moderate fishing pressure, consistent with their high productivity, although, at a global scale, some slow growing cephalopods, such as nautiloids, and deep–sea species, are vulnerable to fishery–induced stock collapse (Dunstan *et al*., 2010, Lyons and Allcock 2014a, Saunders *et al*., 2017). Cephalopods which rely on habitat features such as seamounts, which suffer damage from fishing gear, are also particularly vulnerable (Lyons and Allcock, 2014b).

Resilience in stocks of short-lived, fast growing cephalopods is probably due to phenological and phenotypic plasticity, the existence of several pulses of recruitment (microcohorts) within stocks, and (sometimes) the existence of winter and summer breeding cohorts, such that both spawning and recruitment can extend over several months and some individuals always escape being caught (e.g. Boyle *et al.*, 1995). On the other hand, non-overlapping generations imply that recruitment failure represents extinction, due to the absence of any "reservoir" of older individuals. Some stocks are likely to be more susceptible than others, e.g. slow growing species (nautilus, deep-water octopus), those that are targeted rather than simply taken as bycatch, less mobile species (e.g. octopuses), species which aggregate to spawn and lay eggs on the seabed (e.g. cuttlefish, loliginid squid), small and isolated stocks (e.g. *Loligo forbesii* in the Azores and at Rockall Bank. In the latter case there has been targeted fishing on small and semi-isolated breeding groups and catches have been episodic, perhaps as groups of animals moved into the area and were fished out (Sheerin *et al*., 2022; see also section 2.1).

Stock collapses have been seen in ommastrephid squid (see Figure 2.11 above), perhaps in part explained by environmental conditions (e.g. the El Niño cycle) but very likely exacerbated by overfishing as in the case of *Illex argentinus*, which is subject to high and unregulated fishing pressure in international waters. The patterns of landings of, say, *Todarodes sagittatus* in Norway and *Loligo forbesii* at Rockall are consistent with the occurrence of one or more waves of immigration and subsequent overfishing.

SOLUTIONS: Regulation of fishing effort especially in international waters but also within EEZs, e.g. through Regional Seas Agreements, is needed to avoid stock collapses due to excess fishing pressure (see Arkhipkin *et al.,* 2022). In Europe, cephalopod stocks and fisheries should be brought under the umbrella of the Common Fisheries Policy. Better monitoring (including real-time monitoring), routine stock assessment, fishery forecasting, and management (including better enforcement) is also needed. Protection of spawning areas would also help minimize the risk of stock collapse.

FUTURE RESEARCH: Separating the environmental, fishery-induced and intrinsic components of cephalopod abundance variation is key. Modelling solutions are limited by the availability of sufficiently good and long time-series. Comparisons of exploited and unexploited stocks could provide relevant insights. Better information is needed on IUU fishing.

2.4.4 Challenge 3. Market shocks

THE PROBLEM: The value chain associated with cephalopod catching, processing and consumption is sensitive to market shocks. In addition to the global challenge presented by the natural volatility of cephalopod stocks, exacerbated by overfishing, the COVID-19 pandemic and (at least in Europe) Brexit have negatively affected cephalopod trading.

Southern European countries, Spain in particular, import fresh squid from the UK and Falkland Islands/Malvinas via well–established supply chains. Like many seafood imports from the UK, squid imports have been hit by severe delays since 31 December 2020 due to the new regulations imposed by Brexit. The cephalopod industry in Europe has also been significantly affected by the COVID-19 pandemic. Despite the designation of fishing as an essential service, there was a reduction in landings and fishing activity. For example, due to a combination of environmental conditions and COVID-19 impacts, landings of *Octopus vulgaris* in Galicia (Spain) suffered a 52% reduction (from 2100 tonnes in 2019 to 1000 tonnes in 2020), and their value also decreased by 51% (from €16.1 million to €7.8 million in the same period).

Value chain actors lack reliable data on which to base decisions. In part, this reflects the lack of disaggregation of trade statistics for cephalopod products by species. The complexity of the trade flows, along with variations in (or lack of) labelling systems and official lists of seafood trade names in different countries, can also make it difficult to accurately identify the origin (both geographical and taxonomic) of the raw material used in cephalopod products.

SOLUTIONS: As stated above, forecasting may reduce unpredictability, but it will not affect the variability. Improved fishery management could reduce variability. Producers and the value chain need to diversify to cope with lean years. Identifying changes in the balance of cephalopod supply/demand requires reliable trade statistics, in turn dependent on increasing the level of disaggregation of data on different species (facilitated by better identification of species) and better traceability, identifying the catch area and the species on product labelling.

Using DNA tests can help solve the traceability issue, especially in processed preparations where potentially identifiable anatomical features have been removed and/or multiple species are included, or in products that are made using more than one method.

2.4.5 Challenge 4. Market demand

THE PROBLEM: There is a marked difference in the frequency of cephalopod consumption between northern and southern Europe. The low consumer demand in northern European countries contrasts with the high consumption in southern Europe, as shown in a recent consumer survey, conducted as part of the Cephs and Chefs project. This represents an opportunity as much as a problem. While northern Europeans only eat them abroad, in restaurants, southern Europeans eat them frequently at home.

THE SOLUTION: In northern European countries, campaigns directed at consumers and the education of chefs would help increase knowledge of cephalopods and how to cook them, and thus encourage their (sustainable) consumption. In southern European countries (namely Portugal and Spain), the development of new products, such as smoked octopus and cuttlefish, frozen cephalopods, and ready-to-eat cephalopod meals could increase the value of cephalopods. The establishment and promotion of events directed at sustainable consumption of cephalopods (e.g. food festivals) can also promote sustainable consumption and inform the public about the socio-economic importance of these fisheries.

2.4.6 Challenge 5. Lack of species identification

THE PROBLEM: Cephalopod species are not always easy to identify, especially if damaged or not fresh (see Figure 2.12). Most catches are identified to family level. Due to this lack of species identification, the already limited monitoring data are unsuitable to assess stock status or to provide reliable catch and trade statistics. This is especially true for fishery landings data and until quite recently was also an issue for data from trawling surveys. While some countries (e.g France, Spain) carry out limited market sampling to determine the proportion of different species in catches of the different families, such results cannot be extrapolated to other areas or time-periods; these proportions are likely to vary in space, seasonally and between years.

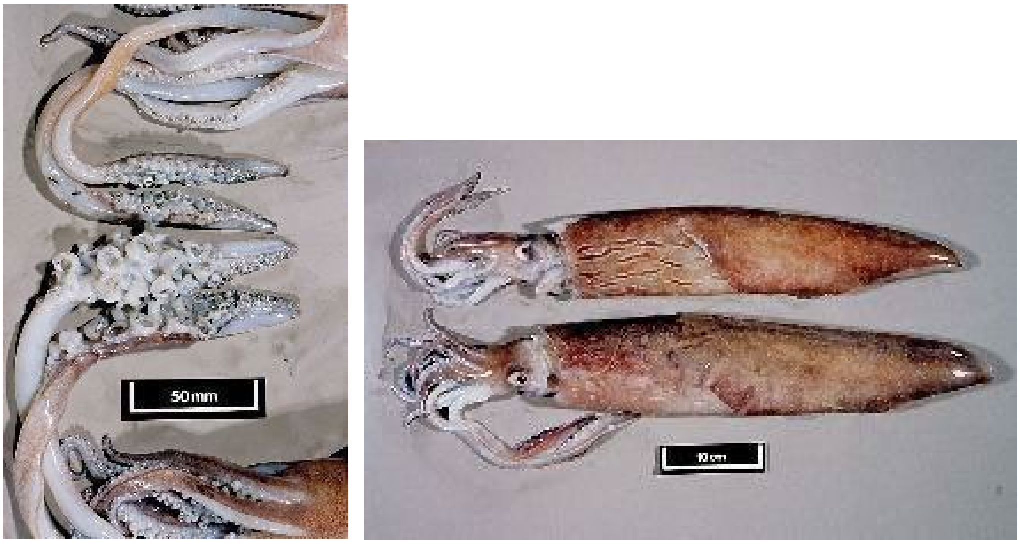


Figure 2.12 Distinguishing cephalopod species morphologically: *Loligo forbesii* (left) (formerly known as *Loligo forbesi*) and *Loligo vulgaris* (right), showing the difference in the suckers on their tentacles.

THE SOLUTION: ICES WGCEPH and UK Cefas (among other organisations) have recently produced new and updated field guides for cephalopod identification (e.g. Laptikhovsky and Ouréns, 2017). Suitable guides need to be made available to fishers, market personnel, other value chain actors and fishery observers.

Genetic barcoding can provide a rapid indication of identity and can occasionally be coupled with morphological traits to aid on–board on port-based sampling and identification (Sheerin *et al.*, in review). In relation to catches these methodologies are only useful however if coupled with sufficient regular sampling of catches to determine the proportions of the different species caught throughout Europe. Genetic barcoding should also be implemented to ensure traceability of products through the value chain, checking the identity of processed products.

Ultimately, artificial intelligence-based image analysis could provide real-time on-board and at-market identification. This requires a review of the most useful distinguishing characteristics, considering what works for damaged and less fresh specimens. Use of 3D imaging should be investigated and a library of training images will be needed.

2.4.7 Challenge 6. Inadequate stock identification, monitoring, and assessment

THE PROBLEM: Cephalopod fisheries are become more important, with an increase of cephalopod landings in many areas. In Europe cephalopod stocks are rarely formally defined geographically (including spatial structure, degree of mixing of stocks from various seas or spawning areas, etc.) and there is almost no routine stock assessment. Routine fishery monitoring lacks the intensity needed for short-lived species and the use of fishery data for assessment is limited by inadequate species identification in catches. Moreover, many standard stock assessment methods are unsuitable for cephalopods due to the short life cycles (hence non-overlapping generations) and highly variable growth rates (so that length is not a reliable indicator of age). Finally, cephalopods' geographic ranges (hence stock-location relationships) ranges are highly variable, responsive as they are to environmental drivers (e.g. Chen *et al.*, 2006, Oesterwind *et al.*, 2020).

THE SOLUTION: Recent studies show that current genetic markers do not allow for accurate classification of small-scale stock units and are therefore not suitable for the development of fisheries management, and at best can only be supportive (Göpel *et al.*, 2022, Sheerin *et al.*, 2022). We therefore recommend a multi-method approach. Studies of population spatial structure (e.g. with statolith shape analysis (Sheerin *et al.*, 2022)) and ongoing monitoring of cephalopod distributions could ensure adequate stock definition.

For squid, and to some extent cuttlefish and octopus, existing fishery surveys using trawls collect data on catches, which can help reveal changes in abundance as well as shifts in distribution and phenology, for example those related to environmental variation and climate change (Laptikhovsky *et al.*, 2022, Oesterwind *et al.*, 2022). Routine monitoring of commercial fishery catches, including sampling of biological data, on a (preferably) weekly basis during the main fishing season, would permit in-season real-time assessment of stock status to inform fishery management.

Age determination from statoliths (and other hard structures, e.g. octopus stylets) would ideally be carried out to inform microcohort analysis as this almost certainly varies throughout the geographic range and is integral to effective stock assessment. Hence, microcohort associated changes in length, age at maturity and lifespan (e.g. Challier *et al.*, 2006, Arkhipkin *et al.*, 2015) should be understood for all commercially exploited stocks.

Depletion methods of stock assessment have been successfully applied in the southwest Atlantic and in the Spanish (Asturias) octopus fishery although in the latter case these form only part of the approach used (Roa-Ureta e*t al.*, 2021). Different solutions are likely to be needed for octopus, cuttlefish and squid, and for directed vs. bycatch fisheries.

Stock status references points (e.g. for abundance and fishing mortality) need to be defined and the information on status needs to feed into appropriate management actions. The potential for use of data-poor methods (e.g. production models) to define reference points and assess stock status in species such as cephalopod has been highlighted in several recent publications (Froese *et al*., 2018; Geraci *et al*., 2021; Tsikliras *et al*., 2021).

2.4.8 Challenge 7. The absence of an ecosystem-based approach

THE PROBLEM: It is self-evident that in the absence of routine assessment and management, cephalopods are not being taken into account in the development of an ecosystem-based approach to fisheries. However, in addition to their increasing commercial importance, some cephalopods, notably squid are known to be important as both prey and predators and may be keystone species in ecosystems (e.g. Gasalla *et al*., 2010, Coll *et al*., 2013, Rodhouse *et al*., 2014). Their relative importance in foodwebs may vary between regions. Thus, in upwelling systems, squid can have bottom–up effects on their predator populations (Coll *et al*., 2013), whereas an elevated trophic position (similar to apex predators) is shown in at least some species the Arctic (Golikov *et al*., 2018), an area which is also experiencing range extensions in various species (Golikov *et al.*, 2013).

THE SOLUTION: Inclusion of cephalopods under the Common Fishery Policy would result in them being given more attention. While squid are sometimes included in ecosystem models, e.g. for the North Sea (Mackinson and Daskalov 2007), there is a need to include all the commercially important cephalopod groups and, consequently, also a need to ensure that diet information and abundance series are available. In general, more information is needed on cephalopod predators and prey, and on their relative importance within marine foodwebs, for the various European Seas. Modern techniques such as DNA metabarcoding help make this a realistic aim.

2.4.9 Challenge 8. Environmental impacts of cephalopod fishing

THE PROBLEM: Fishing for cephalopods has several adverse environmental impacts. Bottom trawling for squid, like all bottom trawling, causes damage to the seabed habitat. Bycatch of fish in directed trawling for squid appears to be quite low but whiting (*Merlangius merlangus*) has been caught in large amounts by trawlers fishing for squid in the UK (Hastie *et al*., 2009a). Traps (including those set for cuttlefish) and bottom-set-nets cause egg mortality in squid and cuttlefish due to their habit of attaching their egg masses to fixed objects on or near the seabed. In one study in the Mediterranean, traps deployed by just 15 fishers were estimated to have destroyed around three million cuttlefish eggs. In addition, contact with fishing nets damages the skin of cephalopods caught in them, reducing their chances of survival, if released alive and their value, if landed. Pots for catching octopus and métiers such as beach seining can destroy *Posedonia* habitat while chemicals used to extract octopus from pots (e.g. bleach, etc.) can harm released octopus. Globally, issues include ghost fishing, bycatch and entanglement of protected species (including whales and dolphins in the USA and South Africa), use of protected species as bait and carbon emissions. Finally, small-scale fishing activity for cephalopods, using traps, pots and other gears is generally poorly documented and, in many cases, monitoring is non-existent.

THE SOLUTION: More selective gears could reduce or eliminate environmental damage caused by the gears. Trawling for squid could be replaced by jigging, which is more selective and less damaging to the squid caught. Although commercial jigging vessels elsewhere in the world mainly target ommastrephid squid, jigging could also be used for loliginid squid. Hand jigs are commonly used to catch loliginid squid in small-scale and recreational fisheries in southern Europe. Providing artificial substrata for egg-laying, inside or in the vicinity of fishing gear, to which squid and cuttlefish can attach their eggs, may significantly reduce egg mortality due to eggs laid on the gear. In a study in the Mediterranean, placing removable ropes inside cuttlefish traps, to which the cuttlefish attached some of their eggs, permitted recovery of around 24% of eggs laid in/on the traps (Melli *et al*., 2014). Alternatively, non–baited pots could be left behind in the breeding season, to provide shelter and substrata for spawning females (Sonderblohm *et al*., 2017).

Other useful measures could include use of ceramic rather than plastic pots, avoidance of harmful chemicals to extract octopus from pots, better control of fishing effort and assuring safe disposal of fishing gear.

2.4.10 Challenge 9. Health and safety risks related to consumption of cephalopod products

THE PROBLEM: According to the European Union's Rapid Alert System for Food and Feed (RASFF Portal), risk notifications for cephalopod products include: heavy metal contaminants absorbed from the aquatic environment (e.g. cadmium, mercury); contamination by bacterial pathogens related to cold chain breach or cross-contamination (primarily *Salmonella enterica* and *Listeria monocytogenes*) and parasitic infestations (primarily nematode species such as *Anisakis* spp.). Most notifications resulting in serious actions relate to visual inspections rather than laboratory analyses. There are also notifications due to fraudulent health certificates, illegal importation or unknown quantity of products.

Although most cephalopods caught in European waters are considered safe to eat, those caught in polluted sites present a risk and even low contamination levels can be hazardous to frequent consumers.

Contaminants like heavy metals tend to be found in highest concentrations in the digestive gland (the cephalopod equivalent of the liver). This is also the part of the animal which accumulates most paralytic shellfish toxins. Contamination by bacterial pathogens can occur at various points throughout the supply chain. Parasites are problematic when edible parts are slightly cooked or consumed raw. In addition, changes in climatic and/or environmental conditions facilitate migration into European waters of non–native cephalopod species for which we have no information on contaminant concentrations or parasite burdens.

THE SOLUTIONS: The generally small risk to consumers from heavy metals (e.g. cadmium) and other contaminants in cephalopod products can be further reduced by not eating the digestive gland or other viscera (i.e. the animals should be gutted prior to consumption). The number of nematodes present in cephalopods tends to be lower than in many marine fish but the risk of ingesting nematodes can be minimised by visual inspection prior to cooking, and adequate cooking should eliminate any risk of infection or allergic reaction to nematode proteins. Seafood should always be sourced from a reputable source.

Ideally any health risks associated with seafood products should be monitored,and prevented, in the country of origin as a condition of access to EU markets, and the scope of EU risk assessment programs should be expanded to include a broader range of contaminants, pathogens and parasites among a wider range of cephalopod species. Finally, since new species migrating into European waters may not be listed in the food safety regulations, species lists should be regularly updated.

2.4.11 Challenge 10. Fraud in the value chain

THE PROBLEM: Seafood is often the target of practices that may affect product integrity, especially in species with high added value. One example of these practices is the abusive and non–reported water addition to compensate for moisture losses or to add weight. In the European Union, the labelling rules that enacted the mandatory Quantitative Ingredients Declaration allow consumers to get comprehensive information about the content and composition of food products for an informed choice while purchasing foodstuffs. In the case of seafood, the amount of added water (more than 5% of the weight of the finished product) must be included in the label of fishery products and prepared fishery products, sold either sectioned or whole. Therefore, consumers do not expect to find an amount of water in the purchased fishery product significantly higher than that stated in the label.

Octopus and squids are the most important cephalopods traded. Despite product demand, consumers often express discontent with the purchased product, in particular regarding the excessive reduction of weight/volume after cooking: it is common to end up with cooked octopus/squid reduced to less than half the purchased weight. Media and scientific reports concerning food fraud, and in particular seafood counterfeiting (a high value species is replaced by a low value one), have increased in recent years and diverse incidents to defraud the general public, restaurants, retailers, and other seafood businesses have been reported. Studies show that most cephalopod processors present in the Portuguese market, and possibly supplying other EU markets, have misleading practices that defraud the expectation of consumers, who are forced to buy octopus with high water content and see the product lose more weight while cooking.

THE SOLUTION: Improved traceability in products (including processed products) which identifies the species contents. A legal framework that regulates the practices aimed at the incorporation of water in cephalopods should be enforced together with the definition of a physico-chemical set of reference parameters in the final product to control its quality and protect consumers.

2.4.12 Challenge 11. Conflicts between different maritime sectors

THE PROBLEM: All fisheries may be adversely impacted by other human activities, e.g. coastal SSF may be impacted by eutrophication, aquaculture, and renewable energy development. Further offshore, oil and gas development, and renewable energy development (e.g. offshore wind farms), may interfere with fishing. Conversely, fishing may impact negatively on conservation objectives, especially in vulnerable areas like VMEs.

SOLUTIONS: In generic terms, maritime spatial planning and an ecosystem-based approach to fishery management offer a means to manage interactions between different sectors.

This may imply a wide range of actions including better monitoring of the distribution of fishing activity, and a governance system that explicitly addresses conflicting objectives of different maritime sectors.

2.4.13 Challenge 12. IUU fishing

THE PROBLEM: There is widespread illegal fishing globally. Fishing for cephalopods in international waters is unregulated and may have caused or contributed to recent collapses in squid fisheries. IUU fishing is widespread in Mediterranean, Galician and Portuguese octopus. In European large-scale fisheries, there are almost no legal restrictions on cephalopod catching. Unregulated squid fishing in the SW Atlantic has likely contributed to the collapses of which in 2009 and 2016 of the single most important squid fishery in the world (for *Illex argentinus)*, which represented major shocks to global cephalopod trade.

THE SOLUTION: Improved traceability and enforcement will help solve the problem of illegal fishing in Europe. In small–scale fisheries, the resources available for enforcement are limited and co-management, with the full participation of the fishing sector may be more effective.

In the SW Atlantic, an international fishery agreement is essential to avoid overfishing of squid (see Arkhipkin *et al*., 2022).

2.4.14 Challenge 13. An absence of suitable management measures

THE PROBLEM: In European waters, catching cephalopods in large-scale fisheries is essentially unregulated. Catching cephalopods is controlled only indirectly, e.g. via restrictions and catch quotas associated with fishing on non-cephalopod species. When large-scale fisheries in Europe target cephalopods there are no catch limits. In fact, fishing regulations may even be relaxed when fishers target cephalopods: e.g. trawl fishers who declare that they are targeting squid are allowed to use a smaller-sized mesh on their nets. Global cephalopod trade is heavily impacted by the volatility of catches, which is dominated by catches of a few squid species, including *Illex argentinus*, the most important squid fishery in the world, much of which is caught in international waters where no fishery agreement applies.

In small-scale fisheries targeting cephalopods, especially in southern Europe, regulatory restrictions on fishing activity are numerous but few regulations are targeted at maintaining the status of cephalopod stocks, the status is not formally assessed and the regulations are not always followed. As a specific example, the number of octopus pots in the sea in Portuguese coastal waters is thought to vastly exceed the permitted number.

Additional issues applying to cephalopod catches in most fisheries include (i) the lack of monitoring and assessment, which if carried out could facilitate informed management actions, (ii) the logistic difficulties of protecting “minor” species in mixed fisheries, (iii) biological knowledge gaps, notably about locations of spawning areas, (iv) uncertainty about the suitability of existing minimum landing size limits: in octopus, small animals caught in pots and returned to the sea will likely survive but trawl-caught cephalopods are usually damaged and might not survive release. Length at maturity tends to be highly variable, making landing size limits only partially effective.

THE SOLUTION: Evidently, adequate monitoring and assessment and research to fill knowledge gaps is needed to underpin sensible management decisions.

Where stocks remain data poor, a precautionary approach to management is needed, e.g. as implemented in Morocco (Kifani *et al*., 2005). Co-management is already implemented in some SSF and could improve compliance with regulations and help ensure that fisher knowledge is integrated into management (e.g. Rangel *et al*., 2019).

Management measures may include effort or catch limits in directed cephalopod fisheries. More selective gears, which cause less damage to individual cephalopods and the habitat, could also offer multiple benefits including lower bycatch of finfish, better survival of released animals, and increased value of catches. Some measures will be species specific. Closed areas are used in Madagascar octopus fisheries. For cuttlefish and loliginid squid, seasonal closures to protect spawning grounds would help ensure recruitment to the next generation.

Fishery Improvement Programmes (FIPs) and Certification schemes offer a route to greater sustainability, which will almost inevitably involve stock definition, monitoring assessment and management.

Cephalopod fishing in Europe needs to be brought under the Common Fishery Policy (or the equivalent), while recognising how cephalopod and finfish fisheries differ, the differences between SSF and LSF, and indeed the differences between different cephalopod species.

2.4.15 **Discussion**

Cephalopod fisheries are well established in Europe, especially small-scale fisheries in southern Europe which target octopus, cuttlefish and to a lesser extent squid. Large-scale fisheries are increasingly important for catching cephalopods, especially cuttlefish and squid, although often as a bycatch. The latter are essentially unmanaged while the former are subject to a multitude of rules but in neither case is there routine assessment and consequently management of SSF does not always respond to cephalopod stock status.

While the historical rationale for this state of affairs is clear, it is a situation that is increasingly incompatible with sustainable fishing. However, the way forward is not obvious. This is essentially a chicken and egg situation. Without management, there is no apparent need for monitoring and assessment but without monitoring and assessment there is little information to inform management.

In general terms, this is no barrier to adopting a precautionary approach to fishery management and comparison with cephalopod fisheries across the globe suggests a range of possible measures, although there is unlikely to be a “one size fits all” solution for all fished species in all fisheries.

In small-scale octopus fisheries, co-management appears to be a useful approach (Rangel *et al.*, 2019, Pita *et al*., 2021,), while one such fishery, in western Asturias, Spain, has been MSC certified and is intensively monitored, assessed using a combination of generalised depletion models and an empirical stock recruitment relationship, and closely managed (Roa-Ureta *et al*., 2021).

2.5 Cephalopods within the Marine Strategy Framework Directive

For the conservation and sustainable use of marine resources, for current and future generations, it is necessary that these resources are in a good environmental status (GES). For the monitoring, respectively the achievement of GES, the Marine Strategy Framework Directive (MSFD) came into force in 2008. Within eleven different descriptors, the EU Member States (MS) with access to marine waters are to assess or maintain the GES in their responsible waters. Although the MSFD has been in place for over a decade, important groups of animals such as cephalopods have received little attention. However, as key species, cephalopods play an important role in marine habitats; both as predators and as a food source for various elasmobranchs, teleosts, seabirds and marine mammals, and should therefore be considered in the assessment. The main reason given by MS for not considering cephalopods is the lack of relevant data or inappropriate indicators. However, diverse datasets from commercial and research based fisheries are already available and have been collected for years under coordination of the International Council for the Exploration of the Sea (ICES) for example, and can already be used for a cephalopod assessment. A subgroup of ICES WGCEPH members have reviewed how Member States deal with this taxonomic class in their reporting and identified and explained the gaps in the cephalopod assessment. They described the main challenges including the limited data and the rarity of dedicated surveys on cephalopods. However, they argue that cephalopods can partly be integrated into the EU–MSFD assessment, illustrating the current opportunities and future possibilities of their integration into the MSFD, mainly using Descriptors 1 to 4 (see Bobowki *et al.*, Accepted).

3 ToR C

3.1 Review of the impacts of human activities on cephalopods

The human impacts manuscript is in progress, initially intended for the October deadline for Marine Biology's 'Advances in Cephalopod Research' topical collection. However, due to the political situation in Russia, and as the manuscript has been contributed to by a Russian scientist (and member of WGCEPH) the paper is currently on hold until further instruction by ICES.

To date, the manuscript provides a comprehensive review of anthropogenic impacts upon cephalopods, including chemical, light and noise pollution, fishing mortality and fishing environmental impacts, habitat loss, climate change, non-native/invasive species, and offshore infrastructure. It is based around the Marine Strategy Framework Directive's (MSFD), requirement of Member States to consider 11 qualitative descriptors to assess good environmental status for marine regions. The review acknowledges cumulative effects and provides management and monitoring implications for fisheries. For the latter, monitoring of cephalopods is poor in many areas, due to the plasticity of many species and to the difficulties or infeasibilities of identifying cephalopods to species level in landings data.

3.2 Review of life history and ecology

The continuation of the review on life history and ecology of European cephalopod species by Lischchenko *et al*. (2021), WGCEPH 2022 set as a goal for ToR C to collect and examine relevant literature from the second half of 2019 onward. The species of concern for this study, which is edited by Alexandra Karatza and is intended to be published soon, are: *Eledone cirrhosa, Eledone moschata, Loligo vulgaris, Loligo forbesii, Alloteuthis subulata, Alloteuthis media, Sepiola atlantica, Octopus vulgaris, Sepia officinalis, Sepia elegans, Sepia orbignyana, Sepietta oweniana, Illex coindetii, Ommastrephes caroli, Todaropsis eblanae, Todarodes sagittatus, Gonatus fabricii* and *Rondeletiola minor*. The studied species list has been expanded in relation to the previous review with two bobtail squid species being added: *Sepiola atlantica* and *Rondeletiola minor*. Although the previous life history and ecology study of European cephalopods covered published literature up to only three years ago, the number of new publications on the subject has been quite extensive in the meantime, especially for certain species such as the ones that belong to the *Loligo* spp. group.

The issues that this review focuses on are the environmental effects, distribution, abundance, life history, ecology and innovative steps toward the species' effective fisheries management and conservation. Furthermore, for certain cephalopod species, the study also concentrates on the impact they may have had on the culture of each country.

3.3 New information on the life cycle of Eledone cirrhosa

During 2019, as part of the Atlantic INTERREG project "Cephs & Chefs", horned octopus (*Eledone cirrhosa*) were sampled from the west coast of Portugal (ICES Division 9a), based on animals caught by the Portuguese trawl fleet operating in this area, with the objective to determine the seasonality of the life cycle. Monthly biological samples were collected from January to December 2019 at the port of Aveiro (n= 664 specimens).

The *E. cirrhosa* captured in Portugal (Aveiro) showed a prevalence of females (n = 516) over males (n = 145), resulting in a significant female biased sex ratio overall (1F:0.37M, X^2=208.2, P<0.001).

The sex ratio fluctuated monthly, with significantly higher abundances of females in every month except from September to December. The analysed *E. cirrhosa* had an average mantle length and total weight of 8.90 ± 2.81 cm and 211.83 ± 180.80 g. There was clear sexual dimorphism in both mantle length and total weight, with females (9.20 ± 2.98 cm, 236 ± 194 g, n=516) reaching a larger average size than males (7.83 ± 1.70 cm, 125 ± 70.6 g, n=145).

Month to month variation in mantle length-frequency (Figure 3.1) and weight–frequency data (Figure 3.2) for females suggested that their life cycle is annual with the largest animals seen in May and June. On the other hand, in August, only small females were present. The *E. cirrhosa* males captured in Portugal (Aveiro) not only matured slightly earlier but also with a smaller body size, compared with females (Figure 3.1, 3.2), since 50% of the females were mature at 10.99 ± 0.12 cm (range of mature animals: 3.9–17 cm), while 50% of the males were mature at 10.10 ± 0.31 cm (range of mature animals: 4–11.2cm) (Figure 3.3). It is notable that males matured only when approaching their maximum mantle length.

Overall, the *E. cirrhosa* captured in Aveiro in 2019 showed a prevalence of immature animals in the sample (stages I and II, 73%), when compared to mature animals (stages III and IV, 23%). There was a clear seasonal peak in female maturity, in May and June, while almost all males were mature during March to June (Figure 3.4). In both sexes mature animals were absent from September to November.

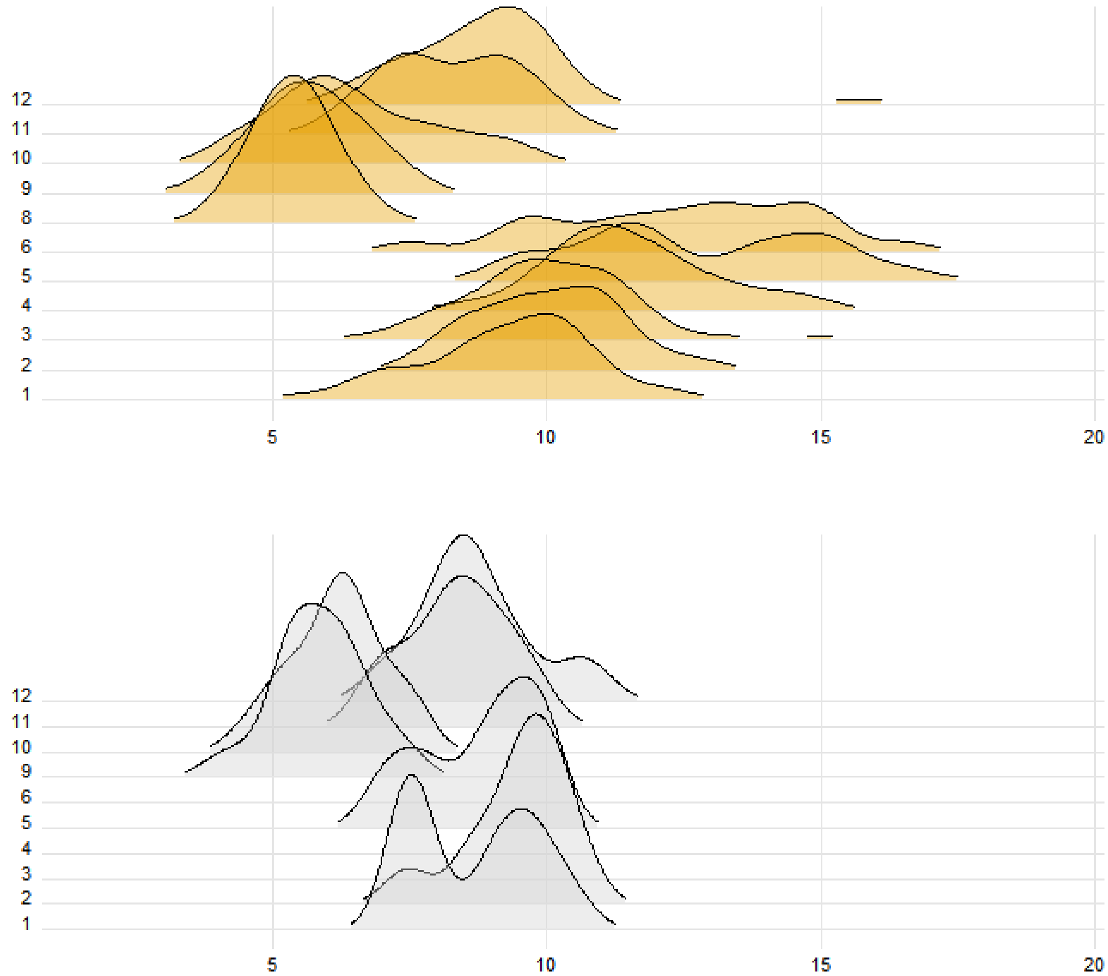


Figure 3.1 Monthly variation of length frequencies of *E. cirrhosa* captured in Portugal (Aveiro) per sex. Length is mantle length in cm. Orange: females; Grey: males. No sample could be obtained in July.

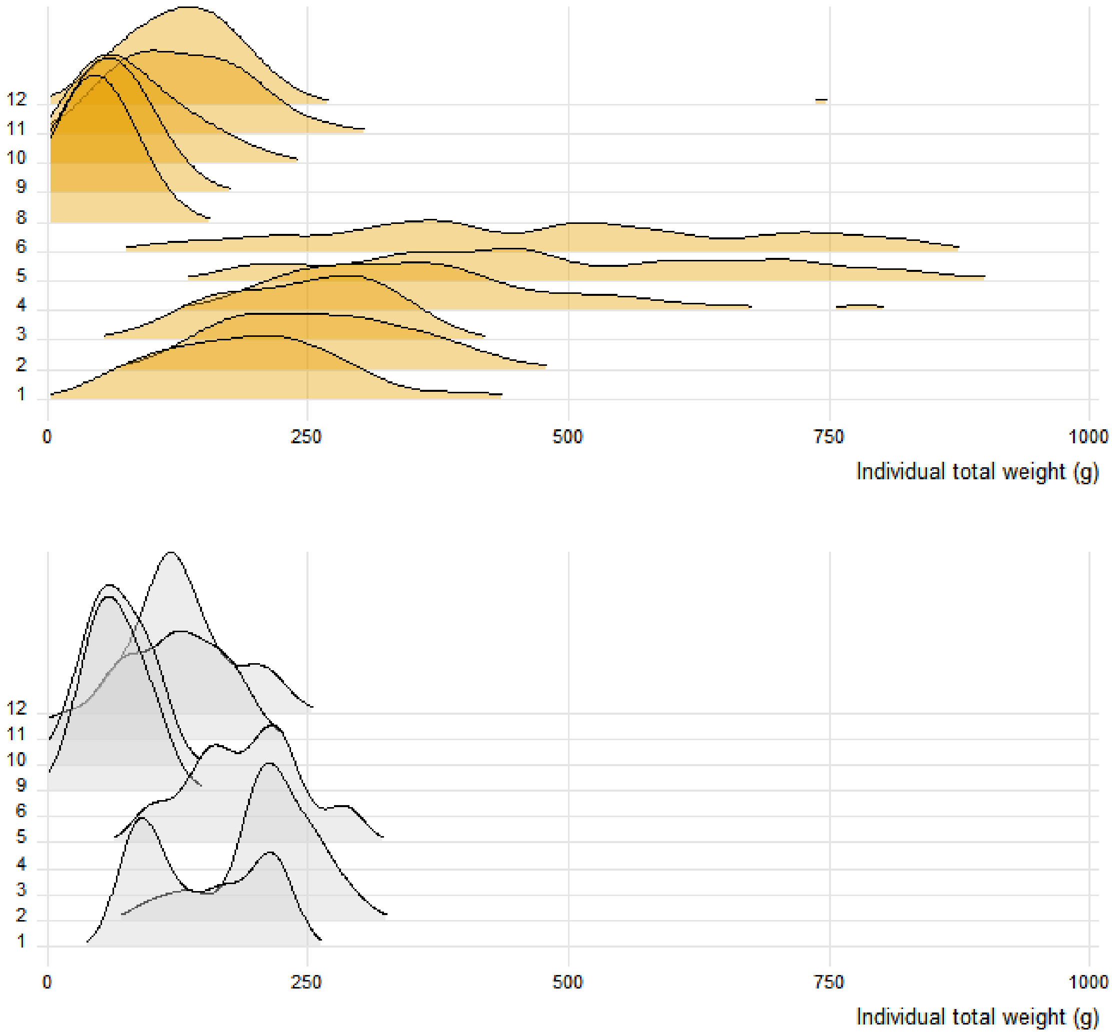


Figure 3.2 Monthly variation of weight frequencies of *E. cirrhosa* captured in Portugal (Aveiro) per sex. Weight is whole body weight in g. Orange: females; Grey: males. No sample could be obtained in July.

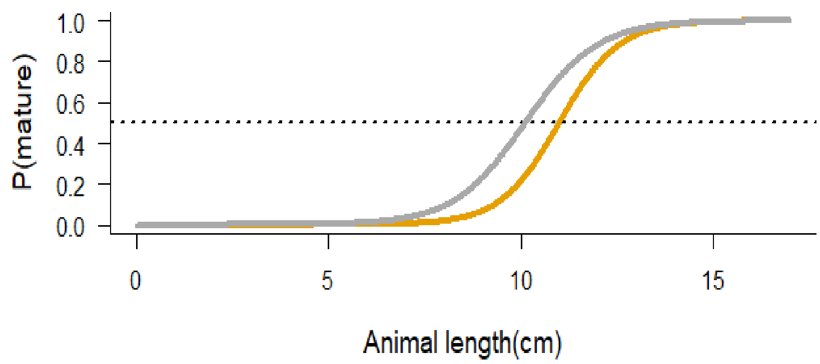


Figure 3.3 Frequency of mature individuals as a function of the mantle length for female (orange) and male (grey) individuals.

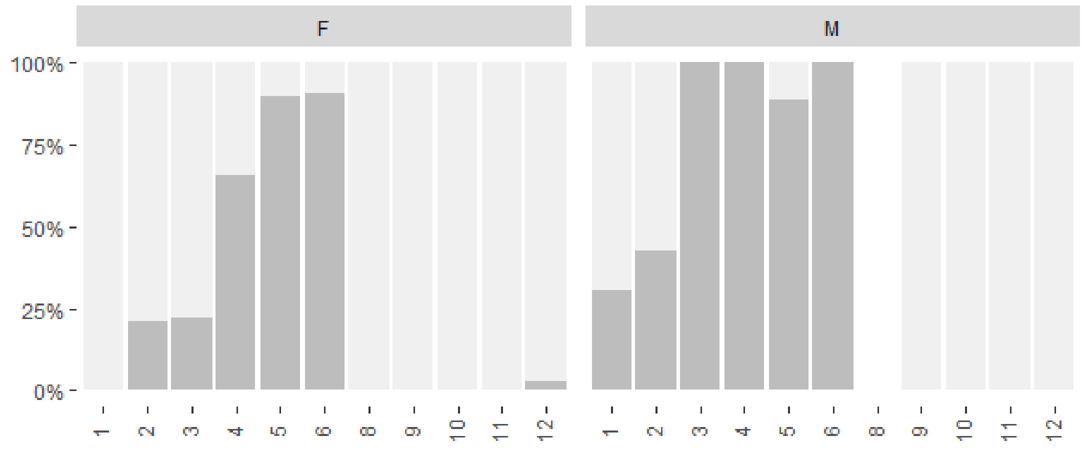


Figure 3.4 Annual maturation process of females (F) and males (M) of *E. cirrhosa* captured in Portugal (Aveiro). Light grey - immature animals (stages I and II); Dark grey - mature animals (stages III, IV and V).

4 ToR D

The background of ToR D is the inconsistent and incomplete species identification of cephalopods in fishery and survey catches. There is a need for easy to use regional ID guides (e.g. for fishers, fishery inspectors/officers, buyers and scientists undertaking sampling). Additionally, the current standard data collection is usually insufficient to support routine assessment.

4.1 Review, develop and recommend tools for cephalopod species identification

One goal was to review and update a list of the current identification guides for scientific samplings (e.g. research surveys) in different regions (see Table 4.1). The source to download texts and photos (if known), as well as their availability online have been added to the original table of the latest report (ICES, 2019). the recent barcoding results under auspices of Cephs&Chefs project were presented in 2021. They indicate that field identifications based on external morphological characters were mostly reliable, with only occasional misidentification, with the exception of *Alloteuthis* species and sepiolids that were often incorrectly identified.

The main goal was to help with species identification of landings and other commercial species by the fishery sector (e.g. fishers, fishery officers and inspectors, buyers), and by scientists undertaking sampling (e.g. at sea observers, at market samplers), by developing simple ID regional guides for fishers. Several ideas were discussed during 2020 and the agreed format of these guides was a plastic simple sheet containing for each commercial species the local common names, scientific name, photo with key features and the FAO code of the species (Figure 4.1.).

The general template was produced and the regions to be covered by the WGCEPH were established in 2021: North Sea, Arctic Ocean, Portugal mainland, Portugal Macaronesia (Azores, Madeira), Ireland, Spain north, Spain southwest, Spain Macaronesia (Canary Islands). Figure 4.2 shows the guide for the Canary Islands region as an example (composed of two pages).

The development of all the regional guides is ongoing in 2022 and planned to be finished within the next period 2023–2025.

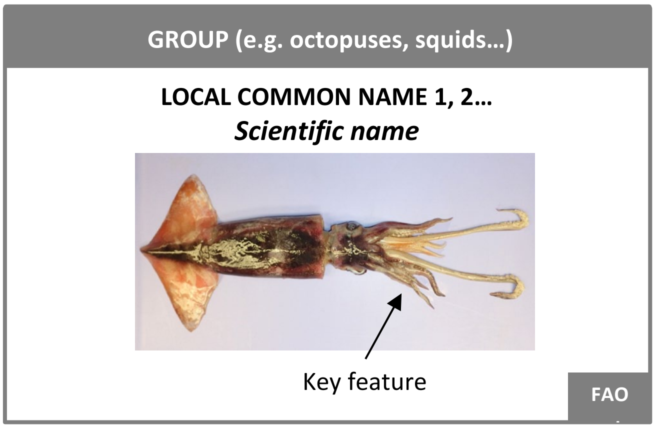


Figure 4.1 Template of information by species in the simple guides for fishers

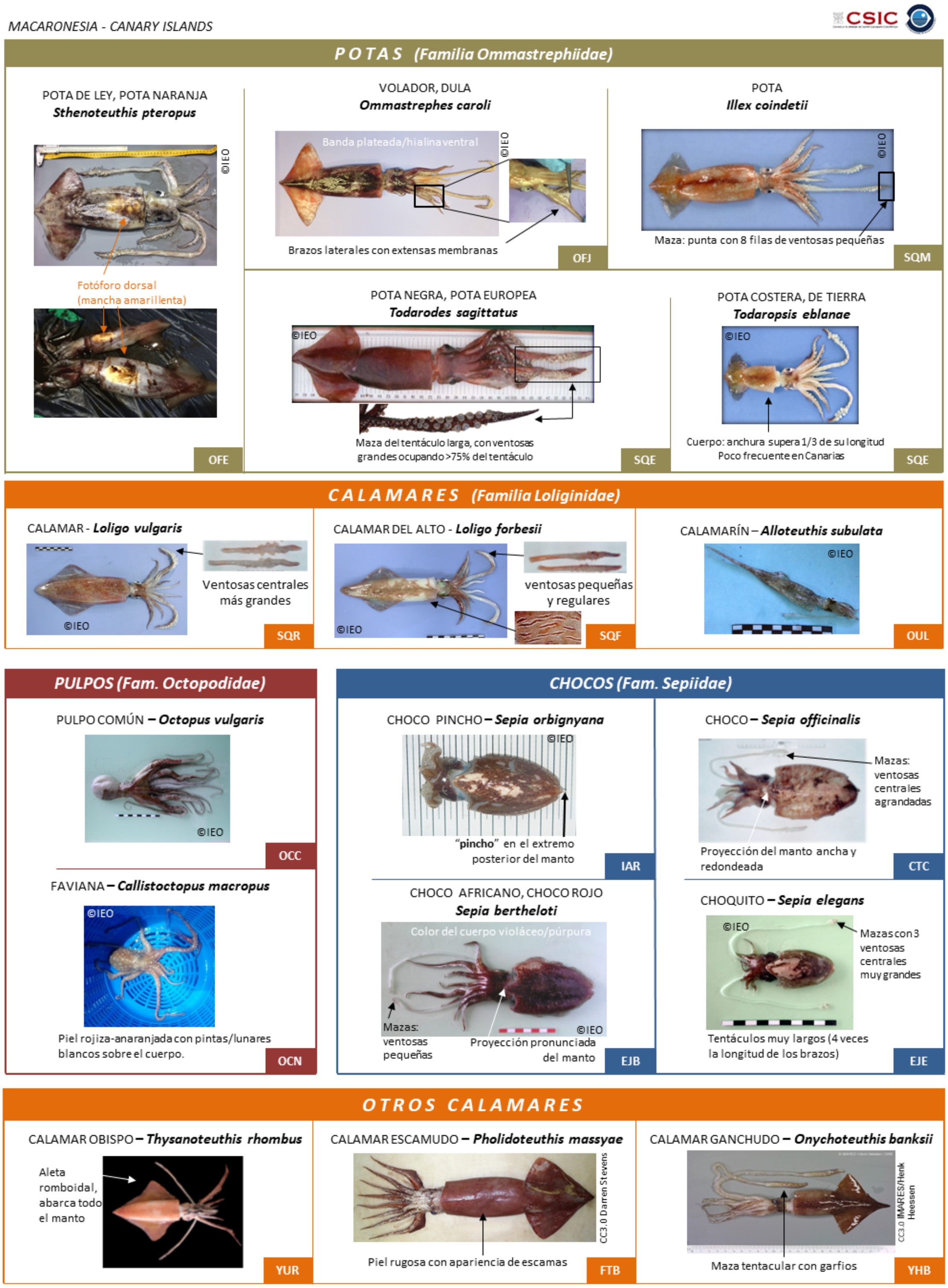

MACARONESIA - CANARY ISLANDS
CSIC
POTAS (Familia Ommastrephiidae)
POTA DE LEY, POTA NARANJA
Sthenoteuthis pteropus
©IEO
Fotóforo dorsal
(mancha amarillenta)
OFE
VOLADOR, DULA
Ommastrephes caroli
Banda plateada/hialina ventral
©IEO
Brazos laterales con extensas membranas
OFJ
POTA
Illex coindetii
©IEO
Maza: punta con 8 filas de ventosas pequeñas
SQM
POTA NEGRA, POTA EUROPEA
Todarodes sagittatus
©IEO
Maza del tentáculo larga, con ventosas
grandes ocupando >75% del tentáculo
SQE
POTA COSTERA, DE TIERRA
Todaropsis eblanae
©IEO
Cuerpo: anchura supera 1/3 de su longitud
Poco frecuente en Canarias
SQE
CALAMARES (Familia Loliginidae)
CALAMAR - Loligo vulgaris
Ventosas centrales
más grandes
©IEO
SQR
CALAMAR DEL ALTO - Loligo forbesii
ventosas pequeñas
y regulares
©IEO
SQF
CALAMARÍN – Alloteuthis subulata
©IEO
OUL
PULPOS (Fam. Octopodidae)
PULPO COMÚN – Octopus vulgaris
©IEO
OCC
FAVIANA – Callistoctopus macropus
©IEO
Piel rojiza-anaranjada con pintas/lunares
blancos sobre el cuerpo.
OCN
CHOCOS (Fam. Sepiidae)
CHOCO PINCHO – Sepia orbignyana
©IEO
"pincho" en el extremo
posterior del manto
IAR
CHOCO – Sepia officinalis
Mazas:
ventosas
centrales
agrandadas
Proyección del manto ancha y
redondeada
CTC
CHOCO AFRICANO, CHOCO ROJO
Sepia bertheloti
Color del cuerpo violáceo/púrpura
Mazas:
ventosas
pequeñas
©IEO
Proyección pronunciada
del manto
EJB
CHOQUITO – Sepia elegans
©IEO
Mazas con 3
ventosas
centrales
muy grandes
Tentáculos muy largos (4 veces
la longitud de los brazos)
EJE
OTROS CALAMARES
CALAMAR OBISPO – Thysanoteuthis rhombus
Aleta
romboidal,
abarca todo
el manto
YUR
CALAMAR ESCAMUDO – Pholidoteuthis massyae
CC3.0 Darren Stevens
Piel rugosa con apariencia de escamas
FTB
CALAMAR GANCHUDO – Onychoteuthis banksii
CC3.0 IMARES/Henk Heessen
Maza tentacular con garfios
YHB

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Table 4.1 Updated list of guides to cephalopod identification (this list excludes guides focused solely on the beaks)

Year	Institution, Country	Contact	Language	Title	Author(s)	Geographical focus	Photos / drawings	Comments	Source of text / photos (if known)	Physical format	Availability
2022	Springer Nature	Erica Vidal, Liz Shea, Heather Judkins	English	Cephalopod early–life stages: an identification handbook	Erica Vidal, Liz Shea, Heather Judkins (Editors)	World Ocean	Photos and drawings	Book with Open Access and printed version focused on cephalopod early–life stages identification worldwide	Several authors from research institutions worldwide	Paper/ Digital	Forthcoming
2019	ICES, Cephs&Chefs Project	Anne Marie Power NUI Galway, Ireland	English	Ireland Cephalopod Reports (The Cephalopod Citizen Science Project) e	Michael Petroni, Anne Marie Power, Ana Moreno, Gavan Cooke, Morag Taite & Halldis Ringvold	North East Atlantic	Photos	It is intended for fishery observers, fishers and divers, particularly with inshore fisheries involving static gear such as traps and pots	Several authors from research institutions and WG CEPH	Digital/Internet	Facebook https://www.facebook.com/groups/2368983596723970/?mibextid=HsNCOg
In prep	Thünen, GEOMAR, Germany	Daniel Oesterwind, Uwe Piatkowski, Anne Sell	German	Cephalopod Guide for the North Sea	Daniel Oesterwind, Uwe Piatkowski, Anne Sell	North Sea	Photos and drawings	Final version expected in summer 2020	Own photos and drawings		Forthcoming
2019	Icelandic Institute of Natural History, Iceland	Alexey Golikov	Icelandic / English	?	A Golikov, RM Sabirov, G Gudmundsson	Iceland	Drawings	Derived from Jereb and Roper, 2010, mainly	Iceland	Digital	http://www.ni.is/biota/animalia/mollusca/cephalopoda
2019	University of Algarve, Portugal; Anglia Ruskin University, UK	Christian Drerup, Gavan Cooke	English	Cephalopod ID Guides for the North Sea, North–East Atlantic and Mediterranean	Christian Drerup, Gavan Cooke	North Sea, North–East Atlantic, Mediterranean	Drawings and photos	From the project: “Cephalopod Citizen Science”	Several e.g.: ICES CRR 325; FAO	Paper / digital	http://drg-mcooke.co.uk/wp–content/uploads/2019/03/

2019	Tree of Life project	R.E. Young, M. Vecchione, K.M. Mangold	English	http://tolweb.org/Cephalopoda/19386	Different authors, depend on group/species	World Ocean (including ICES area)	Drawings and photos	Open source, in development, only digital version	Partly own, partly taken from other sources	Digital	http://tolweb.org/Cephalopoda/19386
2017	CSIC, Spain	Fernando Fernández–Alvarez, Roger Villanueva	English	Towards the identification of ommastrephid squid paralarvae: morphological description of three species and a key to the north–east Atlantic species	Fernández–Alvarez *et al.*	North–East Atlantic	Drawings and photos	Research paper	Published	Digital	http://doi.wiley.com/10.1111/zoj.12496
2017	Instituto de Ciencias del Mar, Spain	Fernando Fernandez –Alvarez, Roger Villanueva	English	Towards the identification of the ommastrephid squid paralarvae (Mollusca: Cephalopoda): morphological description of three species and a key to the north–east Atlantic species	Fernando Fernandez–Alvarez, Catarina Martins, Erica Vidal, Roger Villanueva	Northeast Atlantic	Drawings and photos	Focused on ommastrephid paralarvae	Own photos, drawings based on various cited published sources	Digital	Zoological Journal of the Linnean Society 180 (2), 268–287
2017	Cefas, UK	Chris Lynam, Vlad Laptikhovsky	English	Identification guide for shelf cephalopods in the UK waters (North Sea, the English Channel, Celtic and Irish Seas)	Vladimir Laptikhovsky and Rosana Ourens	North Sea, English Channel, Celtic and Irish Seas, Scotland	Drawings and photos	Guide for the shelf and upper slope cephalopods of the area, depth < 400 m	Photos/drawings from ICES, FAO and individual authors. Copyright agreed.	Paper / digital	http://www.nmbaqcs.org/media/1717/cephalopod–guide–150917.pdf
2015	IFREMER, France	Pascal Laffargue	French	Fiches d'aide à l'identification Poissons, céphalopodes et décapodes mer du Nord, Manche, Golfe de Gascogne et mer Celtique (Version 2015)	F. Garren, S.P. Iglesias, J.C. Quéro, P. Porche, J.–J. Vayne, J. Martin, Y. Verin, J.–L. Dufour, L. Metral, D. Le Roy, E. Rostiaux, S. Martin, K. Mahe	Bay of Biscay, Celtic Sea, Channel, North Sea	Photos and drawings	Guide for cephalopods and fish species. A complementary guide has been specifically developed for Sepiolidae and is not included in that one.	Cephalopod and other invertebrate content mostly taken from Martin J (2011) Les invertébrés du golfe de Gascogne à la Manche orientale. Editions QUAE		excerpt on *Loligo* on ICES IBTS SharePoint.

2015	ICES	Patrizia Jereb, Louise Allcock, Graham Pierce	English	Cephalopod biology and fisheries in Europe: II. Species Accounts	Jereb *et al.*	European waters	Drawings and photos	Species accounts including identification	Mainly the authors; outside sources all acknowledged	Digital	http://www.ices.dk/sites/pub/Publication%20Reports/Cooperative%20Research%20Report%20(CRR)/CRR325.pdf
2015	ICES	Núria Zaragoza, Antoni Quetglas, Ana Moreno		Identification guide for cephalopod paralarvae from the Mediterranean Sea	Núria Zaragoza, Antoni Quetglas, and Ana Moreno	Mediterranean	Drawings and photos	Identification guide for paralarvae	All sources acknowledged	Digital	http://www.ices.dk/sites/pub/Publication%20Reports/Cooperative%20Research%20Report%20(CRR)/CRR324.pdf
2015	Instituto Español de Oceanografía, Spain	@ieodesmar, www.mapdescar.org, www.ieo.es	Spanish	Guía Visual de las Especies Demersales de la plataforma continental de Galicia y Cantábrico	Julio Valeiras, Esther Abad, Eva Velasco, Antonio Punzón, Alberto Serrano, Francisco Velasco	Galician Waters	Photos	From the project: Mapdescar	By the authors	Paper	http://www.repositorio.ieo.es/e–ieo/handle/10508/9230
2014	FAO, Italy		English	Cephalopods Of The World An Annotated And Illustrated Catalogue Of Species Known To Date. Volume 3. Octopods and Vampire Squids	Eds. P. Jereb, C.F.E. Roper, M.D. Norman, J.K. Finn	World Ocean (including ICES area)	Drawings	Available from FAO	Drawings and text from different resources	Paper / digital	http://www.fao.org/3/a–i3489e.pdf
2013	Institute of Marine Research, Norway	Rupert Wienerroither	Norwegian	Nøkkel til BLEKKSPRUTER i norske og tilstøtende farvann	Rupert Wienerroither	Norway and adjacent waters	Drawings	Includes some oceanic and deep–water species	Based on the FAO volumes	Paper / digital	Copy on ICES IBTS SharePoint
2012	Instituto Español de Oceanografía, Spain	Julio Valeiras, Esther Abad	Spanish	PROTOCOLOS BIOLÓGICOS DE CEFALÓPODOS Versión 6.0	Julio Valeiras and Esther Abad	Spanish Atlantic coast	Photos	Originally issued in 2007 and regularly updated.	Photos by the authors	Paper / digital	Available from IEO
2010	Naturalis, Netherlands	A De Heij and J Goud	English	*Sepiola tridens* spec. nov., an overlooked species	A De Heij and J Goud	North Sea and Northeast Atlantic	Photos and drawings	Describes newly recognized *Sepiola* species		Paper / digital	Basteria 74 (1–3), 51–62

				(Cephalopoda, Sepiolidae) living in the North Sea and north–eastern Atlantic Ocean							
2010	FAO, Italy		English	Cephalopods Of The World An Annotated And Illustrated Catalogue Of Species Known To Date. Volume 2. Myopsid and Oegopsid Squids	Eds. P. Jereb and C.F.E. Roper	World Ocean (including ICES area)	Drawings	Available from FAO	drawings and text from different resources	Paper / digital	http://www.fao.org/3/i1920e/i1920e.pdf
2008	GEOMAR, Germany	Uwe Piatkowski, Daniel Oesterwind	German	Cephalopods in the North Sea – A field guide (draft)	Karsten Zumholz,	North Sea	Photos and drawings	In draft form. Plan to produce new guide.	Some photos still without copyright clearance.	Digital	
2008	VNIRO, Russia	V. Bizikov	Russian / English	Evolution of the shell in Cephalopoda	V. Bizikov	World Ocean (including ICES area)	Drawings and photos	Description of vestigial shells of cephalopods, possible to use for identification	Own drawings / photos	Paper	
2006	HCMR and University of Patras, Greece	Evgenia Lefkaditou	Hellenic	Key for the identification of Cephalopods in the Hellenic Seas up to the family level. Diagnostic Characteristics of subfamilies, genus and species of cephalopods occurring in the Hellenic Seas and Species distribution in the Study area (North Aegean , N>39o 50')	E. Lefkaditou	Medit–erranean, Hellenic Sea	Photos and drawings	Annex III in the PhD thesis: "Taxonomy and biology of Cephalopods in the North Aegean Sea"	Own photos/ Drawings from different resources acknowledged (No copy right)	Paper / digital	http://thesis.ekt.gr/thesis-BookReader/id/18122#page/1/mode/2up
2005	FAO, Italy		English	Cephalopods Of The World An Annotated And Illustrated Catalogue Of Species Known To Date. Volume 1. Chambered Nautiluses and Sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae)	Eds. P. Jereb, C.F.E. Roper	World Ocean (including ICES area)	Drawings	Available from FAO	Drawings and text from different resources	Paper / digital	http://www.fao.org/3/a–a0150e.pdf

2004	Greenland Institute of Natural Resources, Greenland	Rikke Petri Frandsen (DTU)	English	Cephalopods in Greenland Waters – a field guide	Rikke Petri Frandsen, Karsten Zumholz	Greenland	Photos and drawings	Technical report no. 58, Pinngortitaleriffik, Greenland Institute of Natural Resources	Various. some from acknowledged published sources	Digital	https://natur.gl/wp–content/uploads/2019/07/57–Technical_Report_57.pdf
2002	Institut Für Meereskunde, Kiel, Germany	Uwe Piatkowski	English	Early life and juvenile cephalopods around seamounts of the subtropical eastern North Atlantic: Illustrations and a key for their identification	Rabea Diekmann, Uwe Piatkowski, Matthias Schneider	Eastern North Atlantic	Drawings and photos	Key plus descriptions, drawings and photos	Own drawings / photos		BERICHTE aus dem INSTITUT FÜR MEERESKUNDE an der CHRISTIAN–ALBRECHTS–UNIVERSITÄT · KIEL Nr. 326
1997	VNIRO, Russia	JuA Filippova, DO Alekseev, VA Bizikov, DN Khromov	Russian	Commercial and mass cephalopods of the world ocean. A manual for identification	D.O. Alekseev, V.A. Bizikov	World Ocean (including ICES area)	Drawings of low quality	Only commercially exploited species, digital version hardly available	Own drawings	Paper / digital	
1995	Istituto Arion, Italy	G. Bello	English	A Key for the identification of Mediterranean sepiolids (Mollusca: Cephalopoda)	G. Bello	Mediterranean sea	Drawings	Only family Sepiolidae	Own drawings	Paper / digital	https://www.researchgate.net/publication/280775230_A_key_for_the_identification_of_the_Mediterranean_sepiolids_Mollusca_Cephalopoda
1995	Marine Institute, Ireland	Colm Lordan	English	Identification of squid in Irish waters	Colm Lordan	Ireland	Photos and drawings	Unpublished, used by Marine Institute	Own photos and drawings	Digital	
1995	Marine Institute, Ireland	Colm Lordan	English	Identification of Sepiolids in Irish waters	Colm Lordan	Ireland	Photos and drawings	Unpublished, used by Marine Institute	Own photos and drawings	Digital	
1994	University of Aberdeen, UK	Cynthia Yau	English	Guide for the identification of cephalopods from Scottish and adjacent waters	Cynthia Yau	Scottish waters	Drawings and photos	Chapter 7 in PhD thesis "The ecology and ontogeny of	Own drawings, phots Andy Lucas	Digital	University of Aberdeen library

								juvenile cephalopods in Scottish waters"			
1992	Smithsonian Institution, USA	M.J. Sweeney, C.F.E. Roper, M.R. Clarke, S. v. Boletzky	English	"Larval" and Juvenile Cephalopods: A Manual for Their Identification	M.J. Sweeney, C.F.E. Roper, K.M. Mangold, M.R. Clarke, S. v. Boletzky	World Ocean (including ICES area)	Drawings	Identification guide for cephalopod juveniles	Roper et al., 1984	Paper / digital	https://repository.si.edu/handle/10088/5414
1992	Instituto de Investigaciones Marinas, Spain	A. Guerra	Spanish	Fauna Iberica Vol. 1: Mollusca, Cephalopoda	Angel Guerra	Spanish waters	Photos and drawings	Complete guide to cephalopods of the Iberian Peninsula (95 species)	Own text, drawings and photos	Paper	Museo Nacional de Ciencias Naturales, CSIC, Madrid. ISBN: 84–00–07267–7
1990	Instituto de Investigaciones Marinas, Spain	A. Guerra	English, Spanish	Fishery potential of North Eastern Atlantic squid stocks	A. Guerra, R. Ledo	North East Atlantic	Drawings	Eurosquid project, unpublished	Drawings and maps from Roper *et al.*	Paper	
1987	Russia	K. Nesis	English (Original in Russian)	Cephalopods of the world: squids, cuttlefishes, octopuses, and allies	K. Nesis (translated by B.S. Levitov, edited by L.A. Burgess)	World Ocean (including ICES area)	Drawings	Translated from the 1982 Russian publication "Kratkiĭ opredelitel' golovonogikh molliuskov Mirovogo okeana". Partially out of date	Own drawings	Paper	
1981	Netherlands		Dutch	De inktvissen (Cephalopoda) van de Nederlandse kust	A.W. Lacourt, P.H.M. Huwae	Wadden Sea		Issue 145 of Wetenschappelijke mededelingen van de Koninklijke Nederlandse Natuurhistorische Vereniging, ISSN 0167–5524		Paper	
1969	Smithsonian Institution, USA		English	An Illustrated Key to the Families of the Order Teuthoidea (Cephalopoda)	C.F.E. Roper, R.E. Young, G.L. Voss	World Ocean	Drawings	Identification only to Family level	Drawings and text from different resources	Paper / digital	https://repository.si.edu/handle/10088/5700

						(including ICES area)					
1963	ICES	ICES	English	ICES Identification sheet: Cephalopoda: Decapoda: Sepioidea	B. J. Muus	North Atlantic	Drawings		Drawings from different resources	Digital	ICES library: compiled within IDPlankton_187.pdf, http://www.ices.dk/sites/pub/Publication%20Reports/Plankton%20leaflets/IDPlankton_187.PDF
1963	ICES	ICES	English	ICES Identification sheet; Cephalopoda: Decapoda: Teuthoidea: Loliginidae	B. J. Muus	North Atlantic	Drawings		Drawings from different resources	Digital	
1963	ICES	ICES	English	ICES Identification sheet: Cephalopoda: Decapoda: Teuthoidea: Ommastrephidae, Chiroteuthidae, Cranchiidae	B. J. Muus	North Atlantic	Drawings		Drawings from different resources	Digital	
1963	ICES	ICES	English	ICES Identification sheet: Cephalopoda: Decapoda: Teuthoidea: Octopoteithidae, Gonatidae, Onychoteuthidae, Histioteuthidae, Branchioteuthidae	B. J. Muus	North Atlantic	Drawings		Drawings from different resources	Digital	
1963	ICES	ICES	English	ICES Identification sheet: Cephalopoda: Octopoda	B. J. Muus	North Atlantic	Drawings		Drawings from different resources	Digital	
1959	Sweden	Barbara Bland	Danish	Danmarks fauna 65: skallus, sötänder bläckspruttor	Bent J Muus	Danish waters	Drawings	Original drawings by Poul H. Winther and the author. Published 1959.	Published by Dansk Naturhistorisk Forening		Available on ICES IBTS SharePoint
1925	Germany	–	German	Schlüssel zur Bestimmung der in der Nordsee vorkommenden Cephalopoden nach äusseren Merkmalen	P. Grimpe	North Sea	no	published within: Grimpe, G. 1925. Zur Kenntnis der Cephalopodenfauna der Nordsee. Wissenschaftliche Meer–esuntersuchungen Helgoland, 16(3): 1–124 [in German].		Paper	

4.2 Update best practice for routine data collection

4.2.1 Maturity data

As stated in the previous report (ICES, 2019), there is a need to standardise sampling protocols to collect maturity data, and review which stages should be considered immature and which mature to obtain the size of first maturity.

The previous ICES Workshops on sexual maturity staging that included cephalopod species were revised (WKMSCEPH 2010, WKMATCH 2012, WKASMSF 2018) to produce a simple and standardized table applicable to the main commercial species of squids, octopuses and cuttlefishes in European waters. The WKMSCEPH workshop (ICES, 2010) was the only one focused on cephalopod species, and produced standardised tables by group of species (squids, cuttlefishes and octopuses), including conversion tables for the scales used in other regions, but no standard table for all groups was produced. Following the general conversions and naming recommendations of WKMATCH 2012 (ICES, 2012), the stage 2b "maturing" was considered confusing with 'maturation' which refers either to the ontogenetic sexual maturation or to the oocyte germinal vesicle migration and or breakdown. It was recommended to use the term "developing and functionally mature". Similarly, the use of stage 3a "mature" was considered inappropriate as it can be confused with 'sexually mature', and renamed as "spawning" (**Table 4.2**).

Table 4.2 Recommended terms and its definitions for the stages 2b and 3a (previously named "maturing" and "mature" respectively). From table 3-6 of ICES (2012)

TERM	DEFINITION
Developing (functionally mature) Stage 2b	A maturity phase; the sex cells have entered the gonadotropin-dependent part of the reproductive cycle: production of follicle-stimulation hormone (FSH) and subsequent estradiol in females. The corresponding sex hormone in males is testosterone
Spawning Stage 3a	A maturity phase during which gametes are produced and released. After completion of developing phase individual becomes developmentally and physiologically able to spawn in this phase, but does not spawn or release gametes continuously. For this reason, this phase can be referred as spawning capable. The period within this phase when individuals are truly releasing gametes can be referred as actively spawning.

The macroscopic maturity scale for coleoid cephalopods included in Annex 3 of the WKASMSF 2018 report (ICES, 2018) was used as baseline to perform a single table applicable to cephalopods. The goal is to have simple descriptions of the maturity stages for any commercial cephalopod species, to use in biological samplings. In particular when no experts perform the data collection. The table was revised by the subgroup to refine the description of each maturation stage applicable to octopuses (Octopoda), cuttlefishes (Sepiida) and squids (Teuthida). The final version (in English) has been translated into German, French, Spanish and Portuguese (Table 4.3 a,b,c,d, e).

Table 4.3a (English). Standardized maturity table for cephalopods. (*) "structure" refers to a granulate appearance (ovary), and to the fine grooves and ridges visible on the surface (testis). Abbreviations: NG=Nidamental Glands; OG=Oviductal Glands; SC=Spermatophoric Complex. O=applicable to Octopoda; T=applicable to Teuthida; S=applicable to Sepiida. A glossary of terms is available at: http://tolweb.org/accessory/Cephalopoda_Glossary?acc_id=587. Additional information of macroscopic anatomy is available at: https://link.springer.com/chapter/10.1007%2F978–3–030–11330–8_3#Sec4 (see section 3.4.2.5.)

State	Stages	Maturation stage	Reproductive apparatus aspect	Sex
	0	**Undetemined**	Sex not distinguished by naked eye. Sex undetermined.	U
SI. Sexually immature	**1**	**Immature**	Ovary semi–transparent, stringy and lacking granular structure*. Small semitransparent NG/OG. Oviduct meander not visible.	F
			Testis small, absence of spermatophores. Vas deferens not visible. SC semi–transparent.	M
SM. Sexually mature	**2a**	**Developing (functionally inmature)**	Whitish ovary with granular structure* clearly visible, not reaching the posterior half of the mantle cavity. Oocytes very small. Oviduct meander clearly visible. NG/OG enlarged. NG covering some internal organs (**T** and **S**). OG with white longitudinal lines at mid–proximal part (**O**).	F
			Enlarged testis with structure* not clearly visible, absence of spermatophores. Penis appears as a small prominence of the SC. Vas deferens whitish or white. The spermatophoric organ has a white strip.	M
	2b	**Developing (functionally mature)**	Ovary occupies the whole posterior half of the mantle cavity, containing reticulated oocytes of different sizes and a few ripe (hyaline) ova could be visible at its proximal part. Maturing oocytes visible to naked eye. Oviducts fully developed but empty. Large NG covering the viscera below (**T** and **S**). OG displaying denticulate proximal region followed by a light brown ring (**O**).	F
			Testis tight, with visible structure*. Few spermatophores, partially or fully developed, in the Needham's Sac (visible as whitish particles). Vas deferens is white, meandering, enlarged.	M
	3a	**Spawning**	Ovary containing higher percentage of large reticulated eggs and some large ripe ova. Eggs medium and big, also visible in oviducts. Ripe ova in oviducts (**T**). Enlarge and turgid NG/OG. OG with larger denticulate proximal region and enlarged brown ring (**O**).	F
			Well–developed testis. Plenty of well–developed spermatophores packed in the Needham's Sac. Sometimes spermatophores in the penis (**T** and **S**). Large and white vas deferens	M
	3b	**Spent**	Ovary shrunk and flaccid. Only immature oocytes attached to the central tissue and a few loose large ova in the coelom (**O**), or few oocytes which may be attached to the central tissue (**T** and **S**). Oviduct may contain some mature ova but are no longer packed. Flaccid NG/OG.	F
			Testis flaccid. None or few disintegrating spermatophores in the Needham's sac and the penis.	M

Table 4.3b (German). (*) "Struktur" bezieht sich auf ein körniges Aussehen (Eierstock) und auf die feinen Rillen und Kerben, die auf der Oberfläche sichtbar sind (Hoden). Abkürzungen: ND=Nidamental Drüse; ED=Eileiterdrüse; SK=Spermatophoren Komplex. O=gilt für Octopoda; T=gilt für Teuthida; S=gilt für Sepiida. Ein Glossar gibt es unter: http://tolweb.org/accessory/Cephalopoda_Glossary?acc_id=587. Weitere informationen zur makroskopischen Anatomie gibt es unter: https://link.springer.com/chapter/10.1007%2F978-3-030-11330-8_3#Sec4 (Kapitel 3.4.2.5.)

Zustand	Phase	Reifephase	Aussehen des Fortpflanzungsapparats	Geschlecht
	0	**Unbestimm-bar**	Geschlecht mit bloßem Auge nicht erkennbar. Geschlecht unbestimm-bar.	J
unreif	**1**	**Unreif**	Ovar halbtransparent, fadenförmig und ohne körnige Struktur*. Klein und halbtransparent ND/ED. Schlängelnder Eileiter nicht sichtbar.	W
			Hoden klein, keine spermatophoren vorhanden. Samenleiter nicht sichtbar. SK halbtransparent.	M
Geschlechtsreif	**2a**	**Reifend (funktionell unausgereift)**	Weißliches Ovar mit körniger Struktur * deutlich sichtbar, reichen nicht bis in die hintere Hälfte der Mantelhöhle. Eizellen sehr klein. Schlängelnder Leiter des Ovidukts deutlich sichtbar. ND/ED vergrößert. ND bedecken einige innere Organe (**T and S**). ED mit weißen Längslinien im mittleren, proximalen Teil (**O**).	W
			Vergrößerter Hoden mit nicht deutlich sichtbarer Struktur*, keine Spermatophoren. Penis erscheint als kleine Vorwölbung des SK. Samenleiter weißlich oder weiß. Das Spermatophorische–Organ hat einen weißen Streifen.	M
	2b	**Reifend (funkttionell ausgereift)**	Der Eierstock nimmt die gesamte hintere Hälfte der Mantelhöhle ein und enthält netzartige Eizellen unterschiedlicher Größe; einige reife (hyaline) Eizellen können im proximalen Teil sichtbar sein. Reifende Eizellen mit bloßem Auge sichtbar. Ovidukte voll entwickelt, aber leer. Große ND, die die darunter liegenden Eingeweide bedecken (**T and S**). ED mit gezacktem proximalem Bereich, gefolgt von einem braunen Ring (**O**).	W
			Hoden fest, mit sichtbarer Struktur*. Wenige Spermatophoren, teilweise oder vollständig entwickelt, im Needham–Sack (als weißliche Partikel sichtbar). Samenleiter ist weiß, sich schlängelnd, vergrößert.	M
	3a	**Laichend**	Eierstock mit höherem Anteil an großen, netzartigen Eiern und einigen großen, reifen Eizellen. Mittlere und große Eier, auch in den Eileitern sichtbar. Reife Eizellen in den Eileitern (**T**). Vergrößerte und geschwollene ND/ED. ED mit größerem gezähntem proximalem Bereich und vergrößertem braunem Ring (**O**).	W
			Weit entwickelter Hoden. Viele weit entwickelte Spermatophoren im Needham–Sack. Manchmal Spermatophoren im Penis (**T and S**). Großer und weißer Samenleiter	M
	3b	**Abgelaicht**	Eierstock geschrumpft und schlaff. Nur unreife Eizellen, die am zentralen Gewebe befestigt sind, und einige lose große Eizellen im Coelom (**O**), oder wenige Eizellen, die am zentralen Gewebe befestigt sein können (**T and S**). Der Ovidukt kann einige reife Eizellen enthalten, die jedoch nicht mehr gebündelt sind. Schlaffe ND/ED.	W
			Schlaffer Hoden. Keine oder nur wenige zerfallende Spermatophore im Needhamsack und im Penis.	M

Table 4.3c (French). [(*)] **"structure" fait référence à une apparence granuleuse (ovaire), et aux fines rainures et crêtes visibles sur la surface (testicule).** **Abréviations: GN=Glandes Nidamentales; OV=Glande Oviductale; SCO=Complexe Spermatophorique. O=applicable à l'ordre des Octopoda; T=applicable à l'ordre des Teuthida; S=applicable à l'ordre des Sepiida. Un glossaire des termes utilisés est disponible suivant le lien : http://tolweb.org/accessory/Cephalopoda_Glossary?acc_id=587. Des informations additionnelles sur l'anatomie macroscopique sont disponibles ici : https://link.springer.com/chapter/10.1007%2F978–3–030–11330–8_3#Sec4 (voir section 3.4.2.5.)**

Etat	Stade	Description	Aspect des appareils reproducteurs	Sexe
	0	**Indéterminé**	Sexe non distinctif à l'œil nu. Sexe indéterminé.	U
SI. Sexuellement immature	**1**	**Immature**	OG petites et translucides. Ovaire semi–transparent, filandreux, et sans structure* granuleuse.	F
			Pas de sperme ou spermatophores dans la poche de Needham. Testicule petit, SCO semi–transparent et canal déférent invisible.	M
SM. Sexuellement mature	**2a**	**Développement (fonctionnellement immature)**	OG agrandies. Ovaire blanchâtre, à structure* granulaire clairement visible, n'atteignant pas la moitié postérieure de la cavité du manteau. Oocytes très petits. Méandre de l'oviducte clairement visible. GN/OV élargi couvrant certains organes internes (**T** and **S**). GN couvrant certains organes internes (OV avec des lignes longitudinales blanches à la partie médio–proximale (**O**)).	F
			Structure du testicule élargi, pas clairement visible. Le pénis apparaît comme petite proéminence du SCO. Absence de spermatophores, bande blanche sur l'organe spermatophorique (= canal déférent blanchâtre ou blanc).	M
	2b	**Développement (fonctionnellement mature)**	L'ovaire occupe toute la moitié postérieure de la cavité du manteau, contenant des œufs réticulés de différentes tailles et quelques ovules mûrs (hyalins) pourraient être visibles dans sa partie proximale. Les ovocytes en cours de maturation sont visibles à l'œil nu. Oviductes pleinement développés mais vides. Large GN couvrant les viscères en dessous (**T** and **S**). OV présentant une région proximale denticulée suivie d'un anneau brun (**O**).	F
			Testicule serré, avec structure* visible. Quelques spermatophores, partiellement ou totalement développés, dans le sac de Needham (visibles sous forme de particules blanchâtres). Le canal déférent est blanc, sinueux, élargi.	M
	3a	**Reproduction**	Ovaire contenant un % plus élevé de gros œufs réticulés et quelques gros œufs mûrs. Œufs moyens et gros également visibles dans les oviductes. Ovules mûrs dans les oviductes (**T**). GN/OV hypertrophiés et turgescents. OV avec une région proximale denticulée plus grande et un anneau brun élargi (**O**).	F
			Testicule bien développé. Beaucoup de spermatophores bien développés, emballés dans le sac de Needham. Parfois des spermatophores dans le pénis (**T** and **S**). Canal déférent large et blanc.	M
	3b	**Post–émission ou Régression**	Ovaire rétréci et flasque. Seulement ovocytes immatures attachés au tissu central et quelques gros ovules libres dans le cœlome (**O**), ou quelques ovocytes qui peuvent être attachés au tissu central (**T** and **S**). L'oviducte peut contenir quelques ovules matures mais ne sont plus emballés. GN/OV flasques.	F
			Testicule flasque. Pas ou peu de spermatophores désagrégés dans le sac de Needham et le pénis.	M

Table 4.3d (Spanish). **(*) "estructura" se refiere a una apariencia granular (ovario), y a las finas ranuras y crestas visibles en superficie (testículo). Abreviaturas: GN=Glándulas Nidamentarias; GO=Glándulas Oviductales; CE=Complejo Espermatofórico. O=aplicable al grupo Octopoda; T=aplicable al grupo Teuthida; S=aplicable al grupo Sepiida. Glosario de términos disponible en: http://tolweb.org/accessory/Cephalopoda_Glossary?acc_id=587. Información adicional de anatomía disponible en: https://link.springer.com/chapter/10.1007%2F978–3–030–11330–8_3#Sec4 (ver sección 3.4.2.5.)**

Estado	Estado	Estado de madurez	Aspecto del aparato reproductivo (identificación visual)	Sexo
	0	**Indeterminado**	Sexo no distinguible a simple vista, indeterminado	I
SI. Sexualmente inmaduro	1	**Inmaduro**	Ovario semitransparente, fibroso y sin estructura granular*. Las GN/GO pequeñas y semitransparentes. Pliegues del oviducto no visibles	H
			Testículo pequeño, sin espermatóforos. Conducto deferente no visible. CE semitransparente	M
SM. Sexualmente maduro	2a	**En desarrollo (funcionalmente inmaduro)**	Ovario blanquecino con estructura granular* claramente visible, sin llegar a la mitad posterior de la cavidad del manto. Ovocitos muy pequeños. Pliegues del oviducto claramente visibles. GN/GO agrandadas. GN cubriendo algunos órganos internos (**T** and **S**). GO con líneas longitudinales blancas en la parte media–proximal (**O**)	H
			Testículo agrandado con estructura* no visible claramente, ausencia de espermatóforos. Pene con forma de pequeña prominencia del CE. Conducto deferente blanquecino/blanco. Órgano Espermatofórico con una franja blanca	M
	2b	**En desarrollo (funcionalmente maduro)**	Ovario ocupando toda la mitad posterior de la cavidad del manto, con ovocitos reticulados de diferentes tamaños y algunos maduros (hialinos) pueden apreciarse en su parte proximal a simple vista. Oviductos completamente desarrollados pero vacíos. GN grandes que cubren las vísceras (**T** and **S**). GO con la región proximal denticulada, seguida de un tenue anillo marrón (**O**)	H
			Testículo firme, con estructura* visible. Algunos espermatóforos, parcial o totalmente desarrollados, en el Saco de Needham (visibles como partículas blanquecinas). Conducto deferente blanco, serpenteante y agrandado	M
	3a	**Puesta**	Ovario con un mayor porcentaje de ovocitos reticulados grandes y algunos maduros, visibles en los oviductos (**T**). NG/GO agrandadas y turgentes. GO con región proximal denticulada más grande y anillo marrón ensanchado (**O**)	H
			Testículos bien desarrollados. Llenos de espermatóforos bien desarrollados empaquetados en el Saco de Needham. A veces se ven espermatóforos en el pene (**T** and **S**). Conducto deferente grande y blanquecino	M
	3b	**Post–puesta**	Ovario contraído y flácido. Solo se aprecian ovocitos inmaduros adheridos al tejido central y algunos grandes sueltos en el celoma (**O**), o unos pocos ovocitos que pueden estar adheridos al tejido central (**T** and **S**). El oviducto puede contener algunos ovocitos maduros pero ya no están empaquetados. NG/GO flácidas	H
			Testículo flácido. Pocos o ningún espermatóforo en el Saco de Needham y el pene	M

Table 4.3e (Portuguese). **[(*)] "textura" refere-se a uma aparência granulosa (ovário), e às finas ranhuras e sulcos na superfície (testículo). Abreviaturas: GN=Glândulas Nidamentares; GO=Glândulas Oviducais; CE=Complexo Espermatofórico. O=aplicável a Octopoda; T=aplicável a Teuthida; S=aplicável a Sepiida.**

Fase	Estados	Estado de maturação	Aspeto das Estruturas Reprodutoras	Sexo
	0	**Indeterminado**	Sexo não discernível a olho nu. Sexo indeterminado	I
SI. Sexualmente imaturo	**1**	**Imaturo**	Ovário semitransparente, fibroso e sem textura* granulosa. GN/GO pequenas e semitransparentes. Pregas do oviducto invisíveis.	F
			Testículo pequeno, sem espermatóforos. Vaso deferente invisível. CE semitransparente.	M
SM. Sexualmente maduro	**2a**	**Desenvolvimento (funcionalmente imaturo)**	Ovário esbranquiçado com textura* granulosa claramente visível, sem atingir a metade posterior da cavidade do manto. Oócitos muito pequenos. Pregas do oviducto claramente visíveis. GN/GO aumentadas. GN cobrindo alguns órgãos internos (**T** and **S**). GO com linhas longitudinais brancas na zona media–proximal (**O**).	F
			Testículo aumentado sem textura* claramente visível, ausência de espermatóforos. O pénis parece uma pequena proeminência do CE. Vaso deferente esbranquiçado ou branco. Órgão espermatofórico com uma faixa branca.	M
	2b	**Desenvolvimento (funcionalmente maduro)**	Ovário ocupando toda a metade posterior da cavidade do manto, com oócitos reticulados de diferentes tamanhos, podem observar–se alguns maduros (hialinos) na sua parte distal a olho nu. Oviductos completamente desenvolvidos, mas vazios. GN grandes a cobrir as vísceras (T and S). GO com a região proximal denticulada e um anel castanho claro (**O**).	F
			Testículo firme, com textura* visível. Poucos espermatóforos, parcialmente ou completamente desenvolvidos no Saco de Needham (visíveis como partículas brancas). Vaso deferente branco, serpenteado e aumentado.	M
	3a	**Desova**	Ovário com uma maior percentagem de oócitos grandes reticulados e alguns maduros (hialinos) visíveis nos oviductos (**T**). GN/GO aumentadas e túrgidas. GO com uma região proximal denticulada maior e um anel castanho maior (**O**).	F
			Testículos bem desenvolvidos. Saco de Needham cheio de espermatóforos bem desenvolvidos. Por vezes observam–se espermatóforos no pénis (**T and S**). Vaso deferente grande e branco.	**M**
	3b	**Pós–desova**	Ovário contraído e flácido. Apenas oócitos imaturos aderentes ao tecido central e alguns grandes soltos no celoma(**O**), ou poucos oócitos que podem estar aderentes ao tecido central (**T and S**). O oviducto pode conter alguns oócitos maduros, mas que não estão empacotados. GN/GO flácidas.	F
			Testículo flácido. Nenhum ou poucos espermatóforos no Saco de Needham e no pénis.	M

4.2.2 Sampling intensity

The goal of this subtask is to produce tools and guidelines to optimize the sampling strategy for an adequate sampling effort. General guidelines on this topic are included in the updated list of recommendations on cephalopod data collection below (see subtask 4.2.3).

A literature review of sampling protocols used for length and biological sampling of cephalopods has been produced during this period (see Table 4.4). Data sources covered both research and commercial sampling programs (at sea, at the market, at the lab), as well as key information on the sample size and sampling frequency by temporal strata. Detailed information on the numbers of individuals by species to be sampled was collected also from the Multiannual Plans of Member States targeting cephalopods under the EU-Data Collection Framework. This review is the baseline for further analysis of sampling intensity in the next period.

A range of statistical approaches might be able to recommend the optimal sampling strategy, whether or not sample size is strictly defined by a source (funds, time).

Length sampling. Adequacy of the size structure might be assessed by a chosen parameter e.g. presence of every available size class in a sample (or a particular percentage of existing size classes found in a sample). Another approach is to assign a particular standard error of the mean (e.g. target ~0.8–0.9, depending on the study). Representation of size classes in population structure might be estimated the same way as biodiversity studies estimate what proportion of species in the ecosystem were discovered. R - package vegan might be used.

A test work on reduction of sampling intensity performed with length data of landings' *Sepia officinalis* was presented by Patricia Gonçalves (IPMA, Portugal) during the meeting of 2022 (see Working Document WGCEPH WD 2022–01). The method (Wischnewski *et al*., 2020) is based on the Admissible Dissimilarity Value (ADV) and analyses length frequency distributions (LFD) of the original sample producing an optimal subsample size using modes–antimodes pairs and amplitude ratio. The result was an optimal subsample size with the same LFD of the original sample but a reduction of 51% in the number of individuals and of 7% in the number of sampled trips. This methodology can be applied to other datasets of WGCEPH and the results of LFD using original sample compared to those obtained with the optimal subsample size.

Sex ratio. A discovery curve (a plot of sex–ratio vs. number of specimens sampled, where the latter is based (for example) on increments of 10 animals sampled, i.e. sample size 10, 20, 30, etc) is useful to define the minimum sample size. For example, sample size could be set at a value such that increasing sample size will result in a change of 1% or less in the estimated overall sex ratio.

Maturity status. A similar approach can be taken to determine minimum sample size. This the minimum sample size could be defined as the number of animals sampled such that adding further animals will result in a change in the estimated percentages of stages 1, 2, 3 etc. animals that is statistically non-significant (based on a *prop.test* or other appropriate R function).

4.2.3 Updated recommendations for data collection

The previous version of recommendations from the latest report (ICES, 2019), with improvements and updating information was circulated to all WGCEPH members. The updated data collection guidelines proposed by the group are:

1. To include the sampling of cephalopods in any fishery that either (a) targets cephalopods by specific fishing gears, (b) targets both cephalopods and demersal fishes or (c) takes

cephalopods as an important bycatch in target fishing activities (or métiers[1] for EU–MAP). Include discards in protocols of fishery observers when cephalopod sampling is not part of their requirements.

2. Size-distribution sampling as well as biological sampling is needed for stock assessment of stock status and fishery characterization in the short-term.
3. Collection of paired length, sex and maturity data for the most important cephalopod fisheries, to facilitate comparison of trends in maturity and size composition data by cohort, from research surveys vs. the fishery, and to assess trends in recruitment and length at 50% maturity (L50). Use standardized sampling protocols, including the collection of subsample weights so the length, sex and maturity data can be scaled up to the catch per tow (or trip), and histology studies to validate the macroscopic maturity stages of the species.
4. Perform age estimation studies to understand population dynamics when there are no previous studies pertaining to intra–annual cohort identification, cohort–specific growth rates and life-cycle duration.
5. The minimum sampling intensity and sample size will be defined by the objectives of the study, the variability of the parameter of interest and the invoked expenses of time and/or funds. Optimize the sampling strategy using statistical approaches that ensure representation of size classes, sexes and maturity stages.
6. Increases in the level of cephalopod sampling (at least monthly) of the landings because given the short life cycle of cephalopods, sampling them on a quarterly basis is not adequate. Focus of the most intensive sampling (i.e. weekly or monthly) during periods of high catches in order to ensure adequate characterization of the length compositions of the multiple micro–cohorts that are often present, while avoiding unproductive sampling effort at times of low catches.
7. Reliable species identification is essential to improve data collected from landings, discards and surveys. For this purpose, support material (e.g. simple regional guides) and training in cephalopod species identification should be given to people involved in sampling and data collection. It would be useful to monitor identification quality using photographic records and/or barcoding.

[1] Métier: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern. Commission Delegated Decision (EU) 2021/1167 (https://eur–lex.europa.eu/legal–content/EN/TXT/?uri=CELEX%3A32021D1167).

Table 4.4 Review of sampling intensity. (1) Commercial sampling programs (at sea, at market, lab), research surveys; (2) Length, reproduction, others; (3) Sample size and sampling frequency by temporal strata.

DATA SOURCE [1]	Species or group	Biological variables [2]	SAMPLING INTENSITY [3]	Seasonality (Temporal strata)	REGION, FISHERY	Protocol reference	URL	Comments
Research surveys (at sea)	***Loligo* spp., *Illex coindetii, Todaropsis eblanae, T. sagittatus , Alloteuthis* spp. and *Sepia officinalis***	Length	By haul. If there are a manageable number of specimens: all ML's are taken By haul. If there was a bulk of squid within the same size cohort: all individuals are mixed to randomise, and a subsample is taken through a series of "splits" (dividions in two) until an acceptable subsample is attained. The overall weight and the final subsample are weight to obtain a raising factor. Subsampling procedure differed with institute By haul: If there was a bulk of squid form different size cohorts: "categorization" in separate units. The categories can be subsampled using the method above	N/A	ICES BTS Ireland	Gerritsen, H. and McGrath, D. 2007. Precision estimates and suggested sample sizes for length-frequency data. Fishery Bulletin, 105: 116–120.	Gerritsen and McGrath 2017	It refers to both fish and cephalopods sampling Sampling under DCF
Commercial (at sea)	***Octopus vulgaris, Loligo vulgaris, Sepia officinalis***	Length	By haul: Minimum 50 indiv. All ML´s are taken if there are less to 50 specimens and there are time after priority species. Catches and discard separately.	8-10 trip by month. Trip duration 1 day	ICES IXaS			
	Loligo forbessi, Sepia elegans		By haul: Minimum 50 indiv. All ML´s are taken if there are less to 50 specimens and there are time after special priority and group 1 priority species.Catches and discard separately.	8-10 trip by month. Trip duration 1 day				
Research surveys (at sea)	***Octopus vulgaris, Loligo vulgaris, Sepia officinalis, Loligo forbesii***	Length	Random sampling up to a min. of 50 indiv/species/haul. Most of hauls, all specimens are measurement. Subsampling only when number of individuals is not manageable.	1 surveys in spring, 1 survey in autumn	ICES IXaS	WKMSCEPH report (2010)		
		Reproductive	Random sampling up to a min. of 10-15 indiv/sex/sizes/species/haul. Most of hauls, all specimens are analyzed. Subsampling only when number of individuals is not manageable.					
	Sepia elegans, Eledone spp, Octopus spp, Sepia spp	Length	Random sampling up to a min. of 50 indiv/species/haul. Most of hauls, all specimens are measurement. Eledone spp: length/sex					
Commercial (at laboratory)	***Octopus vulgaris, Loligo vulgaris, Sepia officinalis***	Length Reproductive	Random sampling up to a min. of 40 kg/month of *Octopus vulgaris* (30-35 ind.), 15 kg/month of *Loligo vulgaris* and *Sepia officinalis* (30-50 ind.)	1 sampling/month (Triennal sampling)	ICES IXaS	WKMSCEPH report (2010)		
Commercial (at sea)	***Octopus vulgaris***	Weight Survival rate Fishery data	Two observers (from a consultancy firm, SIGMA, S.L., hired by the Asturian fishing administration, the Dirección General de Pesca Marítima del Principado de Asturias) get on board the boat selected and spend the whole fishing day checking all traps hauled on board. The yearly coverage of fishing days observed in the on-board observerd program varies from a maximum of 1.4% (2015-16) to a minimum of 0.8% (2018-19), being 1.1% coverage in average. All individuals of octopus and bycatch are weighted. On average (2015-20) 9 boats, 15 fishing days, 116 lines of traps and 4092 traps are sampled every fishing season.	Twice a month on board sampling throughout the fishing season (from December to June). So, two different boats are sampled every month. The on board program started in 2014.	ICES VIIIc in Asturian coastal waters, small-scale octopus trap fishery in Asturias, Spain	González A, Macho G, Quílez G. 2021. Western Asturias octopus (Octopus vulgaris) traps fishery of artisanal cofradias. Public Certification Report. Marine Stewardship Council (MSC). 243pp	Gonzalez et al. 2021	
	Bycatch& bait	Bycatch & bait						
Commercial (at landing sites and laboratory)	***Octopus vulgaris***	Weight & Lenght Reproductive	Random sampling with a minimum target of 200 individuals per month (although not always this minimum was achieved). All individuals are weighted, measured and sexed. All specimens were taken to the laboratory where they were weighed and dissected. The variables registered were Total body weight (W), eviscerated body weight (EW), Ventral mantle length (VML), dorsal mantle length (DML), Ovarian weight (OW), oviduct complex weight (OCW) and oviduct gland diameter (OGD). Several Gonadosomatic female indices were calculated based on this data. Female classification in female maturity stages (M1, M2, M3 and M4) according to the maturity scale of Guerra (1975) is determined.	1 sampling/month (annual sampling, starting in 2002) during the fishing season (from December to June), taken at official landing sites (i.e. cofradías).	ICES VIIIc in Asturian coastal waters, small-scale octopus trap fishery in Asturias, Spain	Fernandez Rueda P. & García-Florez L. 2007. Octopus vulgaris (Mollusca: Cephalopoda) fishery management assessment in Asturias (north-west Spain). Fisheries Research 83:351–354	Fernandez Rueda P. & García-Florez L. 2007.	

DATA SOURCE (1)	Species or group	Biological variables (2)	SAMPLING INTENSITY (3)	Seasonality (Temporal strata)	REGION, FISHERY	Protocol reference	URL	Comments
Commercial (at sea)	***Octopus vulgaris***	Weight	Historical (since 1999) artisanal fishing sampling program run by the Unidade Tecnica de Pesca de Baixura (UTPB, Technical Unit of Artisanal Fisheries) of the Xunta de Galicia (Galician Autonomous Government). On-board observer is assigned to fishing vessels randomly. Over the study period from 1999 to 2016, a total of 2286 fishing trips were monitored counting 15,828 hauls and 1,049,448 octopus traps, although it is unknown what % coverage this represents. Observers have sampled at least 10% of the total fleet, covering the complete boat size range, which can be considered as a representative sample of the total number of boats involved in such a fishery. This monitoring provides a suitable and well-balanced set of data among years, seasons, and spatial coverage within the main fishing grounds of the study area. All octopus individuals are weighted and sexed.	Sampling on-board along the whole fishing season from January to December, excepting during the closed season which is usually 1-2 months in May-June.	ICES VIIIc & IXa in Galician coastal waters, small-scale octopus trap fishery in Galicia, Spain	Alonso-Fernández, A., Otero, J., Bañón, R., Campelos, J.M., Santos, J., Mucientes, G., 2017. Sex ratio variation in an exploited population of common octopus: ontogenic shifts and spatio-temporal dynamics. Hydrobiologia 794, 1–16.	[Alonso-Fernández et al. 2017]	
		Reproductive						
		Fishery data				Bañón R, Otero J, Campelos-Alvarez JM, Garazo A, Alonso-Fernandez A. 2018. The traditional small-scale octopus trap fishery off the Galician coast (Northeastern Atlantic): Historical notes and current fishery dynamics. Fisheries Research 206: 115–128	[Bañón et al. 2018]	
	Bycatch& bait	Bycatch & bait						
Scientific survey of commercial landings (at shore)	***Octopus vulgaris***	Weight, Sex & Maturity	750 ind/year	Quarterly	ICES IXa. Portugal mainland. Vessels operating pots and traps for octopuses in ICES 27.9.a and landing in the main mainland national ports of this metier. Vessels operating pots and traps for octopuses in ICES 27.9.a and landing in the minor mainland national ports of this metier	Portugal Work Plan for data collection in the fisheries and aquaculture sectors 2022-2024. V4	[Portugal Work Plan for data collection in the fisheries and aquaculture sectors 2022-2024. V4]	
Commercial fishing trip. Sampling of landings onshore or onboard commercial fishing vessels using trip as a sampling unit	***Octopus vulgaris***	Weight, Sex & Maturity	90 port/day landing events	Quarterly	ICES IXa. Portugal mainland. Vessels operating pots and traps for octopuses in ICES 27.9.a and landing in the main mainland national ports of this metier.	Portugal Work Plan for data collection in the fisheries and aquaculture sectors 2022-2024. V4	[Portugal Work Plan for data collection in the fisheries and aquaculture sectors 2022-2024. V4]	
Scientific survey at sea. IBTS	***Octopus vulgaris, Eledone cirrhosa, E. moschata***	Length, weight, sex, maturity	Systematic (60 trawls) and stratified random sampling (30 trawls) with three depths stratas 20-100/100-200/200-500 m and 30 min by trawl	Quarterly	ICES Ixa Portugal (all species). Ireland ICES VII-b,f,g,i (*O. vulgaris, E. cirrhosa, E. moschata, S. officinalis*). Spain ICES VIII-c (*O. vulgaris, E. cirrhosa, S. offinalis*), IXa (Gulf of Cádiz, all species).	ICES. (2017). Manual of the IBTS north eastern Atlantic surveys. Series of ICES Survey Protocols SISP, 15, 92.	[ICES. (2017). Manual of the IBTS north eastern Atlantic surveys. Series of ICES Survey Protocols SISP, 15, 92.]	
Commercial (at sea)	***Doryteuthis (Amerigo) pealeii Illex illecebrosus***	Length	100 indiv. per statistical area, for kept and discard separately	Depends on the fishery	North East Fisheries (USA)	Northeast Fisheries Science Center. Fisheries sampling branch observer on-deck reference guide 2016		NOAA Fisheries Service

DATA SOURCE (1)	Species or group	Biological variables (2)	SAMPLING INTENSITY (3)	Seasonality (Temporal strata)	REGION, FISHERY	Protocol reference	URL	Comments
Commercial (at sea)	***Octopus vulgaris* *Sepia hierredda***	Length	Minimum 1 set/zone. Random sampling up to a min. of 100 indiv/species/trip (or up to a clear mode)	1 trip by quarter. Trip duration 25-40 days	CECAF (Guinea-Bissau). Cephalopods and finfish fishery, under SFPA between EU and Guinea-Bissau	Perales-Raya, C., González-Lorenzo, J.G., Brahim, K., Sotillo, B., Camara, A., 2020. Manuel à l'usage des observateurs scientifiques à bord des bateaux céphalopodiers dans les eaux d'afrique occidentale.	Perales-Raya et al. 2020	Protocol developed under the project EU EASME / EMFF / 2016/008. Sampling under DCF.
		Reproductive	Minimum 1 set/zone. Stratified sampling by length class up to a min. of 50 indiv/species/trip					
Commercial (all) and research surveys (at sea)	***Berryteuthis magister, Todarodes pacificus, Ommastrephes bartramii, Todarodes sagittatus, Enteroctopus dofleini, Octopus conispadiceus***	Length, weight, Reproductive	Random. 100 individuals from one haul/area (in case of octopus longline fishery) are sampled on the daily basis.	Commercial depends on th	Far east seas + Barents Sea (when T. sagittatus appeared there)	Филиппова, Ю.А. 1983. Рекомендации по изучению головоногих моллюсков. М.: ВНИРО. 28 с.		Comprehensive overview on the cephalopod samplings (methods used, intensity, maturity scales (updated in the recent articles), etc.)
Research surveys "MEDITS" (at sea)	***Loligo vulgaris, Illex coindetii***	Length	In most of hauls mantle length is measured for all specimen.. When the catch of a given species or a fraction of a given species (e.g. juveniles) is too abundant to be measured in extenso it is taken a representative sub-sample of the catch or fraction, that should be not less than 100 individuals.	1 survey in late spring-summer/ year	Mediterranean GSAs: 1, 2, 5, 6, 7, 8, 9, 10, 11, 15, 16, 17, 18, 19, 20, 22, 23 & 25	MEDITS-Handbook. Version n. 9, 2017, MEDITS Working Group : 106 pp.	http://www.sibm.it/MEDITS 2011/docs/Medits_Handbook_2017_version_9_5-60417r.pdf.	The MEDITS survey is conducted using the experimental trawl et GOC73, in Mediterraean waters of EU M.S. (Spain, France, Italy, Greece, Malta, Slovenia, Croatia, Montenegro, Albania and Cyprus
		Individual Weight/ Reproductive	Sample size for individual weight and maturity stages, proposed per GSA by length class (0.5 cm) and sex is for adults (>MLm25%) 14 individuals and for juveniles (<MLm25%) 6 individuals or portion of the length class less than 5%)					
	Sepia officinalis, Octopus vulgaris, Eledone moschata, Eledone cirrhosa, Todarodes sagittatus	Length	In most of hauls mantle length is measured for all specimen and sex is noted for adults. When the catch of a given species or a fraction of a given species (e.g. juveniles) is too abundant to be measured in extenso it is taken a representative sub-sample of the catch or fraction, that should be not less than 100 individuals.					
Research survey "SOLEMON"	***Sepia officinalis***	Length, weight, sex, maturity	NP	May	GSA: 17	SoleMon Survey – Instruction Manual - Version 4, 2019: 49 pp		The SOLEMON survey is conducted in the North-Central Adriaric Sea, using a modified beam trawl with a rigid mouth, called "rapido{" by Italian fishermen.

DATA SOURCE [1]	Species or group	Biological variables [2]	SAMPLING INTENSITY [3]	Seasonality (Temporal strata)	REGION, FISHERY	Protocol reference	URL	Comments
Covered by a commercial sampling scheme (at sea and on shore) for length	***Eledone cirrhosa***	Length /mean individual weight	**150** ind/Y (GSAs: 11), **250** ind/Y (GSAs: 1, 5, 7), **300** ind/Y (GSAs: 19), **1000** ind/Y (GSAs: 6), **1100** ind/Y (GSAs:9), **2000** ind/Y (GSAs: 18)	Quarterly	GSAs : 1, 5-7, 9-11, 16, 17, 20, 22	Protocols for DCF multiannual programms are described in Work plans and Annual Reports by each MS (present description follows 2019 Annual Reports) In France: OBSMER and DACOR sampling protocols are particularly adapted to small-scale coastal fisheries in GSAs 7 and 8 respectively.	Italian guidelines for the DCF implementation. http://dcf-italia.cnr.it/reserved/lineeguida/1	For Bottom otter trawls, purse seines and boat seines the 100 % of the trips are conducted on board (at sea) of commercial fishing vessels. For the small-scale fishery métiers, the 70% of the trips are conducted on board (at sea) and 30% of the total number of sampling trips are conducted on shore .
	Eledone moschata		**50** ind/Y (GSAs:9), **500** ind/Y (GSAs: 17w), **600** ind/Y (GSAs: 18)**, 1000** ind/Y (GSAs: 17e)		GSAs : 17, 20, 22			
	Illex spp., Todarodes spp.		**50** ind/Y (GSAs: 11), **100** ind/Y (GSAs: 10), **150** ind/Y (GSAs: 7), **200** ind/Y (GSAs: 1, 5), **400** ind/Y (GSA: 2), **1000** ind/Y (GSAs: 6), **1250** ind/Y (GSAs: 16), **1700** ind/Y (GSAs:9) **2000** ind/Y (GSAs: 17w), **3000** ind/Y (GSAs: 19), **8000** ind/Y (GSAs: 18)		GSAs : 1, 5, 6, 9, 10,11, 16, 17w, 18, 19, 20, 22			
	Loligo vulgaris		**50** ind/Y (GSAs: 10), **90** ind/Y (GSAs: 11), **150** ind/Y (GSAs: 19), **200** ind/Y (GSAs: 1, 16), **500** ind/Y (GSAs: 5, 6, 9), **2000** ind/Y (GSAs: 17, 18)		GSAs : 1, 5, 6, 9- 11, 16, 17w, 18-20, 22			
	Octopus vulgaris		**100** ind/Y (17e, 25), **120** ind/Y (GSAs: 10), **200** ind/Y (GSAs:9, 19), **400** ind/Y (GSA: 5, 18), **600** ind/Y (GSAs: 11), **1000** ind/Y (GSAs: 1, 6), **no min** ind/Y (7, 8)		GSAs : 1, 5, 6, 7, 8, 10, 11, 16, 17w, 18, 19, 20, 22, 25			
	Sepia officinalis		**200** ind/Y (GSAs: 1, 10), **250** ind/Y (GSA: 5), **350** ind/Y (GSAs:9), **500** ind/Y (GSAs: 19), **700** ind/Y (GSAs: 6), **1500** ind/Y (GSAs: 18), **4000** ind/Y (GSAs: 17w)		GSAs : 7, 8, 10, 11, 16, 17w, 18, 19, 20, 22, 23			
Selected for sampling of biological variables	***Eledone cirrhosa***	Length, weight, sex, maturity	**100** ind/Y (GSAs: 11, 16, 17), **200** ind/Y (GSAs:10, 19), **280** ind/Y (GSAs: 9), **1000** ind/Y (GSAs: 18)	Quarterly	GSA: 9, 10, 11, 16, 17, 18, 19			Samples for the study of biological variables, may come from research surveys, sampling on board/on shore from commercial vessels anf market. Representative samples covering all observed length classes by month/quarter are proposed.
	Eledone moschata		**50** ind/Y (GSAs:9, 10, 11), **100** ind/Y (GSAs: 19, 20, 22), **200** ind/Y (GSAs: 17w), **300** ind/Y (GSAs: 16), ***500*** ind/year(17e, 18)		GSA : 9-11 11, 16, 17-20, 22			
	Illex coindetii		**100** ind/Y (GSAs: 20), **200** ind/Y (GSAs: 22)		GSA : 20, 22			
	Loligo vulgaris		**300** ind/Y (GSAs: 5), **260** ind/Y (GSAs: 22), **400** ind/Y (GSAs: 20)		GSA : 5, 20, 22			
	Octopus vulgaris		**50** ind/Y (GSAs:9, 17w), **100** ind/year(10, 17e, 20), **150** ind/Y (GSAs: 19), **200** ind/Y (GSAs: 16)**, 300** ind/Y (GSAs: 18), **500** ind/Y (GSAs: 22), **1500** ind/Y (GSAs: 1)		GSA : 1, 9, 10, 16-20, 22			
	Sepia officinalis		**50** ind/Y (GSAs:9), **100** ind/Y (GSAs: 11, 17w, 23), **200** ind/Y (GSAs: 10, 16), **250** ind/Y (GSAs: 20, 22), **400** ind/Y (GSAs: 19), **500** ind/Y (GSAs: 5), **1000** ind/Y (GSAs: 18)		GSA :5, 9-11, 16 17w, 18-20, 22-23			
Commercial (all) and research surveys (at sea)	***Dosidicus gigas***	Length	Random. 120 indiv. per vessel (commercial at market). Weekly	N/A	Jumbo flying squid fishery in Perú	Tafur, R., Mariátegui, L., Yamashiro, C., Sanjinez M. & Mendoza, J. 2019. Protocol for biological and biometric sampling of jumbo flying squid Dosidicus gigas in use in Perú.	Tafur et al. 2019	Monitoring system adopted by SPRFMO
			Random. 120 indiv. per fishing area for artisanal and per operation for industrial (commercial at sea). Daily (industrial) and by output (artisanal)	N/A				
			Random. 120 specimens per set (research survey). Daily	N/A				
		Reproductive	Stratified random. 10 indiv. by sex covering the size range of the catch, by fshing area (commercial at sea). Daily	N/A				
			Stratified random. 10 indiv. by sex and size range by latitudinal degree (research survey). Daily	N/A				

5 ToR E

ToR e: Describe the value chain and evaluate the market drivers of cephalopod fisheries. The deliverables included a paper on cephalopod global value chains (Y1), paper on value chains and market drivers of specific cephalopod fisheries (Y3)

The group has submitted two papers for publication (Ainsworth *et al*., In Press a,b). A paper focused on the role of cephalopods in the transformation towards sustainable seafood systems, linking market drivers to ecosystem services and good quality of life through the IPBES conceptual framework, submitted to People and Nature in April 2022. A second paper focused on identifying sustainability priorities among value chain actors in artisanal common octopus fisheries, submitted to a Special Issue on Artisanal and Small-scale Fisheries and Aquaculture (International Year of Artisanal Fisheries and Aquaculture 2022), on the journal Reviews in Fish Biology and Fisheries, in June 2022.

Ainsworth, G., Pita, P., Rodrigues, J., Pita, C., Roumbedakis, K., Fonseca, T., Castelo, D., Longo, C., Power, A., Pierce, G., Villasante, S. 2022. Disentangling global market drivers for cephalopods to foster transformations towards sustainable seafood systems. People and Nature (*in press*).

Abstract:

Achieving food security and biodiversity conservation presents interconnected challenges. Aquatic food systems are important contributors to global food security to satisfy an intensifying demand for protein-based diets, but global economic growth threatens marine systems. Cephalopod (octopus, squid, cuttlefish) fisheries can contribute to food security; however, their sustainable exploitation requires understanding connections between nature's contributions to people (NCP), food system policies and human wellbeing. Our global literature review methodology examined what is known about cephalopod food systems, value chains and supply chains, and associated market drivers. For analysis, we followed the IPBES conceptual framework to build a map of the links between cephalopod market drivers, NCP and good quality of life (GQL). Then we mapped cephalopod food system dynamics onto IPBES (in)direct drivers of change relating to catch, trade and consumption. This research contributes knowledge of key factors relating to cephalopods that can support transitions towards increased food security: the value of new aquatic food species; food safety and authenticity systems; place-based innovations and empowerment of communities; and consumer behaviour, lifestyle and motivations for better health and environmental sustainability along the food value chain. We outline requirements for a sustainable, equitable cephalopod food system policy landscape that values nature's contributions to people, considers UN Sustainable Development Goals and emphasizes the role of multiple seven overlapping IPBES (in)direct drivers of change: Economic, Governance, Sociocultural and Socio–psychological, Technological, Direct Exploitation, Natural Processes and Pollution. We present a novel market-based adaptation of the IPBES conceptual framework to represent how the cephalopod food system functions and to inform processes to improve sustainability and equity of the cephalopod food system. This synthesised knowledge provides the basis for diagnosing opportunities (e.g. high demand for products) and constraints (e.g. lack of data on how supply chain drivers link to cephalopod NCP) to be considered regarding the role of cephalopods in transformations towards a resilient and more diversified

seafood production system. This social-ecological systems approach could apply to other wild harvest commodities with implications for diverse marine species and ecosystems and can inform those working to deliver marine and terrestrial food security while preserving biodiversity.

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Abstract

The 2022 'International Year of Artisanal Fisheries and Aquaculture' (IYAFA) highlights the challenges producers face in achieving the United Nations Sustainable Development Goals (SDGs). Knowledge remains lacking about which practical actions may help fulfil such goals, however value chain analysis can contribute to finding solutions. Such analysis typically focuses on economic criteria whereas studying the social values that influence stakeholder decision-making can provide a more holistic understanding of how socio–ecological factors influence sustainability outcomes. Our novel 'social value chain analysis' of two Spanish artisanal common octopus (Octopus vulgaris) fisheries (western Asturias - MSC certified, and Galicia - non–certified) elicited stakeholders' perspectives about sustainable octopus production and commercialization. A literature review based on Rapfish sustainability evaluation criteria elucidated perspectives and emphasized the importance of institutional, environmental, economic and ethical indicators. We linked stakeholders' shared sustainability priorities (e.g. integrated fisheries management, knowledge-based management, product traceability) to relevant IYAFA Pillars. This identified how certification incentives and other cooperative approaches facilitate sustainability, support IYAFA priority outcomes (raised awareness, strengthened science-policy interface, empowered stakeholders, partnerships), and help to achieve several UN SDGs: 1 (No Poverty), 2 (Zero Hunger), 5 (Gender Equality), 6 (Clean Water and Sanitation), 9 (Industry, Innovation and Infrastructure), 10 (Reduced Inequalities), 12 (Responsible Consumption and Production), 13 (Climate Action), 14 (Life Below Water), 16 (Peace, Justice and Strong Institutions). Recommendations for fostering a strengthened science-policy interface include incorporating positive examples of actors' sustainable activities into governance frameworks to support effective policy-making for artisanal fishery value chains.

6 ToR F

6.1 Review advances in knowledge of environmental tolerance of cephalopods

Changing oceans impact the whole marine ecosystem in different ways. Rising ocean temperatures can affect the presence and absence of species, especially when local environmental conditions exceed individual species' physiological tolerances (Worm and Lotze 2016). In this case, some species might be replaced by other species (Wernberg *et al*., 2014). A number of studies in different areas of the world indicate that the group of cephalopods have benefited from ocean changes (e.g. Doubleday *et al*., 2016). Indeed, climate change has caused shifts in distribution and expansions for various cephalopods (e.g. Oesterwind *et al*., 2022), with the consequences that fisheries have adapted to the new resources and cephalopod landings are increasing in many areas (e.g. Hastie *et al*., 2009b, Pinnegar *et al*., 2016; Doubleday *et al*., 2016, Arkhipkin 2021). But in some areas a stable or even a declining trend in cephalopod biomass is observable (e.g. declines of *L. forbesii* in Iberia; Chen *et al*., 2006), which might also be linked to unfavourable environmental conditions. Due to their high importance in the ecosystem, especially in foodwebs since they perform top–down pressure on lower trophic levels but also have a bottom-up function caused by their role as major prey for some marine mammals and predatory fishes like sperm whales, dolphins, monk seals and some elasmobranchs (Katağan *et al*., 2015), changes in their distribution are important for the functioning of wider ecosystems.

Information on distribution–associated environmental conditions provide an opportunity to model future occurrence of cephalopods, which is interesting from a fisheries and ecological perspective. Some information about physiological tolerances of cephalopods are known, due to laboratory studies and advances in aquaculture for this group (e.g. Giménez and Garcia, 2002, Rosa *et al*., 2014) as well as from field observations (e.g. Pierce *et al*., 1998, Hastie *et al*., 2009b, Oesterwind *et al*., 2010, Ikica *et al*., 2019, Barrett *et al*., 2021). However, laboratory and aquaculture data are based on explicit (and often narrow) environmental ranges and depend on the experimental design, e.g. they may be selected to optimize growth, but may give information about optimal culturing conditions and might be far away from values of the realised niche (i.e. the where a species survives and grows in the presence of other interacting species; Hutchinson 1957; Pearson and Dawson 2003). Information on the latter is provided by field observations of where a particular species occurs 'in reality', in the presence of competitors, prey, etc., and will be more useful for distribution predictions (Pearson and Dawson 2003). However, both types of information provide almost everything needed to construct a species distribution model, e.g. using a bioclimate envelope approach, in order to understand the environmental contribution to the present and future species range.

The aim of ToR F within the current period (2019–2022) was to review advances in the knowledge of environmental tolerance of cephalopods and to develop simple climate envelope models of cephalopod habitat as a potential forecasting aid and to update the distribution map of various species.

To fulfil the first subtask, we used the ICES DATRAS dataset to first describe the current distribution of cephalopods associated with the European Shelf and second to advance the knowledge regarding their "realised niche" and to produce distribution maps. The coverage of the dataset includes the whole East Atlantic Shelf area (Figure 6.1).

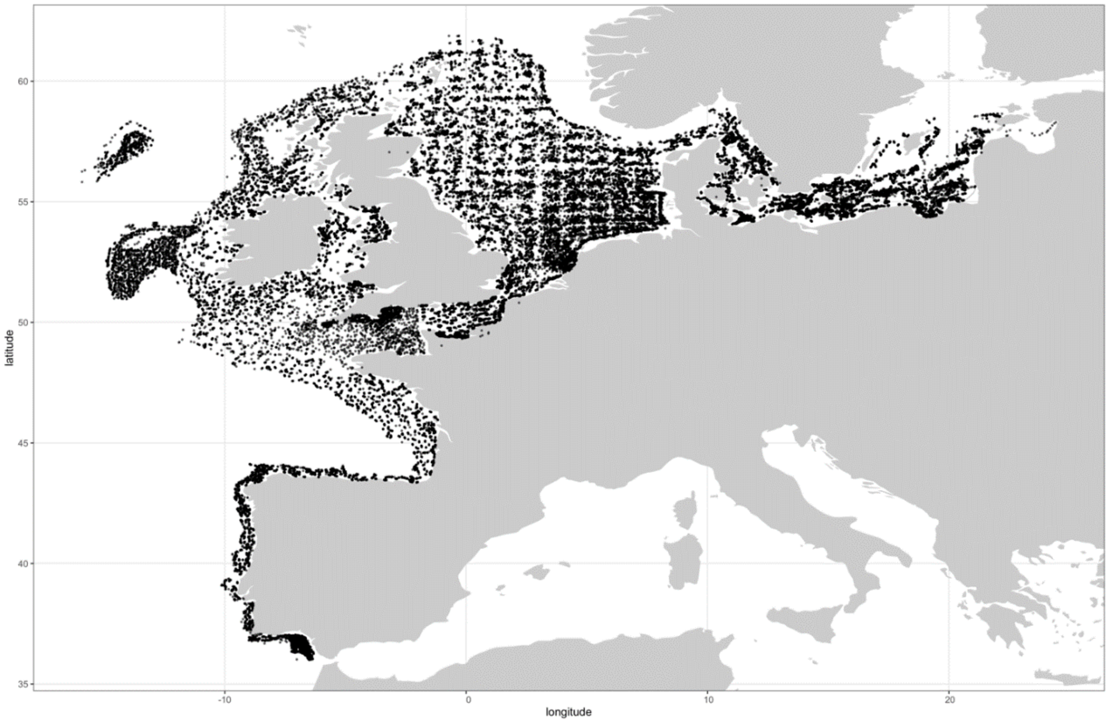

Figure 6.1 Location of sampling stations between 1990 and 2020 referred in the DATRAS database considering the shoot location, each dot represents a fishing operation.

While analysing the exported datasets from DATRAS we encountered some very likely misidentification of species, as some species have been documented far away from their known and accepted distribution. As an example, we combined the dataset of *Illex illecebrosus* and *Illex coindetii* to *I. coindetii* as it is very likely that only *I. coindetii* occurs in the North East Atlantic, particularly on the Irish Shelf where there no *I. illecebrosus* have been verified by barcoding (Oesterwind *et al.*, 2020; [CEPH & CHEFS PROJECT](#).Another example is *Opisthoteuthis agassizii*, which is limited to the western Atlantic (Villanueva 2002) and should be replaced with *Ophsitoteuthis calypso*. We focus, here, on the main relevant species for European fisheries.

Within European waters, species occur in different realised niches and show substantially different environmental tolerances (Table 6.1). Some species that are taxonomically close together have substantially different realised niches, which might support co-occurrence within the same area. The information is somewhat limited due to restrictions of the survey design, including seasonality, depth, mesh sizes and bottom trawling (rather than pelagic sampling), and might therefore not illustrate the total environmental range for oceanic and pelagic species, but it does deliver a good amount of information about species occurrence on the European shelf area for many commercially targeted neritic species, in particular.

Table 6.1 Summary table of environmental tolerances that has been measured in parallel with the fishing hauls, based on ICES coordinated bottom trawl surveys (DATRAS).

	Depth (m)				Temperature (ºC)				Salinity			
Species	Min	Max	range	No. of stations	Min	Max	range	No. of stations	Min	Max	range	No. of stations
*Alloteuthis subulata**	2	265	263	45649	1.1	22.8	21.7	19869	4.92	38.02	33.1	18539
Illex coindetii	10	735	725	31175	5.1	18.7	13.6	9545	25.64	36.96	11.32	9430

	Depth (m)				Temperature (ºC)				Salinity			
Species	Min	Max	range	No. of stations	Min	Max	range	No. of stations	Min	Max	range	No. of stations
Loligo forbesii	4	530	526	73857	1	21.1	34	18556	29.3	38.02	8.72	18802
Loligo vulgaris	4	461	457	21799	5	20.9	15.9	7520	25.74	38.02	12.28	6382
Todarodes sagittatus	25	2000	1975	1987	1	16.7	15.7	1394	25.64	36.42	10.78	1357
Todaropsis eblanae	10	774	764	20044	1	20.8	19.8	10204	25.64	36.96	11.32	10029

*Current research results illustrate high percentage of misidentification (CEPH & CHEFS project https://www.cephsandchefs.com/). Additional preliminary results of a genetic study also highlight taxonomic issues within the *Alloteuthis* genus.

We have not yet been able to analyse the environmental tolerances of different life stages. It is known that certain life stages have a narrower range of environmental tolerances than the respective adult stages. Due to the sampling design of fisheries research cruises, we are able to say that the recorded environmental information is most likely linked to juveniles and adults and not to very small individuals like paralarvae. A manuscript with more details is in preparation and will be submitted as soon as possible.

6.2 Develop simple climate envelope models of cephalopod habitat as a potential forecasting aid

Due to various circumstances, we made minor progress regarding the second subtask. However, we collected potential datasets on environmental conditions. We believe that Copernicus will provide suitable environmental data to complete the task of modelling environmental drivers of distribution shifts. In addition, we finalized the basis for the ecological understanding (Substask 1) and analysed the realized environmental niche for various species. We will continue with the modelling task for *L. forbesii* and *L. vulgaris*, and will analyse which environmental factors drive changes in the species' distribution. Both realized niche (distribution) and environmental information will be used to project species distribution under future climate conditions.

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Annex 2: Resolution

The **Working Group on Cephalopod Fisheries and Life History** (WGCEPH), chaired by Ana Moreno, Portugal; Daniel Oesterwind, Germany; and Graham Pierce, Spain, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2020	2–5 June	by corresp/ webex		physical meeting cancelled – remote work
Year 2021	8–11 June	Online meeting		
Year 2022	13–16 June	Teneriffe, Spain	Final report by 1 September to SCICOM	

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a	Report on cephalopod fishery status and trends: update, quality check and analyse relevant fishery statistics (landings, directed effort, discards and survey catches).	A core ToR of WGCEPH since the inception of the group. It provides an overview of the current status of cephalopod fishing in the ICES area.	5.1, 5.2	Years 1–3	Fishery status reports (Annual)
b	Review relevant advances in stock identification, stock assessment methods (e.g. use of environmental predictors, development of Management Strategy Evaluation) and fishery management measures. Conduct preliminary assessments of the main cephalopod stocks in the ICES area, based on trends and/or analytical methods *inter alia* to support the needs of the MSFD reporting.	While catching cephalopods in large–scale fisheries in the EU is essentially unregulated, fishing pressure is increasing. There is a need to to define stocks / management units. Annual assessments will help to identify threats to stock status and are also relevant to MSFD descriptor 3; review of possible management measures will support formulation of advice, should this become necessary.	5.1, 5.2, 6.1	Years 1–3	Stock status reports (Annual); Review of current cephalopod fishery management in the ICES area and possible future options (Y1)
c	Continue to review advances in knowledge of life history and ecology, identifying knowledge gaps and	Cephalopods show high variation individual life history and population abundance;	1.7, 5.2	Years 1–3	Annual report on relevant new knowledge

	research priorities.	understanding this variation is essential to underpin assessment and management. In relation to the ecosystem role of cephalopods, few studies consider species interactions other than predation. We also need to better understand the roles of fishing and climate change in determining biodiversity.			
d	Review, develop and recommend tools for cephalopod species identification at all life stages (adults, juveniles, paralarvae and eggs) and update best practice for routine data collection.	Cephalopod species identification in fishery and survey catches remains inconsistent and incomplete. Current standard data collection may be insufficient to support routine assessment. There is a need for easy–to–use regional identification guides (e.g. for fishers, fishery inspectors, buyers, and scientists undertaking sampling).	1.6, 3.2, 5.2	Years 1–3	Updated data collection recommendations (Annual); Plan for ID guides (Y1); New and revised ID guides (Y3)
e	Describe the value chain and evaluate the market drivers of cephalopod fisheries.	More information is needed on the social and economic sustainability of cephalopod fishing.	5.8, 7.2	Years 1–3	Case study reports on Iberian octopus (Y1), English Channel cuttlefish (Y2) and squid fisheries (Y3)
f	Review advances in knowledge of environmental tolerance of cephalopods, develop simple climate envelope models of cephalopod habitat as a potential forecasting aid.	Despite high phenotypic plasticity, cephalopod distribution is limited by extremes of temperature, salinity, dissolved oxygen, etc. and it is expected that climate change will lead to range shifts.	1.3, 1.5, 2.5	Years 1–3	Paper on climate envelopes and forecasting range shifts (Y3)

Summary of the Work Plan

Year 1	Routine reporting on all ToRs. Plan for ID guides (ToR d). Reports on management options (ToR b) and socio-economics of Iberian octopus fisheries (ToR e)
Year 2	Routine reporting on all ToRs. Report on socio-economics of English Channel cuttlefish fisheries (ToR e).
Year 3	Routine reporting on all ToRs. Delivery of ID guides (ToR d) and report on socio-economics of squid fisheries (ToR e). Paper on climate envelope models (ToR f)

Supporting information

Priority	The current activities of this Group will inform ICES about the status of cephalopod stocks and fisheries at a time when fishing pressure is increasing. Cephalopods are not covered by the EU Common Fisheries Policy but there is a need to identify sustainability issues and to be in a position to recommend management actions, should the need arise. Furthermore, the planned preliminary assessments of different stocks can support the MSFD reporting in several Member Countries. These activities are believed to have a very high priority. ToRs a–d are envisaged as standing ToRs. ToR a is fundamental to support stock assessment (ToR b) and will involve a Data Call. ToR a will also review stock definition, since past preliminary assessments have been based on arbitrary spatial units and there is a need to define more appropriate management units. ToR c provides a review of recent advances in knowledge of cephalopod biology and ecology; improved understanding of life history plasticity, ecological roles and the high year-to-year variation in abundance remains a priority. ToR d continues efforts to facilitate better routine identification of cephalopod catches to species level. ToR e aims to ensure that social and economic sustainability of cephalopod fisheries are better undeerstood, a key requirement for integrated ecosystem assessment. ToR f addresses effects of ocean warming on cephalopod distribution. Evidently, cephalopods show coniderable plasticity, and climate change may also affect larval transport and predator–prey relationships, which will also affect distribution. Nevertheless modelling likely physiological limits to distribution should contribute to forecasting.
Resource requirements	As noted in several previous reports, participation in WGCEPH is limited by availability of funding, especially as many members and potential members are staff of institutions which have no access to “national funds” for attendance at ICES meetings. Although there are no specific resource requirements, funding to assist wider participation would be beneficial.
Participants	Meetings of the Group are normally attended by around 10–15 members and guests, with wider participation via videoconferencing and e–mail.
Secretariat facilities	None.
Financial	No specific financial implications (but see “resource requirements”).
Linkages to ACOM and groups under ACOM	The results of WGCEPH are potentially relevant to advice in the case that formal assessment and management are introduced for any of these species. .
Linkages to other committees or groups	Possible links with ICES groups working on predators of cephalopod (e.g. WGBIE, WGCS, WGMME). WGCEPH would like to encourage improved data collection on cephalopods during trawl surveys. It will make available (e.g. to IBTSWG) detailed diagrams and protocols for identifying cephalopods and collecting biological parameters during the scientific surveys. WGCEPH will provide information to SCICOM and its satellite committees as required to respond to requests for advice/information from NEAFC and EC DG Fish.
Linkages to other organizations	WGCEPH maintains links with ongoing European and national research projects and with the Cephalopod International Advisory Council.

Annex 3: Supplementary information

Table 1. Landings (in tonnes) of Cuttlefish (Sepiidae) and Bobtail Squid (Sepiolidae)

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.3.a	**58**	**50**	**37**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Denmark	58	50	37													
France												0.0	0.0			
Germany		0.0														
Netherlands								0.0		0.0	0.0	0.2			0.0	
Sweden												0.2	0.1			0.0
ICES Area 27.4.a	**15**	**12**	**9**	**0**	**3**	**0**	**0**	**0**	**0**	**1**	**1**	**4**	**1**	**0**	**3**	**8**
Denmark	11	10	7											0.5		
France	4	2	2	0.0	3	0.3						0.0	0.0			
Germany																
UK (England, Wales, N. Ireland)								0.0		0.0		1.1	0.0		3	
UK(Scotland)		0.0	0.0							0.9	0.7	3	0.6		0.0	8
ICES Area 27.4.b	**22**	**26**	**16**	**2**	**4**	**1**	**2**	**0**	**1**	**2**	**3**	**1**	**1**	**1**	**2**	**1**
Belgium	1	2	4							1	0.6	0.1	0.2	0.2	0.6	0.1
Denmark	21	23	12													
France				1	4	0.7	2	0.1	0.1	0.4		0.0	0.0	0.1	0.1	0.0
Germany															0.0	
Netherlands	0.1	0.6	0.2	0.7						0.2	2	0.3	0.4	0.4	0.6	0.4
UK (England, Wales, N. Ireland)		0.0	0.0				0.3	0.1	0.6	0.2	0.3	0.7	0.3	0.2	0.2	0.1
UK(Scotland)		0.0	0.0					0.0		0.0	0.1	0.3	0.3	0.0	0.3	0.2
ICES Area 27.4.c	**424**	**282**	**286**	**132**	**234**	**34**	**48**	**117**	**38**	**224**	**284**	**107**	**94**	**127**	**392**	**262**
Belgium	57	33	53							41	21	16	4	10	14	21
France	77	84	108	77	89	34	41	114	33	82	61	22	35	22	37	9
Netherlands	287	161	123	55	145					90	192	63	51	88	332	224
UK (England, Wales, N. Ireland)	3	3	2				7	3	5	11	10	6	3	5	7	6
UK(Scotland)		1	0.0									0.0	0.1	1	3	3
ICES Area 27.5.b	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
France									0.0			0.0	0.0			
ICES Areas 27.6.a,b	**0**	**1**	**0**	**10**	**0**	**0**	**0**	**0**	**33**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
France	0.1	1	0.1	10	0.0	0.2		0.2	33		0.0	0.0	0.0		0.0	
Spain		0.0	0.0	0.0		0.0	0.0					0.0	0.0	0.0		
UK (England, Wales, N. Ireland)		0.0	0.0							0.0	0.0	0.0	0.0			
UK(Scotland)		0.0	0.0					0.1				0.0				
ICES Area 27.7.a	**0**	**0**	**0**	**0**	**1**	**19**	**0**	**0**	**0**	**2**	**0**	**1**	**0**	**724**	**1**	**1**
Belgium		0.0	0.0							0.2	0.1	0.2	0.1	724.0	0.6	0.6
France	0.3	0.1	0.0	0.1	0.7	19.5	0.0	0.0	0.4			0.0	0.0			
Netherlands					0.1											
UK (England, Wales, N. Ireland)		0.0	0.0	0.3	0.1	0.0		0.0		1.4	0.1	0.4	0.0	0.0	0.0	0.0
UK (Scotland)															0.0	
ICES Areas 27.7.b,c	**25644**	**30601**	**18954**	**10250**	**19162**	**16564**	**25424**	**17014**	**12174**	**23882**	**20522**	**25203**	**17777**	**21878**	**19331**	**13716**
France	0.4	1.8	0.0	0.7	1.5	1.7	3.5		3.0	2.9	6.9	5.3	3.4	3.3	8.8	4.7
Ireland				0.1	0.2	0.1										
Spain	9.0	9.0	19.0	10.6	73.2	29.0	1.0			0.1	0.1	0.0	0.0	0.0	0.0	
UK (England, Wales, N. Ireland)		0.0	0.0	4.3	0.6	0.1	1.0			0.3	0.6	0.1	0.0			
ICES Areas 27.7.d,e	**12 817**	**15 295**	**9 467**	**5 117**	**9 543**	**8 266**	**12 709**	**8 507**	**6 086**	**11 939**	**10 257**	**12 599**	**8 887**	**10 938**	**9 661**	**6 855**
Belgium	661	1331	801							642	824	802	781	781	865	703
France	8726	9663	5212	3555	6826	6229	7310	5012	3333	5660	4524	4372	3406	4494	4 413	3 281
Germany																5
Ireland								4		7	36	395	410	427	46	1
Netherlands	15	12	31	37	81					90	38	79	171	371	348	313
Channel Islands	3															
UK (England, Wales, N. Ireland)	3412	4279	3416	1525	2637	2037	5222	3337	2752	5540	4834	6932	4111	4850	3 959	2 533
UK(Scotland)		11	7				177	155				19	7	16	31	20

Table 1. Landings (in tonnes) of Cuttlefish (Sepiidae) and Bobtail Squid (Sepiolidae) (cont.)

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.7.f	**30**	**59**	**43**	**8**	**13**	**17**	**46**	**22**	**13**	**52**	**22**	**140**	**50**	**35**	**30**	**35**
Belgium	5	6	7							16	7	42	12	12	5	10
France	17	41	30	8	13	17	37	13	10	21	7	34	5	12	18	13
Ireland								0			0	0	0	0		0.1
UK (England, Wales, N. Ireland)	8	12	6				9	8	3	15	8	61	34	11	7	
UK(Scotland)												3	0			13
ICES Areas 27.7.g-k	**189**	**143**	**170**	**974**	**1 385**	**1 920**	**530**	**22**	**866**	**1 312**	**664**	**576**	**548**	**451**	**372**	**276**
Belgium	5	5	4							20	23	40	16	11	7	4
France	18	9	22	736	999	1 173	402	13	576	799	433	431	485	398	318	244
Ireland		0.0	1	0.2	0.0	1	22			5	2	9	10	2	1	1
Netherlands		0.0	0.0		1					0.0		0.0	0.0	0.0		
Spain		0.1		0.0	0.0	0.0	0.0	8	4	10	9	4	16	0.3	2	1
UK (England, Wales, N. Ireland)	166	129	143	238	386	746	105	1	286	478	198	93	21	40	45	26
UK(Scotland)												0.0	0.2			0.1
ICES Area 27.8	**4 349**	**6 189**	**2 687**	**3 914**	**3 781**	**5 585**	**6 452**	**4 594**	**3 958**	**4 975**	**4 899**	**3 861**	**2 952**	**3 453**	**2 559**	**3 621**
Belgium		17	2							13	9	1	6	2	22	7
France	3954	5586	2227	3666	3508	5158	5693	4147	3690	4667	4512	3793	2754	3303	2 379	3 401
Netherlands		0.0	0.0	0.1												
Portugal	37					24	23	24		8	6	0.0	0.0			
Spain	357	586	458	248	273	403	735	423	268	288	373	66	192	148	159	213
UK (England, Wales, N. Ireland)	1	0.0	0.0	0.0	0.0	0.0	0.4				0.0					
ICES Area 27.9	**2 912**	**2 553**	**2 388**	**2 224**	**3 173**	**2 502**	**2 143**	**2 857**	**2 286**	**2 115**	**2 263**	**1 799**	**1 610**	**1 830**	**2 163**	**1 997**
France										0.0		0.0	0.0			
Portugal	1822	1517	1453	1259	2009	1511	1165	1302	1302	1193	1266	1023	760	797	947	1075
Spain	1090	1036	935	965	1164	991	978	1 555	984	922	997	775	851	1 033	1 216	922
Total	**46 461**	**55 212**	**34 057**	**22 631**	**37 299**	**34 908**	**47 354**	**33 133**	**25 456**	**44 504**	**38 915**	**44 292**	**31 920**	**39 438**	**34 513**	**26 772**

Table 2. Landings (in tonnes) of Loliginids (includes *Loligo forbesi*, *L. vulgaris*, *Alloteuthis subulata*, and *A. media*)

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.3.a	**10**	**0**	**0**	**3**	**1**	**2**	**4**	**4**	**1**	**8**	**3**	**16**	**12**	**5**	**13**	**16**
Denmark												0.0	0.0	0.4	3	4
Germany				3	0.0	0.0	1	0.1	1	2	0.4	2	0.0		0.0	0.0
Netherlands	0.2				1	2	2	0.0			1	3	1	1	1	2
Sweden	10						1	4		6	2	12	12	4	9	11
ICES Area 27.4.a	**677**	**878**	**677**	**1 690**	**2 140**	**807**	**685**	**541**	**1 307**	**727**	**1 467**	**1 522**	**1 451**	**1 922**	**1 381**	**1 094**
Belgium															2	0
Denmark														6	8	2
France	0	0	0	0	3	0	0	0	0	0	8	17	3	1	2	0
Germany	1	1	2	0	1		1	1	1	3	2	6	0		8	0
Netherlands								0		0	0	0	1	6	0	0
Sweden								0		0	0	0	0	1	4	1
UK (England, Wales, N. Ireland)		13	0	15	31	17	12	5	17	1	6	0	0	0	1	1
UK(Scotland)	676	864	675	1674	2105	790	671	535	1289	723	1452	1499	1446	1908	1357	1090
ICES Area 27.4.b	**293**	**381**	**115**	**64**	**633**	**567**	**90**	**145**	**138**	**285**	**259**	**270**	**41**	**321**	**388**	**184**
Belgium	17	20	4							35	39	49	5	42	59	18
Denmark											0.0	0.0		80	9	4
France	54	15	2	7	44	30	2	1	14	7	2	4	0.0	8	10	0.2
Germany	13	21	8	7	8	7	5	1	10	14	16	16	0.0		36	3
Netherlands	16	15	10	5	11			0.0			40	62	2	86	85	11
Sweden								0.1		0.0	1	2	0.3	1	1	1
UK (England, Wales, N. Ireland)	85	65	30	45	111	355	23	13	40	41	110	58	9	51	72	100
UK (Scotland)	107	245	62		459	175	59	130	74	188	51	79	25	54	115	48
ICES Area 27.4.c	**160**	**186**	**329**	**501**	**180**	**99**	**58**	**50**	**662**	**156**	**629**	**345**	**692**	**971**	**1375**	**654**
Belgium	9	7	10							15	22	9	18	194	261	62
Denmark														1	0.0	0.0
France	117	98	235	417	129	96	57	49	644	130	450	233	508	559	573	136
Germany	1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	2	1	1	0.0		11	14
Netherlands	29	77	82	82	50			0.0			133	89	143	177	385	283
UK (England, Wales, N. Ireland)	2	2	2	3	1	2	1	1	18	9	23	12	4	38	59	98
UK (Scotland)	2	1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	19	2	86	60
ICES Area 27.5.b	**0**	**2**	**10**	**8**	**27**	**0**	**0**	**0**	**26**	**20**	**0**	**2**	**2**	**4**	**5**	**6**
Faroe Islands														0.3		
France	0.0	1	0.0	1	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.1	0.1	0.2	0.0	
Poland															5	5
UK (England, Wales, N. Ireland)		0.0	0.0	5	15	0.0			0.0	0.0	0.0	0.0	0.2	3	0.1	1
UK (Scotland)		1	10	2	12	0.0	0.0	0.0	26	20	0.0	2	2			
ICES Area 27.6.a	**137**	**149**	**157**	**244**	**426**	**559**	**107**	**215**	**147**	**157**	**145**	**291**	**639**	**759**	**609**	**530**
France	28	38	29	60	55	44	19	40	23	18	20	31	40	36	14	21
Germany		0.0	4						0.0	10					7	69
Ireland	20	29	15	34	41	57	26	19	13	10	15	26	61	45	33	21
Netherlands			36		5	0.0		0.0		0.0	2	4	12	5	16	13
Poland														6	3	39
Spain		10	3	3	0.0	0.1		0.1	0.0	0.0	4	0.1	0.0	0.5	0.0	0.1
UK (England, Wales, N. Ireland)	1	2	1	2	2	3	3	4	2	0.0	1	1	0.0	0.4	0.2	3
UK (Scotland)	88	71	69	145	323	455	59	152	109	119	104	229	525	666	536	363
ICES Area 27.6.b	**22**	**25**	**842**	**239**	**585**	**726**	**733**	**338**	**786**	**333**	**607**	**1 992**	**559**	**1 218**	**320**	**64**
France	0.0	0.0	0.0	0.0		0.2	0.0	0.0	0.0	0.0	0.0	0.0			0.0	
Ireland	18	13	139	0.0	0.0	25	17	0.3	123	98	607	1435	324	1005	315	2
Spain						0.0	0.0	0.3	0.1	2	0.0	0.0	0.0	0.2	0.1	
UK (England, Wales, N. Ireland)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.2	0.0	0.0	9	5	1
UK (Scotland)	4	12	703	239	585	700	716	337	663	233	0.0	557	235	204		61

Table 2. Landings (in tonnes) of Loliginids (includes *Loligo forbesi* , *L. vulgaris*, *Alloteuthis subulata* , and *A. media*) (Cont.)

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.7.a	**15**	**16**	**18**	**26**	**19**	**54**	**32**	**47**	**14**	**2**	**6**	**6**	**2**	**6**	**2**	**1**
Belgium	1	1	1							0.2	0.2	0.2	0.2	1	1	0.3
France	1	1	1	0.2	1	2	0.5	1	0.2	0.0	0.2	0.1	0.0		0.0	0.0
Ireland	5	5	3	6	3	7	4	2	7	1	3	1	1	1	1	0.1
Isle of Man																
Netherlands					1					0.0	3	4	1			
UK (England, Wales, N. Ireland)	8	9	13	19	13	45	28	44	7	0.2	0.0	0.0	0.0	3	1	0.2
UK (Scotland)		0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0		0.0	0.0	
ICES Area 27.7.b,c	**97**	**119**	**282**	**251**	**526**	**522**	**68**	**45**	**50**	**48**	**81**	**47**	**30**	**33**	**62**	**48**
France	40	56	179	56	114	101	31	31	7	4	6	7	5	7	3	3
Germany											0.0	1	0.0			1
Ireland	20	19	57	61	74	72	22	8	17	6	9	9	13	11	12	18
Netherlands			13	0.3	0.2			1		0.0	1	0.0	0.3		0.2	1
Poland															0.1	
Spain	19	26	28	23	276	277	9	4	4	6	20	5	0.3	3	1	2
UK (England, Wales, N. Ireland)	4	11	4	109	62	69	3	1	14	18	33	25	11	13	46	23
UK (Scotland)	14	7	1	1	1	4	3	0.0	8	14	13	0.5	0.0	0.3	0.0	0.0
ICES Area 27.7.d,e	**3 665**	**3 631**	**2 772**	**3 499**	**3 311**	**2 578**	**1 818**	**2 523**	**3 108**	**3 307**	**4 301**	**5 311**	**4 518**	**3 916**	**2 159**	**2 572**
Belgium	46	106	76							213	374	300	244	264	94	89
Channel Islands	2										635	983	930			
France	3216	2960	2189	2967	2796	2207	1411	2037	2245	2321	2157	3183	2840	2368	1295	1499
Germany															5	14
Netherlands	128	196	195	237	262			1		0.0	0.0	0.3	0.0	878	524	518
UK (England, Wales, N. Ireland)	273	369	313	295	253	371	353	431	863	773	1136	796	438	304	138	310
UK (Scotland)							54	54	0.0	0.0	0.0	49	67	102	102	141
ICES Area 27.7.f	**150**	**324**	**139**	**197**	**271**	**376**	**209**	**344**	**173**	**51**	**119**	**49**	**69**	**32**	**48**	**13**
Belgium	5	4	5		10					13	10	11	5	8	3	1
France	116	179	117	103	187	218	209	201	86	33	93	24	49	18	32	10
Ireland											0.1	4	1	0		
UK (England, Wales, N. Ireland)	29	141	17	94	75	158		143	87	5	17	11	14	5	11	1
UK (Scotland)											0.0	0.1	0.0	0.0	2	
ICES Area 27.7.g-k	**164**	**154**	**198**	**386**	**298**	**469**	**486**	**511**	**565**	**451**	**251**	**258**	**232**	**169**	**237**	**187**
Belgium	3	6	4							1	7	6	4	5	3	1
France	19	18	30	273	197	266	207	217	266	209	93	141	94	71	60	69
Germany				1					0.0	10						
Ireland	52	75	84	20	21	152	181	102	128	15	19	21	51	18	44	57
Netherlands	0.3	1	0.1	3	23	0.0		1		0.0	0.0	1	0.0	0.0	0.0	0.1
Spain		0.1	0.1	0.0	1	0.0		26	11	2	13	6	2	1	9	0.4
UK (England, Wales, N. Ireland)	44	51	73	66	27	20	22	52	87	97	81	70	81	74	122	59
UK (Scotland)	45	3	7	24	30	31	76	113	73	115	38	13	0.4	1		
ICES Area 27.8	**1 786**	**1 812**	**312**	**1 408**	**2 657**	**2 790**	**4 971**	**1 855**	**1 865**	**2 659**	**2 368**	**1 458**	**1 077**	**1 065**	**1 131**	**1 369**
Belgium		2	1							1	1	0.3	0.5	1	0.5	0.5
France	1609	1362		1172	2103	2207	3666	1256	1618	2292	2037	1399	1042	995	1058	1275
Netherlands				2	0.3		0.0	0.0		0.0				1		
Portugal	1					4	18	29	0.0	0.0	0.0	0.0	0.0			
Spain	164	447	311	234	554	579	1273	570	247	366	331	59	35	68	72	93
UK (England, Wales, N. Ireland)		1	0.0	0.0	0.0	0.0	14	0.0	0.0	0.0	0.0	0.0				
UK (Scotland)	12	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
ICES Area 27.9	**347**	**336**	**607**	**485**	**493**	**735**	**809**	**427**	**438**	**757**	**920**	**312**	**878**	**677**	**1059**	**1405**
France							0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	
Portugal	92	128	360	199	207	395	408	226	203	414	301	198	448	443	516	854
Spain	255	209	247	286	286	340	401	201	235	343	619	114	430	234	543	551
ICES Area 27.10	**3**	**721**	**664**	**455**	**554**	**668**	**226**	**476**	**534**	**202**	**105**	**217**	**434**	**923**	**742**	**349**
Portugal*	3	721	664	455	554	668	226	476	534	202	105	217	434	923	742	349
Total	**7 525**	**8 734**	**7 124**	**9 454**	**12 121**	**10 952**	**10 297**	**7 520**	**9 813**	**9 164**	**11 262**	**12 096**	**10 637**	**12 023**	**9 532**	**8 491**

* Landings consist exclusively in *L. forbesii*

Table 3. Landings (in tonnes) of Ommastrephids (*Illex coindetii, Todaropsis eblanae,Todarodes sagittatus, Ommastrephes bartrami*) and other less frequent families and species of Decapod cephalopods.

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.1+2	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
France		0.1	0.01						0							
Norway		0	1													
ICES Area 27.3.a	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**4**	**0**
Denmark															0.02	0.02
Germany												1				
Norway		0	1													
Sweden											0.5			0.4	1	0.2
Netherlands														0.5	3	0.3
ICES Area 27.4.a	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**	**1**	**3**	**1**	**2**
France													1	0.03	0.1	0.8
Germany																
Norway		0	1													
Poland																0.5
Netherlands														2	1	0.3
UK (Scotland)		0	0									10		1		0.5
ICES Area 27.4.b	**0**	**0**	**0**	**0**	**2**	**11**	**0**	**0**	**7**	**0**	**0**	**1**	**0**	**7**	**8**	**2**
Belgium																0.03
France				0.1	2	11	0.1	0.1	7	0.5		0.2	0.1	1	1	0.04
Germany												1				
Netherlands														3	4	0.7
UK (England)													0.4	2	3	2
UK (Scotland)														1	0.02	0.01
ICES Area 27.4.c	**0**	**0**	**0**	**15**	**5**	**19**	**7**	**15**	**99**	**23**	**73**	**38**	**190**	**160**	**67**	**14**
France				15	5	19	7	15	99	23	73	38	190	160	65	13
Germany																
Netherlands														0.02	1	1
UK (Scotland)		0	0													
ICES Area 27.5.a	**0**	**0**	**7**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Iceland		0	7													
ICES Area 27.5.b	**0**	**0**	**41**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**2**
Faroe Islands		0	41													
France													0.1	1	1	1
Netherlands																0.2
Poland																1
UK (Scotland)		0	0	0	0	0										

Table 3. Landings (in tonnes) of Ommastrephids (*Illex coindetii, Todaropsis eblanae,Todarodes sagittatus, Ommastrephes bartrami*) and other less frequent families and species of Decapod cephalopods. (Cont.)

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.6.a,b	**15**	**1**	**264**	**2**	**10**	**1**	**1**	**9**	**0**	**2**	**8**	**0**	**75**	**39**	**17**	**17**
Faroe Islands		0	250													
France	10	1	3	0.03	8	0.03	1	2	0.1	1	0.02	0.02	0.2	1	2	4
Ireland	5	0	11	2	2	1	0.3	6	0.3		0.02	0.1	2	38	15	
Netherlands																5
Poland																7
Spain				0	0	0	0			1	8	0.3	73	0	0.2	
UK (England, Wales & N. Ireland)		0	0	0	0	0										0.02
UK (Scotland)		0	0										0.04	0.05	0.2	
ICES Area 27.7.a	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
France	0.03	0	0.01	0	0.1	0.3	0		0.002							
Ireland		0	1	0.3	0.1	0.0		5								
UK (Englad, Wales & N. Ireland)		0	0	0	0	0						0.02				
UK (Scotland)		0	0	0	0	0										
ICES Area 27.7.b,c	**520**	**431**	**664**	**564**	**1478**	**1272**	**96**	**480**	**173**	**348**	**206**	**253**	**85**	**294**	**351**	**544**
France	46	9	34	9	16	9	10	107	64	104	45	108	39	148	206	286
Ireland	15	1	2	14	49	6	6	18	2		0.2	1	1	3	16	0.3
Spain	458	420	629	541	1413	1257	79	356	103	225	143	136	39	129	123	242
UK (England, Wales & N. Ireland)	1	1	0	0	0	0	0.4		4	19	18					
UK (Scotland)		0	0									8	6	14	6	15
ICES Area 27.7.d,e	**10**	**9**	**10**	**277**	**215**	**384**	**115**	**338**	**281**	**198**	**427**	**536**	**522**	**415**	**264**	**266**
Belgium																0.2
France	10	9	10	277	215	384	114	338	281	198	426	536	520	411	264	266
Ireland														2		
Netherlands																
UK (England, Wales & N. Ireland)		0	0	0	0	0	0.2				0.2	0	1	1	0.3	0.6
UK (Scotland)														0.3		
ICES Area 27.7.f-k	**83**	**72**	**32**	**106**	**97**	**71**	**73**	**354**	**802**	**1217**	**801**	**1367**	**2245**	**1471**	**2535**	**1414**
Belgium																1
France	0	0	4	100	75	53	40	260	162	316	166	199	283	205	497	338
Germany					13											
Ireland	4	12	16	1	1	13	12	87	10		0.2	5	184	235	339	124
Spain	70	43	5	5	8	5			587	856	596	1084	1602	875	1699	839
UK (England, Wales & N. Ireland)	9	17	7	0	0	0	21	7	43	46	40					2
UK (Scotland)		0	0									79	177	156		110
ICES Area 27.8	**441**	**350**	**537**	**722**	**1141**	**1656**	**4449**	**2015**	**2142**	**1048**	**2149**	**327**	**1119**	**1018**	**1175**	**2451**
France	115	100	143	291	243	303	586	972	236	285	411	154	219	406	397	225
Portugal						1	79	252	10	0	0	0				
Spain	326	251	395	430	898	1352	3784	791	1896	763	1738	173	900	612	778	2226
UK (England, Wales & N. Ireland)		0	0	0	0	0	0									
UK (Scotland)		0	0													
ICES Area 27.9	**206**	**108**	**509**	**347**	**740**	**805**	**876**	**721**	**1140**	**464**	**1047**	**166**	**598**	**417**	**447**	**5034**
Portugal	42	21	18	5	10	17	22	288	105	99	144	4	30	49	10	2519
Spain	164	87	491	342	730	788	854	433	1035	365	903	162	568	368	437	2515
Total	**1275**	**971**	**2069**	**2034**	**3689**	**4220**	**5617**	**3937**	**4644**	**3300**	**4712**	**2698**	**4835**	**3824**	**4868**	**9747**

Table 4. Landings (in tonnes) of Octopods (*Eledone* spp. and *Octopus vulgaris* mainly).

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.3.a	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**2**	**5**	**4**	**3**	**5**	**4**
Netherlands											0.00	0.02		0.02	0.05	0.01
Sweden							1	1			2	5	4	3	4	4
ICES Area 27.4.a	**1**	**3**	**3**	**0**	**0**	**0**	**1**	**2**	**0**	**4**	**53**	**17**	**0**	**0**	**9**	**29**
Belgium															0.1	
Denmark												0.3				
Netherlands								0				0.05		0.4	0.1	0.4
Sweden												0.04		0.003	1	0.1
UK (England, Wales, N. Ireland)											44			0.02	0.1	
UK (Scotland)	1	3	3				1	2		4	9	17			8	29
ICES Area 27.4.b	**3**	**1**	**2**	**0**	**0**	**0**	**3**	**1**	**1**	**1**	**3**	**4**	**2**	**6**	**9**	**7**
Belgium	2	1	2								1	1	1	2	4	1
Denmark															0.001	
France						0.2				0.04	0.04	0.02	0	0	0	
Netherlands	0.1	0.1									0.1	1	0.04	1	1	2
Sweden								0.1			0.03	0.1		0.4	1	0.4
UK (England, Wales, N. Ireland)	1	0	0				2	0.4	1	1	2	1	0.5	3	2	2
UK (Scotland)							1	0.2			0.2	1			1	1
ICES Area 27.4.c	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**2**	**24**	**0**	**0**
Belgium		1	0								0.1	0.1	0.03	0.04	0.02	
France										2			0	0	0	0.1
Netherlands	0.1	0.1	0.1	0.5	0.1						0.03	0	0.03	0.1	0.1	0.2
UK (England, Wales & N. Ireland)		0	0					0.01	0.1			0.002	2	24	0.02	0.004
ICES Area 27.6.a,b	**0**	**0**	**2**	**0**	**0**	**0**	**5**	**2**	**0**	**5**	**12**	**3**	**2**	**3**	**0**	**1**
Belgium		0	0										0			
Ireland		0	2	0.1	0.2	0.3	4	0.2	0.3	4	0.1	0.1	0.1	0.04	0.1	0.5
Spain		0	0	0		0	0	0		0.4	0.1	0				
UK (England, Wales, N. Ireland)		0	0	0.2	0	0.05					0.2	0.1	0.04	1		0.002
UK (Scotland)							1	1			12	3	2	1		0.5
ICES Area 27.7.a	**2**	**0**	**1**	**0**	**1**	**1**	**2**	**0**	**3**	**1**	**0**	**2**	**1**	**6**	**3**	**3**
Belgium	2	0	1								0.05	1	1	5	3	3
France										0.4	0.002	0	0.04		0	
Ireland				0.1	1	0.1		0.1	0.2		0.2	0.2	0.3	0.5	0.04	
UK (England, Wales, N. Ireland)		0	0	0.04	0.1	1	2	0.1	3	0.2	0.01	1	0.3	0.02	0.1	
ICES Area 27.7.b,c	**409**	**407**	**384**	**499**	**647**	**993**	**18**	**642**	**38**	**19**	**66**	**66**	**16**	**34**	**57**	**63**
France	10					3	2	8	10	12	23	15	10	13	28	27
Ireland		0	0	1	17	21	0.4	1	2		1	1	0.4	0.1	0.3	1
Spain	389	397	379	389	463	832	4	630	17		22	36	1	13	21	25
UK (England, Wales, N. Ireland)	10	10	5	109	167	138	6	2	9		16	11	5	6	7	8
UK (Scotland)		0	0				6			8	4	3	0.04	1	1	1
ICES Area 27.7.d,e	**30**	**70**	**94**	**97**	**124**	**181**	**250**	**241**	**108**	**162**	**199**	**277**	**355**	**437**	**347**	**313**
Belgium	3	5	8								9	23	41	39	44	60
Channel Islands													46			
France	6				14	7	0	1	7	9	7	8	46	93	71	60
Ireland															1	
Netherlands				0.04	2			0			0.1	0.0	0.0	0.1	0.3	0.1
UK (England, Wales, N. Ireland)	21	65	86	97	108	174	248	235	101	153	183	245	215	301	231	193
UK (Scotland)							2	5					9	4	0.01	

Table 4. Landings (in tonnes) of Octopods (*Eledone* spp. and *Octopus vulgaris* mainly). (Cont.)

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ICES Area 27.7.f	**22**	**26**	**11**	**0**	**1**	**0**	**0**	**0**	**3**	**0**	**14**	**31**	**18**	**29**	**51**	**56**
Belgium	16	20	9								11	25	13	24	43	48
France	1			0.4	1	0.01	0.001	0.003	2	0.03	0.01	0.04	0.1	0.1	0.04	0.02
Spain																
UK (England, Wales, N. Ireland)	5	6	2						2		3	6	5	5	7	7
UK (Scotland)											0	0.03				
ICES Area 27.7.g-k	**169**	**195**	**148**	**33**	**71**	**79**	**152**	**238**	**266**	**149**	**215**	**236**	**147**	**335**	**378**	**383**
Belgium	6	6	3								12	26	24	36	57	63
France	13				11	4	9	181	31	37	48	45	50	107	114	126
Ireland	3	3	7	2	1	23	34	39	8		2	7	6	3	5	4
Spain	36	37	3	1	1				133	112	81	84	2	112	123	120
UK (England, Wales, N. Ireland)	103	137	104	30	58	52	68	13	94		66	62	52	68	79	59
UK (Scotland)	8	12	31				40	5			6	12	12	8		10
ICES Area 27.8	**1 823**	**2 366**	**1 978**	**963**	**2 366**	**2 084**	**1 718**	**1 535**	**1 471**	**1 348**	**1 417**	**488**	**1 324**	**1 559**	**863**	**918**
Belgium	6	15	8					0	0	0	32	24	35	64	18	68
France	95	114	205		106	134	109	184	145	193	227	251	312	381	232	
Netherlands								0	0	0	0	0	0	0	0	0
Portugal	73					15	68	88	62	66	65		0			
Spain	1649	2238	1765	963	2260	1935	1541	1263	1264	1090	1093	212	976	1115	612	850
UK (England, Wales, N. Ireland)		0	0					0	0	0	0	0	0	0	0	0
ICES Area 27.9	**10 238**	**10 479**	**15 994**	**10 360**	**13 527**	**9 621**	**14 501**	**18 967**	**14 004**	**10 892**	**15 026**	**8 124**	**6 784**	**8 504**	**6 138**	**7 961**
Portugal	7074	8452	13258	7940	10471	7266	9654	13062	10728	7609	10568	5851	5048	4433	3881	5376
Spain	3164	2027	2737	2421	3056	2355	4847	5905	3276	3283	4458	2274	1736	4071	2257	2584
ICES Area 27.10	**13**	**19**	**13**	**6**	**14**	**6**	**11**	**24**	**23**	**5**	**7**	**13**	**11**	**6**	**4**	**12**
Portugal*	13	19	13	6	14	6	11	24	23	5	7	13	11	6	4	12
Total	**12 709**	**13 567**	**18 630**	**11 959**	**16 752**	**12 965**	**16 662**	**21 652**	**15 917**	**12 587**	**17 015**	**9 266**	**8 665**	**10 945**	**7 865**	**9 750**

* Landings consist exclusively in *O. vulgaris*

Annex 4: Working Document WGCEPH WD 2022–01: Optimization on length sampling: cuttlefish case study

Working Document presented to the ICES WGCEPH Working Group on Cephalopod Fisheries and Life History (2022)

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1. Introduction

The current sampling scheme from the Portuguese commercial fleet, includes the length sampling of landed cuttlefish, *Sepia officinalis*, on the ports along the coast of Portugal. The main idea behind the optimization of sampling, results on the management of the different resources (e.g. time and money) without compromising the data quality in respect to biological parameters. The identification of the optimal sampling size improves the efficiency of sampling effort distribution and guarantees that the information on the sample itself or on the population will not be compromised. On this study, the 2019 length composition cuttlefish data from the Portuguese landings in the ICES Division 27.9.a has analysed, to evaluate the possibility of reducing the sampling intensity without losing the length frequency distribution (LFD) when comparing with the data from the original sampling scheme. For that purpose, the framework developed by Wischnewski *et al*. (2020), that uses the admissible dissimilarity value (ADV) as a measure of subsample reliability, has been applied to the cuttlefish data.

The ADV approach aims to identify a reduced but still informative sample (subsample) and to quantify the (dis)similarity between reduced and original samples. At the core of the approach is the concept of reference, or benchmark, subsample, which is the minimal representative subsample preserving a reasonably precise length frequency distribution (LFD) for a selected species. An iterative deterministic subsampling procedure, based on defined conditions, returns a reference subsample, quantifies the difference between the original sample and the reference subsample and provides a threshold value. This threshold is called an admissible dissimilarity value (ADV) (ICES, 2022; Wischnewski *et al.*, 2020).

2. Original data

2.1 Original sample length distribution

The numbers-at-length from the 2019 cuttlefish length measurements collected from the landings sampling at the Portuguese ports by quarter and also by fishing fleet, are represented at Figure 1 and Figure 2, respectively.

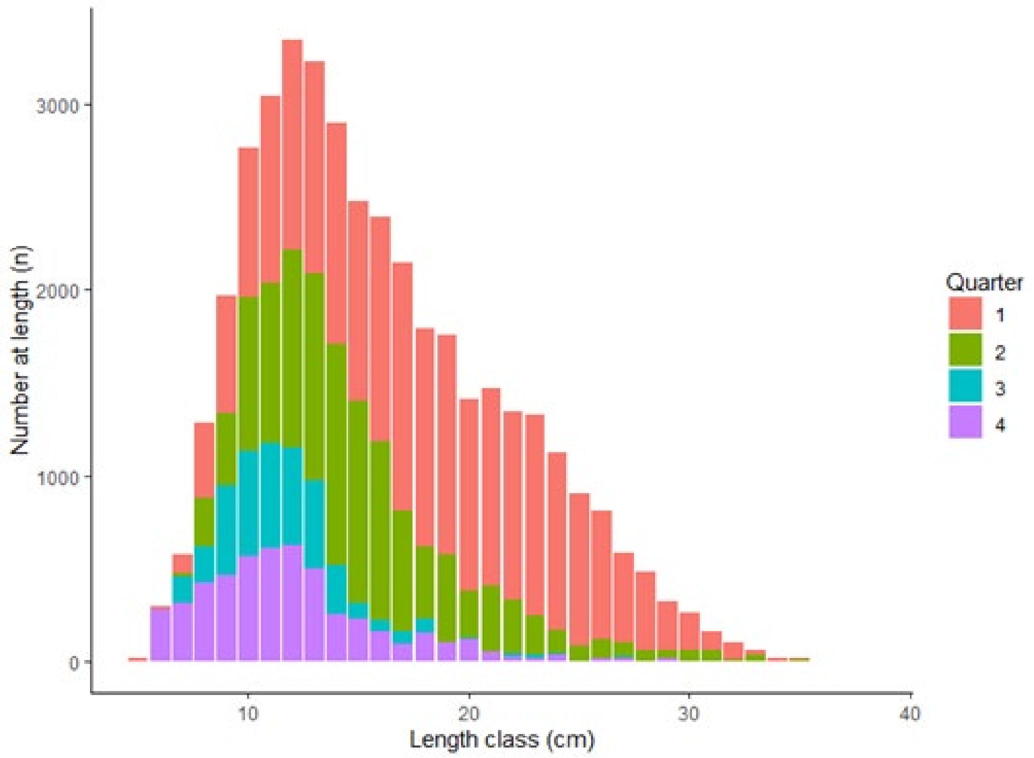

Figure 1 Numbers-at-length from the 2019 length sampling, from the Portuguese landings at ICES Division 27.9.a, by quarter. Total number of trips: 219; total number of length measurements: 40389.

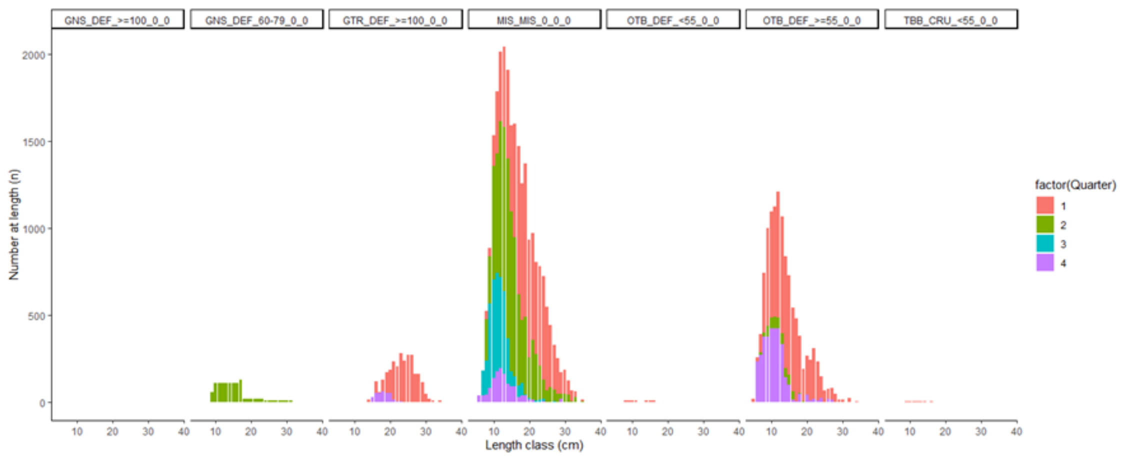

Figure 2 Numbers-at-length from the 2019 length sampling from the Portuguese landings at ICES Division 27.9.a by fishing fleet and by quarter. Total number of trips: 219; total number of length measurements: 40389.

3. Results

The application of the ADV framework on the cuttlefish case-study was tested with two different scenarios. Scenario 1: delta=1 and theta=0.7 (Section 3.1); Scenario 2: delta=2 and theta=0.7 (Section 3.2).

3.1 Scenario 1: Reference subsample length distribution (delta=1 and theta=0.7)

The application of the ADV approach in Scenario 1 resulted on a 51% reduction on the number of length measurements from the reference subsample when compared with the original sample (Figure 3 and Figure 4).

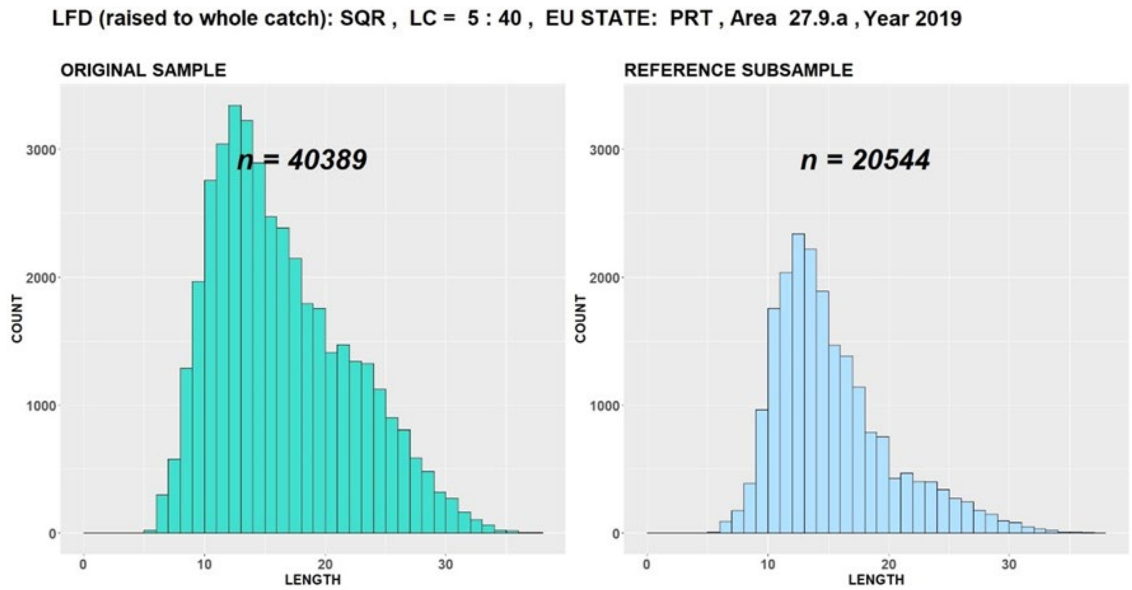

Figure 3 Numbers-at-length from the original sample (n= 40389) and from the reference subsample (n=20544) based on the ADV approach application with a delta=1 and theta=0.7.

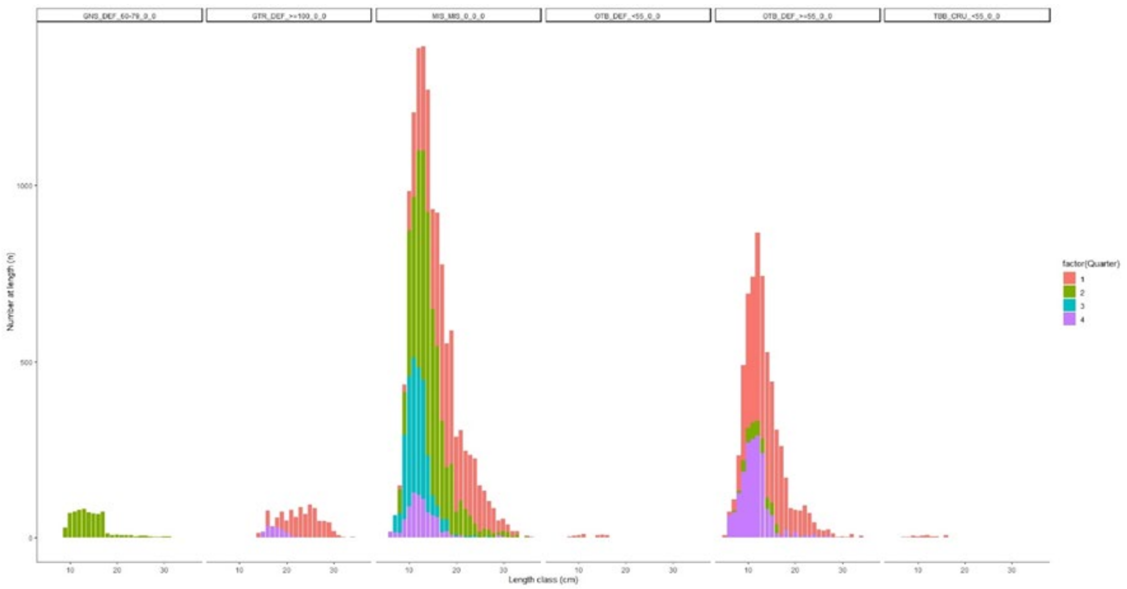

Figure 4 Numbers-at-length from the reference subsample from scenario 1 (delta=1 and theta=0.7) by fishing fleet and by quarter. Total number of trips: 203; total number of length measurements: 20544.

3.2 Scenario 2: Reference subsample length distribution (delta=2 and theta=0.7)

The application of the ADV approach in Scenario 2 resulted on a 51% reduction on the number of length measurements from the reference subsample when compared with the original sample (Figure 5 and Figure 6).

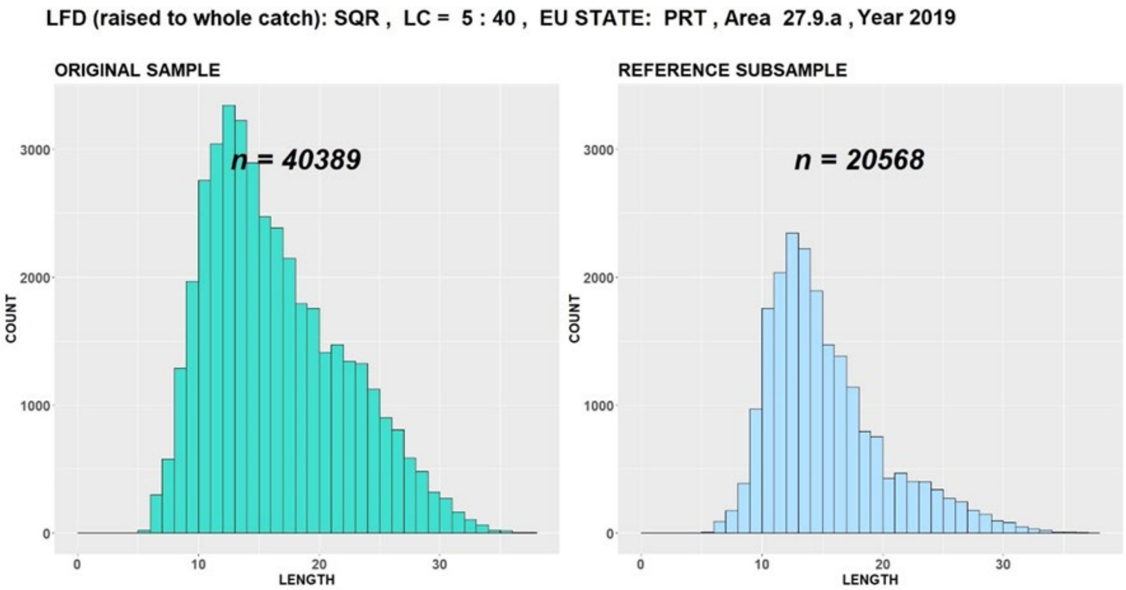

Figure 5 Numbers-at-length from the original sample (n= 40389) and from the reference subsample (n=20568) based on the ADV approach application with a delta=2 and theta=0.7.

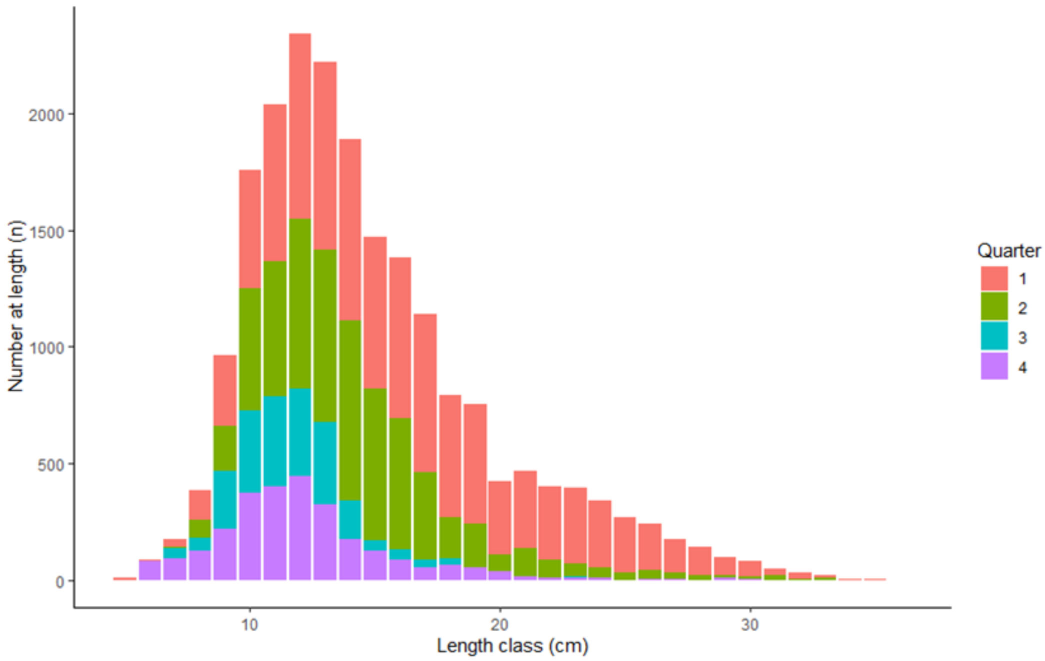

Figure 6 Numbers-at-length from the reference subsample from scenario 2 (delta=2 and theta=07.) by quarter. Total number of trips: 202; total number of length measurements: 20568.

4. Conclusions

The results from this case study on cuttlefish, have shown that is possible to reduce around 50% the number of length measurements, without compromise the LFD from the landings sampling.

5. Next steps

- Applying the same approach to datasets from other years.
- Applying to other cephalopods species.
- Applying the datasets from the simulations and produce the data submitted to WGCEPH.

References

ICES. 2022. Fourth Workshop on Optimization of Biological Sampling (WKBIOPTIM4; Outputs from 2021 meeting). ICES Scientific Reports. 4:69. 80 pp. http://doi.org/10.17895/ices.pub.21103000

Wischnewski, J., Bernreuther, M., Kempf, A. 2020. Admissible dissimilarity value (ADV) as a measure of subsampling reliability: case study North Sea cod (*Gadus morhua*). Environmental Monitoring and Assessment 192, 756 (2020). https://doi.org/10.1007/s10661–020–08668–6