WP.4.2 Deliverable

Fisheries Summaries

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General Introduction

Cephalopod landings from the Northeast Atlantic represent on average 45,000 t annually, around 1.25% of world cephalopod production: 3.6 million tonnes (FAO, 2020). More than 90% of NE-Atlantic cephalopod landings consist of three groups of valuable species, which are the cuttlefish *Sepia officinalis* (Sepiidae), the octopus *Octopus vulgaris* (Octopodidae), and the long finned squids *Loligo forbesii* and *Loligo vulgaris* (Loliginidae).

Due to poor identification of cephalopod species, in fisheries statistics these emblematic species are often pooled at the family level. Such totals will often additional species like the horned octopus *Eledone cirrhosa*, the pink cuttlefish *Sepia orbignyana*, or the small squid *Alloteuthis subulata*), although these other species that can be targeted in some places do not usually represent a significant share of fishermen's revenue.

The locations of the main cephalopod fishing grounds and countries involved in their exploitation are presented in Figure 1, based on 2014–2018 average annual landings. Cuttlefish is the main resource (41% of average annual landings during the period 2000-2018 and is caught in the English Channel, Bay of Biscay and Iberian Peninsula. Octopus (31% of landings) is caught by southern countries (Spain, Portugal) whereas long finned squids (21%) are the main resources in northern areas.

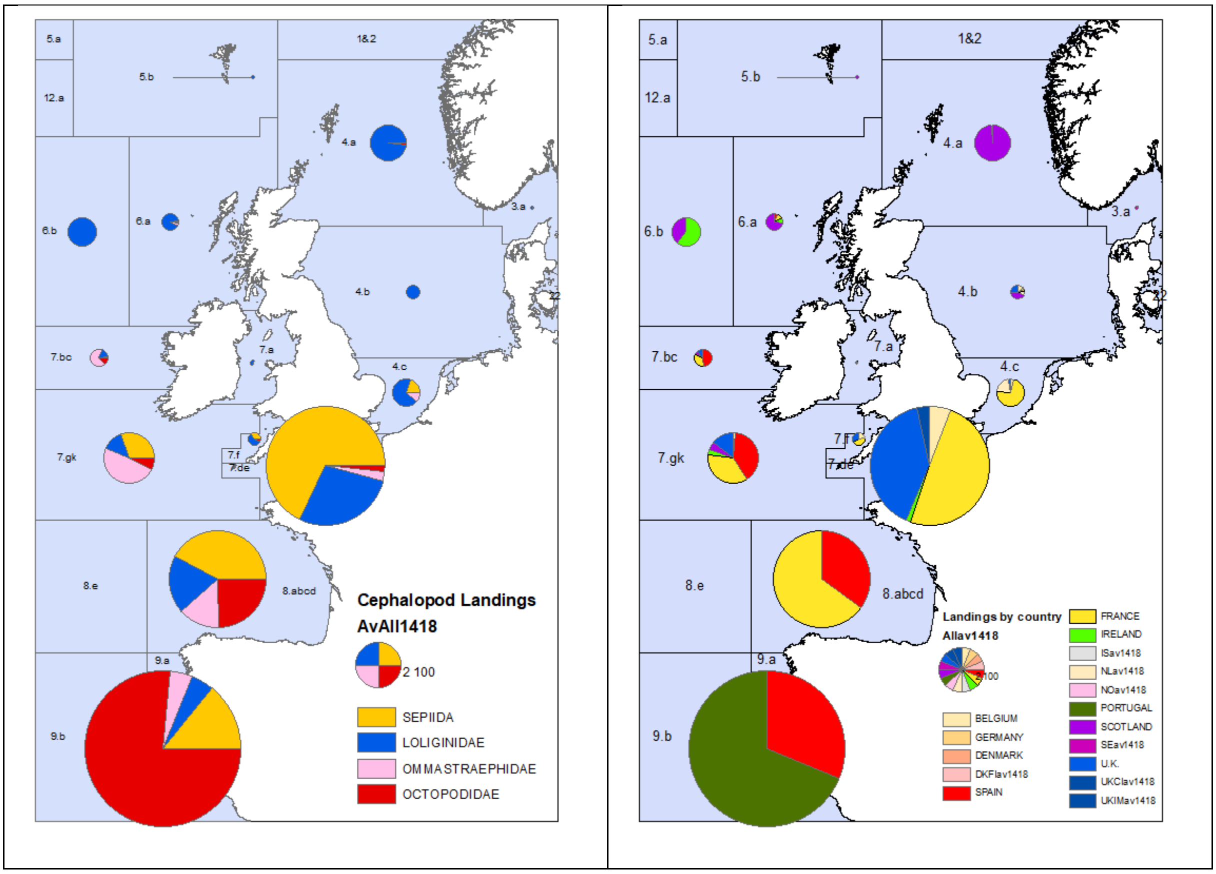

Figure 1. Maps showing the origin of cephalopod landings (average annual landings for the period 2014–2018) per groups of species (left) and per country (right). This Figure is taken from 2020 report of the Working Group on Cephalopod Fisheries and Life History (ICES, 2020a)

Fisheries summaries have been prepared for the four main species fished, with the aim of describing the fishing fleets involved and the exploitation status and trends in those stocks that are monitored for abundance fluctuations.

Northeast Atlantic cephalopods are non-quota species and are not assessed routinely (with the exception of the Asturias octopus fishery, for which assessment is required as part of the requirements of its MSC certification). A wide range of assessment tools have been tried on some stocks (Royer et al., 2002; Young et al., 2004; Challier et al., 2005; Royer et al., 2006; Gras et al., 2014; Alemany et al., 2017). However, the methods tested in these trials were not applied routinely either because of data availability or because the lack of requirement for assessment.

During this project, a common stock assessment framework was applied to a series of management units, namely the fitting of surplus production models using the SPiCT R-package). This exercise provided new stock diagnostics but also highlighted the limitations that can arise due to inadequate data collection or to the peculiarities of cephalopod population dynamics.

More details on the SPiCT exercises can be found in the Annex 1 to this document.

Sepia officinalis

Names:

Common cuttlefish (EN)
Seiche commune (FR)
Sepia común (SP)
Choco vulgar (PT)

Photo: Marie Bournonville, Wikimedia Commons

Fishery definition:

Geographical limits

Although the cuttlefish *Sepia officinalis* has been observed in the Northeast Atlantic from Norway to Senegal (see Figure 2 for the European distribution), in European waters it is only abundant enough to be fished by commercial fleets from the southern North Sea and south of Ireland to the Iberian Peninsula (ICES, 2020)a.

Sepia officinalis lives on or close to the sea bed, with a preference for sandy or muddy substrata at depths ranging from the intertidal zone down to 200m. It has a complex life history with a seasonal migration cycle from inshore spawning grounds to deeper wintering grounds and a lifespan of two years in the northern part of its range and one year to the south. Adults die after a single spawning season (Jereb et al., 2015).

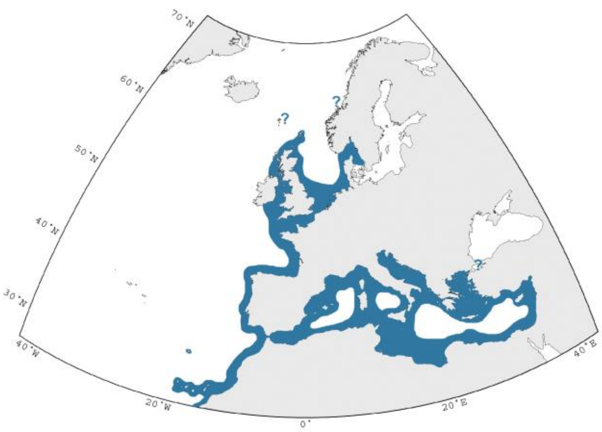

Figure 2*: Sepia officinalis.* Geographic distribution in the Northeast Atlantic and Mediterranean Sea (Jereb et al., 2015). This map is based on compiled historical records and the species is currently generally rare in the northern part of its historical range.

Main countries fishing cuttlefish

Cuttlefish is mainly landed by French and UK fishing fleets (50% and 29% of 2014-2019 average landings respectively) followed by Spain, Portugal, Belgium and Netherlands and Ireland (7%, 6%, 5%, 1%, 1% respectively). The 1992-2019 time-series suggest an increase in the contribution of northern countries (UK, Belgium, Ireland) and a reduction in the contribution of France and Spain (Figure 3).

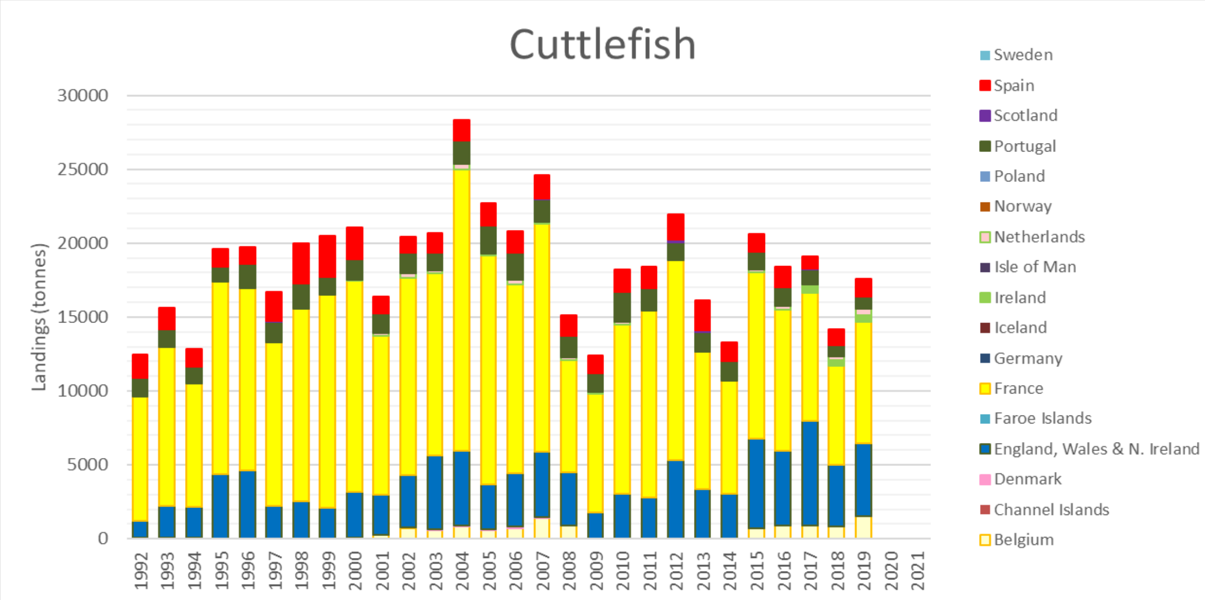

Figure 3. Northeast Atlantic cuttlefish landings by country (ICES, 2020a, supplementary material). Colour codes are the same as in Figure 1.

Fishing gears

The bulk of cuttlefish landed are caught by trawlers (UK and BE beam trawl, FR, SP and PT otter bottom trawl) and the species is either a target or a by-catch depending on the abundance of the cuttlefish and of other demersal species in trawlers fishing grounds. However, in relation to its migration cycle and reproduction in shallow waters, cuttlefish is also caught by a variety of (mainly artisanal) fishing gears like trammel nets, traps, seine, gill nets, and dredges (Figure 4).

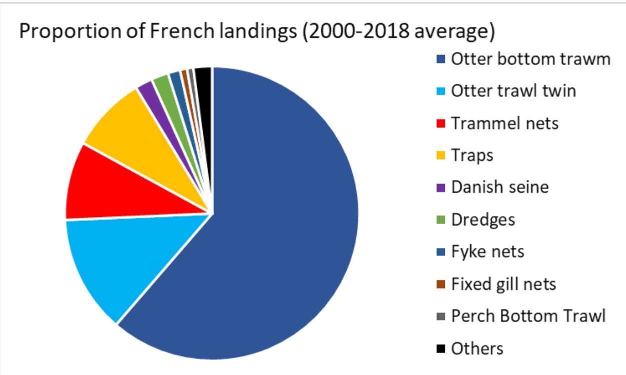

Figure 4: Proportion of French cuttlefish landings split by fishing gear (average 2000-2018).

Artisanal gears are not restricted to southern small-scale fisheries (Figure 5) and the geographic variation in the fishing gears used in inshore waters to catch cuttlefish suggests either regional adaptation to the hydrodynamic context or traditional preferences for nets or traps (Figure 6).

It is worth noting that in all areas where more than 5% of the total cuttlefish catch was taken, the discard rate was usually less than 5%.

Figure 5: Examples of cuttlefish traps used in the UK (Devon, left) and in France (Normandy, right)

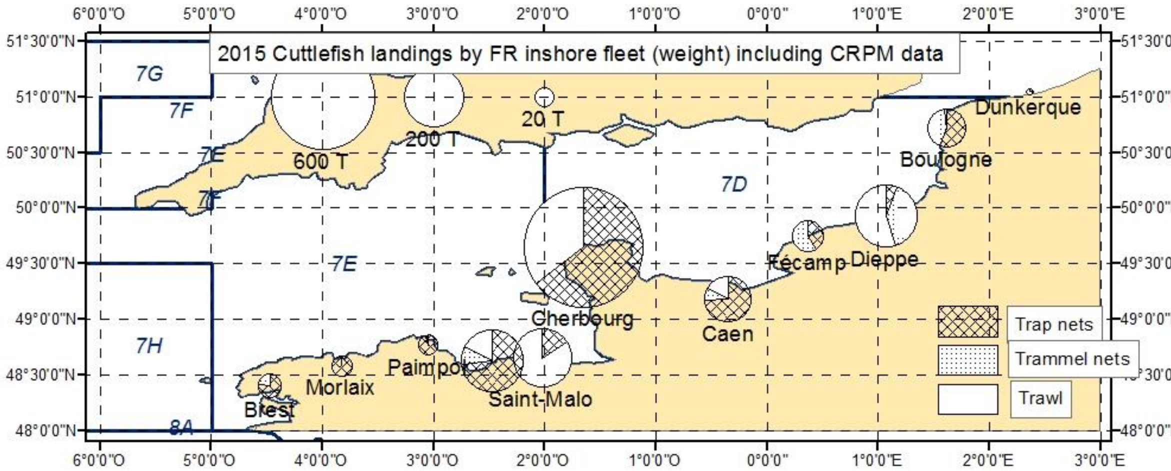

Figure 6: English Channel inshore fishery landings by France from the 3 main fishing gears (trawl, trap and trammel net), by fishing harbour (2015 official fishery statistics supplemented by "Comité des Pêches").

Fishery Trends

Trends in landings

At the scale of the Atlantic Area, cuttlefish landings tend to show a common decreasing trend since around 2004 (Pierce et al., 2019) (Figure 7). However, catches from the Celtic Sea and UK catches in the English Channel show an increasing trend. A striking pattern is the the high inter-annual variability in cuttlefish production.

Trends in abundance

Because cuttlefish perform seasonal migrations from spawning grounds in very shallow waters to offshore wintering grounds (as juveniles) and back again (as adults), and abundance of a cohort will decline over the course of its 1-year or 2-year life cycle, research surveys carried out in one month every year are not always relevant to describe abundance trends. On the other hand, indices derived from commercial trawlers landings per unit of effort (LPUE) cover almost all fishing seasons and fishing areas but can be biased by changes in fishing fleet composition or behaviour. Figure 8 underlines the fact that that abundance indices derived from different sources tend not to show similar trends. In particular, the abundance index for the Bay of Biscay derived from the French EVHOE survey is considered to be unsuitable as it takes place offshore at a time when most young cuttlefish have not yet left inshore waters.

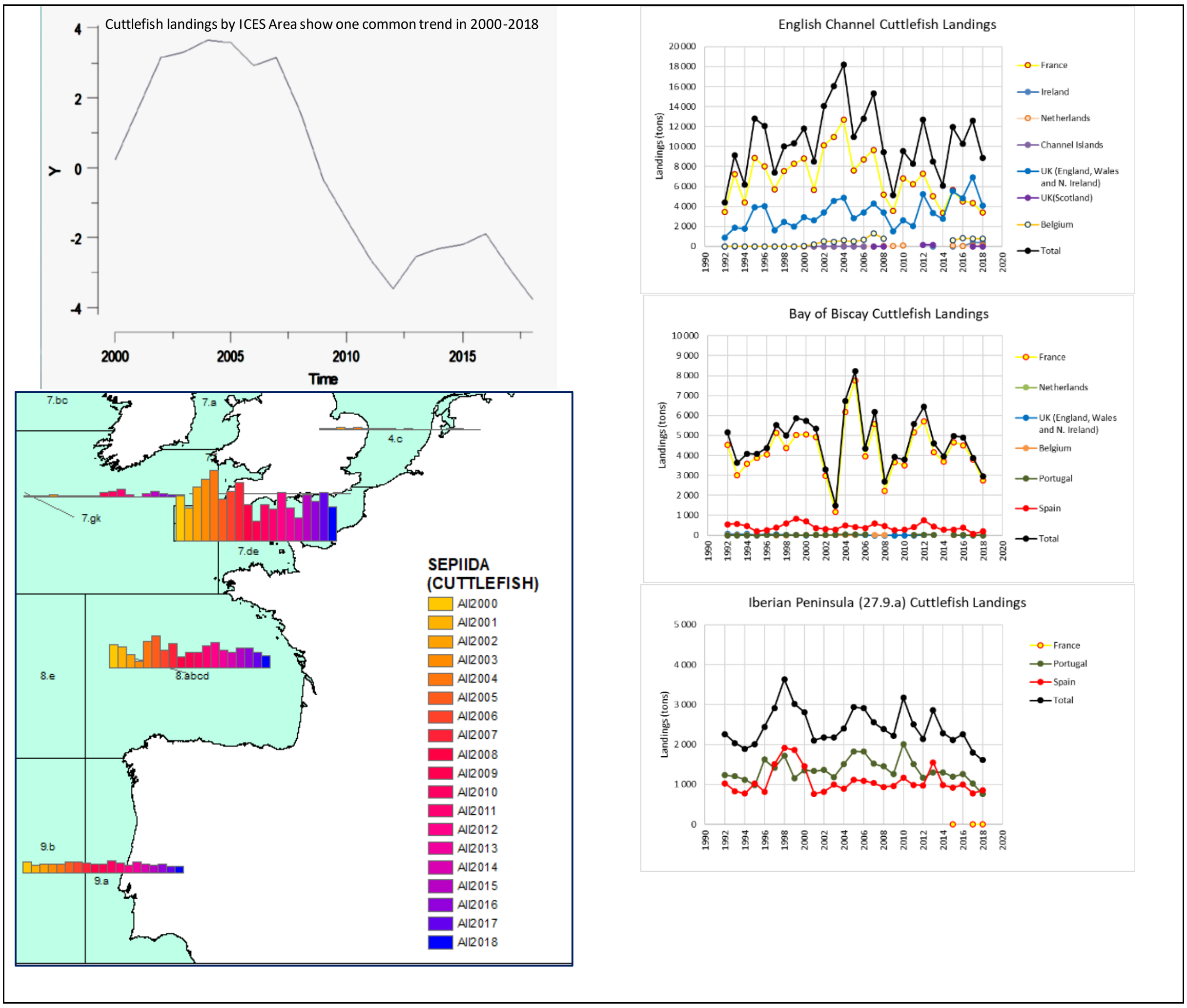

Figure 7: Trends in cuttlefish landings during 2000–2018, including results by country and by fishery division (data from Pierce et al., 2019 and ICES, 2020a).

Stock assessment outputs

Biomass models for stock assessment were fitted to data from English Channel and Bay of Biscay stocks using the R package SPiCT. In spite of wide confidence intervals which prevent us from proposing absolute biological reference points (like a long-term sustainable Total Allowable Catch which could be the basis for quotas), preliminary diagnostics of exploitation levels were obtained.

These diagnostics, which concern both fishing mortality and biomass, suggest that the English Channel stock is reasonably exploited, and has probably been in a better condition since 2008.

In the Bay of Biscay, the model outputs suggest overexploitation between 2000 and 2010 but since 2010 the exploitation seems stabilised at an underexploited level[1].

Stock status and uncertainties

In the Northeast Atlantic *Sepia officinalis* is a resource that is shared by countries and fished by a wide range of métiers. In a context of generally decreasing trend in landings (albeit not in all areas) and of some abundance indices it is worth noting that yield in northern countries is increasing and that

[1] Here we follow the convention of referring to catches below Maximum Sustainable Yield (MSY) as indicative of "under-exploitation", assuming that the objective is to achieve MSY as indicated in the EU Marine Strategy Framework Directive. It should of course be noted that other management objectives (e.g. related to other species or environmental considerations) may favour lower exploitation rates.

updated diagnostics do not reveal overexploitation. However, climate change may increasingly lead to a shift in geographic distribution and affect migration patterns, which need to be better taken into account to monitor abundance of the English Channel stock, and indeed to deal with the consequences of Brexit.

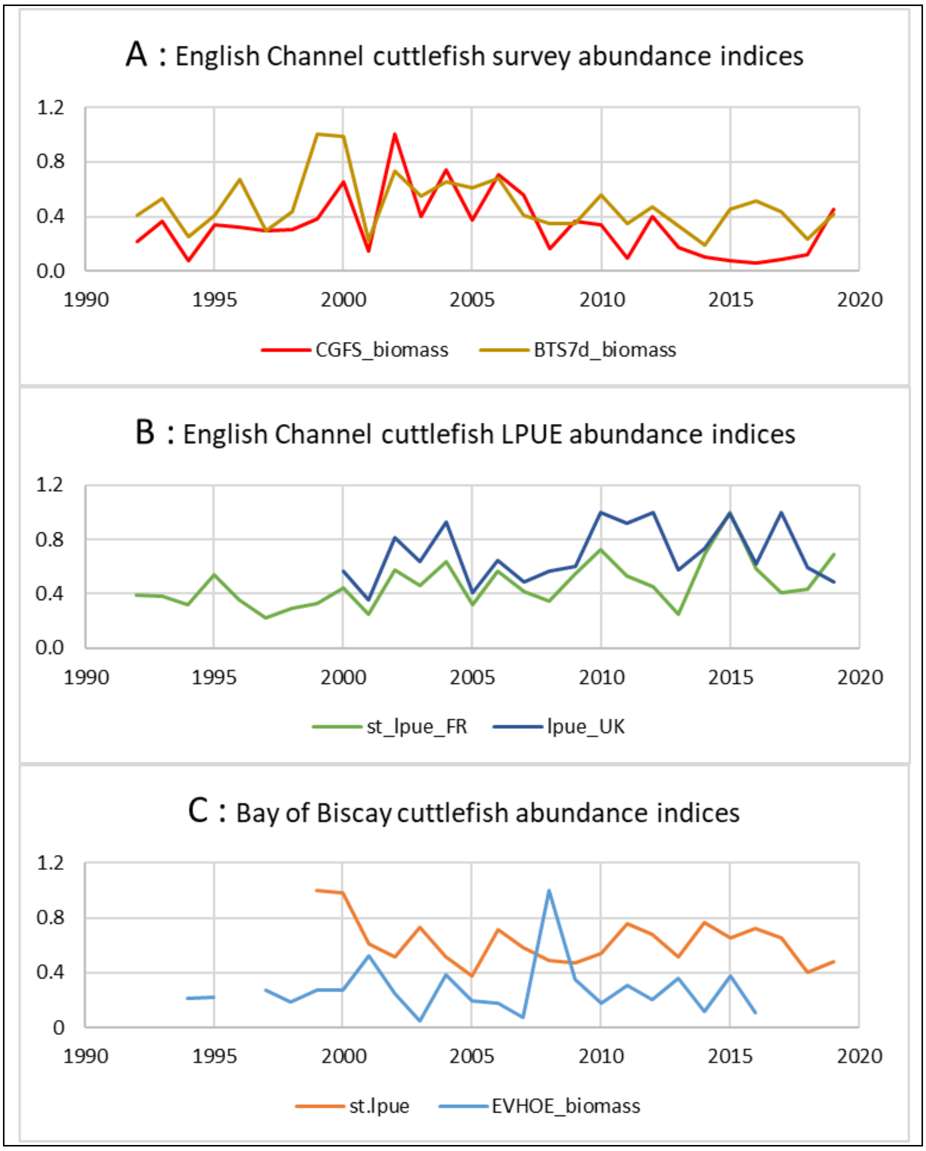

Figure 8: Trends in cuttlefish abundance in the English Channel (A survey data, B commercial trawlers LPUE) and Bay of Biscay (C). All time series are divided by their maximum so as to compare temporal trends.

Octopus vulgaris

Names:

Common octopus (EN)
Poulpe commun, pieuvre (FR)
Pulpo común (ES)
Polvo (PT)

Photo: Albert Kok, Wikimedia Commons

Fishery definition:

Geographical limits

The common octopus *Octopus vulgaris* is currently regarded as a cryptic species complex (Amor et al., 2017) rather than a single species. European animals are considered to belong to the species *Octopus vulgaris sensu stricto* which occurs in the Mediterranean and North East Atlantic.

Octopus vulgaris is found in the Atlantic and Mediterranean and is especially abundant off West Africa. Its distribution extends from the coast to the edge of the continental shelf and occasionally to the bathyal habitat up to 700 m depth (Figure 9, from Jereb et al. (2015). It lives on or close to the sea bed, occurring in highest abundance in moderately warm, shallow, coastal waters (<200 m deep) and continental shelf areas. Local density is affected by the availability of solid material (rocks, stones, shells, anthropogenic litter, etc.) suitable for den construction (Jereb et al., 2015). Within the Atlantic area, it is nowadays only fished in the Southern part of the Bay of Biscay and in the Iberian Peninsula.

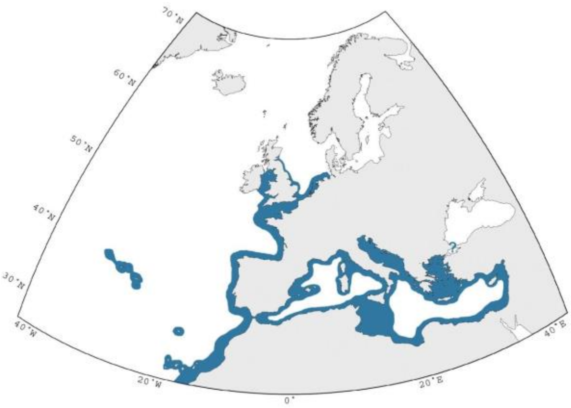

Figure 9: *Octopus vulgaris sensu stricto*. Geographic distribution in the Northeast Atlantic and Mediterranean Sea (Jereb et al., 2015). This map is based on compiled historical records and the species is currently generally rare in the northern part of its historical range

Fishing fleets and gears

In Europe as a whole, the common octopus is mostly targeted by fisheries in Iberian Peninsula and Mediterranean waters where cephalopods have long been important for artisanal fisheries. In European Atlantic waters, *O. vulgaris* is mostly fished by Portugal and Spain, with 61% and 35% of catches, respectively, on average during 2000–2018 (ICES, 2020a). Spanish landings come from the Cantabrian Sea (Division 28.8c), Galician waters (Subdivision 27.9a.north) and the Gulf of Cadiz (Subdivision 27.9a.south) whereas Portuguese landings come from subdivision 27.9a.centre and 27.9a.south (Figure 10).

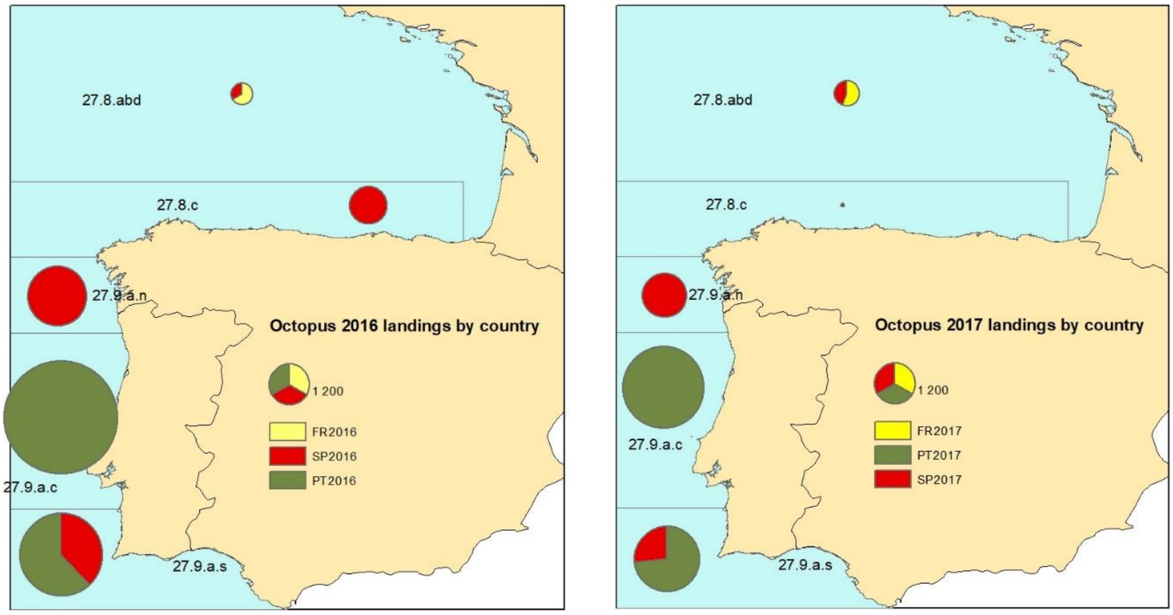

Figure 10: Octopus landings from the Bay of Biscay and Atlantic Waters of the Iberian Peninsula by country in 2016 (left) and 2017 (right). Colour codes: France = yellow; Spain = red; Portugal = green (data from ICES WGCEPH 2018).

Octopus vulgaris is caught by bottom trawlers and small-scale (artisanal) coastal fisheries using pots, traps, hand-jigs, hook and line, and trammel nets in depths from 20 to200 m (Pereira and Nolan, 1999; Silva and Sobrino, 2005). In the Cantabrian Sea (Division 27.8.c) and Galician waters (Subdivision 27.9.a north), the artisanal fleet accounts for 98–99% of *O. vulgaris* landings, mostly caught using 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, trammel nets, traps, pots and hooks lines (Figure 11). In the Gulf of Cadiz (Sub-division 27.9.a.s), the bottom-trawl fleet takes around 60% of the *O. vulgaris* catch and the remaining 40% is taken by the artisanal fleet, mainly using clay pots and hand-jigs.

Due to its high value *O. vulgaris* is rarely discarded and undersized specimens are considered to have a high survival rate when returned to the sea.


Photo: Fernando Jiménez


Photo: Jean-Paul Robin

Figure 11 Examples of artisanal fishing gears used to catch Octopus vulgaris in Spain (left: Lastres, Asturias) and Portugal (right: Tavira, Algarve).

Fishery Trends

Trends in landings

Catches of Octopodidae species are generally low in Division 27.8.a, b, d (Bay of Biscay). Logbook data suggest that *O. vulgaris* account for only 20% of the total Octopodidae landings in this division.

Most landings of *O. vulgaris* originate from Divisions 27.8.c & 27.9.a (Iberian Atlantic coast). In 27.8.c, there was a decrease in *O. vulgaris* landings since 2010-2011. Within this area, year-to-year variation in landings on the Cantabrian coast cannot be explained by changes in fishing effort, although effort by artisanal trap fishing in Asturias seems to have been lower in 2009-2019 than in 2001-2008 (ICES, 2020b, section 2.3).

In Division 27.9.a, (from Galicia to the Gulf of Cadiz), landings since 2000 have shown large year-to-year variation, including a decline between the peak in 2013 and 2018. Total landings ranged from 6784 t in 2018 to 18967 t in 2013 (Figure 12). The marked year to year variation in landings may be related with changes in salinity (linked to rainfall and river discharges), as was demonstrated in the waters of the Gulf of Cadiz in subdivision 27.9.a.s (Sobrino et al., 2020).

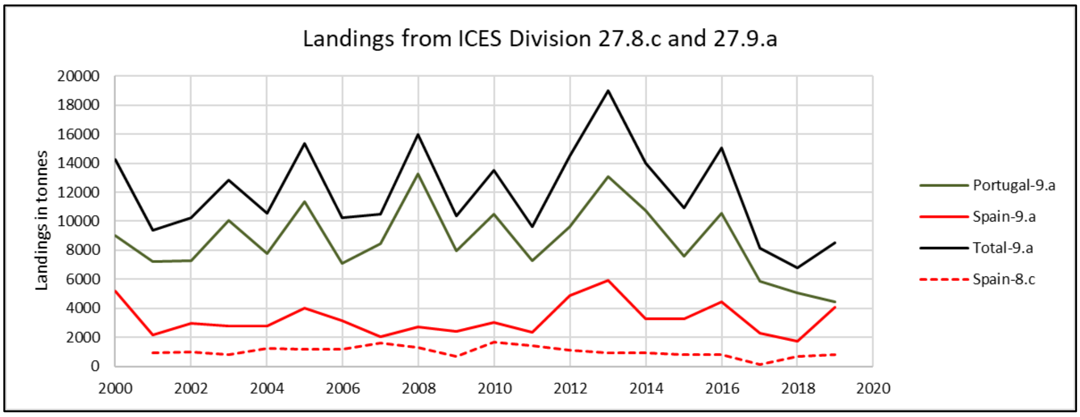

Figure 12: Trends in octopus landings by countries from ICES Division27.8.c (Cantabrian Sea) and 27.9.a (from Galicia to the Gulf of Cadiz) in 2000-2019 (data from ICES WGCEPH 2020). B (right) Landings in the Canaries.

Regional fisheries: South Western EU waters, Outermost Regions (The Canary Islands)

The relative importance of cephalopod catches in the Canary Islands is low (<1% of total catches) they are usually not target species, but they are an important component of fishermen's income. They are taken by a multi-gear metier targeting demersal species (fish and invertebrates). *Octopus vulgaris* is the most important cephalopod species in the multispecies small-scale fishery (around 30% of total cephalopod landings), mainly in fish traps and shrimp traps; year-to-year variation in *O. vulgaris* landings (Figure 13) drives variation in total cephalopod catches. Landings show a seasonal peak in April-May, with a smaller peak in September-October (ICES, 2020a). Variation in octopus landings between years, and differences between islands, are probably related to environmental variation and its effect on larval transport (González-Lorenzo et al., 2018). High landings in Gran Canaria may be due to the presence of a cyclonic eddy south of this island and the influence of upwelling filaments from NW African waters (Brochier et al., 2011; Landeira et al., 2009).

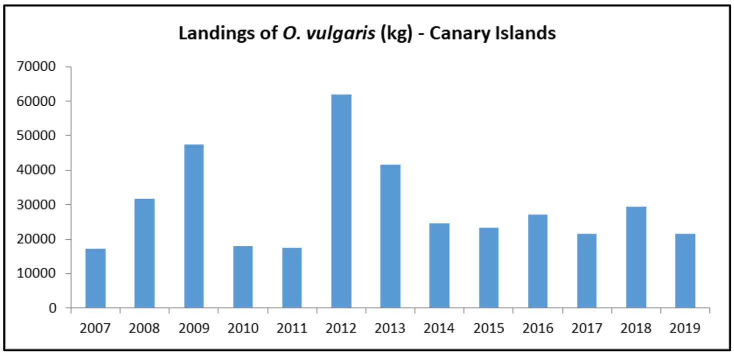

Figure 13: *Octopus* landings in the Canaries.

Trends in abundance

Abundance indices were derived from landings per unit of effort (LPUE) data from commercial fleets (e.g. otter bottom trawl) or from demersal trawl survey catch rates (CPUE). However, because of timing or spatial coverage, surveys are not always useful for *O. vulgaris*. Portuguese survey indices have been very low since 2005. Indices based on LPUE and Spanish surveys CPUE suggest a higher abundance in the South (ICES Division 27.9.a.s) than in the North (ICES Division 27.8.c and 27.9.n). Despite differences in the timing of the peaks and some increase in 2016, a common declining trend is seen since 2013.

It is worth noting that abundance in the Asturias trap fishery was monitored via high frequency data collection and fitting of a generalized depletion model which took into account the different pulses of recruits during each fishing season and the behaviour of females protecting their eggs.

Stock assessment outputs

Three different methods were applied to *O. vulgaris* fisheries which outputs are summarised here.

- The Western Asturias artisanal trap fishery was assessed within the continuation of the MSC certification procedure. Abundance estimates obtained with generalized depletion model were combined to catch data to fit a biomass model (Pela and Tomlinson's surplus production model) and to analyse possible relationships between adult stock and stock renewal by juvenile recruits (Shepherd's stock recruitment relationship, Roa-Ureta, pers.comm.). Results suggest that the biomass fluctuates between two equilibrium points in alternate years. The fishing mortality that is exerted on the stock is low compared to the natural mortality and landings are far less than the Maximum Sustainable Yield (MSY) (ICES, 2020b).
- The Gulf of Cadiz Fishery was included in the list of case studies where SPiCT was applied to fit a biomass model. For this exercise, Spain and Portugal landings were combined and abundance indices derived from Spanish Otter Trawl LPUE. Although the model converged and preliminary diagnostics were obtained, suggesting under-exploitation, these results came with huge confidence limits that prevent to propose long term averages as reference points (see the annex 1 of deliverable 4.2).
- In the Gulf of Cadiz, a forecasting model was developed in order to predict *O. vulgaris* landings using a survey recruitment index and environmental data (rainfall) both available before the fishing season (Sobrino et al., 2020). Model predictions could be very useful for the management of the fishery and the implementation of technical measures such as temporal or spatial closures or catch limitations.

Stock status and uncertainties

Although *Octopus vulgaris* is almost exclusively fished by Spain and Portugal (countries with data collection at the species level) the situation of these southern fisheries can still be rather complex and stock status can hardly be estimated in all the fishing grounds. A number of fishing gears can be involved and in artisanal fisheries data quality can be a problem. In addition, the coastal habitat of the species does not always correspond to the spatial range of scientific trawl surveys.

Landings and abundance indices show high inter-annual variability which depend on upwelling conditions in Galicia (Otero et al., 2008) or other environmental parameters like rainfall in the Gulf of Cadiz. Such environmental drivers could be used for short term predictions and in-season management.

More information about *Octopus vulgaris* trends in abundance, stock assessments and management issues is provided in the Annex 2 of the Fisheries Summaries.

Loligo forbesii

Names:

Veined squid, European northern squid (EN)
Encornet veiné (FR)
Calamar veteado (SP)
Lula riscada (PT)

Photo: Jean-Paul Robin

Fishery definition

Geographical limits

In the Atlantic, its geographic distribution stretches north to Norway, the North Sea and western Baltic (Figure 14), though it is only sporadically seen in the latter area. It is common in Irish and UK waters and the English Channel, and less common south of the Bay of Biscay. Its distribution stretches as far south as west Africa and the Canary Islands, and as far west as Madeira and Azores, however the Azorean population has substantial genetic differences from other Atlantic populations and appears to be reproductively isolated. *L. forbesii* also occurs in the Mediterranean.

This is a near seafloor-dwelling squid which lives on the continental shelf. It can be found in coastal waters, particularly in spawning periods, to a maximum of about 250 m depth in the Atlantic (Hastie et al., 2009). The depth distribution seems to be correlated to season, with squid predominantly found in deeper waters along the shelf edge (100–200 m) at the beginning and the end of the spawning season (November and March) and occurring in waters shallower than 50 m during the peak of spawning (Hastie et al., 2009).

Figure 14. *Loligo forbesii.* Geographic distribution in the Northeast Atlantic and Mediterranean Sea (Jereb et al., 2015). This map is based on compiled historical records and, the species is currently generally rare along mainland Atlantic coasts in the southern part of its historical range.

Fishing fleets (countries, gears, fishing effort trends)

Loligo forbesii is commercially important and sold as fresh or frozen 'calamari' to markets in Continental Europe. *L. forbesii* is not always targeted by fishers but can be bycaught as part of fishing operations for other target species. Where *L. forbesii* is bycaught, it is likely to be landed and sold. There are also some targeted fisheries, notably in Rockall, which is in International Council for Exploration of the Sea (ICES) management division 27.6b and in the Moray Firth, Scotland (ICES 27.4b, - see Figure 15).

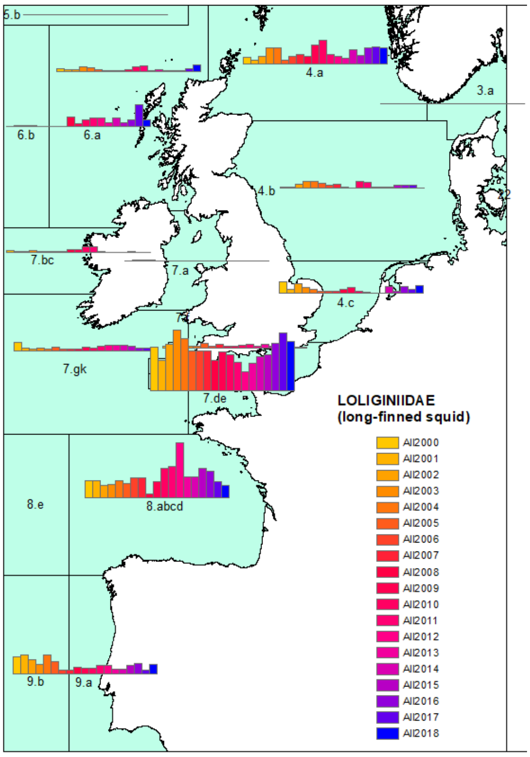

Figure 15 Trends in Loliginidae landings during 2000 – 2018. This Figure is taken from 2020. Working Group on Cephalopod Fisheries and Life History (ICES, 2020a).

Loligo forbesii landings are reported from Atlantic waters for several countries, being fished by France, UK, Spain, and Ireland (in decreasing order of magnitude). Averaged fisheries landings (2014-2018) by taxonomic family 'Loliginidae' are presented in Figure 15. An important drawback with monitoring the fishing of this species is that fisheries landings data are given by taxonomic family, therefore these will include data for *L. forbesii*, *Loligo vulgaris* and *Alloteuthis* spp. In some areas, like Scotland and the north and west of Ireland, these data will be dominated by *L. forbesii* because *L. vulgaris* is rare or absent and *Alloteuthis* is too small to be retained in most trawl nets (unless a smaller mesh size is used, which is allowed for vessels targeting squid, e.g. in the Moray Firth). But in the English Channel, Celtic Sea, and North Sea, the distribution of *L. forbesii* increasingly overlaps with *L. vulgaris*, hence the fisheries landings data are conflated for both species. Landings in the Bay of Biscay, western Iberia, and Gulf of Cadiz are dominated by *L. vulgaris* with *L. forbesii* being rarer.

Loligo forbesii is mainly targeted with trawling gears, which accounted for 92% of loliginid landings in the north east Atlantic in the 2016–2018 period. Trawls were particularly used by the French, UK, Spanish, Irish, Portuguese, German, and Swedish fleets. Less commonly, seine and polyvalent gears are used to target this group, by Danish, Netherlands and Belgian fleets. Jigging has also been suggested to take place in some areas, including the south English coast, the Spanish and Portuguese Atlantic coasts (and Balearic Islands), however this appears to be confined to smaller boats and recreational fishers and is probably most important for catches of *L. vulgaris* on Spanish / Portuguese coasts (Hastie et al., 2009).

Fishery Trends

Trends in Landings

Trends in fisheries landings for Loliginidae including *L. forbesii* (2000-2018) are shown in Figure 15. The eight main areas for fisheries landings of Loliginidae (in order of decreasing importance) are the English Channel (ICES management division 7d,e), followed by the Bay of Biscay (ICES 8a,b,c,d), northern North Sea (ICES 4a) and western Iberia (ICES 27.9a,b), with lower landings at Rockall (ICES 27.6b), southern North Sea (ICES 4c), west of Scotland (ICES 6a) and the Celtic Sea (ICES 7gk). Landings are reported in other areas, but these are relatively low and will not be discussed further.

There has been a weak upward trend in loliginid landings over all areas since the year 2000, with three important peaks, in 2003, 2010 and 2017. In terms of recent trends (2016–2018), loliginid landings were above the long-term mean (2000–2018) in the northern North Sea, southern North Sea, Rockall and English Channel. Loliginid landings were below the mean in the remaining areas.

Summary of fisheries landings, gears, and discards in areas with the most *L. forbesii* fishing

- **English Channel**: Loliginid fisheries landings were 4518 tons in 2018 in the English Channel. These declined slightly in 2018, having increased year-on-year for the previous five years in a row. The main fleets active in this fishery are English, Belgian, Dutch and, especially, the French fleet. Trawling is the main métier but seining accounts for 33% of the loliginid landings in this area. Discards are low (1% of landings) in this fishery.
- **Rockall & Celtic Seas**: Loliginid landings decreased slightly in 2018 to 1077 tons in these areas, having increased for several years previously, particularly in 2017 (~2750 tons). Loliginid landings were uneven across sub-areas: they increased at Rockall but were stable over time and at a relatively low level in the Celtic Sea. The main fleets active in this fishery were Scottish and Irish (at Rockall), and English and French (southern sub-areas), using trawling gear 97% of the time. Moderate discarding was reported, comprising ~6% of landings.
- **North Sea**: Loliginid landings were 2190 tons for 2018 in all sub-areas of the North Sea. Landings were stable over the past 5 years in the northern North Sea, the most important sub-area; landings in 2018 increased slightly in the southern North Sea. Scottish, French and, more recently, Dutch vessels are the main fleets taking loliginids in the North Sea. Trawling is by far the most important métier used in this fishery. Discards are low (1.3% of landings) in this fishery.
- **Bay of Biscay:** Loliginid landings in 2017 summed 1077 tons in the Bay of Biscay, showing a decreasing trend in this area since 2012. French and Spanish fleets are active in this fishery, mainly using trawls (89%) and, to a lesser extent, seine (13%). Discarding rates are decreasing in this area, declining from ~8% of landings to ~2% of landings from 2016 to 2018.
- **Western Iberia and Gulf of Cadiz**: Loliginid landings in 2018 summed 878 tons in these areas, which is the highest landing amount since 2005. Note that this includes 184 tons of *Alloteuthis* spp. Landings have been at a low level over the past 15 years in this area. Loliginid catches in this area are taken equally by Spain and Portugal, 87% by trawling and ~10% by polyvalent artisanal fleet. Discards are variable across fleets and métiers and total discarding rate is difficult to estimate.

Discarding rate is rather heterogeneous across the different areas and fishing seasons. The general picture is that discarding rate is low where and when the catch is high enough to contribute significantly to fishermen's revenue.

Trends in abundance

Abundance refers to the catch per unit effort of *Loligo forbesii* seen in fisheries surveys. These data come with some provisos, and should be considered an 'index' of abundance or biomass, rather than an absolute measure. Biomass is higher in winter than in summer in this species because adults die off after spawning and recruits generally enter the population in the summer months.

Summary of abundance in the most important areas for fisheries landings:

- **English Channel**: *L. forbesii* biomass in the English Channel is at low levels compared to the historical mean and still shows a decreasing trend. There was lower mean biomass in 2016–2018 compared to the 2013–2015 period.
- **Rockall & Celtic Seas**: All surveys in the Celtic Seas indicated an increase in biomass of *L. forbesii* in 2017 and a drop in 2018. This may be associated with very high fisheries landings in these areas,

particularly at Rockall in 2017. Considering trends in 2016-2018 compared to the 2013-2015 period, there was a decrease in mean biomass of *L. forbesii* in all areas except the Porcupine Bank.

- **North Sea**: Survey trends in the North Sea indicate a decrease in loliginid biomass in 2018 (all sub-areas). There was an increase in mean biomass of *L. forbesii* in 2016–2018 compared to 2013–2015, which relates well with the trend in fisheries landings.
- **Bay of Biscay:** *L. forbesii* biomass was generally low in the Bay of Biscay and recent values (2016–2018) were lower than the mean values for the 2013–2015 period.
- **Western Iberia and Gulf of Cadiz**: *L. forbesii* biomass in western Iberia is generally low and recent values (2016–2018) were lower than mean values in the 2013–2015 period. *L. forbesii* was recorded only in the Eastern part of the Gulf of Cadiz, with higher biomass in the most recent 3 years.

Overall, abundance and biomass indices in *L. forbesii* reflect what is seen in fisheries landings – both biomass and fisheries landings are declining in recent years in the southern part of the range i.e. in Bay of Biscay, western Iberia and Gulf of Cadiz.

Stock status and uncertainties

Stock assessment, stock status and uncertainties for both *Loligo forbesii* and *Loligo vulgaris* are dealt with at the end of the following *L. vulgaris* section.

Loligo vulgaris

Names:

European squid, (EN)
Encornet, calmar (FR)
Calamar (SP)
Lula (PT)

Photo: A.M. Arias, ictioterm.es

Fishery definition

Geographical limits

The European squid, *Loligo vulgaris* Lamarck, 1798, is found in the Northeast Atlantic from ca. 55°N to ca. 20°S and throughout the Mediterranean (Figure 16). It is one of the most common squids in coastal waters of the Northeast Atlantic and the Mediterranean (Jereb et al., 2015).

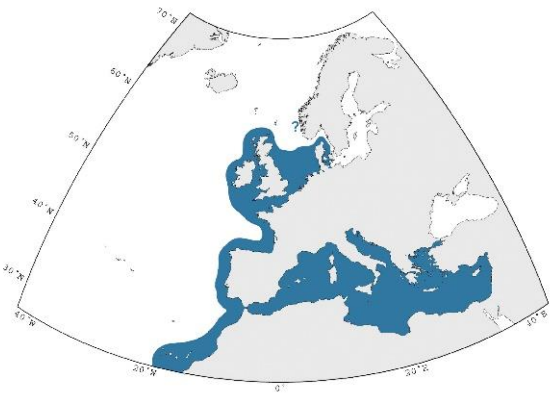

Figure 16. *Loligo vulgaris.* Geographic distribution in the Northeast Atlantic and Mediterranean Sea (Jereb et al., 2015). This map is based on compiled historical records and the species is currently generally rare in the northern part of its historical range.

Loligo vulgaris is neither pelagic nor fully benthic; it is more or less restricted to the sea bottom during the spawning season, but displays pelagic behaviour at other times, e.g. when hunting (Jereb et al., 2015). It can be described as nektobenthic and neritic; it is usually more abundant in water shallower than 100 m (Sánchez and Guerra, 1994; Salman et al., 1997; Sánchez et al., 1998; Tserpes et al., 1999), but is found from the coast to the limits of the upper slope (200–550 m) (Jereb et al., 2015).

In the Atlantic, *L. vulgaris* migrates long distances (south–north and north–south), possibly up to 500 km (Jereb et al., 2015). Horizontal migratory movements by *L. vulgaris* are mainly related to sexual maturation and spawning (Jereb et al., 2015). Onshore and offshore migrations, related to reproduction, are well-described for Mediterranean populations. Large (maturing or mature) animals move towards shallow coastal waters for mating and spawning; some squid mate during this migration.

Fishing fleets (countries, gears, fishing effort trends)

Loligo vulgaris is commercially important and sold as fresh or frozen 'calamari' to markets in Continental Europe. *L. vulgaris* is not always targeted by fishers but can be bycaught as part of fishing operations for other target species. Where *L. vulgaris* is bycaught, it is likely to be landed and sold.

Loligo vulgaris landings are reported for Atlantic waters for several countries, being fished by Portugal, Denmark, Spain, Poland (ICES 5b and 6a) and Ireland (in decreasing order of magnitude). Averaged fisheries landings (2014-2018) by taxonomic family 'Loliginidae' is presented in Figure 15. An important drawback with monitoring fishing of this species is that fisheries landings data are given by taxonomic family, therefore these will include data for *L. forbesii*, *Loligo vulgaris* and *Alloteuthis* spp. In some areas, like Scotland and the north and west of Ireland, these data will be dominated by *L. forbesii* because *L. vulgaris* is rare or absent there. But in the English Channel, Celtic Sea, and North Sea, the distribution of *L. forbesii* increasingly overlaps with *L. vulgaris*, hence the fisheries landings data are conflated for both species. Landings in the Bay of Biscay, western Iberia, and Gulf of Cadiz are dominated by *L. vulgaris* with *L. forbesii* being rarer.

Loligo vulgaris is mainly targeted with trawling gears, which accounted for 92% of loliginid landings in the north east Atlantic in the 2016–2018 period. Trawls were particularly used by the French, UK, Spanish, Irish, Portuguese, German, and Swedish fleets. Less commonly, seine and polyvalent gears are used to target this group by Danish, Netherlands and Belgian fleets. Jigging has also been suggested to take place in some areas, including the south English coast, the Spanish and Portuguese Atlantic coasts (and Balearic Islands), however this appears to be confined to smaller boats and recreational fishers and mainly catches *L. vulgaris* on Spanish / Portuguese coasts (Hastie et al., 2009).

Fishery Trends

Trends in landings

Trends in fisheries landings for Loliginidae including *L. vulgaris* (2000-2018) are shown in Figure 15 (in the *L. forbesii* section above).

Trends in abundance

Abundance refers to the catch per unit effort of *Loligo vulgaris* obtained in scientific research fishing surveys carried out in different areas by several countries. These abundance indices show an approximation to the real abundance of the population, but cannot be considered an exact measure. Biomass is higher in Winter than in Summer in this species because adults die off after spawning and recruits enter the population in the Summer months.

Summary of abundance in the most important areas for fisheries landings:

- **North Sea:** Survey trends in the North Sea starting in 2013 indicate a general decrease in loliginid biomass in 2018. A German-run scientific survey in the 1st quarter of the year indicates the appearance of *L. vulgaris* in the North Sea in certain years (2015, 2017 and 2018).
- **English Channel**: The French scientific survey is the longest and the best data series to derive biomass or abundance indices independent of fisheries for *Loligo* species in the English Channel. *L. vulgaris* is presently the most abundant loliginid in the English Channel, and its mean biomass in 2016–2018 increased compared to 2013–2015 period. The increase in *L. vulgaris* biomass supported the recent increase in squid fishery production in the English Channel.
- **Bay of Biscay:** *L. vulgaris* biomass increased until 2016 and dropped sharply in 2018.
- **Western Iberia and Gulf of Cadiz**: In Western Iberia, the biomass of *L. vulgaris* shows an increasing trend, in particular in Portuguese waters. The highest biomass indices were recorded in 2018 in both Spanish and Portuguese waters. *L. vulgaris* is the most abundant species, in both the western and the Eastern areas of the Gulf of Cadiz. Higher biomass indices of this species were recorded in 2015 in the Eastern area and in 2016 in the Western area.

The general trend of landings seems to indicate that there is a decrease in the abundance of loliginids south of the English Channel in recent years. However, the abundance data derived from scientific research surveys suggest that this decrease is due to *L. forbesii* while there is an increase in the abundance of *L. vulgaris*.

Stock assessment outputs *Loligo forbesii* and *Loligo vulgaris*

Loligo forbesii and *Loligo vulgaris* are not 'quota species' which means no quotas apply to fisheries catches. Data on these resources are collected by national authorities through the Data Collection Framework, and international data sources are pooled and co-ordinated at ICES. However, there is no formal stock assessment and no catch quotas are set in these species.

Despite a lack of formal stock assessment and catch quota, some assessment exercises have nevertheless been made available as outputs from the Working Group on Cephalopod Fisheries and Life History (WGCEPH). These include models to estimate biological reference points and maximum sustainable yield (MSY) proxy reference points using Stochastic Surplus Production model in Continuous Time (SPiCT), which uses both fisheries landings data and survey abundance indices as inputs (Pedersen & Berg, 2017). Outputs provided by SPiCT include MSY reference points (MSY, F_{MSY}, B_{MSY}).

The SPiCT model was applied to Loliginidae landings data broken down by fishing season between 1992 and 2019 in a series of ICES areas. This provided a series of stock assessment outputs, as follows:

- **English Channel**: The model results apply to both *L. forbesii* and *L. vulgaris* as both species are found in this area. The retrospective pattern in the model output demonstrated reasonably consistent trend in recent biomass (both species) being at, or slightly below, MSY and fishing mortality being at, or slightly above, MSY. Hence fishing was at the upper end of what is sustainable in this area.

- **Rockall & Celtic Seas**:

  West coast of Scotland and Ireland (ICES 6a and 7b,c) **-** The model outputs exclusively apply to *L. forbesii* in this area. These showed an increasing trend in both relative fishing mortality and relative biomass from 2015 to present day, hence caution about sustainability of fishing levels relative to stock biomass is warranted. But confidence intervals were very wide, hence the assessment of the loliginid stock in these areas was uncertain.

  Rockall (ICES 6b) - The model exercise did not converge and showed unreliable outputs so the stock could not be confidently assessed in this sub-area. This is unfortunate since a targeted *L. forbesii* fishery operates in this area (mainly Scottish and Irish trawler fleets). This is also probably not surprising since it likely to be a small population which may be present around Rockall during only part of the year and may be replenished from time to time by immigration from other areas.

  Celtic Sea (ICES sub-area 7g,h,j,k) **-** The assessment mainly applies to *L. forbesii* as *L. vulgaris* has negligible biomass in this area. The assessment suggests that the stock is in good condition, as relative biomass > 1 and relative fishing mortality < 1. Given the agreement between the different model specification trials, it can be said that this stock being exploited at sustainable levels. The average catch from the previous four years (227.5 tonnes) was calculated to be smaller than the estimated stochastic MSYs.

  Irish Sea (ICES sub-area 7a) - The assessment mainly applies to *L. forbesii* as *L. vulgaris* has low biomass in this area. The assessment suggests that the stock is in good condition, as relative biomass > 1 and relative fishing mortality < 1. Given the agreement between the different model specification scenarios, it can be said that this stock is being exploited at sustainable levels. The average catch from the prior four years was 5.03 tons, falling well below the estimated stochastic MSY.

- **North Sea**: The model outputs were unreliable and assessment using SPiCT was not possible for this area.

- **Bay of Biscay**: The model results are mostly assumed to apply to *Loligo vulgaris.* Relative biomass is < 1 and relative fishing mortality is > 1 and hence this area is not being exploited at sustainable levels. It is worth noting however that these ratios are similar to those of a surplus production model fitted to the same stock a few years ago with a different procedure (Ibaibarriaga et al., 2015). Wide confidence intervals make it difficult to say precisely how far retrospective biomass and mortality indices are above MSY and for how long this has been the case. Results of the model are still highly uncertain and the biological reference points derived from this exercise should be considered as preliminary indications.

- **Western Iberia and Gulf of Cadiz**:

  Gulf of Cadiz (ICES 9a) **-** The assessment mainly applies to *L. vulgaris* as *L. forbesii* is rare in this area. Relative biomass was > 1 and relative fishing mortality < 1 since 2005, indicating the stock to be in good condition and sustainably exploited.

  Western Iberia - The model outputs were unreliable and assessment using SPiCT was not possible for this area.

<u>Summary of SPiCT stock assessment exercise *Loligo forbesii* and *Loligo vulgaris*</u>

Loligo forbesii in the Irish Sea and Celtic Sea is being exploited below the maximum sustainable yield, hence these are under-exploited. Whereas, *L. forbesii* in the English Channel and west of Scotland are at or above the limit of sustainable exploitation. *L. vulgaris* is not separated from *L. forbesii* in the fisheries landings (which are inputs for these models). This does not matter in the west of Scotland, where stock assessment results apply only to *L. forbesii*, but the results in the English Channel apply to both *L. vulgaris* and *L. forbesii*. The results for English Channel loliginids are consistent with previous assessments using depletion models (Royer et al., 2002). Sampling of the fisheries landings in the English Channel Port-en-Bessin suggests that the proportion of *L. vulgaris* in the fisheries landings is increasing over time and that the proportion of *L. forbesii* is decreasing over time (Figure 17). Unfortunately, model outputs were unreliable for Rockall, which has a targeted fishery for *L. forbesii*. No stock assessment exercises were possible in the remaining areas. Assessment in the Gulf of Cadiz and Bay of Biscay mainly applies to *L. vulgaris*. In the Bay of Biscay, scientific fishing surveys indicate that in autumn, *L. vulgaris* represents, on average, 83% of biomass indices. Model results suggest the biomass is at an acceptable level but the fishing intensity should be reduced. In the Gulf of Cádiz the stock of interest appears to be exploited at a sustainable level.

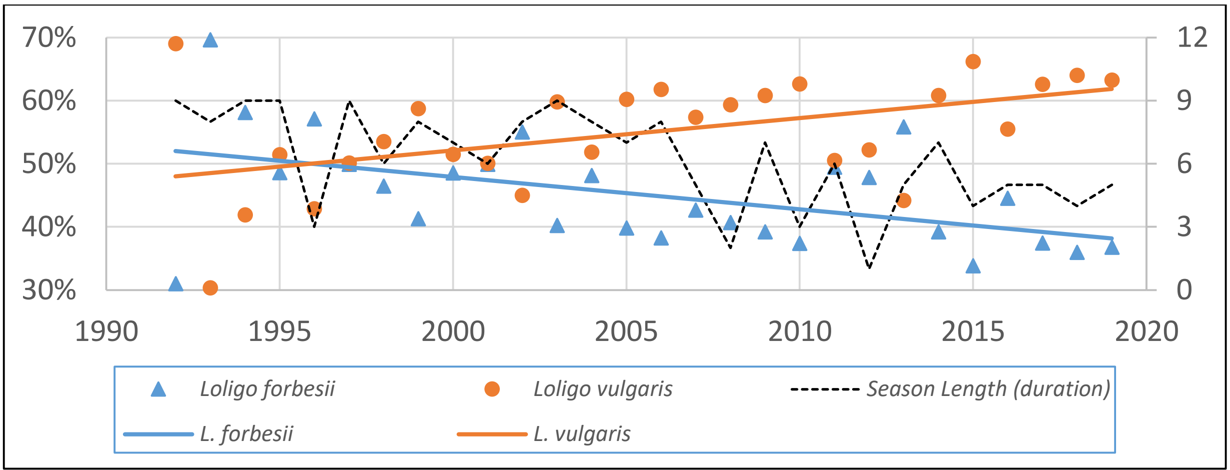

Figure 17. Proportions of loliginid squid species in Port-en-Bessin (English Channel) landings at port, showing that the proportion of *L. forbesii* has decreased over the 27-year time series.

<u>**Stock status and uncertainties in *Loligo forbesii* and *Loligo vulgaris***</u>

As we have seen above, fisheries landings data are recorded and reported by family rather than by species, which creates uncertainties in the landings data. Fisheries landings of *L. forbesii* and *L. vulgaris* are still reported mainly at the family (Loliginidae) – hence this includes (and conflates) catches of *L. forbesii*, *Loligo vulgaris*, and *Alloteuthis* spp. in areas where distributions overlap. Exceptions are Portugal and Spain, which record data at species level – however note that *L. forbesii* landings in these areas are lower in recent years than they have been historically, possibly because the centre of species abundance has shifted northwards and away from the southern part of the distribution since the early 1990s (Chen et al., 2006). In Port-en-Bessin, in the English Channel, a 27-year time series examined the relative proportion of *L. forbesii* and *L. vulgaris* that were landed at the port. This showed that the proportion of *L. forbesii* has decreased over time whereas the proportion of *L. vulgaris* has increased over time. Landings from northern areas like Rockall, west of Ireland and west of Scotland are likely to be dominated by *L. forbesii*, whereas landings in southern areas like the Bay of Biscay and Gulf of Cadiz are likely to be dominated by *L. vulgaris* in recent years.

The fisheries surveys routinely carried out to assess demersal (i.e. seabed-dwelling) fish report abundance data that include *L. forbesii* in most areas. However, species of *Loligo* are not separated in all surveys in the North Sea or Celtic Seas. As *Loligo* squid are not quota species, biological data such as length and maturity data, are rarely collected in a systematic way in all areas where landings are reported. Fisheries surveys may not take place at an appropriate time of year to capture the relevant abundance and biological data in *Loligo*, which has a short lifespan (1-1.5 years) that is flexible in response to the environment and highly variable from location to location and also from year to year. Frequent (i.e. weekly or monthly) data collection is required to capture the dynamics of abundance and fisheries exploitation in these species.

Fishery management (all cephalopod species)

In European waters, catching cephalopods in large-scale fisheries is essentially unregulated. Because they are often not the target species, catching cephalopods is controlled only indirectly, e.g. via restrictions on the types of fishing gear that can be deployed and the catch quotas issued for 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. As previously noted, there is no routine assessment and the quality of available monitoring data sometimes precludes assessment.

In small-scale fisheries targeting cephalopods, especially in southern Europe, regulatory restrictions on fishing activity are numerous but and as such they impose some limits on fishing effort and indirectly help to limit the amount of cephalopods removed. However, in the absence of routine assessment (and indeed in the absence explicit stock definitions), stock status is often unknown and regulations therefore cannot respond to stock status. They may also be ineffective at controlling fishing effort, not least due to lack of enforcement. Thus, the number of octopus pots in the sea in Portuguese coastal waters is thought to vastly exceed the permitted number.

The MSC-certified *Octopus vulgaris* fishery in Asturias is possibly the only example of a European cephalopod fishery where the stock is routinely assessed (applying “depletion” model for in-season assessment among other methods) and management measures can thus be adjusted to account for stock status: catch quotas are set based on assessment of “latent productivity”.

Some lessons can be learned from cephalopod fisheries around the world, for example in the southwest Atlantic, where in season assessment, supported by regular (daily) monitoring of catches has been used to adapt to the unpredictability of abundance, with the option available to close the fishery when the abundance falls too low. The approach used for many years, depletion models, as also currently used in the Asturias octopus fishery, seems to be one of the best options (Arkhipkin et al., In Press). Recent work by Sobrino et al. (2020), on *Octopus* fishing in the Gulf of Cadiz provides one example, which demonstrates of the potential utility of forecasting models to help plan fishing effort for the forthcoming season, a theme developed more fully in a recent paper by Moustahfid et al. (In Press).

Aside from inadequate monitoring and the lack of routine assessment, there are some other barriers to effective management of cephalopod fisheries:

- the logistic difficulties of protecting “minor” species such as cephalopods in mixed fisheries for (mainly) quota species,
- biological knowledge gaps, notably about locations of spawning areas,
- uncertainty about the suitability of existing minimum landing size limits. For example, small octopus caught in pots and returned to the sea will likely survive but trawl-caught cephalopods below the MLS are usually damaged and are less likely to survive release.

Evidently, adequate monitoring and assessment would be useful and would permit sensible decisions about effort or catch limits in directed cephalopod fisheries. For cuttlefish and loliginid squid, protecting the spawning grounds during the spawning season would help ensure recruitment to the next generation. Greater use of more selective gears (such as jigs for squid), which cause less damage to individual cephalopods and to the habitat, could also offer multiple benefits including lower bycatch of finfish, better survival of released animals, and increased value of catches.

The example of the MSC-certified octopus fishery in Asturias suggests that certification could be a route to achieve sustainability in other directed cephalopod fisheries in Europe.

General conclusion

Due to the particular bio-ecological nature of cephalopods and the remaining knowledge gaps still existing, the definition of stock units to assess and to apply conservation and management measures, is one of the main obstacles to manage their fisheries (Pierce & Guerra, 1994; Rodhouse et al., 2014). This fact generates an inherent degree of uncertainty when estimating the status of the assessed stocks and the effectiveness of certain management actions. Consequently, concluding on the sustainability of cephalopod fisheries can represent a complex challenge.

Cephalopods are classified as 'data-limited stocks' by ICES. This brings uncertainty to their status, trends and assessment. As these species have short lifecycles and strong environmentally-driven fluctuations in abundance, their assessment requires high-frequency data collection, but this is not carried out at present.

The stock assessment exercises carried out during this project are sensitive to data inputs. These exercises were not successful in all areas, possibly because the methods were unsuitable for short cephalopod life cycles, where the equilibrium between the cephalopod biomass and the environmental conditions are frequently out of phase. Though stock assessment models did perform and provide results, the confidence intervals for many model exercises were large, giving low precision on the sustainability metrics.

Current management of cephalopod fisheries in Europe still leaves a lot to be desired but options exist to improve sustainability, especially in directed fisheries. One crucial issue is that any new measures need to be introduced with the full involvement and cooperation of the industry, thus helping to ensure their successful implementation (e.g. Silva et al., 2019).

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