Environmental effects of cephalopod fishing techniques

WP.4.4 Deliverable

Cephalopods small-scale fisheries in European waters: a review of the environmental impacts

Angela Larivain[1], Graham J. Pierce[2], Julio Valeiras[3], Anne Marie Power[4] Jean-Paul Robin[1]

[1]BOREA: Biologie des ORganismes et des Ecosystèmes Aquatiques, Université de Caen Normandie, 14032 Caen, France ; larivainangela@gmail.com, jean-paul.robin@unicaen.fr
[2]Consejo Superior de Investigaciones Cientificas, Departamento de Ecología y Recursos Marinos, Eduardo Cabello 6, 36208 Vigo, Vigo, Spain & CESAM & Departamento de Biologia, Universidade de Aveiro, 3810-193 Aveiro, Portugal g.j.pierce@iim.csic.es
[3]IEO, Instituto Español de Oceanografia, Centro Oceanografico de Vigo, Subida a Radio Faro 50, 36390 Vigo, Spain julio.valeiras@ieo.es
[4]Ryan Institute, School of Natural Sciences, National University of Ireland Galway, H91 TK33 Galway, Ireland annemarie.power@nuigalway.ie

ABSTRACT

During the past years (2000-2018), catches and global landings of cephalopods are increasing, although the Northeast Atlantic mainly shows inter-annual variability. Though they are caught by both large and small-scale fisheries, the environmental impacts of the latter are less reported. This lack of documentation is related to the fact that small scale fisheries are very diverse and that these species are not regulated under the Common Fishery Policy (CFP) and so no catch quotas exist for them. They are also difficult to assess with respect to biologically safe limits, and they are often ‘data poor’.

This overview aims to compile the environmental impacts with an emphasis on small-scale fisheries (SSF) targeting cephalopods in EU waters. Special attention is given to interaction between cephalopods fisheries and possible damage caused to the whole ecosystem. It highlights the potential of using certain type of gear in order to better contribute to SSF management for a sustainable exploitation of this resource.

Keywords: Cephalopods, small-scale fisheries, environmental impacts, by-catch, management

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1. Introduction

This deliverable is part of the Integrated Ecosystem Assessment (IEA) Work Package 4, Action 4 of the CEPHS&CHEFS Interreg project. A lack of small-scale fisheries (SSF) documentation in cephalopod fisheries is related to the fact these species are difficult to assess, they are not subject to catch quotas and are not regulated under the Common Fishery Policy (CFP). Hence one could consider these 'data-poor' fisheries. Small scale fisheries in general are more geographically dispersed and difficult to monitor, so these are generally associated with having less data available to assess their impact.

1.1 Common Fisheries Policy (CFP)

The Common Fishery Policy (CFP) defined rules for managing European fishing fleets and for conserving fish stocks since the 1970s. Reform of the CFP took place on 1rst January 2014 according to the UE 1380/2013 (relative to the CFP) and UE 1379/2013 (relative to the market organization in sea products). The main goals were to give equal access to EU waters and fishing grounds, except in the 12 miles' coastal water zones where an historical rights regime exists. Implementation of the reformed CFP also mandates the progressive reach of catch limits to maintain fish stocks at the Maximum Sustainable Yield (MSY) by 2020 (European Union, 2015).

Although this policy is relevant, cephalopod SSFs are seldom covered by the CFP and the consequence is that there are no catch quotas for these species. Most SSF fishing methods occur in coastal waters and, as a result, are managed nationally or regionally.

1.2 General statement about Small-scale fisheries

Small-scale fisheries (SSF) are very important in the EU and 84% of the 25 EU Member State fleets are considered to be SSFs, with (in increasing order) Greece, Spain, Portugal, Italy and France accounting for the largest share of the total small-scale fleet (Lloret *et al.*, 2018). SSFs are recognized to play a major role in worldwide fish catches, food supplies and food security (Alonso-Fernández *et al.*, 2019). In particular, SSFs play a crucial role in some EU regions, which suggests that the EU should support them to become sustainable fisheries. Ensuring long-term sustainability requires better knowledge of small-scale vessels and more precise reporting of their catches and fishing areas (Pascual-Fernández *et al.*, 2020). SSFs are characterized in Gil *et al.* (2018) by the use of 'small boats' (< 15 m) with wide variety of fishing techniques, gears and targeted species. Therefore these can be difficult to define because many criteria exist, resulting in differing concepts among countries and between regions within countries (Alonso-Fernández *et al.*, 2019; García-Flórez *et al.*, 2014). For example, the Common Fisheries Policy defines SSF as "fishing carried out by fishing vessels of an overall length of less than 12 m or not using towed fishing gear", which allows trawlers < 12 m in the United Kingdom (U.K.) to be considered as SSF. These fisheries have been widely defined through scientific and grey literature, for example, Smith & Basurto (2019) analysed the evolution of the definition of SSF through 1,723 articles published between 1960 and 2015. They found among articles providing a definition, that technologies such as the fishing boats (length, type) and gear type appeared to be the most used. The absence of a clear definition by scientific and political stakeholders may cause issues, particularly when fisheries are considered ‘small’ when they are not, creating disadvantages for other SSF operators.

García-Flórez *et al.* (2014) proposed the classification of SSF (comprising coastal artisanal fisheries) based on a scoring system of seven numerical descriptors approach (NDA). This classification allows the selection of four technical or structural descriptors (overall vessel length [m], gross tonnage[GT], engine power [kW] and type of gear [passive, purse seine or active]) and three functional (number of fishing licenses issued, number of fishermen per boat and daily landings) on the basis of data available in EU (Table 1). Based on this scoring system, a fishing vessel was considered ‘artisanal’ when achieving 21 points or less, with subsequent sub-division into ‘coastal artisanal vessels’ (15 - 21 points) and so-called ‘small-scale artisanal vessels’ (≤ 15 points).

Table 1. Scores allocated to the value ranges of the seven descriptors used for the definition of artisanal fisheries, from Garcia-Florez *et al.*, 2014

Descriptor	Scores allocated to the ranks of values				
	1	2	3	4	5
Overall vessel length (m)	< 10 m	≥ 10– < 12	≥ 12– < 18	≥ 18– < 24	≥ 24
Gross tonnage (GT)	< 50	≥ 50– < 75	≥ 75– < 100	≥ 100– < 200	≥ 200
Engine power (kW)	< 5	≥ 5– < 10	≥ 10– < 25	≥ 25– < 50	≥ 50
Type of gear	Passive gear	–	Purse seine	–	Mobile gear
Fishing licenses allowed (number per year)	≥ 5	4	3	2	1
Crew members (number)	1	2–3	4–5	6–7	≥ 8
Daily landings (kg/day with sales registered)	< 200	200– < 300	300– < 400	400– < 500	≥ 500

Among the seven descriptors used for the definition (Table 1), *daily landings* (kg/day), *overall vessel length* (m) and *engine power* (kW) were found the most frequent explanatory variables to define small-scale vessels. The implementation of new descriptors (e.g. operational range of the vessels and fishing effort, time spent at sea as well as other socio-economic indicators) needed to be improved for this method to be suitable in all EU countries (NDA applied on ‘southern’ European fleets e.g. Principality of Asturias, Gulf of Cadiz, Basque Country in Spain; Algarve in Portugal and French Atlantic regions).

The 2017 FAO Workshop on SSF (FAO, 2017) proposed another index, which seems in line with what García-Flórez *et al.* (2014) proposed as this includes socio-economic descriptors (Table 2). This index should therefore be suitable to take variation between developed and developing countries into account, as well as distinguishing SSFs in marine and inland waters.

Table 1. Proposed index for small-scale fisheries characterization, found in FAO, 2017

Score	0	1	2	3
Size of fishing vessel (or equivalent range for fixed gears)	No vessel	< 12 m, < 10 GT	< 24 m, < 50 GT	> 24 m, > 50 GT
Motorization	No engine	Outboard engine	Inboard engine < 400hp	Inboard > 400 hp
Mechanization	No mechanization	Small power winch/hauler powered off engine	Independently powered gear deployment/ hauling	Fully mechanized gear deployment and hauling
Refrigeration/ storage on board	No storage	Ice box	Ice hold	Refrigerated hold
Labour/crew	Individual and/or family members	Cooperative group	< 2 paid crew	> 2 paid crew
Fishing unit/ ownership	Owner/operator	Leased arrangement	Owner	Corporate business
Time commitment	Part-time/ occasional	Full-time, but seasonal	Part-time all year	Full-time
Day trip/multiday	< 6 hours	Day trip	< 4 days	> 4 days
Fishing grounds/ zone/distance from shore	< 100 metres from shoreline	< 3 km from shoreline	< 20 km	> 20 km from shoreline
Disposal of catch	Household consumption/ barter	Local direct sale	Sale to traders	Onboard processing and/ or delivery to processors
Utilization of catch, value added/ preservation	For direct human consumption	Chilled	Frozen	Frozen/chilled for factory processing (for human consumption or fishmeal)
Integration into economy and/ or management system	Informal, not integrated (no fees)	Integrated (registered, untaxed)	Formal, integrated (licensed, landing fees)	Formal, integrated (licensed, taxed)

Shared global characteristics of SSF according to FAO

- Highly dynamic
- Labour-intensive (with labour often the largest component of operating costs)
- Require a relatively low capital investment in boats and equipment per fisher on board compared with more industrialized operations
- Employ a wide range of low-level fishing technology with low catch per fishing craft and productivity per fisher (using relatively smaller vessels in a given region or in some cases none at all, e.g. beach seines or fish traps)
- Cover a relatively short geographic range (though migration is a feature of many small-scale fishers)
- Target multiple species
- Require minimal infrastructure for landing, with catch sold at scattered landing points

Sources: FAO 2016a; FAO 2008 – 2017; Béné 2006; in Basurto et al., forthcoming.

As defined by FAO, SSF produces two-thirds of all catches of marine species with 95% of small-scale fisheries landings traditionally occurring in coastal waters and being destined for local consumption (The World Bank, 2012). Unlike large-scale fisheries (LSF), SSF can target multiple species (fish, shellfish, cephalopods…) with various techniques and gears. This is mostly seasonal, following species dynamics/migration. For example, Villasante *et al.* (2015) illustrated the seasonal evolution of target species caught along the Galician coast (Table 3).

Table 2. Seasonal distribution of catches for multi-specific small-scale fisheries in Galicia, from Villasante *et al.* (2015)

	MONTHS OF THE ANNUAL FISHING SEASON											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Fishing gear	Trammel Net	Trammel Net	Trammel Net	Gillnet	Gillnet	Gillnet	Trap	Trap	Gillnet	Gillnet	Gillnet	Trammel Net
Targeted species	SOL ESE	SOL ESE	SOL ESE	HAK MAC HMAC SURM POU	HAK MACK HMAC SURM POU	HAK HMAC SURM POU	OCT VCR SHR	OCT VCR SHR	POU HAK HMAC SURM	POU HAK HMAC SURM	POU HAK HMAC SURM	SPC

Source: interviews with small-scale fishers (this study). *Acronyms used for targeted species: ESE: European seabass, SOL: European sole, HAK: European hake, HMAC: Horse mackerel, MAC: Mackerel, OCT: octopus, POU: Pouting, SHR: Shrimp, SPC: Spider crab, SURM: Surmullet, VCR: Velvet crab.

As we can see above, data about SSFs are important, but are difficult to collect. Some challenges in SSFs include overexploitation and illegal, unreported and unregulated (IUU) fishing in the context of a global change (Agapito *et al.*, 2019). Data paucity is particularly sharp in SSFs due to the diversity, complexity, dynamics and issues of scale in the socio-economic systems involved and in the relevant supply chains (Chuenpagdee *et al.*, 2017).

Because of these two characteristics of SSF (heterogeneity of fishing techniques and data paucity) the analysis of environmental impacts in cephalopod SSF is a challenging task.

1.3. Cephalopods fisheries in Northeastern Atlantic

The barcoding report of Cephs&Chefs project (2018-2020) showed 30 species of cephalopod are found in the Northeast Atlantic Area using genetic markers including 18 species of squid (including loliginid and ommastrephid), seven of bobtail, three of cuttlefish and 10 of octopus. The biology of the main species was reviewed by Hastie *et al.* (2009) and Jereb *et al.* (2015). The bulk of Northeast Atlantic cephalopod landings consists of seven species (one cuttlefish, two long-finned squids, two short-finned squids and two octopuses).

Cephalopods play a significant role in marine ecosystems and are important fisheries resources within the north-eastern part of the Atlantic. Since 2015, the cuttlefish *Sepia officinalis* has been the most commercially important cephalopod in the U.K. waters (ICES, 2020a), with annual landings (average 2014-2019) in the NE Atlantic of 17,200 tons (Table 4). Four nations in the region account for more than 90% of the total NE Atlantic cephalopods catch, being French, U.K, Portuguese and Spanish fleets.

Table 4. Total annual cephalopod landings (in tons) in all ICES areas of the NorthEast Atlantic waters, separated into main cephalopod species groups (1992-2019). From WGCEPH ToRA tables (ICES, 2020a)

	Year													
Group	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cuttlefish	12,454	15,611	12,876	19,603	19,736	16,676	20,016	20,510	21,062	16,397	20,458	20,666	28,313	22,706
Long-fin squid	10,586	10,182	9,65	10,004	9,645	11,519	10,401	10,407	9,054	8,055	9,840	12,064	11,458	8,381
Short-fin squid	2,914	1,483	1,774	1,703	4,221	6,145	5,841	7,719	5,529	4,238	2,509	1,729	2,040	2,574
Octopods	16,077	12,729	13,27	16,226	17,658	15,802	13,043	15,743	16,451	11,447	12,841	14,854	13,214	17,883
Total	42,031	40,005	37,57	47,536	51,26	50,142	49,301	54,379	52,096	40,137	45,648	49,313	55,025	51,544
	Year													
Group	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cuttlefish	20,826	24,621	15,122	12,397	18,212	18,376	21,936	16,119	13,284	20,625	18,400	19,094	14,147	17,562
Long-fin squid	7,525	8,734	7,124	9,454	12,121	10,952	10,297	7,52	9,813	9,164	11,262	12,096	10,637	12,023
Short-fin squid	1,275	971	2,069	2,034	3,689	4,220	5,617	3,937	4,644	3,300	4,712	2,698	4,835	3,824
Octopods	12,709	13,567	18,630	11,959	16,752	12,965	16,662	21,652	15,917	12,587	17,015	9,265	8,665	10,342
Total	42,335	47,893	42,945	35,844	50,774	46,513	54,512	49,228	43,658	45,676	51,389	43,153	38,284	43,751

The proportion of landings by SSF and LSF is quite different according to the group of species (Figure 1). It is not surprising to see oceanic species like Ommastrephid squids being caught mainly by LSF offshore trawlers. In cuttlefish (Sepiidae), the graph underlines the high proportion of the catch taken in offshore wintering grounds although this may be biased by unreported landings by the artisanal fleet in official fishery statistics.

Since this review is mostly about small scale fisheries the description of environmental impacts will be more developed in resources which are significantly caught by artisanal gears or when specific issues arise with such gears.

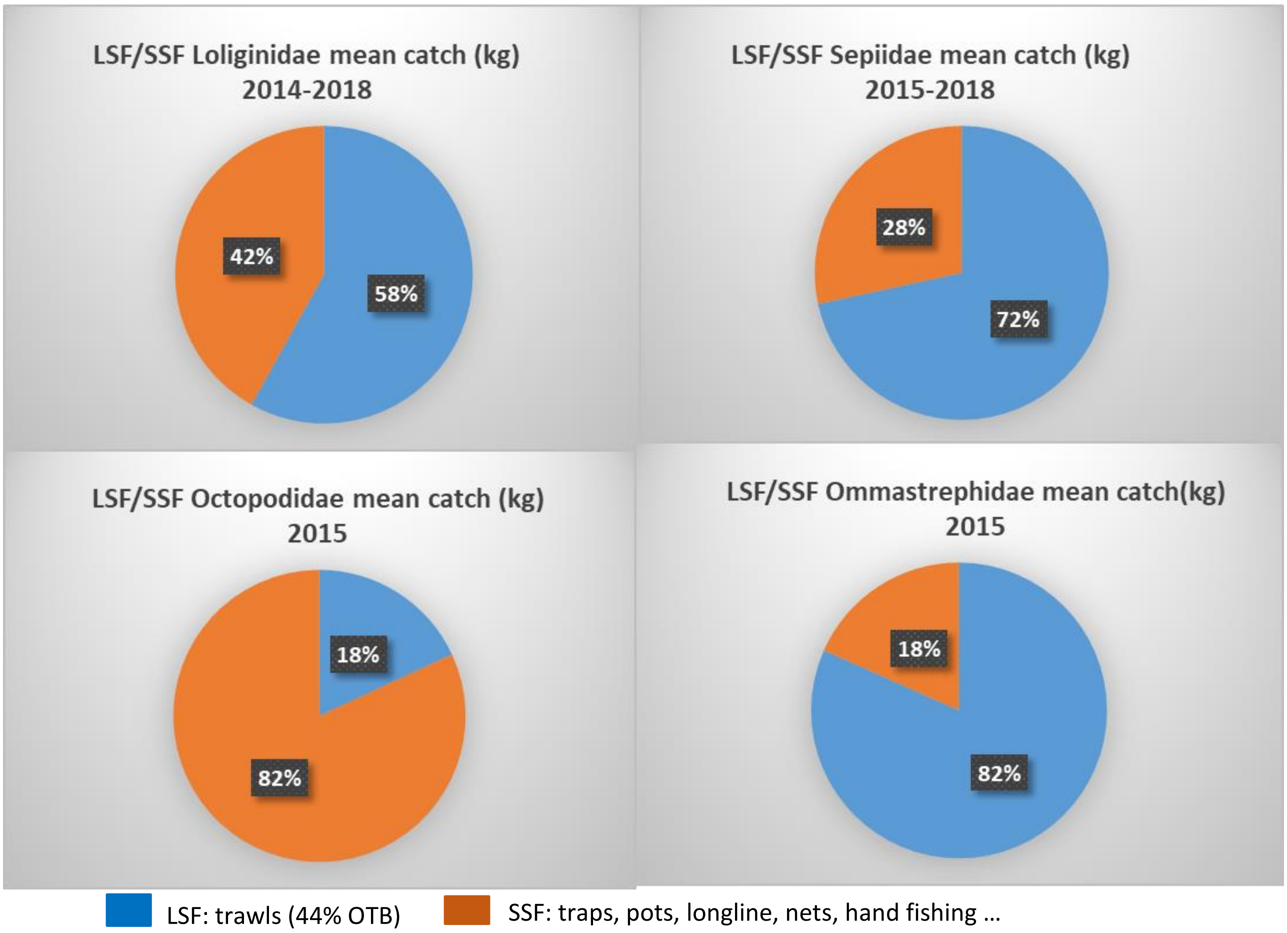

Figure 1 share of large scale fisheries (LSF) and small scale fisheries (SSF) in landings of the 4 groups of cephalopod resources fished in Northeast Atlantic Waters. Redrawn from ICES WGCEPH Intercatch data.

The general characteristics of cephalopod fisheries in the Atlantic Area are presented in the "Fisheries Summaries" (WP4.2 deliverable) and reference to information contained in this report will appear as "Cephs&Chefs_WP4.2".

From a fishery manager perspective, the main points to keep in mind are as follows.

- Cephalopod resources are not included in the EU CFP system of Total Allowable Catch (TAC) and quotas.
- In spite of numerous stock assessment exercises the only fishery to be routinely assessed is the Asturias *Octopus vulgaris* trap fishery which is also the first European cephalopod fishery certified sustainable according to MSC.
- Fin fish regulations such as trawlers mesh size also apply to cephalopod fishing especially when cephalopods are by-catch species. *On the other hand, there are exemptions to the French rule that bans trawlers within the 3 miles' zone that are given to catch cuttlefish inshore.*
- EU Regulation 2406/96 on landings commercial categories indicates the minimum size of specimens in the smallest category (but this is not used as a minimal landing size)
- Many inshore fisheries have developed the monitoring of fishing effort via fishing licenses. In some cases, additional rules limit fishing effort via the number or gears

(traps) or via seasonal closures and limit juvenile mortality via minimum landing size (or weight) but local situations are quite diverse.

2. Environmental impacts

Fishing is among the most ancient and most widespread human activity occurring at sea and its consequences on marine ecosystems have been reviewed since decades. Jennings and Kaiser, (1998) highlighted the multiple aspects of environmental impacts of fishing with direct and indirect impacts and effects on habitats, fish community and food web interactions.

At the EU level, the implementation of the Ecosystem Approach to Fisheries is promoted by several regulations: the Habitats Directive (1992/43/EEC) the Marine Strategy Framework Directive (2008/56/EC and 2017/845) and the revision of the Common Fisheries Policy (2013). However, the analysis of the impact of fishing gears was mostly focused on towed gears such as otter trawls, dredges and beam trawls, which are already quite well-studied and documented (Løkkeborg, 200 ; Colloca *et al.*, 2017 ; ICES 2018 ; ICES 2020b).

Trawling vessels can range from as small as 3 m long to over 70 m, which can lead to misunderstanding when talking about trawl fisheries (Rathjen, 1991). Both large and small-scale fisheries can include trawlers, so it is important to specify, especially noticing that trawling is the main fishing gear used by LSF to catch cephalopods (Figure 1).

Coastal fishers use a variety of different types of gear, many of which disturb habitats and cause direct or indirect impacts on fish species (Reis-Filho *et al.*, 2019). Here, the gear variety that could catch cephalopods will be described as well as the reported environmental impacts from by-catch, discards and other effects (community level, ecosystem, pollution, etc.). While focusing on known impacts in European waters, lessons learned for SSFs targeting cephalopods from situations "outside" this sector or overseas will be included.

Among fisheries impacts, lost fishing gear, such as nets, traps and longlines, continue to be caught for a very long time. Different species can be trapped unnecessarily and the decomposition of these catches can attract predators that will in turn be trapped. This is called "ghost fishing" (Jennings and Kaiser, 1998). Its impacts are multiple and concern species, habitats and underwater landscapes.

To assess the environmental impacts of lost fishing gear, the caught species could be recorded with also information on the impacted area of such catch (http://www.aires-marines.fr/Proteger/Proteger-les-habitats-et-les-especes/Les-filets-fantomes-et-autres-engins-de-peche-perdus).

2.1 Small-scale fisheries (SSF) targeting cephalopods

Environmental impacts of Cephalopod SSF are presented according to the type of gear (active -towed- gears and passive gears) and by analysing the existence of bycatch or discards, the effect on the seabed and benthos and other alterations of the habitats and when available other ecosystem effects like changes in the trophic network.

Although SSF account for a lower discard rate than in LSF (Sartor *et al.*, 2018), the fishing effort in such artisanal fisheries should not be neglected. While SSFs are mainly concentrated near the shore, more attention is needed on the different impacts on coastal areas particularly ecologically sensitive habitats (spawning areas, nursery areas, biodiversity hotspots, areas which already face anthropogenic pollution, and marine protected areas (MPAs).

2.1.1. Trawlers < 12 m

Gear variety description

As previously described in the general statement on SSF, trawlers that are < 12 m length are small-scale vessels. Two main gear types are associated with cuttlefish and Loliginidae (squid) catches are otter trawls and beam trawls (ICES, 2020a). Otter trawling (OTB) derives its name from the large rectangular otter boards which are used to keep the mouth of the trawl net open. The boards are heavy and act like a plough digging into the seabed. As it moves forward, it catches live species close to the bottom such as cod, hake, monkfish or Nephrops, among other species such as cephalopods.

The bottom beam trawl (TBB) consists of a beam attached to two metal runners which form a rigid structure to which the trawl (net) is attached, with chains fixed under the net. TBB is generally used to harvest the benthic fauna (invertebrates and fish) of large size and since it is the main type of trawl used in the U.K., it seems responsible of the majority of catch of *Loligo forbesii*.

In Normandy the inshore trawl fishery takes place over approximately 8 months of the year, from mid-April or early May, and until October-November (Basuyaux & Legrand, 2013). In France, cuttlefish is targeted at different stages of development, both juveniles and adults being caught by bottom otter trawlers (OTB) in the Western Channel (division 7e) during autumn and winter, with inshore adults being captured in spring by trawling and by traps and gillnetters (7.d and 7.e). In addition, cuttlefish may occasionally be caught as a by-catch in the autumn scallop fishery using dredges (7.d).

Described bycatch or discards

The commonest situation in trawl fisheries is that cephalopods appear as by-catch of fishing operations targeting demersal fin fish. In such cases the main question (which the WGCEPH group is addressing through the ICES data call and InterCatch) is how much of the cephalopods are landed or discarded. The question of the status of other species caught with cephalopods is generally not addressed.

There are however at least three cases where the consequences of inshore trawl fishing for cephalopods on the nektonic community and its habitats have been analysed.

The most comprehensive analysis concerns the Northwest Atlantic fishery for the neritic squid *Doryteuthis pealeii*. This resource may be fished by both small scale and large scale fisheries however, the interactions between the targeted squid catch and butterfish (*Peprilus triacanthus*) by-catch have been thoroughly investigated (Lange and Waring, 1992). This analysis has led to fishery closures in order to keep butterfish by-catch below 6%. In addition, increased in cod-end mesh size proved to be significantly improving gear selectivity (Hendrickson, 2011).

The inshore trawl fishery targeting *Loligo forbesii* in the Moray Firth (Scotland) has been analysed in an ecosystem perspective (Wangvoralak, 2011) including the consequences of increased fishing pressure on other fish species. The list of species caught by the same gear indicate that Norway lobster, Monkfish or adult Whiting would be directly impacted although negative effects on squid predator species like saithe, long rough dab, baleen whales, mackerel, seals, and toothed whales and positive effects on squid preys would likely be greater.

English Channel cuttlefish migrate inshore for spawning and young of the year leave coastal waters in autumn to reach offshore wintering grounds. During the coastal phase of the migratory cycle cuttlefish are fished with trawls. In spring, catches made with this gear are less selective than those made with traps. Basuyaux and Legrand (2013) underlined that when traps would collect only 2 years old cuttlefish, trawl catches were much less selective catching the two age groups. In autumn exemptions from the French rule that bans trawl fishing within the 3 miles' limit are obtained in order to let trawlers fish for juvenile cuttlefish. Such exemptions are criticized by fishery scientists which point out two problems: fishing for juvenile cuttlefish is a waste of biomass in the light of the very fast growth of the species; inshore trawlers are suspected to catch more undersized flatfish (sole, plaice) than cuttlefish. On board observations of these autumn catches are difficult to organise since illegal practice (like the addition of a small mesh "sock" in the codend) are common.
Scientist from Ifremer of the University have repeatedly indicated that the exemptions were not a good practice (Eric Foucher, pers. comm.) As a result, in some areas like West Cotentin, exemptions are now obtained for shorter periods of two weeks in late summer – autumn but nevertheless this activity has not disappeared.

Other related effects

SSF bottom-trawling (<12 m boat) on squid in the Moray Firth was associated with adverse effects on squid spawning grounds by severely damaging egg masses or substrata for egg mass attachment, to such an extent that this was considered more important than direct fishing mortality (Hastie *et al.*, 2009).

EU mesh size regulations that apply to catch cephalopods are originally derived from that for fin fish (i.e. 80-100 mm). This may not be sufficient to avoid fishing smaller individuals because of their shape (lots of arms, soft body, etc.), leading them to be easily entangled. Even if escape from nets can take place, cephalopods are almost certain to be damaged by passing through a net and survival can be poor. The immediate survival of cuttlefish discarded by UK trawlers is much lower in juveniles (31%) than in adults (98%) (Revill, *et al.* 2015).

2.1.2. Jigging

Jigging mostly targets oceanic squid including ommastrephids, for example this is the main method of catching *Illex argentinus* which is a major fishery in the south west Atlantic. Although most commonly associated with deep-dwelling oceanic squid, jigging is also reported in neritic species. In Europe, this includes *Loligo forbesii* and *L. vulgaris* (Guerra *et al.* 1994; Hastie *et al.*, 2009), more occasionally *Sepia officinalis* (mainly in Iberia) and *Octopus vulgaris* (in southern Europe and west Africa) (Caverivière *et al.*, 2002; Hastie *et al.*, 2009). Jigging is also reported from Norway (Rathjen 1991), Azores (Martins, 1982; Hanlon, 1987) and from England, Spain and mainland Portugal (Hastie *et al.*, 2009).

A summary of jigging as a fishing method is given by Hamabe *et al.* (1982). Advantages of jigging are the lack of environmental damage to the seabed caused by trawling, less scope for bycatch and incidental catches (jigs are more targeted gear) and less damage is likely to occur to the squid themselves when they are caught by jigs. This means that less of the catch is likely to be wasted during jigging than is the case for squid caught in trawls (Jereb & Roper, 2010). Squid are soft-bodied and can be destroyed due to the weight and pressures experienced at the cod end of a trawl. Environmental disadvantages of jigging include potential damage to seabirds and marine mammals, including from lost fishing gear. Some seabirds and marine mammals may interact with the squid captured on hooks before they are landed. A low percentage (<4%) of Australian fur seals directly interacted with squid jigging operations by pulling squid from the lures in southern Australia. No negative impacts were reported to the seals (Arnould *et al.*, 2003). A further 29% of seals were observed foraging on squid close to the vessel (Arnould *et al.*, 2003). Squid fishing in this area is mainly targets arrow squid *Nototodarus gouldi*. Although bycatch of seabirds during squid jigging operations on the Patagonian shelf was low, some deliberate catches by the crew for food were reported, including black-browed albatross and anecdotal reports of wandering albatross and various penguin and petrel species (Reid *et al.*, 2021).

Industrial jigging operations often take place at night and use light to attract the squid. However, not all jigging takes place by night e.g., *Loligo* fishing operations in Azores take place during the day (Rathjen, 1991). The environmental associations with cpue of 'recreational jigging', i.e. using handlines rather than mechanical winches and in coastal areas rather than deeper waters, was evaluated in the Balearic Islands (Cabanellas-Reboredo *et al.*, 2012). The authors found that cpue was higher for *L. vulgaris* around sunset - no lights were used but natural light was still sufficient at sunset to allow the squid to see the lures. These catches were also seasonal, being higher in winter months than in summer (Cabanellas-Reboredo *et al.*, 2012).

2.1.3. Trap/pots

Description of the fishing techniques

Traps or pots are fishing gears generally used to capture crustaceans and molluscs such as lobster, crabs, spider crabs and whelk, however these are also used in several parts of the world to catch octopuses and cuttlefish. Traps are comprised of a rigid structure covered with net and an opening to let in the target species, which is attract by placing a bait inside. Normandy fishers fishing for cuttlefish may even select one or two females as bait in early season (Basuyaux & Legrand, 2013). Traps are placed on the seabed for several hours before being hauled up to land live prey, having first sorted the catch according to species and size.

Octopuses are attracted to any receptacle that provides them with shelter. They are traditionally caught in pots made from a wide range of materials; the most traditional material is earthenware, which is mostly used in Mediterranean and Southeast Asia fisheries, however octopus pots may also be built with plastic piping, steel piping, old tyres and large empty mollusc shells (Nédélec, 1975).

Cephalopod pots are usually set overnight, attached to a longline with up to 100 pots by line depending on the coverage of the grounds and the size of the vessel. Oversized or non-targeted species are usually released alive (Bañon *et al.*, 2018; Pita *et al.*, 2015).

In Normandy the cuttlefish trap fishing season takes place during 7 to 12 weeks (April to June) depending on the meteorological factors of the years.

Fishing impact

Traps have similar impacts to trammel nets in terms of size-selectivity when used to catch cuttlefish (~ 123-230 mm Dorsal Mantle Length (DML). This makes them highly sustainable and low impact (Pereira *et al.*, 2019).

Natural spawning substrates for cuttlefish range from seagrass (*Zostera* sp.) algae and animals like hydrozoans (*Nemertesia* sp.) or polychaete tubes (*Sabella pavonia*) (CRESH, 2012). However, they can also lay their eggs on rope, traps nets or trap surfaces (Melli *et al.*, 2014; Basuyaux & Legrand, 2013). In a local study of the West Cotentin cuttlefish trap fishery Basuyaux (2016) estimated the mean number of eggs attached to traps at about 1,000 eggs per trap. This could be a problem for the renewal of the cuttlefish population because eggs are removed from traps with destructive methods (pressure washers). This leads to the destruction of millions eggs each season. It is difficult to estimate the consequences on the cuttlefish population since of the number of eggs attached to natural substrates remains to be estimated (CRESH, 2012). To avoid this impact, Pereira *et al.* (2019) suggested to leave eggs attached to trap frameworks, to facilitate their development. In addition, rather than taking traps out the sea during the closed fishing season, non-baited pots could be left as these provide shelters which may be used by spawning females (Sonderblohm *et al.*, 2017).

Other cephalopod species like *Loligo vulgaris* may also attach their eggs to the traps but they are not caught by this gear and there are no observations of the impact of this fishing gear on other marine resources. In the Northern coast of Brittany, the cuttlefish fishing season is followed by a period when traps are used to catch crustaceans (the European Spider crab *Maia* *squinado*) and it was suggested to adapt the traps to this species so as to keep the traps under water until cuttlefish eggs hatch (Malgrange, 2009). Again, this showed concern about the targeted resource more than about other components of the ecosystem that might have been impacted by this fishing activity.

2.1.4. Nets

Net variety description

In Southern Europe, coastal SSFs mainly employ set nets like trammel nets or (less commonly) gillnets (Martínez-Baños & Maynou, 2018).

Referred-to as a passive fishing technique, gillnets are rectangular nets held vertically in the water with floats and weights. These are positioned at varying depths depending on the habitat of the target species. Nets are set (spun) and left for a few hours before being hauled out again. Species such as monkfish, skate, sole, lobster or sea bass are fished with this method. Three types of gillnets are described: the less well known wedged gillnet where the net is weighted down / wedged and set on the seabed; the drifting gillnet where the net may be slightly weighted and kept on the surface by the action of floating buoys; and the trammel nets made up of three superimposed gillnets.

Described bycatch or discards

In the Murcia Region (SE Spain), SSFs mainly deployed trammel nets during the year targeting S. officinalis (cuttlefish) in winter and spring with a seasonal rotation (Martínez-Baños & Maynou, 2018). This species was present in all sampled nets with a 1.43 kg/100 m h yield, on average, and other commercially important species also being caught (seabass, scorpion fish or the octopus *O. vulgaris*). Fifty-three different taxa were discarded, damaged or undersized (in the case of commercial species). The un-wanted part of the catch within the non-commercialized category are mostly sea cucumbers and sea stars.

Fixed nets have substantial bycatch and also squid may lay their eggs on them. In a comparative study Ganias *et al.* (2021) underlined that discards were more important with trammel nets than with traps.

Beach seine associated with cephalopod bycatch fishery

This section describes environmental impacts of SSF fishing practices which do not target cephalopods but which obtain commercially important bycatch that includes cephalopods. Cetinić *et al.* (2011) examined the fishing catch from a boat seine fishery targeting Picarel *Spicara smaris* over seagrass (*Posidonia oceanica*) meadows in the eastern Adriatic Sea was evaluated. *Posidonia* seagrass is an important ecosystem component which offers ecosystem services including carbon capture and nursery grounds for juvenile fish and a range of invertebrate biodiversity. The fishing technique is a very long-established one in the Mediterranean (the practise goes back hundreds of years) which was traditionally termed ‘beach seining'. A net with a weighted footrope was deployed from the beach using a small boat to spread one end of the net while the other end was held fast at the beach, before both ends of the net being hauled ashore again by hand. Hand-hauling the seine nets was gradually replaced by mechanical winches on boats transforming the practise into 'boat seining', albeit in similar shallow water depths as before (*Posidonia* extends to depths of ~35m depth). Commercial species bycaught in the boat seines include cephalopods with *Loligo vulgaris* being one of the most frequently occurring species in this fishery. Both *L. vulgaris* and *L. media* were always retained and never discarded (Cetinić *et al.*, 2011). Beach and boat seining is widespread in the Mediterranean involving boats typically <12 m long and hence fitting the definition of SSF. Beach seining in many Mediterranean areas is associated with *Loligo* squid and other cephalopod catches including *Octopus vulgaris* and *Eledone moschata*, and these species are normally retained to be sold (Lefkaditou *et al.*, 1998; Akyol, 2003). *Posidonia* root systems (=rhizomes) were not noted in the cod-end however there is clear potential for indirect damage through chronic disturbance, along with disturbance of the associated biodiversity via bycatch (91 fish and cephalopod species were recorded in the catches in the eastern Adriatic – Cetinić *et al.*, 2011). Hence, cephalopods bycatch fishery operations are potentially associated with causing ecological damage. Beach seining is also practised in the Atlantic e.g. Portugal (Cabral *et al.*, 2003). Like the Mediterranean, the number of species and biomass of fish is higher in areas of seagrass (in this case *Zostera marina*) than in adjacent grass-free sediment (Pihl *et al.*, 2006). EU and national legislation prohibits fishing using towed gear over seagrass meadows without management plans being established, but this is not always enforced (EU Council, 2006).

2.2 Large scale fisheries (LSF): impacts summary

Large scale fisheries in the Northeast Atlantic are dominated by bottom trawl fishing. The consequences of bottom trawling on benthic habitats is widely documented. Løkkeborg (2005) underlined the differences between bottom habitats with erect organisms (sponges and corals) and sandy bottom communities. Since that time a series of ICES expert groups are working on the evaluation of seabed abrasion due to the trawl, resilience of benthic communities and opportunities for compensatory measures (WGECO, WGSFD, WGFBIT). Most studies underline that results depend on the benthic community and on the characteristics of the fishing gear (Rijnsdorp *et al.*, 2020). Recent studies underline the need to apply a sound methodological framework to state about the recovery of benthic communities (Jac *et al.*, 2020)

3. Implications for management

Large-scale fisheries (LSF) in EU waters are regulated under the auspices of the Common Fisheries Policy (CFP), under which management is generally based on MSY and fishing pressure is adjusted mainly by setting catch quotas. However, cephalopods are not quota species and therefore regulation by these means is generally not taken into account. Some countries impose their own MLS limits, while others relax mesh size restrictions if fishers declare that they are targeting cephalopods. Artisanal fishing fleets targeting cephalopods are regulated by national and regional rules. However, since the status of most cephalopod stocks is not formally assessed, these rules are not necessarily sensitive to declines (or indeed increases) in abundance.

Cephalopod fisheries are difficult to manage due to the biological characteristics of the cephalopods (short life span, high interannual variability, rapid growth and sensitivity to environmental conditions) (Rodhouse *et al.*, 2014; Emery *et al.*, 2016; Keller, 2016). Although measures such as the Landings Obligation (i.e. the 'discards ban'), catch quotas and spatio-temporal restrictions exist in large-scale fisheries and could be extended to include fishing for cephalopods, they are not necessarily appropriate in small-scale fisheries.

In general, small-scale fisheries (SSF) probably have a lower environmental impact than LSF (e.g. Colloca *et al.*, 2017) although some of the evidence for this is weak. Thus, Kelleher (2005) estimated that SSF accounted for only 11% of global fishery discards, but this result needs to be reassessed as complete data on discard rates were only available for fewer than half of the SSF considered and, for the others, anecdotal evidence was used to assign a discard rate of 1% or less.

Measures to reduce SSF impacts are usually gear- and site-specific so the fishery impact is highly linked to gear design and target species (Melli *et al.*, 2014). Lloret *et al.* (2018) proposed four steps to manage SSF. "i) diagnose the fishery regularly; (ii) enable an adaptive management system; (iii) constrain exploitation within ecological limits; and (iv) share management responsibilities. Such actions would help address conflicts between commercial and recreational fisheries should they exist".

3.1 Marine Protected Areas

Marine Protected Areas (MPAs) are widely implemented tools for the conservation of marine life and fisheries management. Their positive effects on the abundance of exploited fish species (i.e. spillover effects) are well-studied, even if many studies refer to the likelihood of such benefits rather than demonstrating them empirically (e.g. Buxton *et al.*, 2014; Cabral *et al.*, 2020). Few studies have looked into their efficiency for enhancing populations of fished cephalopod species.

Cephalopod species vary in terms of life history traits (Batista *et al.*, 2009). Thus, some commercial species perform extensive oceanic migrations whereas others are mostly neritic. In general, short-finned squids tend to have the longest migrations, followed by long-finned (loliginid) squid and cuttlefish. In the latter two groups there is an inshore-offshore component to migrations, with spawners moving inshore and recruits moving offshore. Octopus, at first sight are the least mobile species. However, unlike cuttlefish they have highly mobile planktonic paralarvae. In the upwelling system in Galicia the paralarvae of *Octopus vulgaris* display inshore-offshore movement (Otero *et al.,* 2009). The lesser octopus *Eledone cirrhosa* displays sex-segregated inshore-offshore movements during its life cycle (Boyle, 1997)

Such characteristics are relevant because many MPAs are also mainly located in neritic zones and because it is doubtful that any MPA could encompass the whole range of species which undertake extensive migrations (e.g. Ross-Smith *et al.,* 2012). Abecasis *et al.,* (2013) studied both behavioural and demographic data to understand the impacts of a small (53 km²) coastal MPA on cuttlefish (*Sepia officinalis*) in Portugal. Cuttlefish showed low site fidelity inside the reserve, which can be explained by its high migratory potential between shallow and deeper waters (Abecasis *et al.,* 2013; Hastie *et al.,* 2009). Hence small MPAs may not be the best tools to protect cephalopods due to their large movements and the inter-annual variation in recruitment (Royer *et al.,* 2006). In addition, considering that fishing is probably the main anthropogenic threat to these species, it is essential that fishing is prevented within MPAs to ensure that cephalopod stocks benefit. The beneficial effects of MPAs for protecting important spawning substrates such as seagrass or kelp habitats are extremely important (Blanc and Daguzan, 1998; Arkhipkin *et al.,* 2000; Carrasco and Pérez-Matus, 2016; Scapin *et al.,* 2019).

There is an apparent contradiction between the objective of favouring fishing of large specimens and the idea of protecting areas where adults spawn (and die). Although it sounds logical to protect habitats that are used for egg laying in cephalopods (and often by other species), inshore fishing for adult cephalopods is not a condemnable strategy per se. A distinction may be made between generally excluding damaging fishing activity from such areas and permitting a controlled amount of targeted fishing on cephalopods (plus fishing which does not damage the relevant seabed habitat and has no bycatch of cephalopods). Better adapting fishing periods in particular areas to enhance egg and juvenile survival is certainly desirable. Seasonal closures may also better prevent the mortality and discards of juveniles for migratory species like cephalopods. The successful application of all such measures requires detailed information on the species' distribution during sensitive life stages.

3.2 Fishing gear

The selectivity of fishing gear is crucial to manage bycatch and reduce discards from fishing. Damage to the seabed habitat can be minimized by avoiding the use of bottom trawls (e.g. bottom otter trawls, beam trawls). Certain types of gear may be considered relatively benign, such as jigging (for squid) - due to the low bycatch and the absence of damage to the seabed – similarly, use of pots for capturing octopus – bycatch is minimal because an animal which enters can easily leave again.

In other cases, modification can improve selectivity. The modification of trammel nets with the application of ‘guarding nets’, which are mesh devices added to the footrope (Fig. 2), has been shown to reduce discard rates. Sartor *et al.* (2018) showed that guarding nets significantly reduced the discarded biomass in the caramote prawn fishery, which was 75% lower than with unmodified trammel nets. However, in bottom-fisheries like those targeting flatfish, the ‘guarding net’ also reduced the catchability of target species, which is not acceptable for fishers (Szynaka *et al.*, 2018).

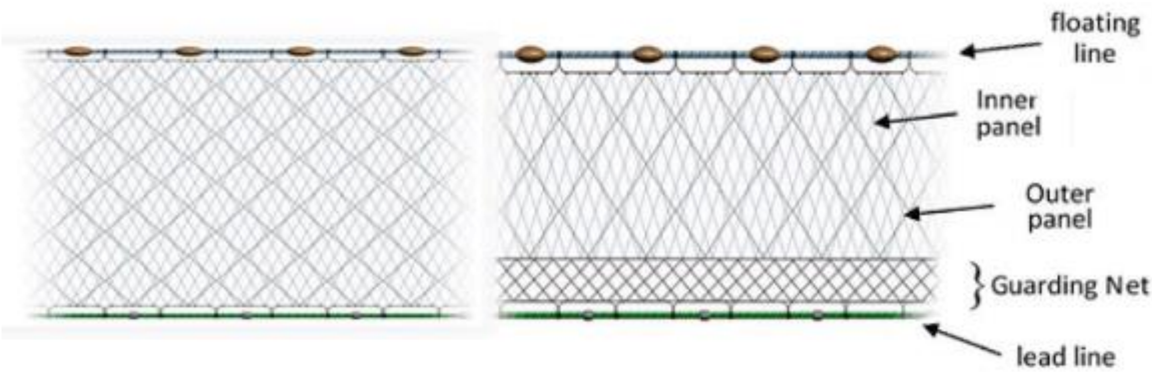

Figure 2. Standard trammel net (left) and with a guarding net (right) scheme, from Sartor *et al.* (2018)

A combination of guarding nets and LED lights in the south east Spain SSF (targeting cuttlefish with trammel nets) showed a significant increase in the target catches (up to 95%) with a decrease in unwanted damaged or non-commercialized organisms (Martínez-Baños & Maynou, 2018). The authors suggested that guarding nets prevent commercial species being damaged by reducing the abundance of predatory epifaunal invertebrates (also contributing to the conservation of the latter group).

An issue of particular concern, albeit not specifically related to fishing for cephalopods is bycatch of protected, endangered and threatened species (PETS). This includes cetaceans, bycatches of which have led to calls for fishery emergency measures in the Bay of Biscay and Baltic. Most research has focused on acoustic deterrents (“pingers”) placed on fixed nets but there is currently considerable interest in the use of acoustic deterrents on towed nets. For example, the LICADO project led by the French Institute of the Marine Research (IFREMER), which started in June 2019 for three years (https://wwz.ifremer.fr/Espace-Presse/Communiques-de-presse/Licado-un-nouveau-programme-pour-limiter-les-captures-accidentelles-de-dauphins). This project aims to improve acoustic repellents already implemented by this fleet for pelagic trawling and develop a directional acoustic repellent with new functionalities that is more reliable in terms of autonomy. Using a hydrophone, this tool will allow dolphins near the fishing area to be detected. It will then emit repulsive sounds to keep them distant. The objective is to further improve the efficiency of the device in order to reduce as much as possible the number of incidental catches of common dolphins by pelagic trawls. The LICADO project also plans adaptations in gillnet fisheries and trials at sea started in autumn 2019 in the Bay of Biscay.

Hendrickson *et al.* (2011) showed that increasing the codend mesh size in the bottom trawl fishery for *Loligo pealeii* could significantly reduce bycatch (and hence discarding) of Atlantic butterfish *Peprilus triacanthus* and silver hake *Merluccius bilinearis.* Although some reduction in squid catch is also expected this would mostly be of small *Loligo* which are currently discarded (probably dead).

Conclusion

The general statement indicating that environmental impacts of small-scale fisheries are less dramatic than that of large-scale fisheries also applies to European Cephalopod Fisheries. To a large extent this is due to the fact that fishing gears used by artisanal fisheries have less impact on the seabed and marine habitats than trawling. However, inshore trawling by artisanal fleets also exists and should be banned in very shallow waters.

In a number of inshore fisheries fishermen are aware of some of the destruction caused by their activity (like the loss of eggs attached to the traps) and concerted management of this should be promoted. Examples of gear modifications to improve selectivity and reduce by-catch and loss of eggs (such as removable structures on which eggs would be laid or guarding nets to reduce bycatch that have been tested by fishers) indicate the path for progress.

MPAs with no cephalopod catch could be justified on the basis of the conservation of special habitats but the fact that cephalopods are migratory does not make the creation of marine areas to protect them very effective.

The quality of small scale fisheries data is often low and in the case of well monitored fisheries the integration of these data sets in population and ecosystem assessments could be developed in order to better estimate both resource abundance and effects on other species.

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