ANNEXE 2 to WP4.2 Fisheries Summaries

Fisheries for Octopus vulgaris in the INTERREG Atlantic area (detailed version)

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Octopus vulgaris **<u>Names:</u>** Common octopus (EN) Poulpe commun, pieuvre (FR) Pulpo común (ES) Polvo (PT)	 Photo: Albert Kok, Wikimedia Commons

1. 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 especiall**y 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 1, 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). It is nowadays only fished in the Southern part of the Bay of Biscay and Iberian Peninsula.

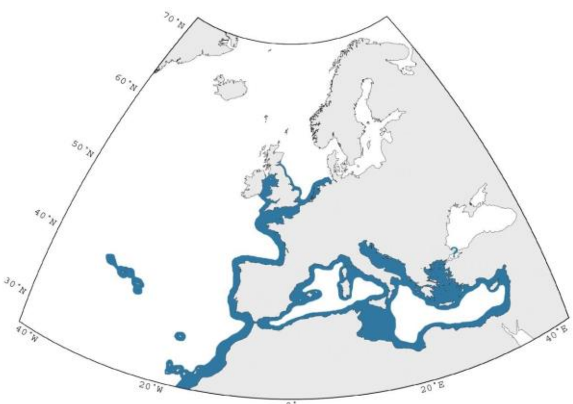

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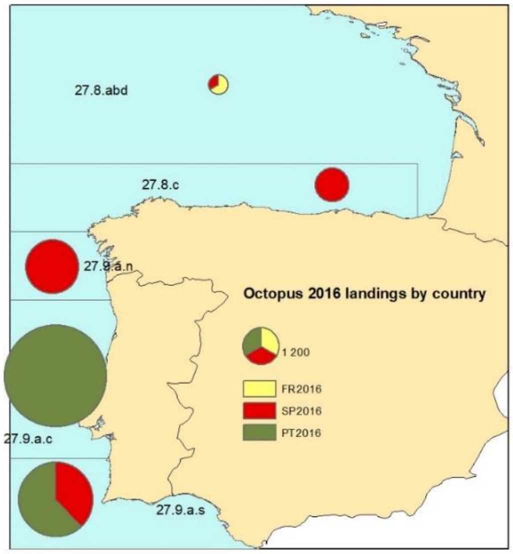
Figure X. *Octopus vulgaris sensu stricto.* Geographic distribution in the Northeast Atlantic and Mediterranean Sea

Fishing fleets and gears

In Europe, 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, 2020). 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 (Fig. 8).



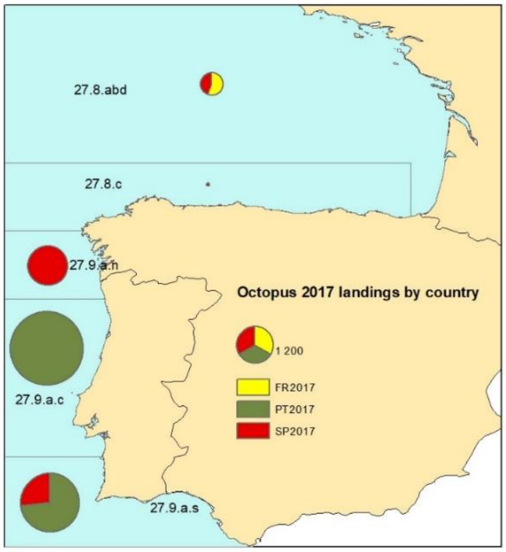


Figure 8: Octopus landings from the Bay of Biscay and Atlantic Waters of the Iberian Peninsula by country in 2016 (left) and 2017 (right). Colour codes : France = yellow ; Spain = red ; Portugal = green.

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 9). 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 9: Examples of artisanal fishing gears used to catch Octopus vulgaris in Spain (left: Lastres, Asturias) and Portugal (right: Tavira, Algarve)

2. Trends in landings and abundance

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 (Roa-Ureta, personal communication).

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 (Fig.10). 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).

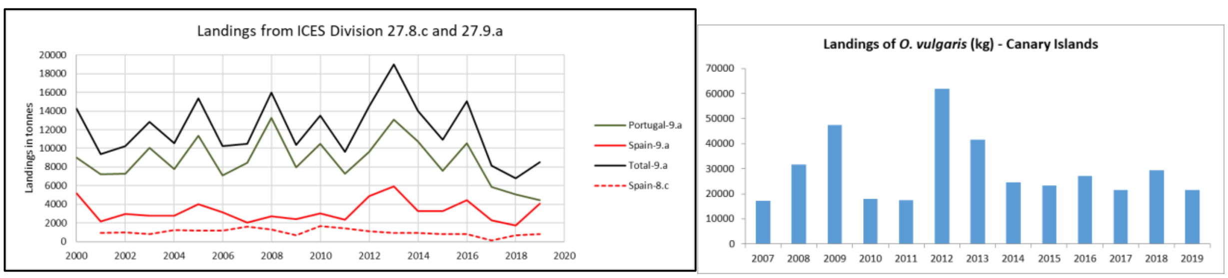


Figure 10: a (left): Trends in octopus landings by countries from ICES Division27.8.c (Cantabrian Sea) and 27.9.a (from Galicia to the Gulf of Cadiz) in 2000-2019 (data from ICES WGCEPH 2020). B (right) Landings in the Canaries.

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 (Fig. 10 b) drives variation in total cephalopod catches. Landings show a seasonal peak in April-May, with a smaller peak in September-October (González-Lorenzo et al., 2019). 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, 2019). 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).

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.

Environmental drivers of abundance and distribution.

Recent studies on environmental effects on *Octopus vulgaris* in European waters, concerning external factors affecting the distribution, migration and survival of wild populations were summarized by Lishchenko et al. (2021).

Changes in bottom salinity and river runoff are major influences on *O. vulgaris* distribution and abundance (Moreno et al. (2014). Although octopuses can survive reduced water salinity (not lower than 30 psu), at least for short periods, decreased salinity during runoff events can be fatal to octopus due to disruption of osmoregulation (Raimundo et al., 2017). Salinity changes also affect the intensity of feeding and survival of octopuses (e.g. Iglesias et al., 2016), with low salinity leading to reduced food consumption and the cessation of feeding.

Habitat temperature is one of the key drivers, with high temperature leading to a younger age at maturity (Schwarz et al., 2018) and affecting both the onset and duration of spawning, as well as the the number of spawning peaks and the duration of both the embryonic and paralarval phases (García-Martínez et al., 2018). There also seems to be an effect of depth on the sex ratio of settled individuals, which also varies seasonally and with substrate, the latter presumably reflecting the fact that females remain inside their dens when brooding their eggs (Alonso-Fernández et al., 2017). Abundance of the planktonic paralarval stage in northern Spain, abundance is related the upwelling system.

Abundance of the planktonic paralarval stage in northern Spain, abundance is apparently related the upwelling cycle, although not necessarily in a consistent way: Otero et al. (2016) found that higher abundance was associated with downwelling conditions, i.e. when shelf currents flowed polewards, water temperature was high and water column stability was low. However, in the same region, Roura et al. (2016) observed higher abundance under strong *upwelling* intensity. Interestingly, older paralarvae tend to be found further from shore suggesting that paralarvae disperse from coastal waters and develop in the open ocean, transported by upwelling ‘filaments’ (i.e. long narrow bodies of cold water protruding from an upwelling front into a warm oligotrophic ocean) (Perales-Raya et al., 2018; Roura et al., 2019)

Human impacts on coastal habitats can have both negative and positive effects on octopus. Sillero-Ríos et al. (2018) found that antioxidant enzyme activity (an indicator of stress) in octopus from a marine reserve was significantly lower than in octopus from two anthropogenically-impacted areas. However, human-altered coastal habitats characterized by abundant shelters, abundant food and absence of predators, can act as settlement and growth areas for juveniles and adults of *O. vulgaris* (Arechavala-Lopez et al. 2019). Certainly the availability of suitable sites to octopus dens is a critical habitat feature for this species (e.g. Katsanevakis and Verriopoulos, 2004; Guerra et al., 2014).

3. Stock Assessment results

Overview

Three different methods were applied to *O. vulgaris* European fisheries, outputs of which are summarised below. In cephalopod fisheries off west Africa (Saharan Bank), Pella and Tomlinson (1969) production models have been applied to assess octopus stocks (e.g. Bravo de Laguna 1989)..

- 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 (Ricker's stock recruitment relationship). 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) (Roa-Ureta, personal communication).

- 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 precluded determination of long term averages as reference points (see the annex 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.

Western Asturias artisanal trap fishery

A stock assessment model has been developed for data collected from octopus fishing in Asturias and adapted to population dynamics rapid characteristic of these organisms. A total of 19 fishing seasons have been evaluated from 2001 to 2019 and parameters of abundance, natural and operational fishing mortality in each of these seasons, with good numerical quality, statistical precision and biological realism. The recruitment, defined as the growth of new juveniles of the year to weight minimum capture occurs in the middle of winter and the escape of spawned females to take care of their eggs occurs later, also in winter. The fishing mortality that is exerted on the stock is low compared to the natural mortality, exploitation rates are low, especially after 2008 and up to the present, and landings are considerably less than the productive capacity of the stock, represented by the average total latent productivity, especially in recent years. The exploitation is biologically sustainable by a good margin but the economic return it is below the sustainable productive potential of the fishery. The sustainable harvest rule obtained from the results of this study is that the total catches per annual season is lower than the average total latent productivity, estimated at 239 tons (Roa-Ureta, personal communication).

Assessment of Octopus in the Gulf of Cadiz

The influence of environmental parameters (Sea Surface Temperature; Sea Surface Salinity; Surface Chlorophyll; Surface turbidity; NAO Index; Rain; WeMoi Index; AMO index; River discharges) on the abundance of this species in the Gulf of Cadiz was investigated by Sobrino et al. (2020). The abundance of octopus in the Gulf of Cadiz was influenced mainly by rainfall in the previous year and secondarily by the surface sea temperature in April of the previous year. Abundance was also found to be related to a recruitment index obtained from the autumn demersal survey, especially in certain key areas "recruitment zones") and to improve forecasting of the following year's landings, it was necessary to take into account the number of hauls inside these recruitment areas. The final model used to forecast the landings was

$$\text{Landing}_{i+1} = \text{s(Recruitment index}_i) + \text{s(Rain}_i) + \text{as.factor(Hauls in recruitment zone}_i)$$

We applied the model with data from 2016, 2017 2018 and 2019 (Recruit Index in November of 2016, 2017 2018 2019 and 2020 and rain during October 2015 to July 2016, October 2016 to July 2017, October 2017 to July 2018, October 2018 to July 2019 and October 2019 to July 2020). In the report of WGCEPG2019 we predict that the landing during the period November 2018 to October 2019 will be 2553 tn (1777-3676 95%CI) and the landing in these period was 2866 tn, very close to valour predicts.

In table 1 and figure 1 we present the results of the landings forecast for the last five fishing seasons (Mean and 95% confidence intervals) and the total landings of the commercial fleet in these periods. In both cases, the true value of the total landings falls within the confidences intervals.

Table 1. Model validation for the periods 2016-2017, 2017-2018, 2018-2019 and prediction for 2019-2020. Mean of forecast landings with 95% confidents intervals (CI).

Period	Rain^{-1} (l/m^2)	Recruit index	Hauls inside in zone recruit	Forecast landings (tn) Min (95% CI)	mean	Max (95% CI)	Landings (tn)
2016/2017	478	1.29	4	513	**902**	3056	**1589**
2017/2018	587	0.32	3	270	**416**	642	**476**
2018/2019	488	4.1	3	1743	**2706**	4200	**2866**
2019/2020	335	1.73	4	885	**1618**	2960	**1146**
2020/2021	404	0.81	3	578	**897**	1391	

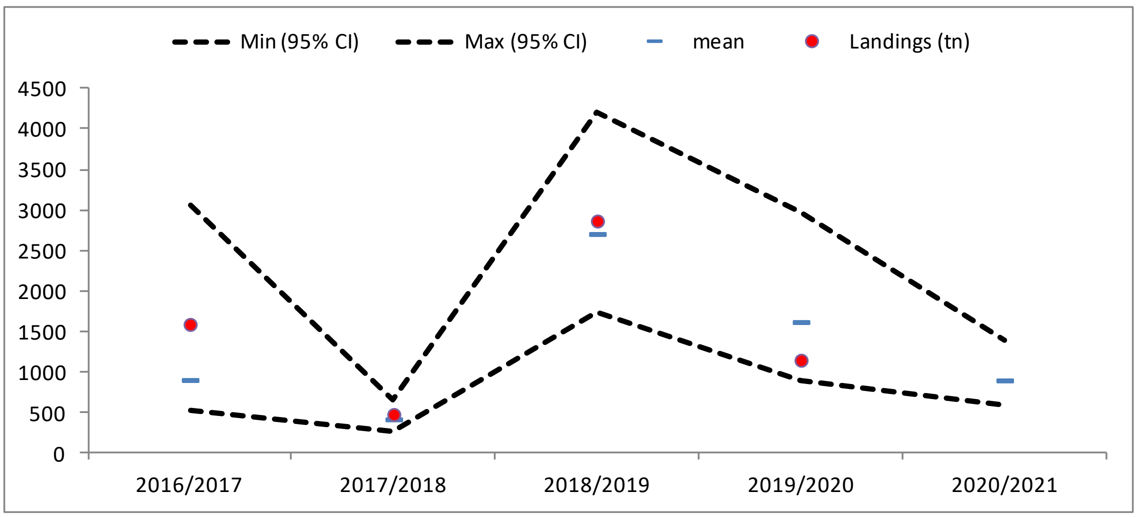


Figure 1 Model validation for the periods 2016-2017, 2017-2018, 2018-2019, 2019-2020 and prediction for 2020-2021.

Using the 2020 data, the model predicted a mean landing of 897 with a interval (95%) of 578 to 1391 tn for the period of 2020-2021.

The model predictions could be very useful for managing these fishing grounds. In this way, at the beginning of the fishing season in November we would be in a position to predict how the season will develop and, based on that, include technical measures such as the establishment of daily quotas, extending or shortening fishing periods, modifications of the first catch weight, establishment of zone closures to protect recruits, etc.

4. Stock status and uncertainty; sustainablity

Overview

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 currently cannot 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.

Sustainability issues

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.

Recent studies on Fishers' preferences for management in the Portuguese artisanal fishery of *O. vulgaris* (using traps and pots) were analysed by Silva et al. (2019). Their results indicate that octopus fishers preferred management measure is fishery closure and they welcome a participatory co-management-based. The demand for the establishment of a close season in the Algarve octopus fishery arose from participatory workshops involving fishers, as reported by Sonderblohm et al. (2017). Bañón et al. (2018) highlighted a need for more flexible and adaptative management measures that take into account spatio-temporal variability in effort and decisions on fishing strategies in the small-scale trap fishery targeting common octopus in the north-west coast of Spain, proposing a move to a hybrid system incorporating both effort and catch controls.

In the case of the Asturias (Northwest Spain) Octopus vulgaris trap fishery, several studies indicated the existence of a fine spatial substructure in populations in the Atlantic (Cabranes et al., 2007), allowing to consider the local stock as part of a metapopulation with partial isolation or moderate connectivity (Bureau Veritas, 2016). Assuming these bio-ecological features, this fishery is managed mainly based on spatio-temporal measures and catch limits per boat and season (10 tonnes), though no formal TAC is applied. These measures are formally adopted through an annual management plan with key contribution from the fishers' guilds, implying certain degree of co-management. The management plan includes the establishment of a closed season (from December to July), a minimum capture weight of 1000 g per individual, a limitation of effort (350 traps per boat) and the definition of traps as the only authorized fishing gear. The plan also includes monitoring activities during the fishing season. Beyond the compliance with the measures of the management plan, this fishery has implemented further improvements incentivized to maintain its MSC certification for sustainable fisheries (MSC certified since 2016 and first octopus fishery MSC certified in the world). As mentioned in the previous section, new stock assessment models and approaches are under development to allow define proper harvest control rules adapted to the dynamics of the species and fishery. The management plan has been improved including explicit short- and long-term objectives and specific measures to control the environmental impacts of the fishing activity and not only the exploitation rates of the target species. In addition, there have been established specific actions to increase the transparency and responsiveness in information and decision-making processes related to the fishery throughout an Octopus Fishery Monitoring Committee. Finally, the regional government has implemented a vessel tracking monitoring system and an onboard observer program to collect detailed information on fishing areas (Bureau Veritas, 2016; Bureau Veritas, 2020a; Bureau Veritas, 2020b).

Despite of these improvements, the Asturias octopus trap fishery still face some challenges to maintain a sustainable management. These challenges are mainly related to the need to analyse the responsiveness of the harvest strategy to the status of the stock considering the existing uncertainties, and therefore the need for a precautionary application of the harvest control rule. Information about the species used as bait should be also improved to better understand the indirect effects of the octopus fishing operations on other species. And the establishment of a consolidate system to guarantee the operationalisation of the monitoring, control and surveillance system beyond the successful pilot implementation (Bureau Veritas, 2020b).

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