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Report of the Working Group on Cephalopod Fisheries and Life History (WGCEPH)

14–17 June 2016

ICES Headquarters, Copenhagen, Denmark

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Executive summary

Cephalopod resources in the ICES area have fluctuated in recent years with no clear trend. Reported landings varied from a minimum of 17 802 tonnes in 2006 to a maximum of 32 801 tonnes in 2013. However, a decreasing trend has been detected in the last 3 years (2013–2015). In general each nation maintains a consistent proportion of the total share of annual landings.

In 2016, a new data request was launched, targeting specific countries exploiting cephalopods in the ICES area.

The CPUEs series for individual metiers and surveys have been updated. The CPUE from the ARSA survey in Division IXa appears to closely follow trends in LPUE from the commercial fleet. Analytical assessments were attempted for *Loligo* spp. in the Bay of Biscay and *Sepia officinalis* in the English Channel.

The need to monitor cephalopods by means of assessment, even if this assessment is not analytical, is highlighted. There is a need for assessment models suitable for estimating cephalopod population levels and exploitation rate to be integrated into the forthcoming ecosystem-based fisheries assessment and management.

Recent European Policies and Directives which mention cephalopods (or indirectly, affect them) have been reviewed, considering possible implications for fisheries, ecosystem effects and research. This expert group is also producing a literature database for recent publications on cephalopod biology, fisheries, and ecology. Planned future products of this expert group include papers on (1) cephalopod trends across North Atlantic eco regions and (2) the socio-economic status of the fleets exploiting cephalopods.

WGCEPH has finalised its new 3 year plan. ToRs and proposed products have been redefined based on a clear direction of the group: contributing to ICES science and advice based on two basic pillars: i) fisheries: statistics and stock status; and ii) ecosystem: knowledge revision and integrated assessment.

1 Administrative details

Working Group name

Working Group on Cephalopod Biology and Life History (WGCEPH)

Year of Appointment

2014

Reporting year within current cycle (1, 2 or 3)

3

Chair(s)

Marina Santurtún, Spain

Jean-Paul Robin, France

Meeting dates and venue

16–19 June 2014; Lisbon, Portugal

8–11 June 2015; Tenerife, Spain

14–17 June 2016; ICES HQ, Copenhagen, Denmark

2 Terms of Reference

ToR	Description	Background	Duration	Expected Deliverables
a	Report on status and trends in cephalopod stocks: fishery statistics (landings, directed effort, discards and survey catches). Produce and update CPUEs and survey data series for main cephalopod métiers and species. Start exploring economic data collected under Data Call.	Baseline work of the ToR is the result of the data call.	Year 1 (2014), 2 (2015) and 3 (2016)	Peer-review paper in relation to status and trends (Year 3).
b	Preliminary assessments of the main cephalopod species in the ICES area. Assess production methods (Y1). Explore other methods (Y2). Carry out assessment (Y3).	Data is collected with the purpose of assessing cephalopod status for Integrated Ecosystem Assessment (IEA).	Year 1, 2 and 3	Report on the cephalopods assessed.
c	Implications of the application of some Policies and Directives on cephalopods: e.g. CFP (no discards); New regulation of Manipulation of Animals for research; Natura 2000, Blue growth (wind farms)	There are no policies or management measures directed to cephalopods but pressures and activities would affect them.	Year 1, 2 and 3	Report on effects of directives and policies on cephalopod assessment .

d	Review main population parameter: length distribution, sex ratio, first maturity at age, first maturity at length, growth, spawning season (Year 2).	Update main population parameters to assess stock status.	Year 2	Peer review paper in relation to population dynamics, biology. (Year 2) Report of a methodological paper about sampling resolution for best data collection for each stock/species. (Year 2)
e	Review and report on cephalopod research results including all relevant aspects of: biology, ecology, physiology and behavior, in field and laboratory studies (Year 1, Year 2 and Year 3)	Need of updating knowledge.	Year 1, 2 and 3	Database of scientific articles. Data base on already existing tools (e.g. Mendelei,). Report.
f	MSFD and Integrated Ecosystem Assessment: Relevant MSFD indicators (biodiversity, community role, exploitation and contaminants) applied to cephalopods.	Need to describe the state and pressure of cephalopods under MSFD descriptors and indicators.	Year 1, 2	Report on MSFD descriptors applicable to cephalopods.
g	Collect and explore social and economic data (Y2), final analysis (Y3). Data on: landings in value; effort; number of licenses; number of fishers and vessels and governance measures.	Cephalopods are increasingly important for small-scale fisheries across Europe.	Year 2, 3	Peer-review paper in relation to socioeconomic importance, management and governance of cephalopods in Europe (Year 3)
h	Produce short section for the ICES Ecosystem Overviews on the state of cephalopod diversity/populations, for each of the following ICES ecoregions: North Sea, Celtic Seas, Bay of Biscay & the Iberian coast and Baltic Sea.	Section address the overall state and pressures accounting for changes in state.	Year 2, 3	Contribution to report on ICES Ecosystem Overviews Year 2 and update in Year 23

Summary of Work plan

Year 3: 2016	Peer-review paper in relation to status and trends (Year 3). Report on the cephalopods assessed Database on scientific articles in relation to the topic worked out every year. Peer-review paper in rela-tion to socioeconomic importance, management and governance of cephalopods in Europe (Year 3).

3 Summary of Achievements of the WG during 3-year term

During 2014, the first year of the new multiannual ToRs, the expert group reported on four of the above Terms of Reference

- Cephalopod assessments (b);
- Effects of directives and policies on cephalopod assessment (c);
- Database of scientific articles on the topic (e);
- MSFD descriptors applicable to cephalopods (f).

During 2015 (Year 2), the expert group was able to deliver the following products:

- Report on the update of the CPUEs of commercial fleets and surveys and the trial in assessment for the four species groups in significant ICES areas.
- Updated section of report on effects of directives and policies on cephalopods.
- Section of report about the need of cephalopod monitoring.
- Database on scientific articles in relation to the topic updated.
- An update on MSFD descriptors applicable to cephalopods.
- Section contributing to ICES Ecosystem Overviews.

During 2016 (Year 3), the expert group has been able to deliver the following products:

- A draft scheme of a review paper in relation to status and trends (work is still in progress and will be finalised in 2017).
- An update of the section on cephalopods assessed.
- An update of the section on directives and policies.
- Database on scientific articles updated.
- After the three years of data calls, the group also delivered:

  Individual country databases on landing, discards and effort, as well as a scientific surveys data base. These data have been stored at the WG Share Point since 2010.

4 Final report on ToRs, workplan and Science Implementation Plan

Among the basic outputs of WGCEPH are the data calls. They constitute the basis for compling statistics, evaluating trends and carrying out assessment. Data delivered to the expert group through the Secretariat has represented a great progress on the previous data collecting process. The group is generally pleased with the answers obtained from most European countries in relation to the data call. The data call format was designed in 2014, to facilitate data compilation ahead of the meeting and data analysis and assessment during the meeting. It was recommended that all countries followed the data format. However, the format may need to be updated in line with formats used for Intercatch or FishFrame data bases which will probably be used in the future.

The information received was sufficiently comprehensive and of sufficient quality to allow preliminary analysis of trends. The group was able to review and update LPUE trends and survey indices. Thus work under ToRs a, b and c could be fully accomplished.

On the other hand some data issues still require solutions, including species identification in the catches and discards. Quantities are is usually reported at the standard sampling level, i.e. cephalopods are usually identified to family level only. There is also a need to review existing data to identify surveys, fleets and periods of time suitable for further analysis; this is something that has not previously received sufficient attention. Preliminary review identified some errors and inconsistencies in previously compiled data. In addition, the capability of the group to manage this large amount of information has been limited over the last 2 years by the relatively low number of attendees.

Progress and fulfilment of objectives, by ToR

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

Work on this ToR (a standing ToR) has been completed. Some data quality problems were encountered for some countries, e.g. inconsistencies between species/species groups allocated to metiers year by year, also issues with data format and timely delivery of data.

ToR b. Conduct preliminary assessments of the main cephalopod species in the ICES area. Assess utility of production and/or depletion methods, if feasible (YEAR 1). Explore other possible assessment methods if needed (e.g. early season assessment); (YEAR 2). Carry out assessment of species with the methods chosen (YEAR 3)

The main aim of analysing LPUEs and CPUEs for individual metiers and surveys to check whether catch trends in the commercial fishery can be considered as a good index of abundance was fulfilled. For example LPUE and catch trends from the commercial fleet in Division IXa closely followed trends seen in CPUE from the ARSA survey. Analytical assessments were carried out for *Loligo* spp. in the Bay of Biscay and *Sepia officinalis* in the English Channel. This work appears to be promising so it will continue for the next period. There is still a need for assessment models suitable for estimating cephalopod population levels and exploitation rate to be integrated into the forthcoming ecosystem-based fisheries assessment and management. In the longer term, cephalopods could be incorporated as fundamental ecosystem components, then being incorporated in the Integrated Ecosystem Assessment.

ToR c. Implications of the application of some Policies and Directives on cephalopods

Legislation and policy initiatives reviewed, to identify possible implications for fisheries, ecosystems and research, included new regulations on the handling of animals for research, conservation measures such as Natura 2000 and the MSFD, and blue growth policies (e.g. in relation to development of wind farms). Of particular interest is the EU Directive 2010/63/EU on the protection of animals used for scientific purposes, in which, for the first time, invertebrates (including cephalopods) have been incorporated.

ToR d. Review data availability for the main cephalopod species in relation to the main population parameters: length distribution, sex ratio, first maturity at age, first maturity at length, growth, spawning season

WGCEPH reported on this in year 2 of the present 3-year cycle (see WGCEPH 2015).

ToR e. Review and report on cephalopod research results in the ICES area, and if feasible in waters other than Europe, including all relevant aspects of: biology, ecology, physiology and behaviour, in field and laboratory studies

WGCEPH synthesised new knowledge based on recent publications on cephalopod biology, fisheries, and ecology. Summaries were included in the annual reports and a database of cephalopod articles was created at:

https://www.zotero.org/groups/cephalopod_research/items/

ToR f. MSFD and Integrated Ecosystem Assessment: Relevant MSFD indicators (biodiversity, community role, exploitation and contaminants) applied to cephalopods

During 2014 and 2015, special attention was paid to the role of cephalopods in ecosystems and the possibility of the use of cephalopods as indicators and descriptors of GES (Good Environmental Status) under the Marine Strategy Framework Directive. Thus, sections of the 2014 and 2015 reports were devoted to discussing relevant MSFD descriptors and indicators as a means of assessing good environmental status for cephalopod stocks, checking the applicability of each descriptor and indicator to cephalopods and providing an updated list of cephalopod species covered in the initial 2010 MSFD assessment report for each of the member states.

ToR g. Collect and explore social and economic data on cephalopod fisheries

Analysis was focused on five southern European countries with important artisanal cephalopod fisheries. The current socio-economic status of small-scale cephalopods fisheries in each country, the management arrangements in place, and the opportunities and challenges for the future of the cephalopods fisheries in the five countries are analysed.

Science highlights

Science Plan priority	**How your EG addresses this priority**
2. Quantify the nature and degree of connectivity and separation between regional ecosystems	We consider that we contribute to this by studying migrating species and also stocks that do not follow the same spatial patterns as finfish. However, there is little or no current work on cephalopod stock connectivity in EU waters.
3. Quantify the different effects of climate change on regional ecosystems and develop species and habitat vulnerability assessments for key species	Environmental variation appears to be responsible for much year-to-year variation in distribution and abundance. We are also interested in essential habitats of cephalopods. However, knowledge is lacking on the effect of climate change on such habitats.
6. Investigate linear and non-linear ecological responses to change, the impacts of these changes on ecosystem structure and function and their role in causing recruitment and stock variability, depletion and recovery.	We are studying population level responses to fishing and climate (e.g. in relation to cephalopod recruitment and stock variability). There is little current work on ecosystem level effects on cephalopods - although cephalopods have been included in several ecosystem models. This could be a future focus for the group.
9. Identify indicators of ecosystem state and function for use in the assessment and management of ecosystem goods and services	We have considered cephalopods as indicators of ecosystem state in the context of the MSFD and have in the past reviewed the trophic importance of cephalopods. In addition, cephalopod stocks provide "ecosystem goods" and we are working to describe stock status and propose management tools.
10. Develop historic baseline of population and community structure and production to be used as a basis for population and system level reference points.	We have compiled time-series of population parameters and we are looking for reference points in our cephalopod stocks
11. Develop methods to quantify multiple direct and indirect impacts from fisheries	The group is developing tools for cephalopod stock assessment (addressing direct impact from

as well as from mineral extraction, energy generation, aquaculture and other anthropogenic activities and estimate the vulnerability of ecosystems to such impacts.	fisheries). We have also analysed anthropogenic impacts such as pollutants on our species. We are not currently looking at indirect impacts from cephalopod fisheries and we are not studying anthropogenic effects on the whole ecosystem.
12. Develop approaches to mitigate impacts from these activities, particularly reduction of non-target mortalities and enhancement/restoration of habitat and assess the effects of these mitigations on marine populations	By developing tools for stock assessment we are also investigating optimal fishing pressure. Cephalopod resources are more and more targeted and if not they often represent valuable by-catch. Specialised gears used in small-scale cephalopod fisheries (e.g. pots, trps, jigs) probably have low by-catches of other species but cephalopod byctah in other fisheries may need more attention, notably the “bycatch” of cephalopod eggs on fixed gears such as gill nets.
15. Develop tactical and strategic models to support short and long term fisheries management and governance advice and increasingly incorporate spatial components in such models to allow for finer scale management of marine habitats and populations	Cephalopod stocks are often exploited by a range of métiers (small- and large-scale) which operate in different fishing grounds so to take into account spatial spatial patterns is important in the management of these stocks, e.g. protection of spawning and nursery grounds.
20. Provide priorities and specifications for data collection frameworks supporting IEA's.	The group has repeatedly advocated a better identification of exploited cephalopod species in the DCF and this still represents major barrier to monitoring, assessment and management of cephalopods in EU seas.
25. Identify monitoring requirements for science and advisory needs in collaboration with data product users, including a description of variable and data products, spatial and temporal resolution needs, and the desired quality of data and estimates	The group has repeatedly advocated a better identification of exploited species in the DCF. Improved identification of species is needed both for fisheries (on-board and port sampling) and during surveys. Additional requirements are related to the frequency of sampling that is relevant to monitor and model short-lived cephalopod stocks.
27. Identify knowledge and methodological monitoring gaps and develop strategies to fill these gaps	See responses to points 2, 3, 6, 9, 10. 11, 12, 15, 20, 25
30. Allocate and coordinate observation and monitoring requests to appropriate expert groups on fishery dependent surveys and sampling and monitor the quality and delivery of data products.	There are no current survey programmes designed specifically to monitor cephalopod resources but the group has provided advice about how multispecies surveys could better describe Cephalopod stock fluctuations and it will continue to issue data calls to ensure it receives appropriate fishery and fishery-independent data
31. Ensure the development of best practice through establishment of guidelines and quality standards for (a) surveys and other sampling and data collection systems; (b) external peer reviews of data collection programmes and (c) training and capacity building opportunities for	The group has listed data collection needs for cephalopod resources (see points 15, 20). Additional needs include information on gear selectivity so as to improve comparability of data arising from different surveys. There is certainly a need for quality control in cephalopod data collection. Development of a user-friendly guide to cepha-

monitoring activities	lopod identification would be useful (WGEPH is aware of at least three past or recent initiatives, which could usefully be combined.

4.1 Sepiidae in Subareas VIIde, VIIIabd, VIIIc & IXa

In this section, the species *Sepia officinalis* and *Sepia elegans* are included. Taking into consideration the year 2014-2016 multiannual work plan, this section will focus on assessment of Sepiidae.

4.1.1 Fisheries in ICES Division VIIde

4.1.1.1 Commercial catch-effort data

Standardized French bottom trawl LPUE data are plotted in Figure 4.1.1.1 for the period 1992–2014. The Delta-glm method was used to estimate LPUE. As explained in the annexed working document WD 4 (Alemany *et al.* 2015), LPUE variability is explained by 4 variables: year, month, ICES rectangle and engine power of the vessel.

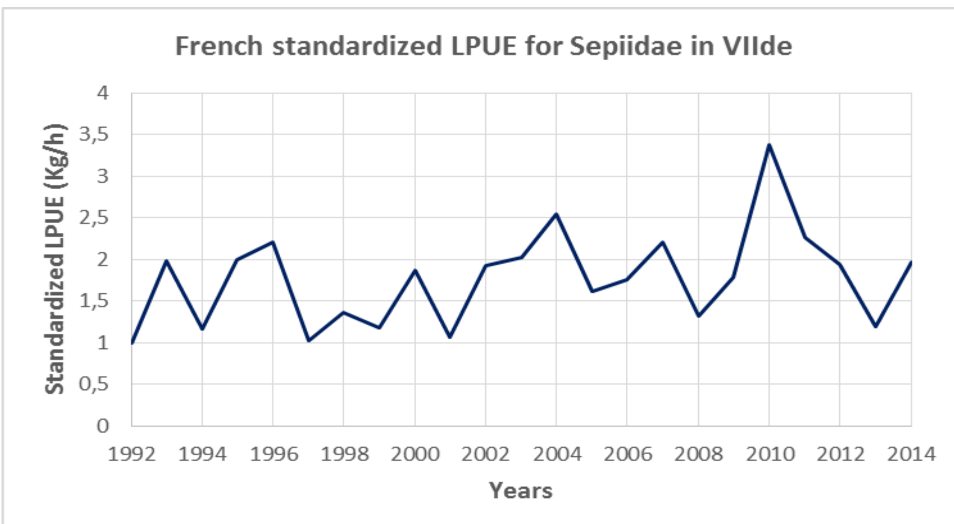

Figure 4.1.1.1. French standardized landings per unit effort using a Delta-GLM method. All values are divided by the first value of the time-series.

4.1.1.2 Fishery independent information and recruitment

The United Kingdom provided abundance indices in kg per hour from the BTS Survey carried out in division VIId in July. France provided abundance indices for the CGFS survey carried out in October each year in division VIId. Both survey indices are displayed in Figure 4.1.2.1. They have followed similar trends since 2002.

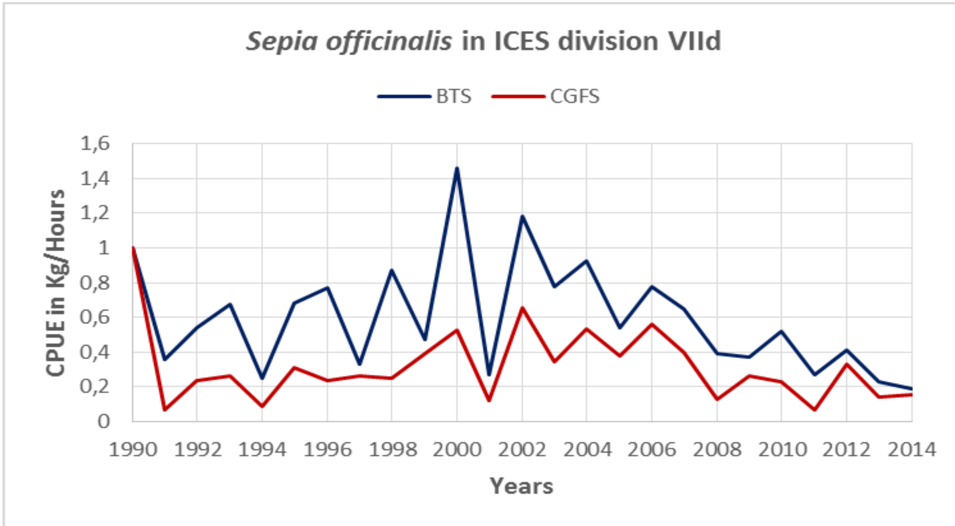

Figure 4.1.2.1. ***Sepia offcinalis*** **abundance indices in division VIId. CPUEs (kg/h) for BTS survey carried out by Cefas in July and CGFS survey carried out by Ifremer in October. All values are divided by the first value of the time-series.**

4.1.1.3 Stock assessment with a two-stage biomass model

In The English Channel (Divisions VIIe and VIId), an exploratory assessment of the cuttlefish stock was available, using a two-stage biomass model (Gras *et al.*, 2014). The most recent update of the English Channel cuttlefish stock is provided for this report and is presented with more details in the annexed working document (WD 4).

The two-stage biomass model with a Bayesian implementation of the initial model (WD 3) has been used for *Sepia officinalis* in areas VII e and VIId. This allows a more accurate estimation of uncertainty using the resampling method of Monte Carlo simulation instead of bootstrapping, and less time is needed to run the model. Also, this method allows inclusion of various sources of information. A method that makes use of ancillary length frequency data is developed to provide an informative prior distribution for the intrinsic biomass growth rate parameter and its annual variability. The new Bayesian model provides a substantial improvement to the existing stock assessment method used by ICES. Considering a time-varying *g* parameter improves model fit and improves the ecological realism of the model according to the sensitivity of the cuttlefish population dynamics to environmental fluctuations. The model also provides predictions of the unexploited biomass in winter based on survey data, to help managing the stock in case of strong depletion.

In accordance with the conclusions of Gras *et al.* (2014), we did not find any stock-recruitment relationship. In their work, they did not detect any trend in exploitation rates between 1992 and 2008. Our study adds 6 years of data, and results differ as we detect a decreasing trend of exploitation rate from 2001 to 2009. Our results show that the highest exploitation rates occur in 2001 and 2011, with a slightly higher exploitation rate in 2001. Exploitation level from 2001 should be a limit reference point for future management. This recommendation was also specified in (Gras *et al.* 2014).

4.1.1.4 Management Considerations

Sepia officinalis is managed only in inshore areas in Divisions VIIe and VIId. Along the coast of Normandy a license system is supposed to limit fishing effort and access to the fishery. In France, inshore trawling is banned within the 3 mile limit but exemptions are given in some French coastal zones in spring and in late summer. As highlighted by Revill *et al.* (2015), measures that potentially reduce the initial capture of small cuttlefish or increase the survivability could benefit the fisheries in the long term.

It is worth to keep in mind that inshore catches depend on the proportion of cohorts that escape offshore exploitation in the wintering grounds (Royer *et al.* 2006). There is no specific regulation of offshore trawling on the cuttlefish stock although regulations defined for ground fish apply.

4.1.2 Fisheries in ICES Division VIIIabd

4.1.2.1 Commercial catch-effort data

The time-series of French LPUE is short (2009–2014) because of changes in effort recording after 2008. LPUE for French bottom otter trawlers in the Bay of Biscay was calculated using the Delta-GLM method with R software in order to standardize outputs. Explanatory factors used were statistical rectangle, vessel power, effort in hours of fishing and year. Results displayed in Figure 4.2.1.1 show an increase between 2009 and 2012, and a subsequent decrease.

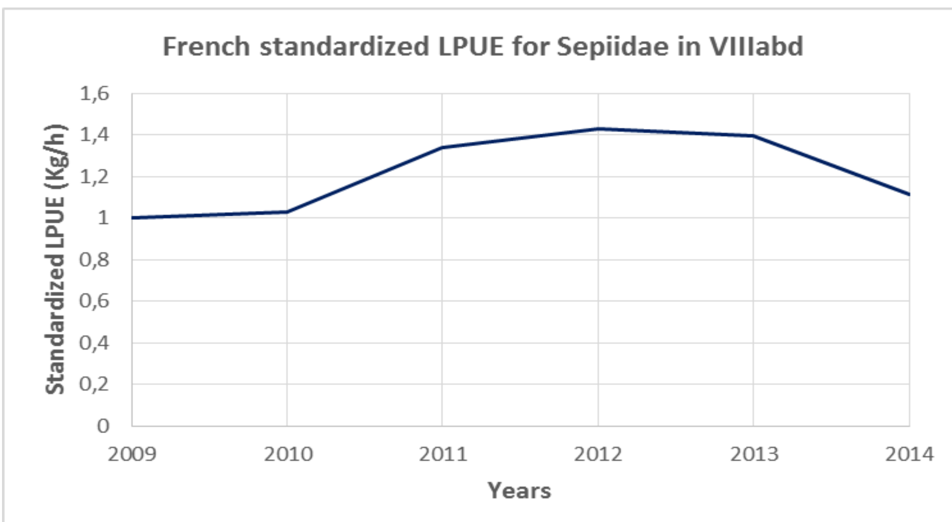

Figure 4.2.1.1. Annual standardized French LPUE for *Sepia officinalis* in Divisions VIIIa,b,d. All values are divided by the first value of the time-series.

4.1.2.2 Fishery-independent information and recruitment

In the Bay of Biscay, the annual survey EVHOE carried out by IFREMER in November provides CPUE for Sepiidae. The last update was collected for this report (Figure 4.2.2.1). A decrease is observed in the last year (2014), agreeing with the French LPUE trend (Figure 4.2.1.1); CPUE for *Sepia officinalis* remains well below the peak values seen in 1998 and 2008.

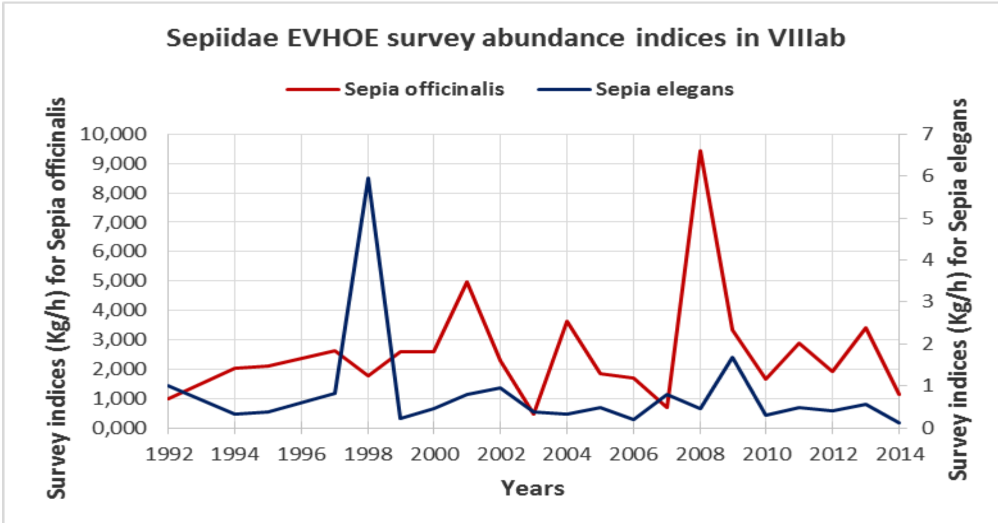

Figure 4.2.2.1. Sepiidae CPUEs (kg/h) according to the Ifremer "EVHOE" survey carried out in Subarea VIIIa,b from 1992 to 2014. All values are divided by the first value of the time-series.

4.1.3 Fisheries in ICES Division VIIIc & IXa

4.1.3.1 Commercial catch-effort data

Spanish OTB LPUE in kg per fishing trip shows a high interannual variability in cuttlefish abundance (Figure 4.3.1.1). Over the whole period a weak increasing trend can be observed in commercial LPUE in Division IXa South (solid blue line) which is not evident in Divisions IXa North and VIIIc (solid red line). In 2014, a decrease is observed.

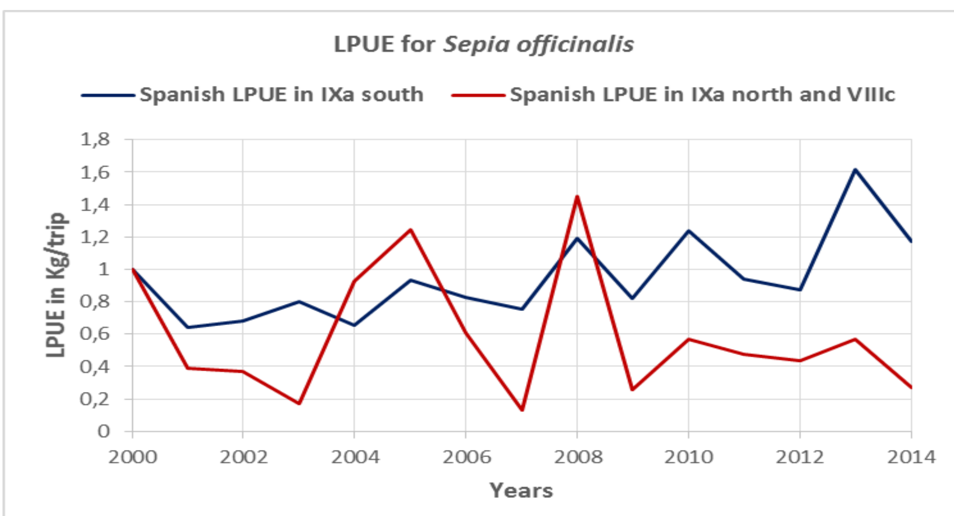

Figure 4.3.1.1. ***Sepia officinalis*** **LPUE in Divisions IXa South and IXa North/VIIIc. All values are divided by the first value of the time-series.**

4.1.3.2 Fishery-independent information and recruitment

Time-series of abundance indices were updated for areas IXa and VIIIc (Figure 4.3.2.1). Both commercial LPUE (Figure 4.3.1.1) and survey abundance indices (Figure 4.3.2.1) seem to follow the same trend in Division IXa south.

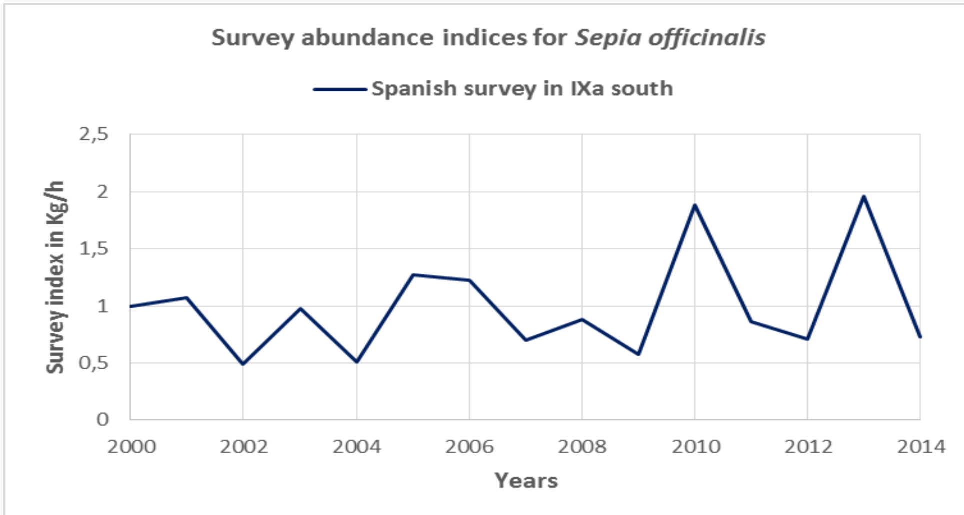

Figure 4.3.2.1. ***Sepia officinalis*** **abundance indices in Division IXa South. All values are divided by the first value of the time-series.**

At the present time, Portuguese commercial fleet indices are only ones available for the last 4 years. Landings per unit effort (in Kg/day) was 10.1 in 2013 and increased to 11.9 in 2014, following the opposite trend to that seen in Spanish LPUE.

4.2 *Loliginidae*

Introduction

Catches of long-finned squid (*Loliginidae*) may be composed of *L. vulgaris*, *L. forbesii*, *A. subulata* and *A. media*. Since 2009, with DCF implementation, some effort has been made to discriminate cephalopod species in official fishery statistics, enabling the analysis of landings by species for some countries. In the cases where no species identification of commercial catches was provided, catches are expected to be composed mostly of *Loligo* spp. Currently *Loliginidae* are not assessed at a regular basis and there is no TAC for the stocks.

This section presents results from analysis of catches in 2015, by ICES division/sub-area. Stock status of *Loligo vulgaris* and *L. forbesii* in the English Channel was evaluated in the English Channel by means of surplus production models and for the other areas by the examination of the CPUEs and/or survey trends. Almost three quarters of northeastern Atlantic loliginid landings come from three areas, the English Channel (Division VIId,e 37%), Cantabria / Bay of Biscay (Sub-area VIII, 20%) and the North Sea (Division IV, 16%) (Figure 4.2.1). In 2015, loliginid landings showed some decrease (Figure 4.2.2). Reductions in landings from the North Sea, Rockall, the Bristol Channel and the Azores are responsible for this general decrease. On the other hand, landings from the Bay of Biscay southwards to Cadiz increased from 2014 to 2015.

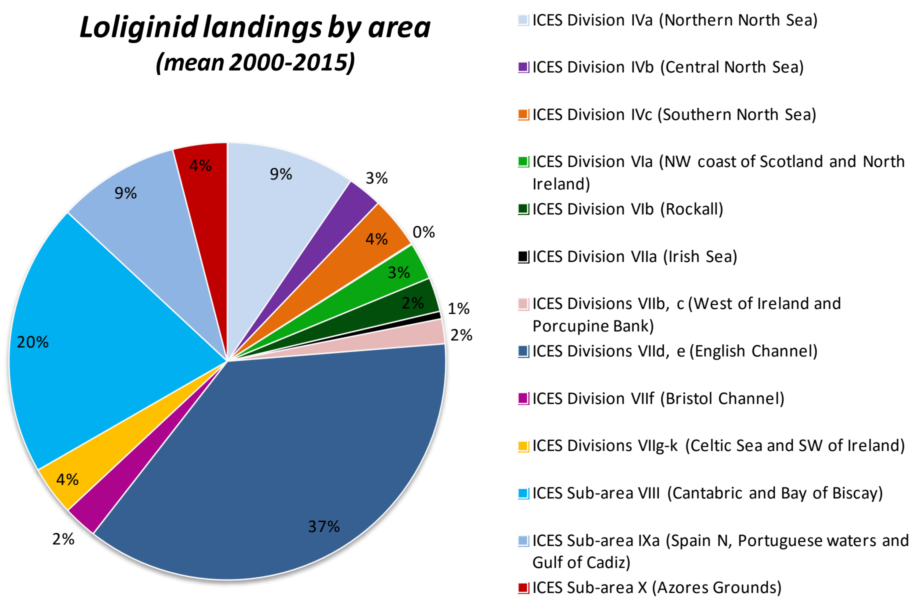

Figure 4.2.1. Percentage of loliginids laded by ICES divisions/sub areas (mean 2000 to 2015).

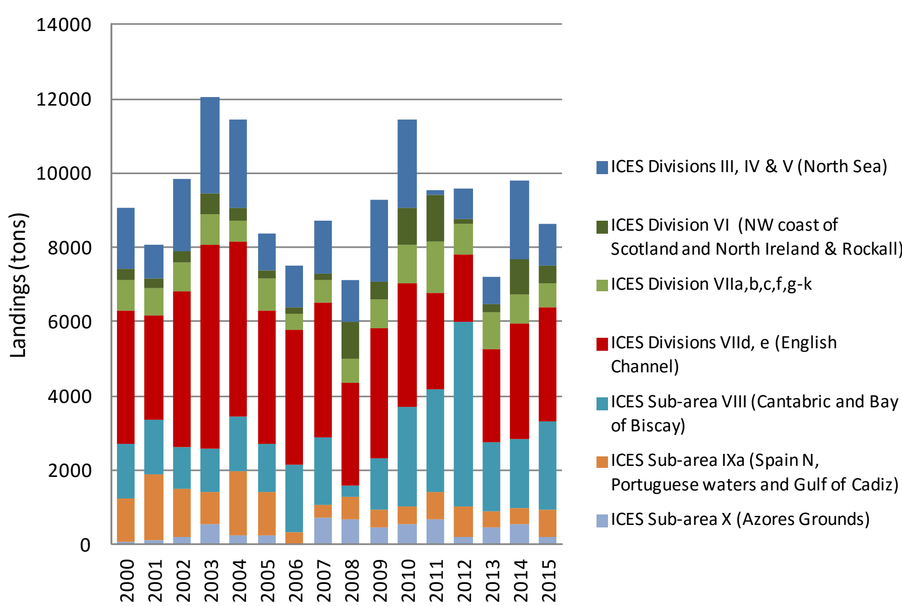

Figure 4.2.2. Landings of loliginids by ICES areas and sub areas between 2000 and 2015.

4.2.1 *Loligo* spp. in ICES Division IV (North Sea)

Catches in 2015

Commercial landings and discards

Provisional fisheries statistics indicate that catches in 2015 were 25% lower than the 2000–2014 average. The reduction is mainly observed in the southern North Sea (Division IVc) and to a lesser extent in the north (Division IVa). The fishing fleets exploiting this resource are unchanged, with Scottish vessels dominating in the north and central North Sea and French vessels in the south.

Fishery-independent information

The analysis of squid catches from a unique 35-year time-series of bottom trawl survey data in the North Sea (1980–2014) showed that squids in general have become more widely distributed within the North Sea and both *Loligo* and *Alloteuthis* showed increasing trends (van der Kooij *et al.*, 2016). The genus *Loligo*, mainly recorded in the northern North Sea during the 1980s, has also been widespread in the southern and central North Sea during the most recent two decades. The *Loligo* biomass in sub-area IV is largely dominated by *L. forbesii* (98.4%).

4.2.2 *L. forbesii* & *L. vulgaris* in ICES Subarea VIId,e (English Channel)

Catches in 2015

Commercial landings and discards

English Channel squid production in 2015 was very close to that of 2014 (3103 and 3108 t respectively). These values are slightly below the 2000–2015 average. Monthly statistics indicate that the autumn peak in 2015 was much lower than in 2014 which is likely to imply a lower total for the 2015/2016 fishing season compared 2014/2015 (in line with the timing of the life cycle, squid fishing seasons in this area are considered to run from June in one year to May in the next). France accounts for 75% of the catch.

Discards data from France, England and Wales seem to indicate that the amount of loliginid squids discarded may be higher in the Western part of the Channel (VIIe division) than in the Eastern part (where it is below 4%). However, this is based on a very limited number of sampled fishing operations and the consistency of squid recording in observation programmes for discards is questionable.

Fishery-independent information and recruitment

The CGFS survey indices confirm the low recruitment at the beginning of the 2015/2016 fishing season. *Loligo forbesii* and *Loligo vulgaris* seem to be both at historical low levels (Figure 4.2.2.1)

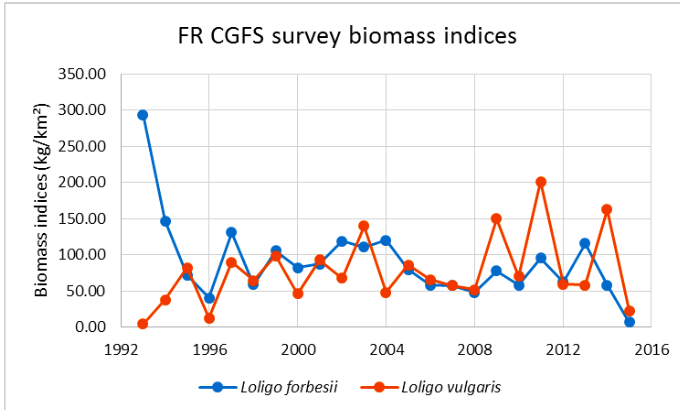

Figure 4.2.2.1. Time-series of France CGFS survey Biomass indices (kg/km²).

Stock status: Surplus production models fitted to English Channel (*Loligo forbesii* and *Loligo vulgaris*)

The assessment of English Channel loliginid squid stocks was updated (including provisional estimates for the end of the 2015/2016 fishing season). The framework for this exercise was the classical Schaefer model (Schaefer, 1954) complemented by a linear effect of an environmental variable on stock parameters (r and K) as described by Barros (2007). The classical model was fitted with a two-step procedure with initial values estimated by non-equilibrium multiple linear regression followed by nonlinear estimation using time-series fitting (both methods described by Hilborn and Walters, 1992). Input data were total catch by France and UK vessels and a series of abundance indices derived from French OTB LPUE, standardized with Delta-GLM (Gras *et al.*, 2014). All computations were carried out using R software. The delta-glm function is available in the R–package "cuttlefish-model" (Gras & Robin 2014). Since the standardization takes into account the effect of year, month, rectangle and vessel power it requires fishery statistics for the FR OTB gear detailed by fishing trip. The environmental variable is a linear combination of hydroclimatic variables that can be used to predict the peak of recruitment (peak observed in July in *Loligo forbesii* and in October in *Loligo vulgaris*). Input variables for mixed loliginids are plotted in Figure 4.2.2.2 "A".

Three models were prepared: one for mixed loliginids (*Loligo forbesii* and *Loligo vulgaris*) and one for each species separately, using the monthly fish market sampling carried out by the University of Caen since November 1992 to split catch and abundance. The 2015 model outputs showed that abundance of mixed loliginids was similar to the sum of outputs of both species-specific models. In 2016, results for mixed loliginids were consistent with previous trials but model fits for both species-specific models implied unrealistic values for parameters (K and r) and we therefore consider that the biomass estimates (MSY, B_{MSY}) were also unrealistic.

The mixed loliginids assessment suggests that in a constant environment the MSY is 4600t for this resource. However, the model including environmental variation indicates that MSY can vary between 2880 and 7430 t (Figure 4.2.2.2 "C"). The non-linear time-series fitting involves optimizing the residual sum of squares (RSS) between observed and computed abundance indices. By taking environmental variation into account a better fit is obtained, with RSS around 30% lower (Figure 4.2.2.2 "B")

Stock status indicators linked to MSY, namely the ratio of observed catch to MSY (Ci/MSY) and the ratio of relative biomass Bi/B_{MSY}, are illustrated in Figure 4.2.2.2. "D" and "E". Whichever model (i.e. with or without environmental effect) is used, the catch tends to be at or below MSY, suggesting that there is no major over-exploitation. However, the relative biomass seems to be consistently low which may indicate either a problem with the model or an unbalanced situation for the stock.

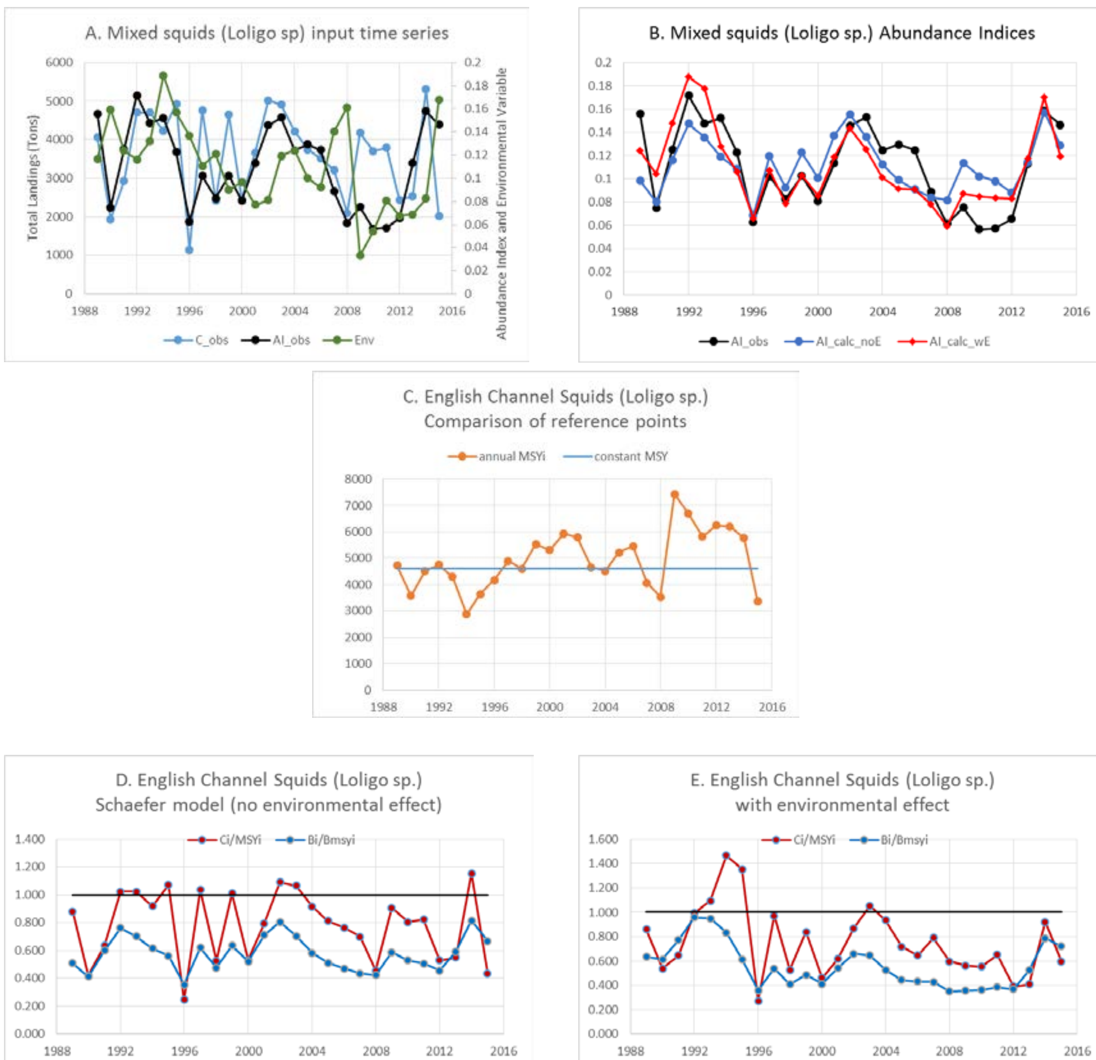

Figure 4.2.2.2. Surplus production model fitted to the English Channel loliginid squids : A input time-series, B observed and fitted abundance indices (noE = classical Schaefer model, wE = model with r and K influenced by the environment variable), C estimates of Maximum Sustainable Yield (annual MSYi corresponds to environmental variations of r and K) D and E benchmark ratios Ci/MSY and Bi/B_{MSY}

Quality of the assessment

The assessment exercise is still at a preliminary stage since species-specific models showed unrealistic outputs (very large K and MSY). The quality of the data used in the assessment should not be the main source of trouble since in the English Channel squid are mainly caught by offshore trawlers whose catch is rather well recorded. However, the partitioning of loliginid catches between the two species is based on market sampling and it may be worth investigating whether more extensive sampling would alter the picture we have of the relative abundance of both species.

4.2.3 *Loligo* sp. in ICES Divisions VIIIa,b,d (Bay of Biscay)

Catches in 2015

Commercial landings, effort and discards

In 2015 squid catch from the Bay of Biscay was higher than in 2014 (2410 and 1840 t respectively). This production is the fourth highest in the time-series 2000–2015 (the highest values were in 2010–2012, with sharp drop to 2013); there appears to be an overall upward trend in abundance during 2000–2015. The bulk of the catch is made by France (more than 95%); (Figure 4.2.3.1.). It should be noted that the contribution of Spain has continued to decline since the peak in 2012.

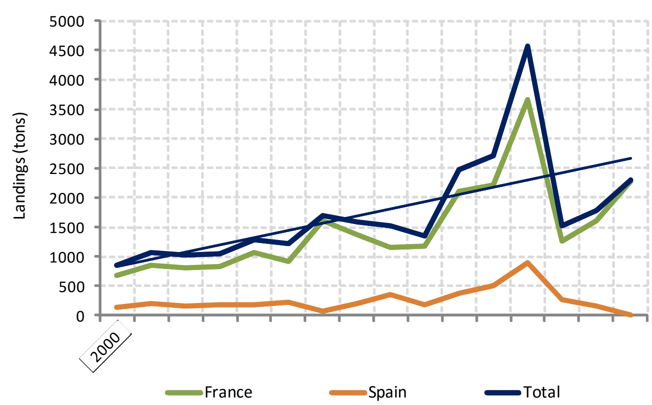

Figure 4.2.3.1. Trends in loliginids landings from sub-area VIIIabd for the years 2000 to 2015.

During 2015 the largest monthly landings of squids by the Basque Country from Div. VIIIa,b,d, were recorded during November and December. Similar to elsewhere, loliginid landings have a strong seasonality, generally with higher catches from October to February (Figure 4.2.3.2.).

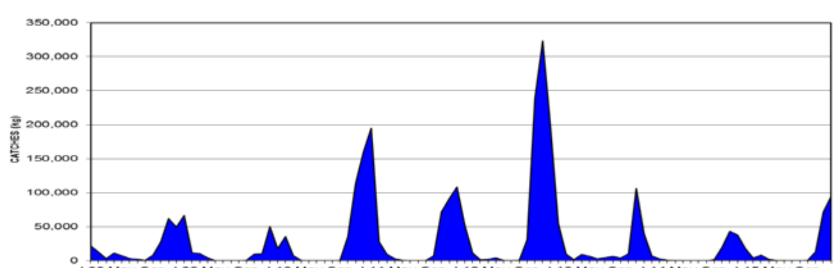

Figure 4.2.3.2. Seasonality of loliginids landings of the Basque Country considering all areas together (VI, VII, VIIIabd and VIIIc) for the years 1994 to 2015.

It is important to note that loliginids in division VIIIa,b,d appear to be important accessory species for the Basque trawlers in some years due to reduction of quotas of some traditional demersal species. This generates important shifts in the fishing exploitation pattern (see WD 2). Discard sampling programmes do not report any observation of *Loligo* discards in the area in 2015.

Fishery–independent information

The French EVOHE survey carried out in November provides abundance indices for loliginid squids (Figure 4.2.3.4). The peak observed in 2012 landings was also observed in the *Loligo vulgaris* survey abundance index. The 2015 index value is very close to the average of the series. Unlike the landings time-series these survey indices do not show an increasing trend.

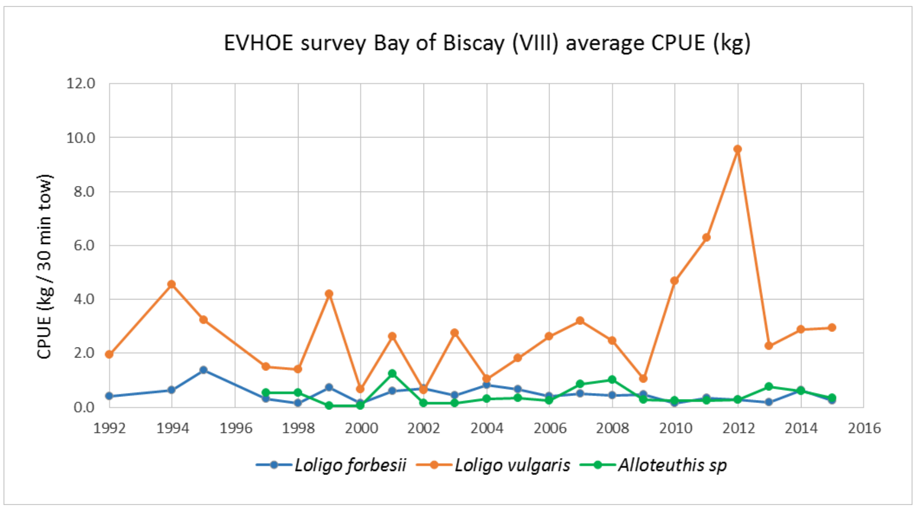

Figure 4.2.3.4. Loliginid squid abundance indices (CPUE in kg/30min tow) observed in the EVHOE survey.

Stock status

Assessment

Surplus production models applied to squid in the Bay of Biscay in 2014 showed that the stock seems to be in a rather stable situation, with the estimated biomass above B_{msy} and the fishing mortality only slightly larger than F_{msy}. Unfortunately, this assessment could not be updated.

Quality of the assessment

Considerations about the quality of the assessment highlighted the large uncertainty in both relative biomass and relative fishing mortality time-series and difficulties in accommodating the large year-to-year fluctuations in catches. We consider that having additional biological information incorporated through the prior distribution could help to improve the results and additional information on the stock, e.g. a recruitment index, would allow consideration of alternative models more suitable for short-lived stocks.

4.2.4 *Loligo* sp. stock trends in ICES Divisions VIIIc & IXa (North and west Spanish Atlantic coastal waters)

Catches in 2015

Commercial landings, effort and discards

In 2015 loliginid landings from sub-areas VIIIc and IXa were higher than in 2014 (810 and 522 t respectively). A general decreasing trend in production since 2000 is apparent. Nevertheless, since 2006 landings have been relatively stable but at a lower level. Catches in this area are taken mainly by Spain (ca. 60%) and Portugal (ca. 40%); (Figure 4.2.4.1.).

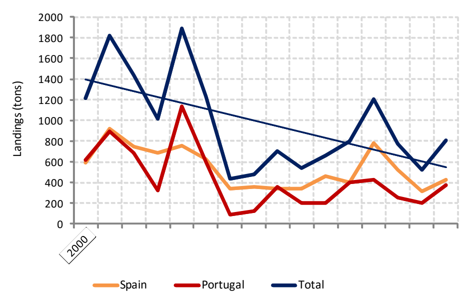

Figure 4.2.4.1. Trends in loliginid landings from sub-area VIIIabd for the years 2000 to 2015.

Fishery-independent information

Four survey cruises in IXa south provide abundance indices for loliginid species: SP Q4 GFS in VIIIc and IXa north; PT Q4 GFS in IXa (Demersal) and SP Q1 & Q4 GFS (ARSA); (Figures 4.2.4.2). *Alloteuthis* sp. indices in sub-area IXa do not show a consistent trend between 1997 and 2015. The 2015 indices were lower than those in 2014 and below the average of the autumn survey series. *L. vulgaris* abundance indices in sub-area IXa show an increasing trend between 1997 and 2015, especially in the Gulf of Cadiz, with high peaks in November 2012 and 2015. In general, the 2015 indices are well above the average of each survey series. In both *Alloteuthis* sp. and *L. vulgaris*, the abundance indices estimated from ARSA and PT demersal autumn surveys are well correlated with each other, but there was no significant correlation between these indices and the SP demersal indices, indicating regional differences in the abundance trends for the two species. Within sub-area IXa, *L. forbesii* is more abundant in the Gulf of Cadiz during November, although in 2014 and 2015 indices were rather low in this area. There is no correlation between *L. forbesii* abundance estimated from ARSA and the other surveys, but SP Q4 GFS and PT Q4 GFS have a reasonable correlation. Loliginid landings time-series and species survey indices do not show similar trends. Nevertheless, the major peaks in *L. vulgaris* survey abundance in 2004, 2012 and 2015 were well reflected in higher loliginid landings in those years.

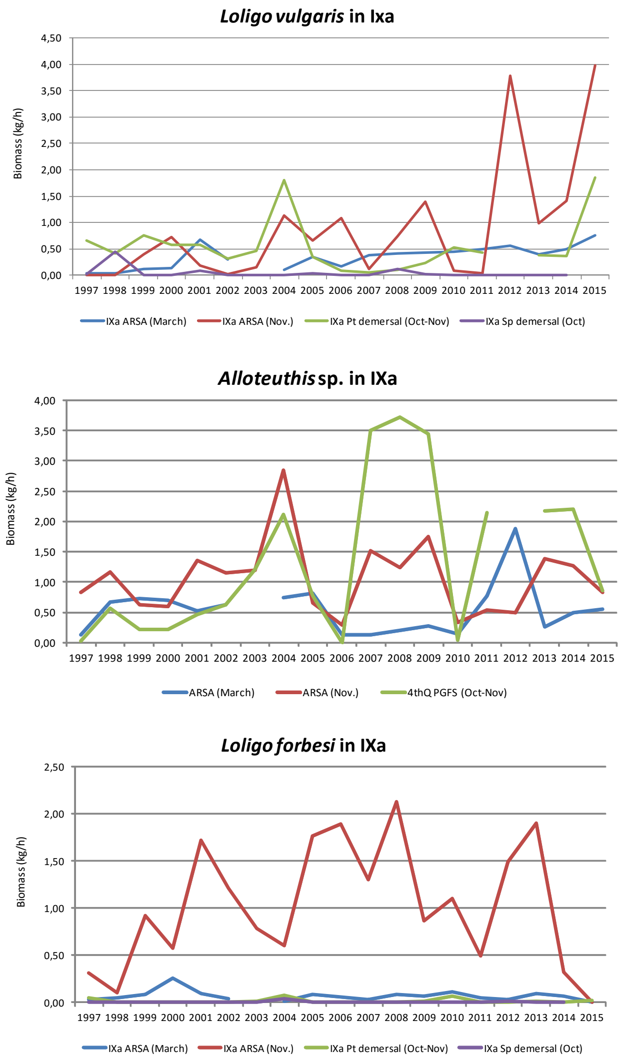

Figure 4.2.4.2. Loliginid squid abundance indices (kg/h tow) observed in the SP Q4 GFS in IXa north, PT Q4 GFS in IXa (Demersal) and SP Q1 & Q4 GFS (ARSA) in IXa south.

Stock trends of *Loligo* sp.

Trends in abundance of *Loligo* sp. in divisions VIIIc and IXa were analysed using the survey CPUE and fishery LPUE time-series as abundance proxies. Abundance increased in 2015 in the three areas analysed. This increase was more significant in Portuguese waters: abundance was five times higher than in 2014 and times higher than the mean (2000–2015).

Survey abundance continues to indicate that *Loligo* sp. Abundance in Atlantic Iberian waters is highest within the Gulf of Cadiz (Figure 4.2.4.3.). The commercial CPUE and survey indices obtained by Spain for area VIIIc and the northern part of IXa present conflicting trends, although they were reasonably correlated in the last 4 years.

Loliginid fisheries LPUE for all fleets combined and *Loligo* sp. survey abundance in Portuguese waters present similar trends. Uncoupled abundance trends from the several indices analysed indicate probable regional differences in abundance and/or shifts in distribution of the stock which need to be taken in account in the future to create more reliable indices of abundance.

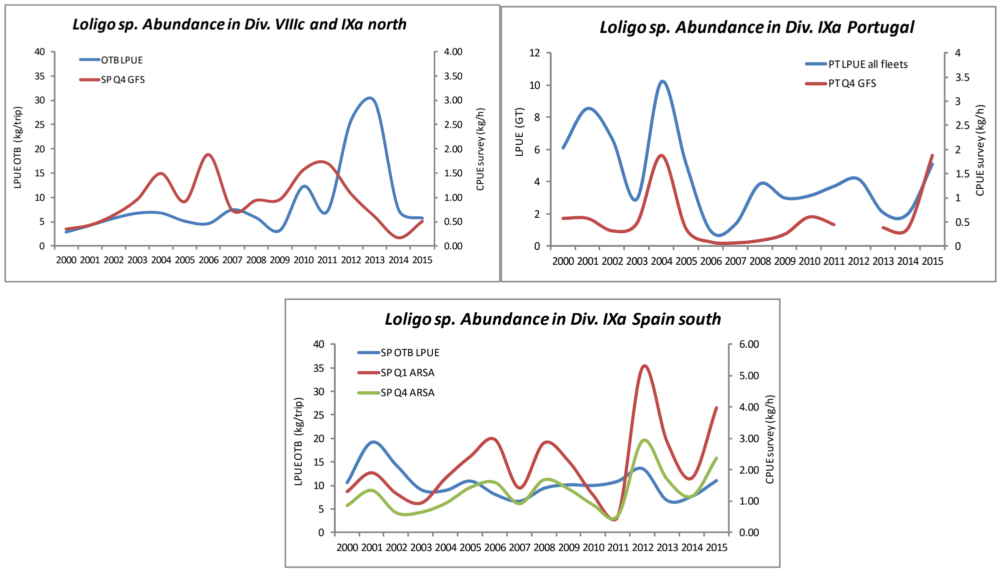

Figure 4.2.4.3. ***Loligo*** **sp. abundance indices in Div. VIIIc and IXa.**

Conclusion

It is evident that abundance trends differ between the various ICES subdivisions, suggesting that wide-scale analysis of finer-scale data could be useful to identify natural assessment units – although it is possible that trends show continuous spatial variation.

Some limitations have become apparent in undertaking this exercise. Firstly, different surveys in the same area may provide contrasting trends, possibly related to differences in the gear used in some cases but also possibly linked to the annual life cycle of loliginids and/or the spatial patchiness of their distribution. Shifts in the seasonality of the life cycle events could result in apparent trends in abundance differing between seasons for example. Possibly the greater sampling coverage (in space and time) provided by fishing vessels offers the best opportunity to get a comprehensive view of spatiotemporal variation in loliginid abundance but any such analysis would require spatial disaggregation of catches and effort data.

A second and obvious point is that loliginids occasionally show "outbursts" of very high abundance. Depending on if / when such peaks fall in the time-series examined, abundance may appear to be increasing, declining or even stable.

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4.3 *Ommastrephidae* in Subarea II, III, IV, V, VI, VII and Divisions VIIIabd, VIIIc & IXa

4.3.1 Introduction

The short-finned squids of the family *Ommastrephidae* (broadtail shortfin squid *Illex coindetii*, lesser flying squid *Todaropsis eblanae*, European flying squid *Todarodes sagittatus* and neon flying squid *Ommastrephes bartrami*) and other less frequently captured families and species of decapod cephalopods are included in this section. All these species occur within the area that includes ICES Subarea III to Div. IXa, Mediterranean waters and North African coast.

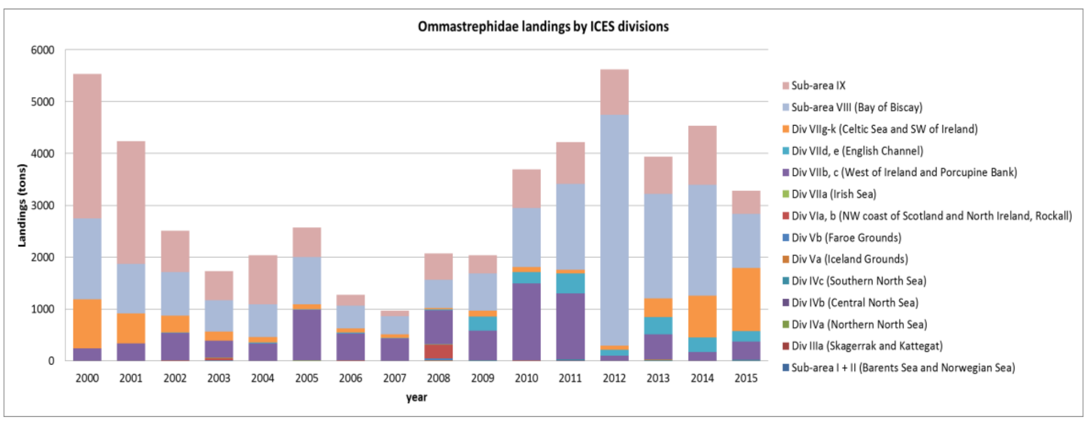

Figure4.3.1.1. *Ommastrephidae* landings from year 2000 to 2015 for all countries and ICES divisions.

In Figure 4.3.1.1 landings of *Ommastrephidae* from all countries combined are presented by ICES divisions. Catches in Div. VIIb,c are mainly taken by Spain. France takes all reported catches of *Ommastrephidae* in Div. VIId,e. Catches of this species group averaged around 1700 t annually along the data series, although catches have decreased somewhat since the peak in 2012, mainly due to the decrease in Spanish catches in Div. VIIb,c but in year 2013 an increase is observed again. In the last three years, an increase of landings from Divisions VIIg-k is evident, mainly comprising Spanish catches.

For more southern areas (Div. VIIIabd, VIIIc and IXa), the main countries exploiting these species are France, Spain and Portugal, with no catches recorded by England, Scotland or

Ireland. *Ommastrephidae* are usually exploited by multispecies and mixed fisheries trawlers.

Catches of *Ommastrephidae* are thought to be composed mainly of *Illex coindetii, Todaropsis eblanae* and *Todarodes sagittatus*. However, no species identification has been provided for any country or area. WGCEPH reported on the species composition of ommastrephid squid in Galicia (NW Spain) in 2009 and 2010 (ICES 2009, 2010); No similar information for other areas or more up-to-date information for Galicia has been reported to WGCEPH.

4.3.2 Fisheries in ICES Division IV

Data from the IBTS DATRAS dataset were provided by ICES (downloaded on 9 June 2015) and included data from Denmark, France, Germany, Netherlands, Norway Scotland and Sweden. The quality of the data seemed to be insufficient because in 2011 and 2012 species were listed as 'teuthida', showing that problems with species identification occur. Therefore, ommastrephids were considered as a single group for analysis. This is a general issue for most relevant surveys including Cefas surveys (England; data not in DATRAS but analysed separately).

Based on the ICES DATRAS IBTS dataset, a trend analysis was performed based on surveys carried out in the first quarter of the year. After a decrease in CPUE in 2011 the data show an increase in RFAs 1 and 2 and stable and low CPUE values in the other RFAs.

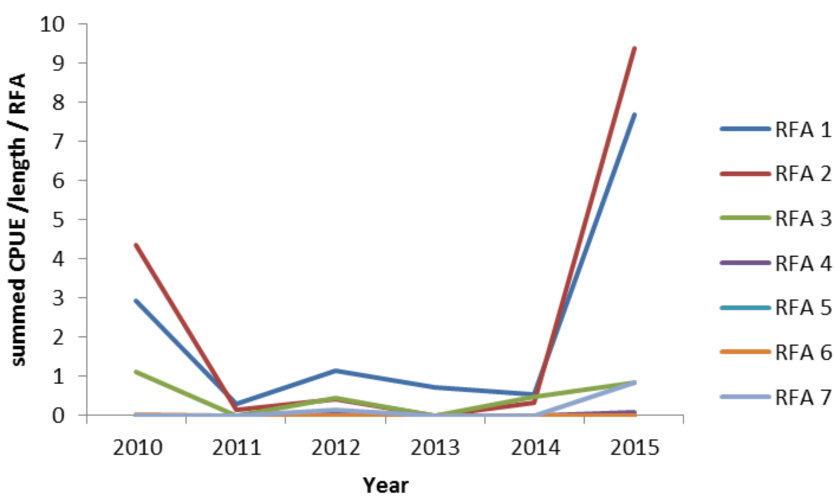

Figure 4.3.2.1. Summed CPUE per length per area (1-7) based on the ICES IBTS DATRAS (download 9th of June 2015).

Based on the Cefas IBTS data (quarter 3 North Sea survey), average annual catch rates were extracted as well as standardized rates (based on a GAM that also accounted for spatial and day-of-year variation); (Figure 4.3.3.2).

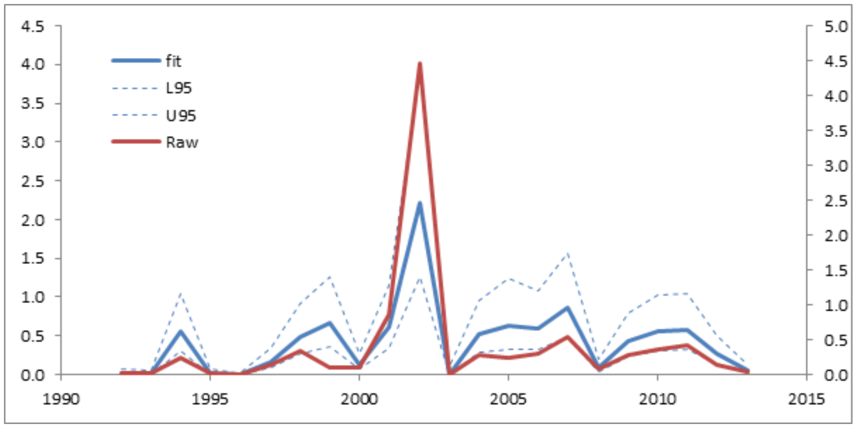

Figure 4.3.2.2. Ommastrephid squid caught per 30-minute haul in the Cefas IBTS3E survey): raw data (red, left axis) and standardized for effects of spatial and seasonal patterns (blue, right axis).

4.3.3 Fisheries in ICES Division VIIabcdegk

Available commercial landings data indicate that between 300 and 1200 t are landed per year in area VII. Most of these landings were reported by Spain in VII b+c and VIIg+k and by France in VIId+e and VIIg+k. However, data from England, Scotland, Northern Ireland, Ireland, Wales, Netherland and Germany report undifferentiated landings of loliginids and ommastrephids. Therefore, it is questionable how useful these available landings data are.

Cefas survey data permit some analysis of trends in area VII. The VIId beam trawl survey (BTS7D) and the northwest ground fish survey NWGFS caught too few ommastrephids to examine trends. Trends extracted from three other survey programmes look rather different but in all cases confidence limits are wide. Catch rates were low in Q1SWBEAM (quarter 1) but a general upward trend in ommastrephid catch rate was seen from 2006 to 2015. Catch rates in Q4IBTS (quarter 4) were also low, rising from 2003 to a peak in 2008 and then falling again to 2011. Catch rates in WCGFS were higher than in the other two survey series and suggested a general increase from 1982 to 1993 followed by a decline to 2004. These trends are illustrated below.

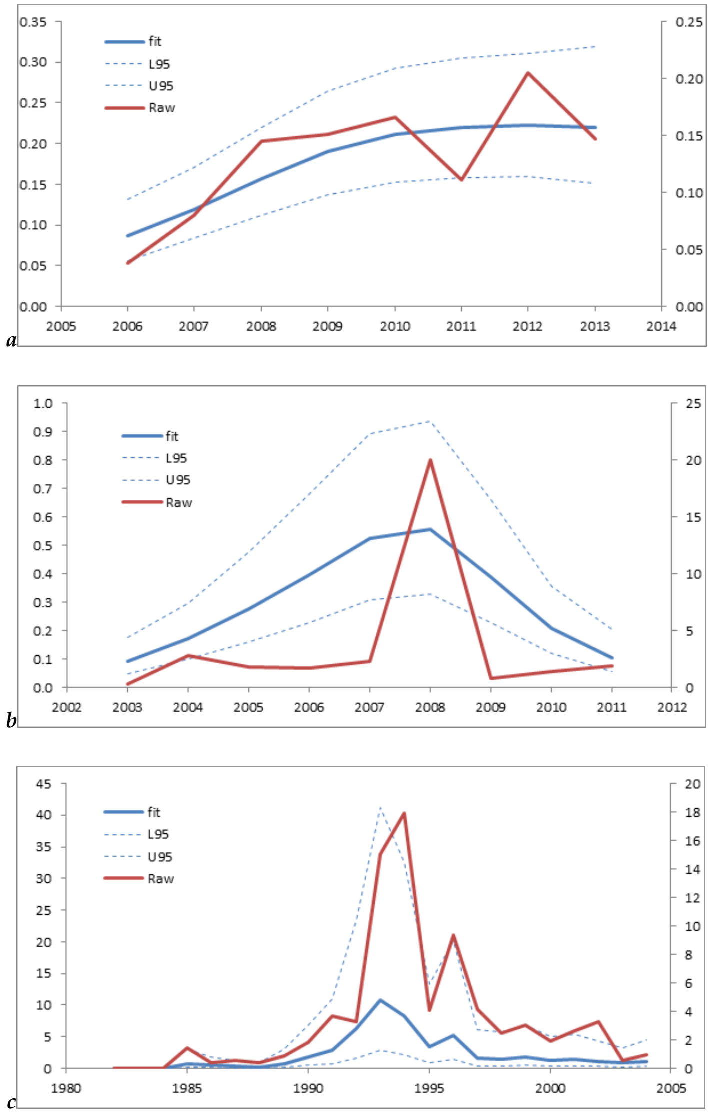

Figure 4.3.3.1. Trends in ommastrephid catch rates (numbers per 30-minute haul) in area VII from Cefas surveys: (a) Q1SWBEAM, (b) Q4SWIBTS, (c) WCGFS. Each graph shows raw data (red, left axis) and standardized for effects of spatial and seasonal patterns (blue, right axis).

As for area IV, there are concerns about the lack of taxonomic resolution in the data. There are also concerns about the suitability of some of the trawl gears used and indeed doubts about the consistency of reporting.

4.3.4 Fisheries in ICES Division VIIIabd

The countries contributing to ommastrephid catches in Division VIIIabd were France and Spain. In 2015, France landed 280 t of ommastrephids (87% of catches) from Div. VIIIabd, while Spanish landings amounted for 42 t (13%).

No assessment was attempted. Spanish Commercial LPUE and French EVHOE Survey abundance indices present conflicting trends. As *Ommastrephidae* are not among the target species for those fleets and, in particular, catches may not always be landed, the

LPUE and CPUE values obtained could not be considered as abundance indices for this group of species.

4.3.5 Fisheries in ICES Division VIIIc & IXa. Assessment

Overall, landings of ommastrephids amounted to 1172 t caught by Spain and Portugal, 62% from ICES Div. VIIIc and around 38% from Div. IXa. Spain takes 99 % of the catches of these species in Div. VIIIc and 82% in Div. IXa.

Variation in abundance indices from Spanish commercial and survey series showed some correspondence. Thus, high abundances were seen at the beginning of the data series in 2000, low abundance for most intermediate years and increasing abundance from around 2011 although with high fluctuations.

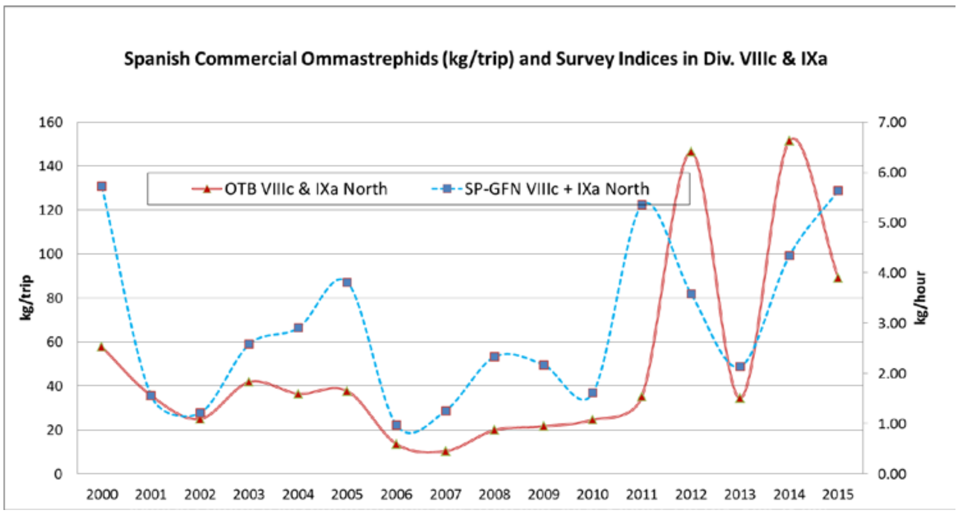

Figure 4.3.5.1. Comparison between commercial LPUE (kg/trip) and survey CPUE abundance Indices (kg/h), from the Spanish commercial fleet and scientific surveys in Divisions VIIIc & IXa North respectively.

The coincidence in trends of the indices obtained in the Spanish surveys has to be treated with some caution. A survey may generate a representative abundance index if it covers the whole area of distribution of the species and if the gear used and timing of survey were appropriate considering the characteristics and dynamics of the species. However, it has to be noted that at least 2 to 3 species are represented in these indices.

For Div. IXa south, commercial and survey data series provided by Spain again appear to coincide in trends and in peaks of abundance detected. However, the survey index did not show the marked high abundance seen in the commercial LPUE series in 2011. As commented above, for Div. VIIIc and IXa, high abundances were seen the first years (2000–2003) of the data series and in 2010–2012. These promising results enhance the possibility of using these data series as abundance indices for ommastrephids.

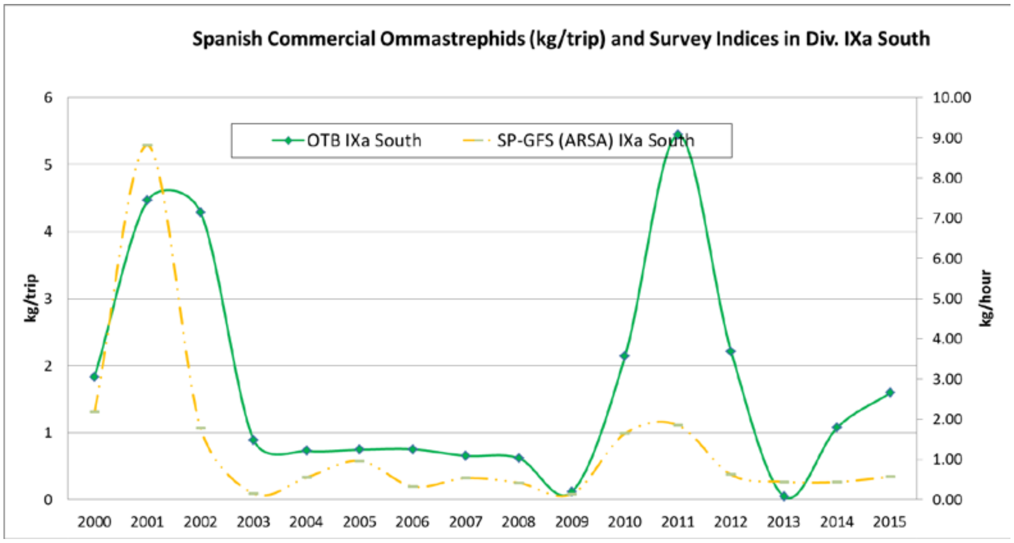

Figure 4.3.5.2. Comparison between LPUEs (kg/trip) and Abundance Indices (kg/h) trips of the Spanish commercial fleet and Scientific Surveys in Divisions IXa south.

If species can be identified from survey information, a trial of a two-stage biomass model assessment is proposed, but in the absence of such information, no assessment has been done. In some survey series (e.g. Cefas data), ommastrephids are occasionally identified to species and it is possible that ratios of the species could be estimated. More promisingly, landings of ommastrephids in Galicia (Spain) have been identified to species during market sampling, at least in the past (see Working Document 1 in the WGCEPH report from 2009). However, in general the lack of identification to species in both survey and commercial data is an ongoing problem.

4.4 *Octopodidae* in Subarea II, IV, V, VI, VII, VIIIabd, VIIIc&IXa

Octopus vulgaris, *Eledone cirrhosa* and *Eledone moschata*

4.4.1 Introduction

Octopus (*Octopus vulgaris*), horned octopus (*Eledone cirrhosa*) and musky octopus (*Eledone moschata)* are included in this section. The first two species are distributed from ICES Subarea III to Div. IXa, Mediterranean waters and North African coast. *E. moschata* inhabits southern waters from Div. IXa towards the south.

Most of the catches recorded from Subareas III to VII were taken by trawlers and are expected to comprise mainly of *E. cirrhosa* although catches are usually not identified to species.

Only a small proportion of reported catches of *Octopodidae* derive from Subareas III, IV, V and VI (Figure 4.4.1.). Anecdotal evidence from Scotland indicates that *E. cirrhosa* is usually discarded, although its presence is confirmed by regular occurrence in small numbers in survey trawls (see MacLeod *et al.* 2014).

For more southern areas (Div. VIIIabd, VIIIc and IXa), the main countries exploiting these species are Spain, Portugal and France. These countries provide the greatest catches of octopods, with 62% reported by Portugal and 36% by Spain on average for the 2000–2015 period, mainly in Div. VIIIc and IXa. Species identification has been provided only for Spain and Portugal in Div. VIIIc and IXa.

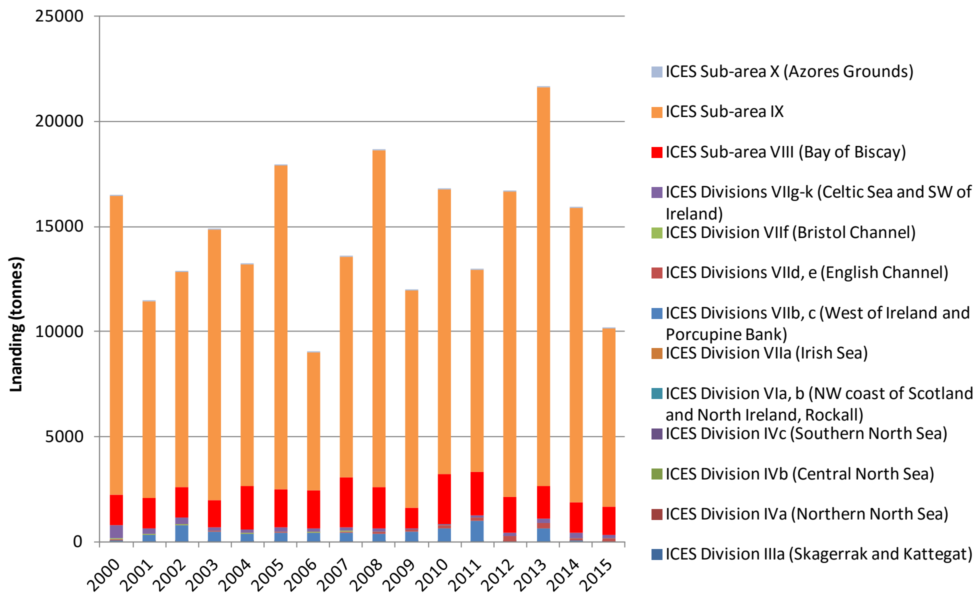

Figure 4.4.1. ***Octopodidae*** **landings by ICES Division during 2000–2015.**

4.4.2 Commercial catches and discards in Subarea VII

Catches in Div. VIId,e are almost all (99%) reported by England, Wales and Northern Ireland. French catches in these Divisions are minimal. Reported English catches of this group averaged around 19 t from 2000 to 2006 although they have subsequently increased, to a maximum of 248 t in 2012 with a similar amount in 2013. In the last two years, the catches were about 130 t.

Catches in ICES Divisions VIIg-k (Celtic Sea and SW of Ireland) in 2013 were reported by England, Scotland, Ireland and France. Spain presented important catches of *Octopodidae* in the first years of the data series, but since 2008 catches decreased and no data were provided for 2011 and 2013. In 2015, only Spain and France reported catches, with 112 and 37 t, respectively. English catches (generally the largest amounts) averaged around 88 t annually, with a minimum of 13 t in 2013.

Sweden, United Kingdom, The Netherlands, Germany and Ireland provided data in relation to discards, landings and effort in Subarea III, VI and VII respectively for at least 2011 and 2013. Also for both areas survey data are provided. The Netherlands and Germany did not record any *Octopodidae* records in its waters.

4.4.3 Fishery and survey data, trends, assessment, and data requirements for Subarea VIIIa,b,d (Bay of Biscay)

In ICES Divisions VIIIa,b,d, catches of *Octopodidae* species are generally low. *E. cirrhosa* accounts for more than 95% of the total catches, although in the logbooks it appears as

Octopodidae, which are not identified. These catches derive from otter trawlers. The countries contributing to *Octopodidae* catches in Division VIIIabd were France and Spain. Spain reported landings *O. vulgaris* of less than one ton.

French landings of *Octopodidae* in Div. VIIIabd have followed a stable trend with an average of around 125 t in most years, although with peaks of 205 t in 2008 and 184 t in 2013. The Spanish commercial fleet operating in Division VIIIabd is mostly composed of vessels with base ports in the Basque country. For Spain, landings from Division VIIIabd varied from 2 t in 2009 to 300 t in 2007, reaching 130 t in 2013, and decreasing in the last two years.

No estimate of *Octopodidae* discards has been delivered to the group by France. AZTI-Tecnalia is responsible for monitoring cephalopod discards (monthly, by gear) in Div. VIIIabd for the Basque Country, thus covering around 95 % of the Spanish fleet operating in the Bay of Biscay. As was the case for landings by the Spanish fleet, *Octopodidae* discards appear to be highly variable, ranging from a minimum of 2% of catches in 2008, to a maximum of 74% in 2011.

LPUEs (kg per fishing trip) for the Basque country fleet were calculated for *O. vulgaris* and *E. cirrhosa* separately, pooling data for Bottom Otter trawl and Bottom Pair trawl. LPUE for *Octopus vulgaris* LPUEs were low during 2000–2012, never exceeding 2 k/trip (Figure 4.4.2). In 2013 and 2014, LPUE increased to almost 30 kg/trip. Horned octopus LPUEs were generally higher than those for *O. vulgaris* (Figure 4.4.3) and ranged from 0 kg per trip in 2008 to more than 230 kg per trip in 2013 (this peak corresponding to that seen in *O. vulgaris*.

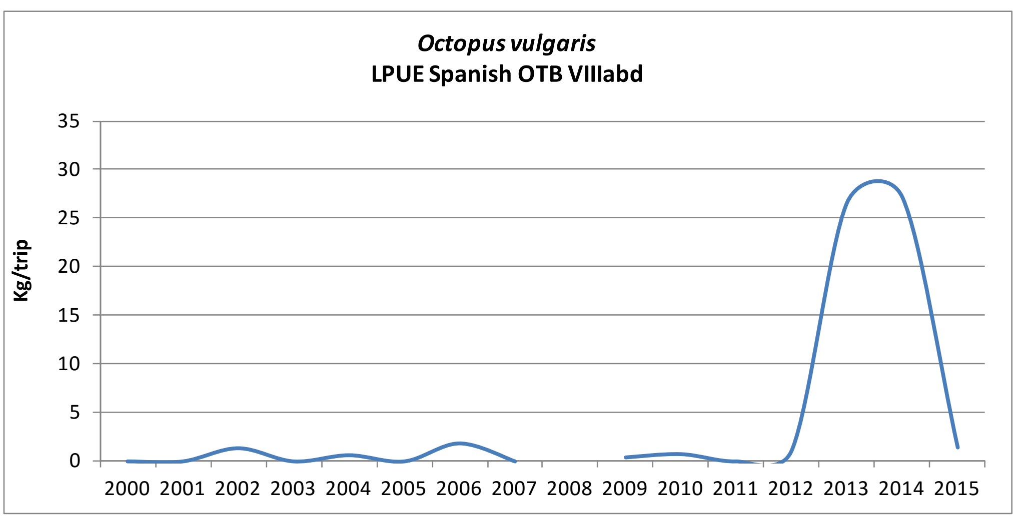

Figure 4.4.2. Commercial LPUE trends of the Spanish (kg/trip) OTB fleet in Div. VIIIabd for *O. vulgaris.*

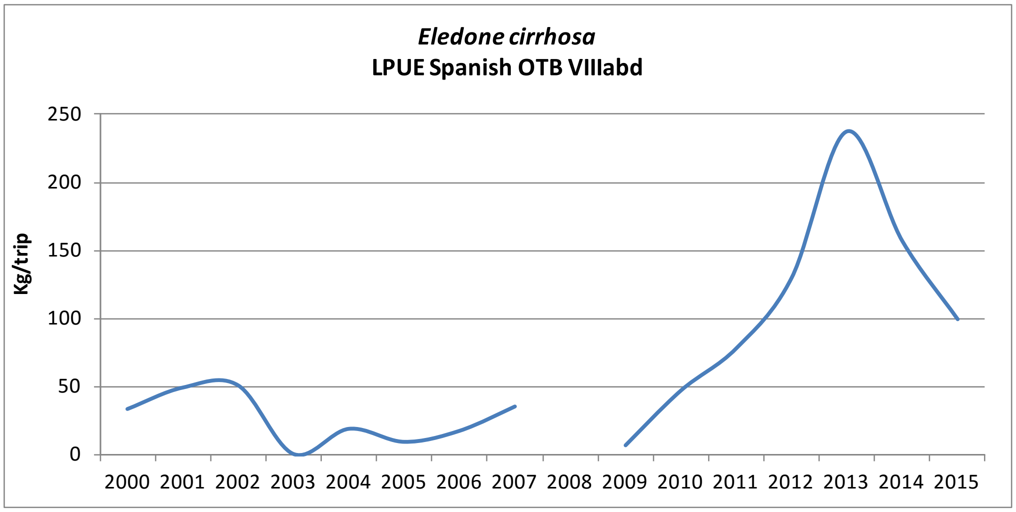

Figure 4.4.3. Commercial LPUE trends of the Spanish (kg/trip) OTB fleet in Div. VIIIabd for *Eledone cirrhosa*.

The recent high LPUE values for *Octopodidae* by Basque trawlers may reflect increased targeting of cephalopods. In 2009–2012, the metier targeting cephalopods (OTB_MCF) showed an increased number of trips and increased cephalopods catches. The increase in the OTB_MCF metier seems to be related to the decrease in the metier targeting demersal species like hake, megrim or anglerfish (OTB_DEF). In the last two years, this trend has changed (see WD1).

No data on *Octopodidae* from the survey taking place in Div. VIIIabd, FR-EVHOE were delivered to the group. No exploratory assessment was attempted due to the lack of French Survey data for Div. VIIIabd.

In Div. VIIIabd, the relative importance of the two main gears (Bottom Otter trawl and Bottom Pair trawl) changes along the data series (WD 2 & 3). It will be useful to analyse LPUE series from both gears separately and carry out a more detailed analysis based on metiers and species. It will also be useful to monitor the future importance of the cephalopod-targeting metier in the Basque trawl fleet, to see whether there has been a real shift in fishing strategies to increase targeting of species without TAC or Quota limits or if the situation during 2009–2013 simply represented a tactial response to high abundances of cephalopods.

4.4.4 Catches and discards for Subareas VIIIc & IXa

In Spain, *O. vulgaris* is caught by artisanal and trawler fleet. In the Cantabrian Sea (Division VIIIc) and Galician waters (Subdivision IXa north), the artisanal fleet accounts for more than 98% of *O. vulgaris* landings mostly from traps. In Portuguese waters (Subdivision IXa-centre), a large percentage of *O. vulgaris* come from the polyvalent (artisanal) fleet (91–97%), using a range of gears which includes gillnets, trammel nets, traps, pots and hooks (lines). In the Gulf of Cadiz (Sub-division IXa south), over most of the time-series the bottom-trawl fleet accounted for around 60% of the *O. vulgaris* catch on average and the remaining 40% is taken by the artisanal fleet using mainly clay pots and hand-jigs. In the last two years the proportion f catches attributed to the artisanal fleet increased to 72%, due possibly to tighter official control of landings (i.e. artisanal catches may not have changed but the proportion recorded in official statistics has increased.

Total catches of *O. vulgaris* in 2015 in Division VIIIc and IXa were 8359 t (around 6000 t lower than in 2014), mainly by the artisanal fleet, with zero discards. Portugal contributed around 72 % of these landings. Over half of the amount landed (5029 t) was taken from subdivision IXa-centre (Portuguese waters). Bottom trawling contributed significantly to landings only in Subdivision IXa-souths.

The available landings data for *O. vulgaris* in Spain covers sixteen years, from 2000 to 2015. In Portuguese waters (Subdivision IXa-center) the series starts in 2003. Total landings ranged from 6542 t in 2006 to 18 967 t in 2013. The marked year to year changes in amounts landed (WD1) may be related with environmental changes such as rainfall and discharges of rivers, as it was demonstrated in waters of the Gulf of Cádiz (Sobrino *et al.*, 2002).

Data on commercial discards of *O. vulgaris* in Iberian waters are only available for bottom otter trawl metiers that operate in this area. The data were collected by the on-board sampling programme (EU-DCR) during last eight years. In VIIIc and IXa north the pair bottom trawler (PTB) metier is also sampled, although no *O. vulgaris* was discarded. The sampling methodologies are described in WDa.3 (Spain) and WDa.4 (Portugal) of the WGCEPH 2012 report. Generally, amounts discarded were low or zero, possibly related with the high commercial value of this species (see also WD 2.4, WGCEPH 2014)

The two *Eledone* species are not separated in landings statistics but, except in the Gulf of Cadiz (Subdivision IXa south) where both *E. cirrhosa* with *E. moschata* are present, landings of *Eledone* will normally be *E. cirrhosa. E. cirrhosa* is caught by trawlers in both Divisions, mainly as a by-catch due its low commercial value. In Portuguese waters (Subdivision IXa centre), a small percentage (12%) is caught by artisanal vessels using a range of gears which includes gillnets, trammel nets, traps, pots and hooks (lines), classified under the polyvalent gear type group. Monthly landings of *E. cirrhosa* in IXa-centre show a marked seasonality, with much higher landings during spring months.

Total catches of *Eledone* spp in Div. VIIIc and IXa in 2015 were 1143 tonnes. The landings data for *Eledone* spp. in Spain cover 16 years, from 2000 to 2015. (WD 1) Annual landings ranged from 1333 t in 2000 to 460 t in 2008. Landings decreased from 2003 to 2008 in all areas, with a slight increase at the end of the time-series (mainly in IXa-south), with 1003 tonnes landed in 2015. Discards of horned octopus by Portuguese vessels seem to be low, although higher in OTB_DEF that in OTB_CRU (see WD 2.4). In the case of Spanish vessels, discards from the OTB metier varied between areas and years but were always less than 20%. However, 100% of the PTB metier catch of *Eledone* was discarded.

4.4.5 LPUE for areas VIIIc and IXa

Fishing effort data are available for the Spanish OTB metier, in terms of numbers of fishing trips, in all areas of the Iberian waters. The LPUE series (*O. vulgaris* catches/fishing trip) for the OTB metier in the north (Division VIIIc and IXa) and south (Div.IXa-south) indicate a much higher CPUE in the north, and the trends are also different in the two areas (Figure 4.4.4.).

Portuguese LPUEs (catcher per day) are available for a shorter period but indices for trawl and polyvalent fleets show similarities, with peaks in 2010 and 2013 and the sharp decline from 2013 seen for Spanish trawlers in the north is also seen for Portuguese trawlers in IXa centre.

Figure 4.4.5. shows the trends in LPUE (*Eledone* spp./fishing trip) for the Spanish OTB metier in the north (VIIIc, IXa-north) and south (IXa-south). As was the case for *O. vulgaris* both absolute values and trends differ between the two areas.

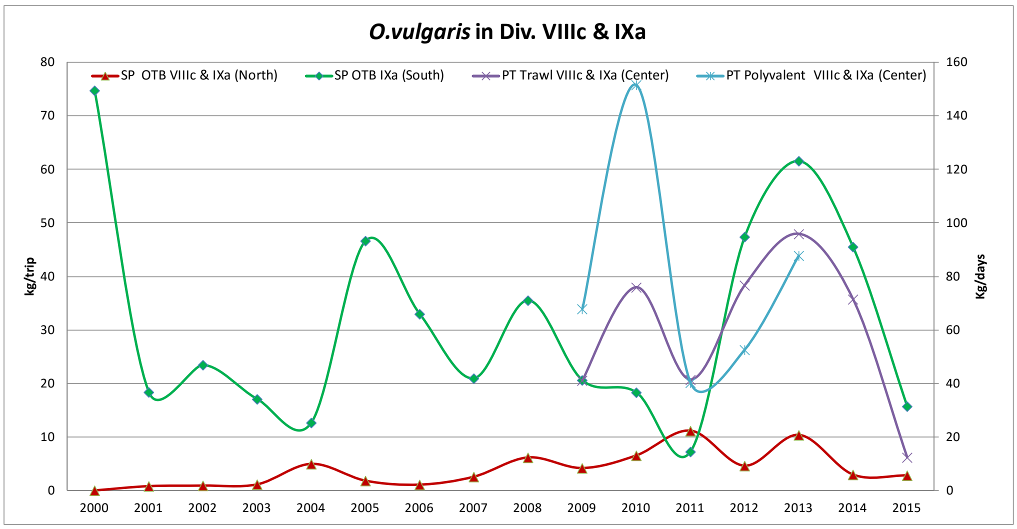

Figure 4.4.4. Commercial LPUE trends for *O. vulgaris*: Spanish trawlers (SP) bottom (kg/trip) in the north (VIIIc, IXa north) and south (IXa south), and Portuguese (PT) (kg/d) fleets in Div. IXa centre.

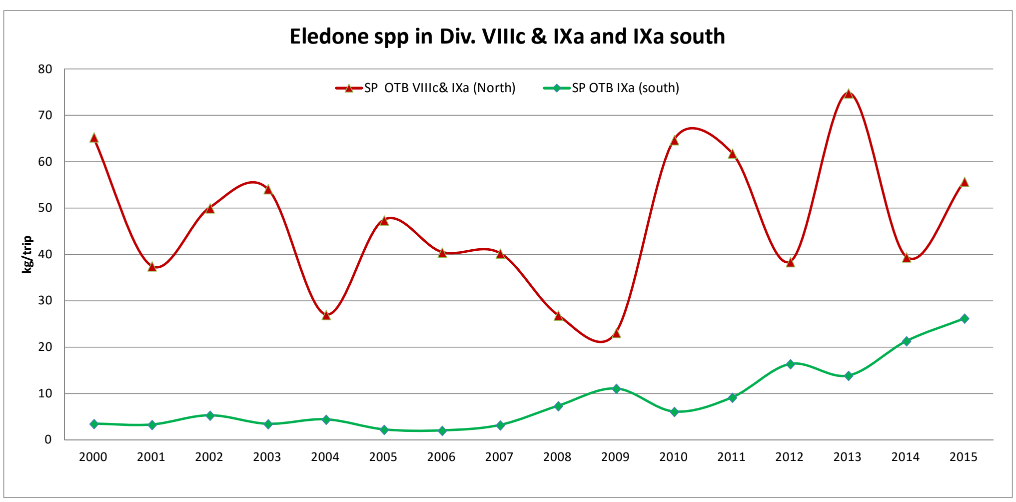

Figure 4.4.5. Commercial LPUE for *Eledone* spp.: trends for the Spanish (kg/trip) fleets in the north (VIIIc, IXa north) and south (IXa south).

4.4.6 Fishery-independent information and recruitment for VIIIc and IXa

Fishery-independent information was supplied for different surveys carried out annually in Iberian waters by Portugal and Spain: SP-NGPS "DEMERSALES" carried out in VIIIc and IXa north, PGFS in IXa-centre by Portugal and SP-GCGFS "ARSA". The information on biomass indices estimated in this survey over the time-series is given in WD 1.

The estimated yields (kg/hour) of *Octopus vulgaris* in Spanish DEMERSALES survey in the north during 2000–2015 (Figure 4.4.6.) fluctuated widely, reaching a maximum values in 2012 (2.5 kg/h) but dropping to minimum (0.15 kg/h), in 2015. In the ARSA survey in the south, again strong fluctuations are evident, with a peak in 2013 (6.9 kg/h) in 2013 and a minimum of around 1 kg/h seen in six years in the series, most recently in 2014..

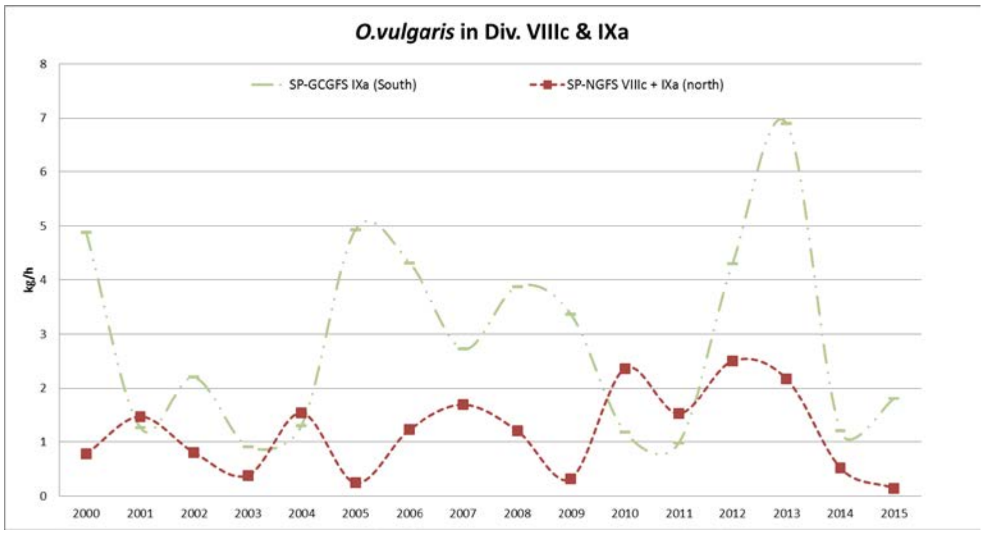

Figure 4.4.6. Abundance indices (Kg/h) of the Spanish (SP-GCGFS; SP-NGFS) scientific surveys in Div. VIIIc and IXa.

The estimated yields (kg/hour) of *E. cirrhosa* in the DEMERSALES survey also fluctuated over the time-series, tending to be slightly higher than values for *O. vulgaris* with a sharp increase in 2013. In ARSA survey, CPUE reached its highest value in 2015 (4.1 kg/h). Note that in all years of the ARSA survey time-series, the yield of *E. moschata* was higher than the yield of *E. cirrhosa* (see WD1).

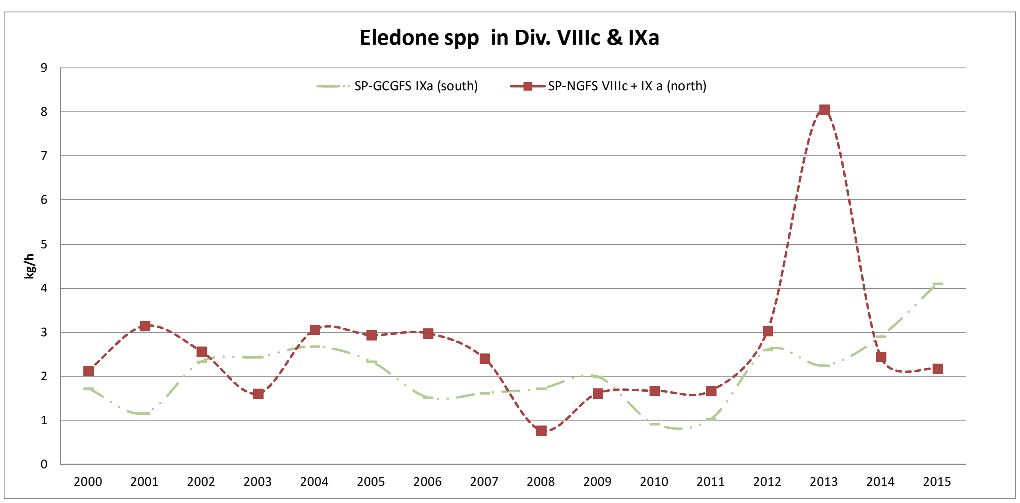

Figure 4.4.7. Abundance indices (Kg/h) of the Spanish scientific survey in Div. VIIIc and IXa.

4.4.7 Trends in *Octopodidae* abundance in VIIIc and IXa

In order to evaluate the quality of the CPUE series as abundance indices, these have been plotted alongside with corresponding commercial fishing CPUE series for "Baca" Otter trawlers are used in the analysis. In all series, it should be noted that the fishing effort was not effort directed at catching *O. vulgaris* (or *Eledone*). The CPUE series in the north of Spain refers to VIIIc and IXa north together, since the "DEMERSALES" survey covers these two areas. In division IXa south, Gulf of Cádiz, the survey index used is the average value of the two survey carried out during the year in this area (Spring-Autumn).

Figure 4.4.8 shows the Spanish DEMERSALES survey biomass index for *O. vulgaris* plotted jointly with annual data series coming from the Spanish commercial bottom trawl fleet "Baca" (OTB) in VIIIc and IXa north and LPUE indices for Portuguese trawl and polyvalent gears. In this species the main similarities in the trends are the peak in 2010 (not evident in the Spanish survey) and a clear decrease from 2013 to 2015 in all series. The abundance index series for *O. vulgaris* taken by the commercial fleet (OTB) and ARSA survey biomass index in Subdivision IXa south are shown in Figure 4.4.9. In this case, the trend of both sets of data show high similarities along the time-series.

The DEMERSALES survey biomass index for *E. cirrhosa* in VIIIc and IXa north is plotted alongside the annual CPUE series from commercial bottom trawl fleet "Baca" (OTB) in Figure 4.4.10. While there are some similarities in the trendsIn this species can be observer some similarities in the trend of the series in same periods, the trends were opposite during 2001 to 2004 and 2010 to 2012. Both series show a strong peak in 2013. The ARSA survey biomass for *Eledone* spp and CPUE series of the otter bottom trawl fleet "Baca" (OTB metier) in subdivision IXa south are plotted together in Figure 4.4.11. The trends in both series are quite similar, especially since 2009.

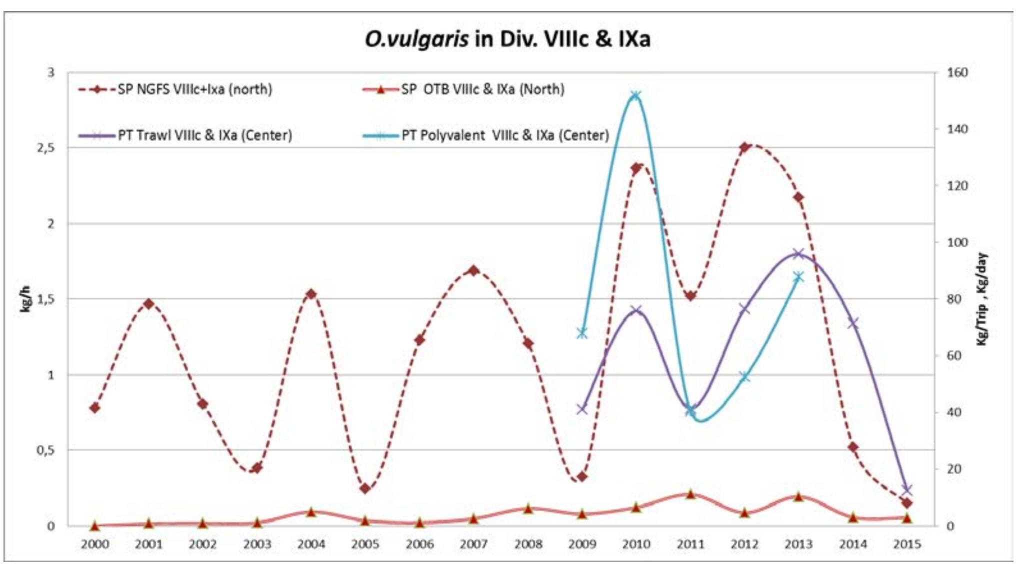

Figure 4.4.8. Comparison of commercial LPUE trends of the Spanish and Portuguese (kg/trip; kg/d) fleets and Spanish scientific survey (kg/h) in VIIIc, IXa north and IXa centre, for *Octopus vulgaris*.

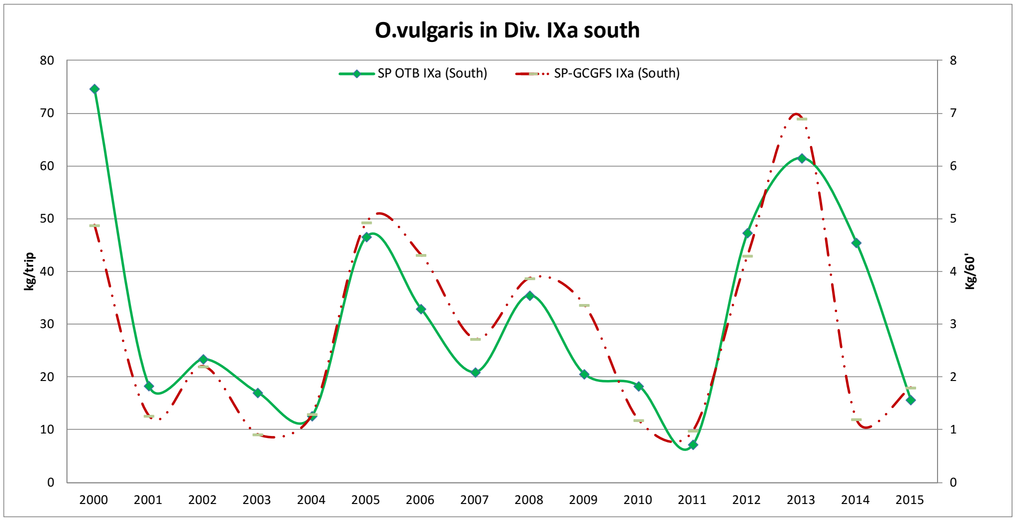

Figure 4.4.9. Comparison of commercial LPUE trends of the Spanish (kg/trip) fleets and Spanish scientific survey (kg/h) in Div. IXa south, for *Octopus vulgaris*.

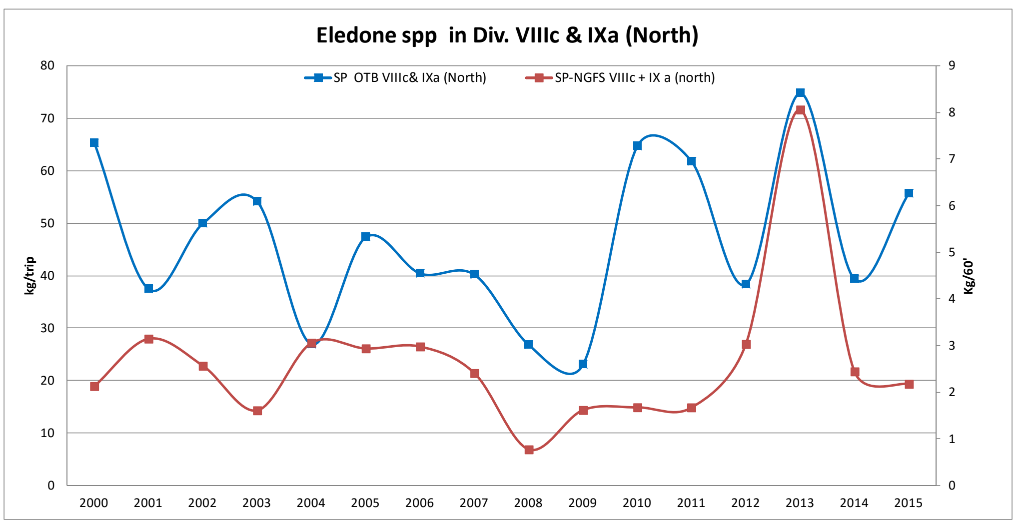

Figure 4.4.10. Comparison of commercial LPUE trends of the Spanish (kg/trip) fleets and Spanish scientific survey (kg/h) in VIIIc and IXa north for *Eledone* spp.

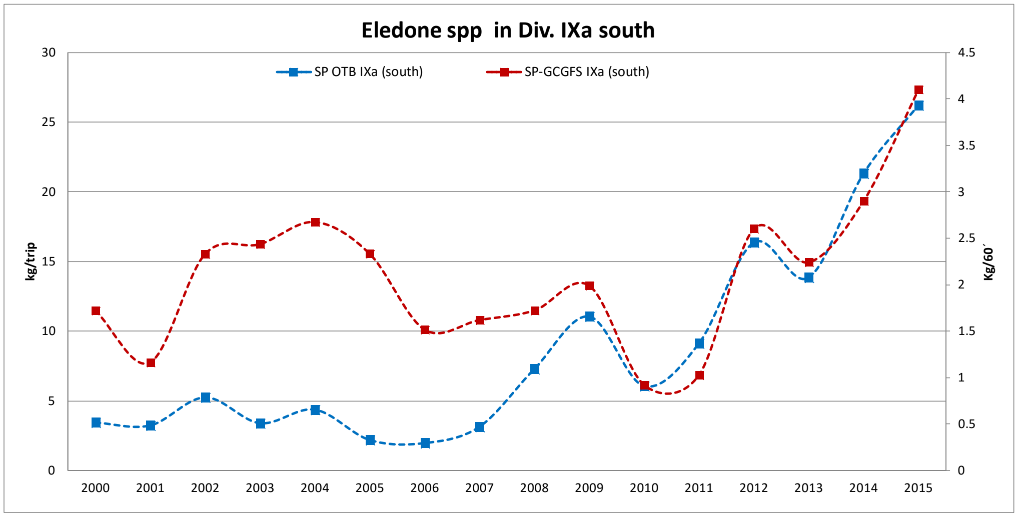

Figure 4.4.11. Comparison of commercial LPUE trends of the Spanish (kg/trip) fleets and Spanish scientific survey (kg/h) in Div. IXa-south for *Eledone* spp.

Looking at the above figures, the correspondence of survey and commercial abundance series is much more apparent in IXa south than in the northern area, possibly because the northern area is much larger and encompasses a wider range of habitat conditions. Indices in the north may need to be refined, for example dividing the region into smaller areas. In any case, survey indices did capture peaks and troughs of octopod abundance at least in the most recent years of the years showed the marked high and low abundances shown by the commercial LPUEs series. Discards are negligible for *O. vulgaris* but more variable in *E. cirrhosa*, which needs to be considered when using commercial data. We can be cautiously optimistic that these data series can in future be used as abundance indices for octopods.

4.4.8 Assessment of Octopus in the Gulf of Cadiz

In this section we present results of assessment of *Octopus vulgaris* in the Spanish part of the Gulf of Cadiz (IXa south), updated since 2014. We used Biomass Dynamic Models (Punt and Hilborn, 1996) including the effect of environmental factor.

Biomass Dynamic Models (with environmental effect)

The abundance of octopus in the Gulf of Cadiz is highly correlated with environmental parameters like the rainfall in previous years (Sobrino *et al.* 2002). For this reason we considered the effect of rainfall in the model of biomass dynamics. We defined the effect of rainfall as Rain Factor (Rf) = 1/(Rain periods/mean of rain periods) for each year and we use the value of Rf in each year as a multiplier for either carrying capacity (K) and growth rate (r) or carrying capacity only. In this new model we can observe how the K and r values are affected in the last 20 years. In dry years we obtained a K value of 21 981t but in rainy years the value of K fell to 5664 t. In the figure 4.4.12 we present the results of the model applied to data from 1993 to 2013.

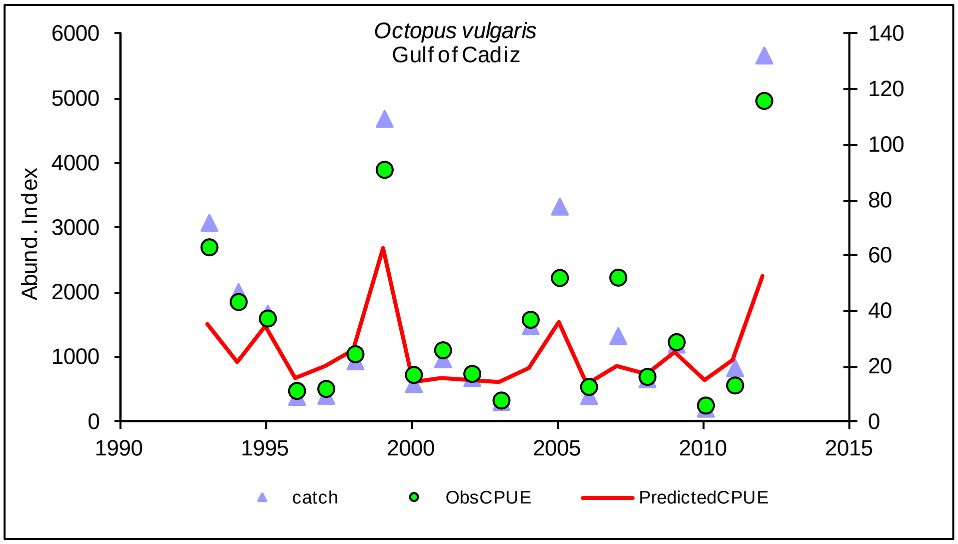

Figure 4.4.12. Result of biomass dynamic model with rainfall influence applied to *O. vulgaris* catches 1993–2013.

We can observe that the model does not explain the high landings in 2013 and in general observed CPUE varied more widely than predicted CPUE. A possible issue is that we used a linear relationship between rainfall and landings and probably this relationship is not linear. We have to work in the future to improve knowledge of the influence of environmental parameters on the recruitment of octopus and include these effects in the dynamic production model.

With this model it is possible to forecast landings for the next year because we have the rainfall data of the year in September and we can estimate the rain factor, as well as K and r values for the next year, and also Maximum Sustainable Yield (MSY). In figure 4.4.13 we compare predicted MSY values, based on the model fitted to data from 1993–2013, with actual landings. We can see a correlation between capture and MSY that has been calculated using dynamic models of biomass with environmental effect. We can observe that the landings are below the MSY in most of years, although landings are likely underestimated, especially for the artisanal fleet. We can also observe in the period 2014/2015 that MSY increased to 4295 tons while the landings decreased to 1121 tons.

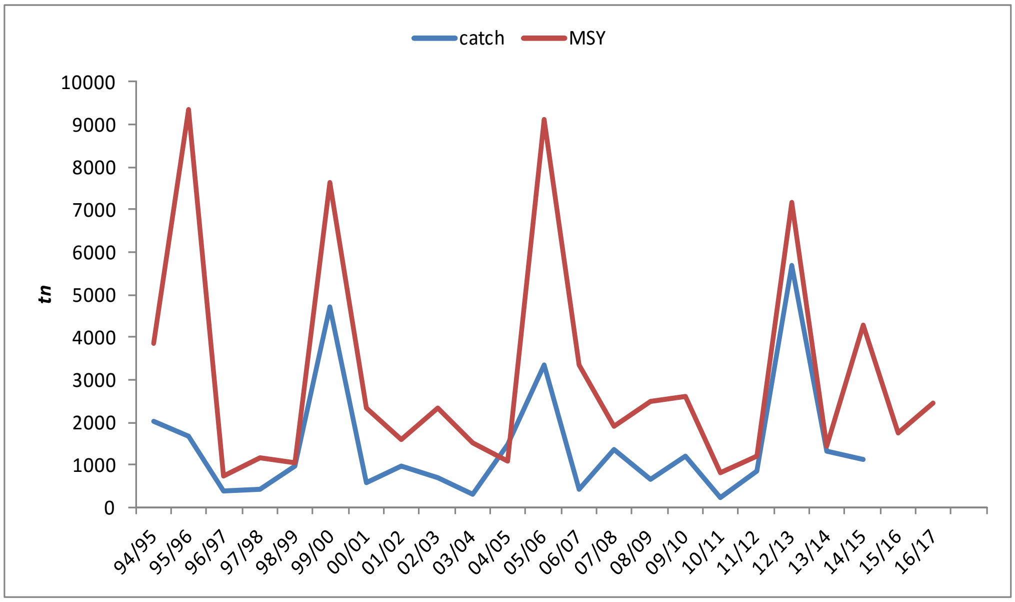

Figure 4.4.13. Trend of landing with MSY calculated in each period.

During the WG meeting we also used another fitting procedure (script in R and spreadsheet in Excel) developed by the University of Caen. The results showed a good agreement between observed and fitted abundance indices and the model can explain the high value of 2013 (Figure 4.4.14). Despite this, values calculated for carrying capacity (Ki) very high in relation to observed landings (C_obs) and estimated biomass (B_cal); (Figure 4.4.15). It may also be observed that in several years landings exceeded estimated stock biomass.

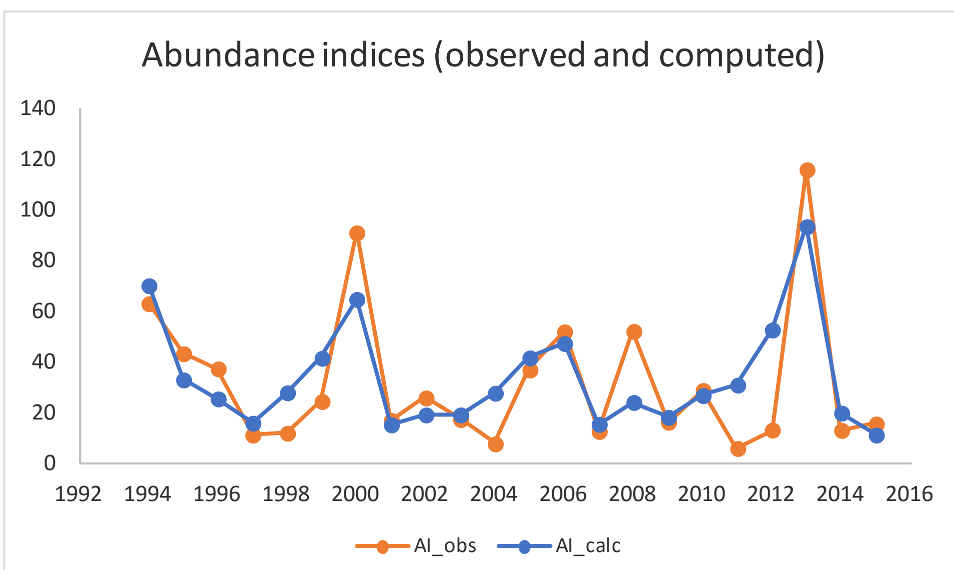

Figure 4.4.14. Trend of abundance indices (cpue) observed and computed for *Octopus vulgaris* in the Gulf of Cadiz.

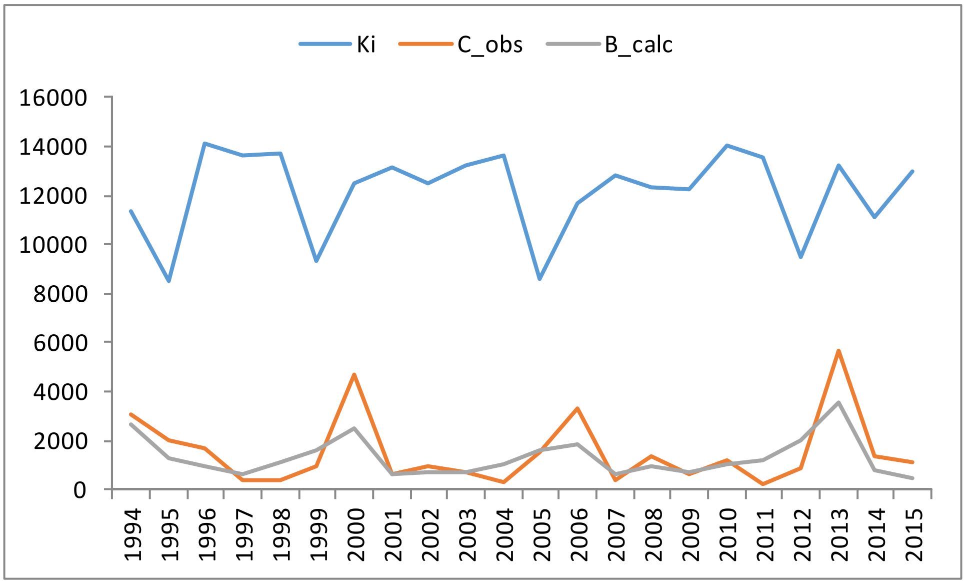

Figure 4.4.15. Trends of carrying capacity (ki), landings (C_obs) and current biomass (B_cal).

In future studies the models should be improved by trying to take into account environmental parameters other than rain that can affect the *Octopus* population. It may also be useful to test another form of effect for the environmental variables (e.g. exponential instead of linear).

4.5 Business under ToR e) Database of scientific articles

The current database on cephalopod literature is located at the following url:

https://www.zotero.org/groups/cephalopod_research/items/

The tool was created in June 2014. Anyone can view the references although it is necessary to register if you wish to add/edit/delete references in the database.

The references are grouped in collections and organised on an annual basis (Ceph_Res_2013 / Ceph_Res_2014 / Ceph_Res_2015/Ceph_Res_2016). It is not a problem to organise references by year since the whole database can be searched also directly.

There is also a collection that contains references more distantly related to Cephalopods (Other_distantly_related_papers_2013_2014). There has been identified a list of tags: Behaviour, biochemistry, culture, ecology, ecotoxicology, fisheries, food processing, genetics, physiology, population dynamics, reproduction and taxonomy.

Tags can be used to filter references very quickly. Tags are also in the process to be deployed as some of them sound vague (ecology) or others could be included (evolution). These tags should help us to indicate more clearly within the data base which are the articles in relation to the topic worked out every year as indicated in ToR e. Most references include the abstract.

The database was updated on 17 June 2016 (collection Ceph_Res_2016 and contains 45 references at this time).

At the time of finalising the present report, a new initiative to develop a reference database for cephalopods was being discussed on the FASTMOLL discussion list (Cephalopod International Advisory Council) and results to date appear at: http://www.citeulike.org/group/20546. It is recommended that consideration is given to joining these initiatives.

4.6 Business under ToR g) Collect and explore social and economic data (Y2), final analysis (Y3)

An important aspect of cephalopod fishing in many parts of the world is the high importance of these resources for small-scale artisanal fisheries (Pierce *et al.* 2010). This is the case in southern European waters, mainly in Portugal, Spain, Italy, Greece and France, where inshore local small-scale fishing fleets targeting cephalopods are of considerable socio-economic importance in terms of providing employment and income in coastal fishing communities. According to EUROSTAT statistics, in 2011, these four countries together accounted for 69% of all squids, cuttlefishes and octopuses landed in the EU, representing 77% of the value of all cephalopods landed.

In the European Union (EU), despite the increasing economic importance of cephalopod fisheries, these species have long been regarded as minor resource species and very little information exists on the human dimensions (social, economic, cultural and institutional aspects) of these fisheries. As such, a framework for the collection of this data was defined by the University of Aveiro, which collected social, economic and governance data from the main cephalopod fisheries in European waters, namely the octopus fishery in Portugal, Spain, Italy and Greece, and cuttlefish in France.

The information collected has been analysed and a peer-reviewed paper entitled "Cephalopods fisheries in Europe: socioeconomic importance and management" is at its final stages of preparation. The paper describes the various fisheries (octopus fishery in Portugal, Spain, Italy and Greece, and the cuttlefish fishery in France), the management of these fisheries in each country, the involvement of the fishing industry in the management of these fisheries, and the opportunities and challenges for the future of these fisheries. The paper will be submitted to a special issue about small-scale fisheries to be published in the journal Marine Policy. A final paper will be produced by the next cephalopod working group meeting in June 2017.

5 Cooperation

Cooperation with other EGs:

Links could be formed with groups working on predators of cephalopods (e.g. WGBIE, WGCS, WGMME).

WGCEPH would like to encourage improved data collection on cephalopods during trawl surveys. It will make available (e.g. to IBTSWG) detailed diagrams and protocols for identifying cephalopods and collecting biological parameters during the scientific surveys.

Contribution to advice

The results of WGCEPH are potentially relevant for advice in the case that formal assessment and management are introduced for any of these species.

Cooperation with external bodies

Linkages to other organizations and projects could include theCost Action (FA 1301) CephsinAction, Cephalopod International Advisory Council (CIAC).

6 Summary of Working Group self-evaluation and conclusions

A copy of the full Working Group self-evaluation is included in the report in Annex 4.

Annex 1: List of participants

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Annex 2: Recommendations

Recommendation	Adressed to:
1. WGCEPH will review the current format and design of the data requirement. The, group will get in contact with experts by country to inform them about WGCEPH working procedures for 2017 in relation to data required.	ICES Secreatriat and National correspondants.
2. Routine collection of cephalopod length–frequency data, by species, during research bottom trawl surveys (e.g. IBTS) is suggested, in addition to provision of these data to the WGCEPH prior to the next meeting. Note that much existing survey data on cephalopods does not include identification to species level, limiting its usefulness.	IBTSWG Chair, and National correspondant.
3. In relation to sampling and monitoring for achieving Integrated Ecosystem Assessment, WGCEPH recommends that for major cephalopod stocks in which assessment and management are likely to be necessary in the near future, data collection under the EU MAP should be modified to reflect the additional data requirements imposed by the short life cycles. We recommend: (a) Increases in the level of cephalopod sampling in metiers where these are highly valuable, based on the short life cycle of cephalopods. Thus, sampling of cephalopod species on a quarterly basis is not adequate. (b) Focus of the more intensive sampling (i.e. weekly or monthly) during periods of higher catches in order to ensure adequate characterizations of the length compositions of the multiple microcohorts that are often present, while avoiding unproductive sampling effort at times of low abundance. (c) Collection of maturity data for the most important cephalopod fisheries, to facilitate comparison of trends in maturity and length composition data by cohort, from research surveys versus the fishery, in order to assess trends in recruitment and length at 50% maturity (L50).	National Correspondents

Annex 3: WGCEPH terms of reference 2017–2019

The **Working Group on Cephalopod Biology and Life History** (WGCEPH), chaired by Graham Pierce*, UK, and Jean-Paul Robin, France, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2017	6–9 June	Madeira, Portugal	Interim report by 1 September to SSGEPD	
Year 2018			Interim report by DATE to SSGEPD	
Year 2019			Final report by DATE to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
A	Report on cephalopod stock status and trends: Update, quality check and analyse relevant data on European fishery statistics (landings, directed effort, discards and survey catches) across the ICES area.	This task is fundamental to support the assessment task and will involve a Data Call.		Years 1, 2 and 3	Annual report
B	Conduct preliminary assessments of the main cephalopod species in the ICES area by means of trends and_or analytical methods. Assess the relevance of including environmental predictors.	The purpose is to assess the status of cephalopods stocks and contribute to Integrated Ecosystem Assessment and Management.		Years 1, 2 and 3	Peer-reviewed manuscript on assessment methodologies and results (year 3)
C	Update information on life history parameters including variability in these parameters. Define cephalopod habitat requirements.	There is a need to undesrtand variability in life history parameters in the wild and to provide knowledge to support captive rearing.		Years 1 and 2	Publication on rearing conditions and habitat preferences (Year 2)
D	Evaluate the social and economic profile of the cephalopod fisheries, with emphasis on small scale fisheries and mechanisms that add value to cephalopod products (e.g. certification).	There is a need to better quantify the social and economic of cephalopod fisheries across Europe.		Year 1, 2 and 3	Report on social and economic importance of cephalopod fisheries (Year 3)
E	Recommend tools for identification cephalopod species and update best	Currently cephalopods are not consistently		Year 1, 2 and 3	Manual for cephalopod field

practices for data collection.	identified to species in commercial and survey catches.	identification and data collection (Year 3)

Summary of the Work Plan

Year 1 (2017)	Report on updated trends in Cepahlopod landings and abundance indices .(a) Report on updated cephalopod stock assessments (b) Report on scientific articles in relation to life-history and habitat requirements (c) Report on social and economic profile of cephalopod fisheries (d) Report on available information for species identification (e)
Year 2 (2018)	Report on status and trends in cephalopod stocks (a and b)) First draft of paper in relation to population modeling and assesment tools (b) Peer review paper on rearing conditions and/or habitat preferences (c) Report on mechanisms that add value to cephalopod products (e.g. certifications) (d) Draft of Manual for cephalopod field identification and data collection (e)
Year 3 (2019)	Report on updated trends in Cephalopod landings and abundance indices .(a) Peer-review paper on cephalopod population modeling and assesment tools (b) Report on socio-economic issues related to cephalopod management options Manual for cephalopod field identification and data collection guidelines (e)

Supporting information

Priority	The current activities of this Group will inform ICES about the role of Cephalopods in the ecosystem and evaluate their importance as part of directed and indirected fisheries. Cephalopods are important components of marine ecosystems, as predators and as prey, more important than their biomass might suggest due to their high productivity and large year-to-year variation in abundance. Cephalopod catches are replacing depleted finfish catches in some fisheries and ecological replacement is also hypothesised. Thus, for promoting the sustainable use of the seas and conserving marine ecosystems, cephalopod biology and life history has to be understood. As an example, directed cephalopod fisheries, especially small-scale fisheries, are increasingly important and it is necessary to have in place a useful system of data collection and stock evaluation that would be adequate to support managementthese activities are considered. These activities are believed to have a very high priority.
Resource requirements	As noted in several previous reports, participation in WGCEPH is limited by availability of funding, especially as many members and potential members are university staff with no access to "national funds" for attendance at ICES meetings. Although there are no specific resource requirements, funding to assist wider particupation would be beneficial.
Participants	In recent years the group has fluctuated from around 15 attendees and as few as 6 to 8 regular members, with a strong bias towards participants from the Iberian peninsula. There is a need to broaden participation to ensure good attendance every year
Secretariat facilities	None.
Financial	No specific financial implications (but see resource requirements).
Linkages to ACOM ar	The results of WGCEPH are potentially relevant for advice in the case that

groups under ACOM	formal assessment and management are introduced for any of these species.
Linkages to oth committees or groups	Possible links with groups working on predators of cephalopod (e.g. WGBIE, WGCS, WGMME). WGCEPH would like to encourage improved data collection on cephalopods during trawl surveys. It will make available (e.g. to IBTSWG) detailed diagrams and protocols for identifying cephalopods and collecting biological parameters during the scientific surveys. WGCEPH will provide information to SCICOM and its satellite committees as required to respond to requests for advice/information from NEAFC and EC DG Fish.
Linkages to oth organizations	Cost Action (FA 1301) CephsinAction, Cephalopod International Advisory Council (CIAC).

Annex 4: WGCEPH self-evaluation

a) Working Group name: WGCEPH: Working Group **on** Cephalopod Biology and Life History

b) Year of appointment: 2014

c) Current Chairs: Marina Santurtún, Spain and Jean Paul Robin, France

d) Venues, dates and number of participants per meeting:

	Meeting dates	Venue	Reporting details	NUMBER OF PARTICIPANTS PER MEETING
Year 2014	16-19 June	Lisbon, Portugal	Interim report by 1 August 2014 to SSGEPD	15 people, from those, two members worked by correspondence
Year 2015	8-11 June	Tenerife, Spain	Interim report by 1 August to SSGEPD	14 people, from those, two members worked by correspondence
Year 2016	14-17 June	ICES HQ, Copenhagen, Denmark	Final report by 1 August to SCICOM	8 people

WG Evaluation

5. If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG makes a significant contribution.

WGCEPH contributes to a range of Science Plan priorities as listed below:

2. Quantify the nature and degree of connectivity and separation between regional eco-systems

3. Quantify the different effects of climate change on regional ecosystems and develop species and habitat vulnerability assessments for key species

6. Investigate linear and non-linear ecological responses to change, the impacts of these changes on ecosystem structure and function and their role in causing recruitment and stock variability, depletion and recovery.

9. Identify indicators of ecosystem state and function for use in the assessment and management of ecosystem goods and services

10. Develop historic baseline of population and community structure and production to be used as a basis for population and system level reference points.

11. Develop methods to quantify multiple direct and indirect impacts from fisheries as well as from mineral extraction, energy generation, aquaculture and other anthropogenic activities and estimate the vulnerability of ecosystems to such impacts.

12. Develop approaches to mitigate impacts from these activities, particularly reduction of non-target mortalities and enhancement/restoration of habitat and assess the effects of these mitigations on marine populations

15. Develop tactical and strategic models to support short and long term fisheries management and governance advice and increasingly incorporate spatial components in such models to allow for finer scale management of marine habitats and populations.

20. Provide priorities and specifications for data collection frameworks supporting IEA's.

25. Identify monitoring requirements for science and advisory needs in collaboration with data product users, including a description of variable and data products, spatial and temporal resolution needs, and the de-sired quality of data and estimates

27. Identify knowledge and methodological monitoring gaps and develop strategies to fill these gaps

30. Allocate and coordinate observation and monitoring requests to appropriate expert groups on fishery dependent surveys and sampling and monitor the quality and delivery of data products.

31. Ensure the development of best practice through establishment of guidelines and quality standards for (a) surveys and other sampling and data collection systems; (b) external peer reviews of data collection programmes and (c) training and capacity building opportunities for monitoring activities

6. In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

Publications arising from the work of the Group and its members:

The key output, based on work by the present WGCEPH and some of its previous incarnations, was a Co-operative Research Report (Jereb *et al.*2015), while members of WGCEPH also contributed to a second CRR (Zaragoza *et al.*2015):

Jereb, P., Allcock, A.L., Lefkaditou, E., Piatkowski, U., Hastie, L.C. & Pierce, G.J. (Editors), 2015. *Cephalopod biology and fisheries in Europe II: Species Accounts*. Co-operative Research Report No 325, International Council for the Exploration of the Sea, Copenhagen, 360 pp. ISBN 978-87-7482-155-7.

Zaragoza, N., Quetglas, A. and Moreno, A. 2015. Identification guide for cephalopod paralarvae from the Mediterranean Sea. ICES Cooperative Research Report No. 324. 91 pp.

Two promised publications, on stocks trends, and a socioeconomic assessment (for ToRs a and g respectively, see below) are presently still in preparation. However, some of the material originally intended for the second paper has been published separately as a book chapter:

Pita, C.B., Pereira, J., Lourenço, S., Sonderblohm, C. & Pierce, G.J., 2015. The traditional small-scale octopus fishery in Portugal: framing its governability. In: Jentoft, S. & Chuenpagdee, R. (Editors). Interactive governance for small-scale fisheries: global reflections. Mare Publication Series 13. Springer, pp. 117-134.

Data products:

Among the basic products of this Expert Group is the information collected through data calls. This constitutes the basis for analysis of status and trends. Data delivered to the expert group through the Secretariat represented a great progress on the ad-hoc data collecting process that used to be followed by this group. The group is generally pleased with the answers obtained from most European countries in relation to the data call. The data call format was designed in 2014, to facilitate compilation and data analysis during the meeting, but will need to be updated, e.g. to allow use of Intercatch or FishFrame databases in the future. The amount of information received by the group was large and of sufficient quality to allow preliminary trend analysis. The group was able to review and update some preliminary LPUE trends and survey indices based on submitted data. In this sense ToRs a, b and c could be fully accomplished. Some data issues still require solution, e.g. identification of cephalopods in catches and discards is often only to family level only, there are inconsistencies in allocation of species/species groups to metiers year by year and some data arrived late and/or were in the wrong format.

ToR a. Reports on status and trends in cephalopod stocks (Years 1, 2, 3): Update, quality check and report relevant data on: European fishery statistics (landings, directed effort, discards and survey catches) across the ICES area. The manuscript on trends is not yet completed but should be ready this calendar year but otherwise work on this ToR has been completed.

ToR b. Conduct preliminary assessments of the main cephalopod species in the ICES area. Assess production and/or depletion methods utility, if feasible (YEAR 1). Explore other possible assessment methods if needed (e.g. early season assessment) (YEAR 2). Carry out assessment of species with the methods chosen (YEAR 3). The main aim of identifying CPUEs for individual metiers and surveys to check whether catch trends in the commercial fishery can be considered as a good index of abundance was fulfilled. Thus, LPUE trends from the commercial fleet is Division IXa closely follow those from the ARSA survey. Analytical assessments were deployed in relation to *Loligo* spp. in the Bay of Biscay and *Sepia officinalis* in the English Channel. This work is delivering promising results, so it will be continued for the next period. There is still a need for assessment models suitable for estimating cephalopod population levels and exploitation rate to be integrated into the forthcoming ecosystem-based fisheries assessment and management. In the long term, these species could be incorporated as fundamental ecosystem components, then being incorporated in the Integrated Ecosystem Assessment.

ToR c. Implications of the application of some Policies and Directives on cephalopods (YEARS 1, 2 and 3). Recent EU Policies and Directives which mention cephalopods (or indirectly affect them) were fully reviewed for possible implications for fisheries, ecosystem effects and research. Of particular interest is the EU Directive 2010/63/EU (on use of animals in research) in which, for the first time, invertebrates (including cephalopods) have been incorporated.

ToR d. Review data availability for the main cephalopod species in relation to the main population parameters: length distribution, sex ratio, first maturity at age, first maturity at length, growth, spawning season (YEAR 2). This task was subsumed within the work on the longer delayed CRR on the biology and ecology of cephalopod species of fishery interest in Europe, which was delivered in 2015.

ToR e. Review and report on cephalopod research results in the ICES area, and if feasible in waters other than Europe, including all relevant aspects of: biology, ecology, physiology and behaviour, in field and laboratory studies (YEAR 1, YEAR 2 and YEAR 3). WGCEPH synthesised new knowledge based on recent publications on cephalopod biology, fisheries, and ecology. Summaries were included in the reports and a web-based DataBase of cephalopod articles was created at https://www.zotero.org/groups/cephalopod_research/items/

ToR f. Report on MSFD and Integrated Ecosystem Assessment (YEAR 1 & 2): The application of relevant MSFD indicators (biodiversity, community role, exploitation and contaminants) to cephalopods was reviewed. During 2014 and 2015, special attention was paid to the role of cephalopods in ecosystems and the possibility of the use of cephalopods as indicators and descriptors of GES (Good Environmental Status) under the MSFD. Sections of the 2014 and 2015 reports were devoted to try to identify relevant MSFD descriptors and indicators as a means of assessing good environmental status for cephalopod stocks, check the applicability of each descriptor and indicator to cephalopod species and provide an updated list of cephalopod species covered in the initial 2010 MSFD assessment report for each of the member states.

ToR g. Collect and analyse social and economic data. Although book chapter on octopus fisheries was published, a manuscript on small-scale cephalopod fisheries is still in preparation.

ToR h. Produce short section for the ICES Ecosystem Overviews on the state of cephalopod diversity/populations, for each of the following ICES ecoregions: North Sea, Celtic Seas, Bay of Biscay & the Iberian coast and Baltic Sea. This has been completed.

7. Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

The WG contributed to the identification of Advisory needs together with the Crangon Working Group. Discussions during the Workshop on the Necessity for Crangon and Cephalopod Management (WKCCM)) in October 2013, remain relevant and have helped shape both the current and proposed future ToRs of WGCEPH. The essence of the conclusions was:

There was evidence that assessment and management of commercially exploited cephalopod species is needed. In the few cases where assessments had been undertaken, populations were considered to be fully exploited or overexploited (e.g. *Sepia officinalis* in the English Channel). Also, some evidence of growth overfishing could be detected in Octopus in Portugal (WKCMM, 2013). Changes in fishing efficiency and/or effort were expected as a response to the new Landing Obligation Regulation. Thus, the workshop concluded that there was a significant risk that if no assessment were implemented (i.e. if no knowledge about abundance were obtained) and, for some species, management were not implemented, there could be negative consequences for both cephalopod populations and marine ecosystems.

Reflecting the relatively high importance of cephalopod fisheries in some areas and the important role of cephalopods in marine food webs, the workshop also pointed to the need to monitor cephalopods by means of assessment (even if not analytical). Monitoring would allow formulating measures and having them readily available in the event that populations reached unexpected low levels, thus jeopardizing sustainability.

8. Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

Members of the WGCEPH have participated in a current COST Action linked to the new regulations on use of cephalopods in research and contributed to a current INTERREG proposal.

WGCEPH members are also active in the Cephalopod International Advisory Council and there is a plan to merge the literature databases held by WGCEPH and by CIAC.

9. Please indicate what difficulties, if any, have been encountered in achieving the workplan.

During 2014 and 2015, attendance at WGCEPH was good, but the lower attendance in 2016 (as in some previous years) imposes limitations, especially in relation to the group's ability to undertake stock assessments and to respond to all ToRs.

Future plans

10. Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

WGCEPH members believe that the rationale for a dedicated cephalopod group within ICES remains as strong as ever, with an increasing importance of cephalo-pods in EU fisheries. In recognition of the difficulty of attracting a large membership the groups proposes a modest scaling down of the ambitions of the Terms of Reference, centring them on the fisheries and role of cephalopods in the ecosystem.

11. If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.
    No
    (If you answered YES to question 10 or 11, it is expected that a new Category 2 draft resolution will be submitted through the relevant SSG Chair or Secretariat.)

12. What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

The group would possibly benefit from the participation of population modellers.

13. Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)

Most of the knowledge synthesised on the life history and the trends in CPUE could be of utility for, at least, future stock assessment even if management advice is not applied. In addition, exploitation trends and trends in population abundance are useful in a series of MSFD descriptors (D1, D3, D4)

Annex 5: Working Documents

Working Document presented to the ICES WGCEPH Working Group on Cephalopod Fisheries and Life History.

Copenhagen, Denmark, 14-17 June 2016

AN UPDATE OF CEPHALOPOD LANDINGS-DISCARD DATA OF THE SPANISH FISHING FLEET OPERATING IN ICES AREA FOR 2000-2015 PERIOD.

Luis Silva, Ignacio Sobrino and J. Antonio Canseco Rodríguez
Instituto Español de Oceanografía, Centro Oceanográfico de Cádiz
Puerto Pesquero, Muelle de Levante s/n
11006 Cádiz, SPAIN
Telf.(34)956294189
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Data of Spanish landings of cephalopods on an annual basis were collected both by the *Instituto Español de Oceanografía's* (IEO) Sampling and Information Network, for catches from the ICES sub-areas VII, VIIIabd, VIIIc and IXa. It has been used both the information from logbooks and sales sheets which have been provided by the Fishing General Secretary of the Spanish Government.

Table 1 shows the Spanish annual landings (in tons) by species group (*Octopodidae*, *Loliginidae*, *Ommastrephidae* and Sepiidae) and the total annual for the 2000-2013 period. The 2011 landings have been updated in relation to the information reported last year. Landings data of 2015 should be considered as provisional because of gaps of information still present in some subdivisions. However, the 2014 landings will be considered in further analysis of trends henceforth presented.

Table 1. Spanish cephalopod annual landings (in tons) caught in the ICES Area by species group and total annual during the 2000-2015 period.

Year	Loliginidae	Octopodidae	Ommastrephidae	Sepioidea	*Total*
2000	676	7032	2017	1637	**11361**
2001	1052	3896	1305	1129	**7383**
2002	958	5150	1718	1133	**8959**
2003	917	4888	1164	1286	**8256**
2004	980	4882	1471	1394	**8726**
2005	880	6040	1950	1635	**10505**
2006	441	5238	1018	1456	**8152**
2007	598	4643	834	1563	**7637**
2008	765	4920	1636	1412	**8734**
2009	546	3935	1314	1224	**7019**
2010	1109	5776	3023	1535	**11444**
2011	1196	5122	3397	1423	**11138**
2012	1683	6391	4718	1714	**14505**
2013	814	7798	1580	1985	**12177**
2014	496	4689	3508	1257	**9950**
2015	453	4484	2209	1058	**8203**

Figure 1 shows the trend of total annual landings through the analyzed time period (2000-2015). Mean annual landings along the time-series were around 9730 tons, with a minimum of 7019 t in 2009 and a maximum of 14504 tons in 2012. The highest landings belonged to the *Octopodidae* group which accounted for 55 % of the averaged landings for the analyzed period, followed by *Ommastrephidae* (21 %), Sepioidea (15 %) and *Loliginidae* (9 %). The trend presents a drop of landings from 2000 to 2001, followed by a slight increase until it reaches a peak in 2005 of 10500 t. Afterwards, a new decrease appears until 2009, with a great increase in 2010 of about 63% in comparison to 2009. In 2011, the landings showed similar values to previous years, with a new increase in 2012 reaching the highest value of the time-series. In 2013, the landings decreased 16% with regard to the previous year due to the reduction of *Ommastrephidae*. This decrease continued in 2014, with an 18% reduction compared to 2013, which coincided with a decrease in abundace of *Octopodidae*. By the year 2015, there was a general reduction in catch which affected all taxonomic groups and was similar to that reported in 2014 (17.5%).

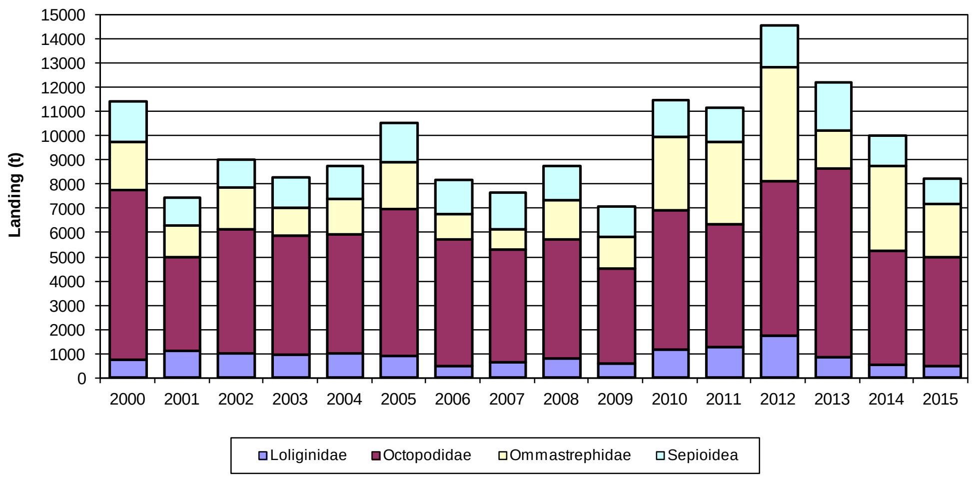


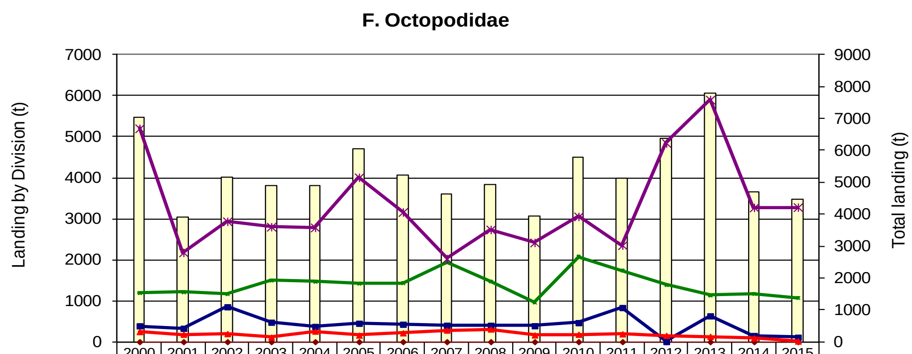
Figure 1. Spanish cephalopod annual landings (in tons) caught in the ICES area by species group for the 2000-2015 period. (2015: provisional data)

Octopodidae

Commercial landings of octopods (Fam. *Octopodidae*) comprise common octopus, *Octopus vulgaris* and horned octopus, *Eledone cirrhosa*, plus musky octopus, *Eledone moschata* in Sub-Division IXa-South. Figure 2 shows the total octopods landings trend by Subarea/Division in the last fourteen years. Total annual catch ranged between 3895 t in 2001 and 7798 t in 2013, which represents a very important increase along the time-series. A slight increase until reaching a peak in 2005 of 6039 t can be observed. Afterwards, a new decreasing trend appears until 2009 with 3935 t, followed by a great increase in 2010 of about 46% with regard to 2009, maintaining a similar value in 2011. In the last two years, a sharp increase can be observed until it reached the highest value of the time-series in 2013 with 7798 t. More than 87% of *Octopodidae* were caught along the Spanish coast (Divisions IXa and VIIIc), where common octopus *O. vulgaris* is the main species caught. In Division VIIIc and Subdivision IXa-north most of the *O. vulgaris* were caught by the artisanal fleet using traps, comprising more than 98% of octopus landings (Figure 3). The rest of landings is reported by the trawl fleet. However, this species is caught by the bottom-trawl fleet in the Subdivision IXa-South (Gulf of Cadiz), accounting for around 60% of the total catch on average, and the remaining 40% by the artisanal fleet using mainly clay pots and hand-jigs (Figure 3). In the last four years, the artisanal landings have exceeded significantly the trawl landings, providing around 70%-80% of the total catch. This may be due to a progressive increase in the declaration of artisanal landings at the octopus market as a consecuence of greater pressure by the fishing control. Subdivision IXa-South contributes to the total landings from the Division IXa with variable percentages that ranged between 16 % (285 t) in 2011 and 80% (2871 t) in 2005, with a 48% on average through the time-series. In figure 3, it can be observed these strong fluctuations in the octopus landing along the time-series in Subdivision IXa -South, with the minimum values in 2011 (285 t) and maximum values in 2013 (3785 t). However, this interannual fluctuations are less pronounced in Subdivision IXa-North. Possibly, such oscillations in

Subdivision IXa-south may be related with environmental changes such as rainfall and discharges of rivers (Sobrino *et al.*, 2002).

Most of the horned octopus *Eledone cirrhosa* is caught by the bottom-trawl fleet, which landings account for the bulk of the octopod landings in Subarea VII (416 t of average) and Subdivisions VIIIabd (180 t) (Figure 2). In the last two years, the trend tended to decrease. Horned octopus landings in Division VIIIc account for 24% (283 t), on average, of total octopods landings along the time-series. In Sub-division VIIIc-east the fishery statistics for the '*Octopodidae*' mixed species group correspond to *E. cirrhosa* landings in the case of the trawl fleet and to *O. vulgaris* for the artisanal fleet. The contribution of *Eledone* spp in the total cephalopod landings from Division IXa is higher in Subdivision IXa north, with 16% (339 t) of total landings and tending to decrease in the last two years, than in Subdivision IXa south, which contributed with only 6% (193 t) (Figure 4). In this last Subdivision, the main landed species is the musky octopus *Eledone moschata* instead of *E. cirrhosa*, that is caught in the Gulf of Cadiz by the trawl fleet as a by-catch due to its scarce commercial value (Silva *et al.*, 2004). This has been changing in the three last years, as it is possible to observe in the increase of landings during the past year, with almost 600 tonnes in 2015.

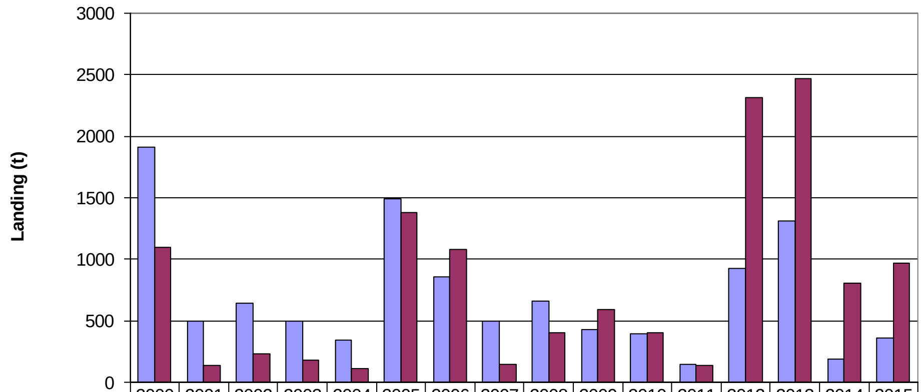


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	7032	3896	5150	4888	4882	6040	5238	4643	4920	3935	5776	5122	6391	7798	4689	4480
VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VII	387	326	851	475	371	449	425	400	399	389	464	832	4	630	149	108
VIIIabd	247	182	197	112	257	161	216	282	308	164	181	191	153	130	92	15
VIIIc	1193	1209	1165	1498	1466	1421	1433	1933	1476	961	2075	1743	1387	1133	1172	1075
IXa	5205	2179	2936	2804	2787	4010	3164	2027	2737	2421	3056	2355	4847	5905	3276	3283

Figure 2. Spanish landings (in tons) of octopus species (Fam. *Octopodidae*) by ICES Subarea/Division for the 2000-2015 period.

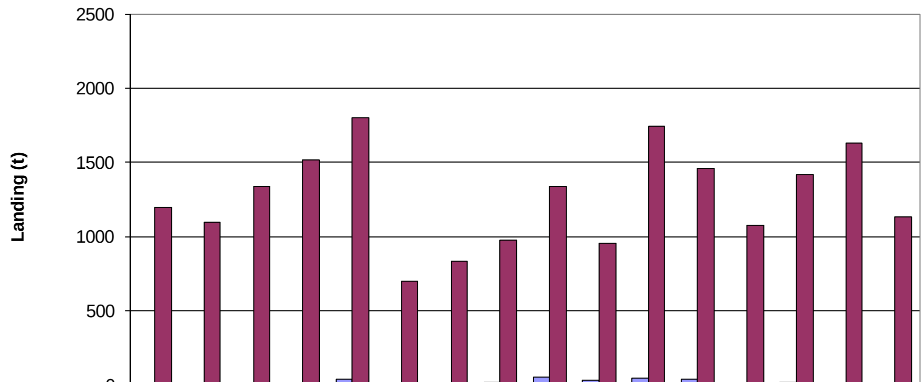
Octopus vulgaris

Subdivision IXa- South



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Trawler fleet	1915	498.4	644.6	495.6	342.2	1490	855	497	662.8	433.9	395.8	145.9	927.3	1317	186.8	359
Artisanal fleet	1101	139.2	234.3	181.5	112.3	1381	1077	149	401.9	595	402.7	139.3	2315	2468	803.4	973.6

Subdivision IXa- North

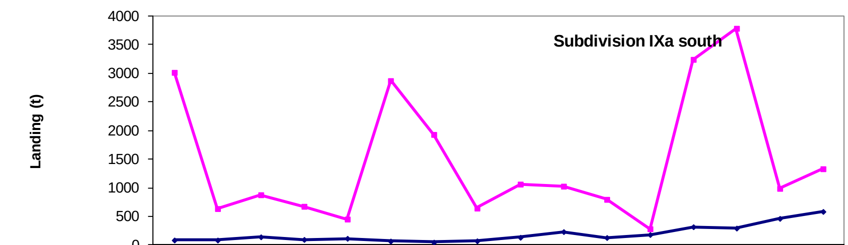


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Trawler fleet	0	6.546	4.857	9.793	37.35	4.169	3.835	18.19	53.88	28.84	49.58	42.48	11.81	18.13	8.807	2.99
Artisanal fleet	1201	1097	1337	1518	1798	700.8	836.6	977.4	1342	957.8	1741	1463	1078	1416	1633	1133

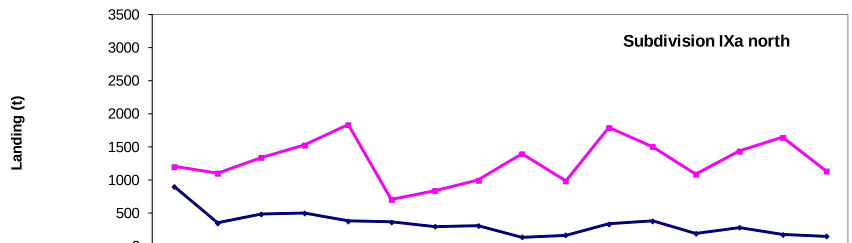
Division VIIIc

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Trawler fleet	5.818	7.388	3.925	5.33	50.88	3.966	22.89	15.49	15.81	2.976	79.58	55.1	36.59	76.16	19.51	16.7
Artisanal fleet	842.9	1126	914.3	881	1195	1168	802.2	1648	1412	859.5	1659	1502	1075	639.3	942	795.3

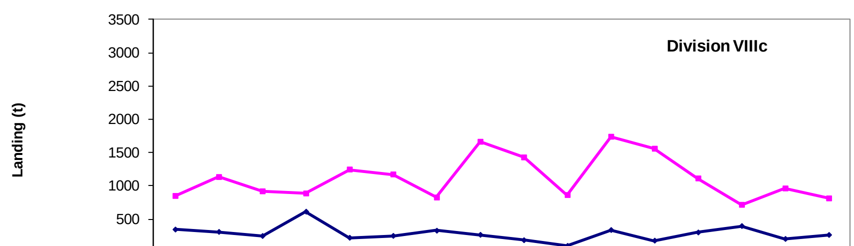
Figure 3. *O. vulgaris* landings (in tons) by fleet in Sub-division IXa south, Sub-division IXa-north and Division VIIIc, for the 2000-2015 period.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Eledone spp	88	88	144	99	118	70	51	74	136	235	132	184	320	296	466	587
O. vulgaris	3016	638	879	677	454	2871	1932	646	1065	1029	799	285	3243	3785	990	1333



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Eledone spp	901	350	486	501	380	364	301	311	141	170	335	380	194	286	175	154
O. vulgaris	1201	1104	1342	1528	1835	705	840	996	1395	987	1791	1505	1090	1435	1642	1136

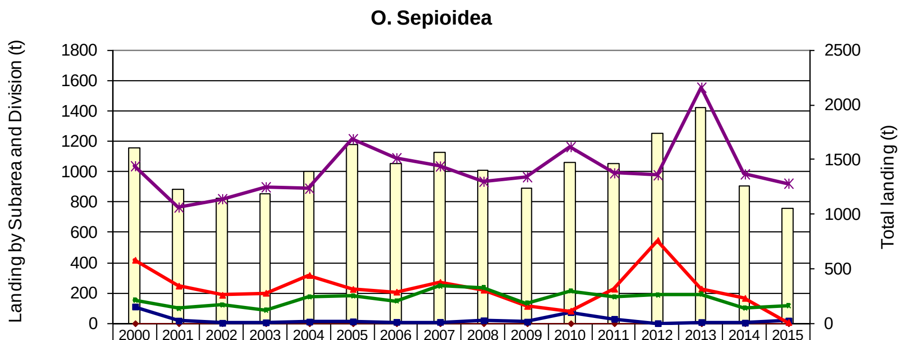


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Eledone spp	344	308	247	612	220	249	326	264	184	99	337	177	300	396	203	263
O. vulgaris	849	1133	918	886	1246	1172	825	1663	1428	863	1739	1559	1112	715	962	812

Figure 4. *Octopodidae* landings by species in Division VIIIc and IXa (north and south) for the 2000-2015 period.

Sepiidae

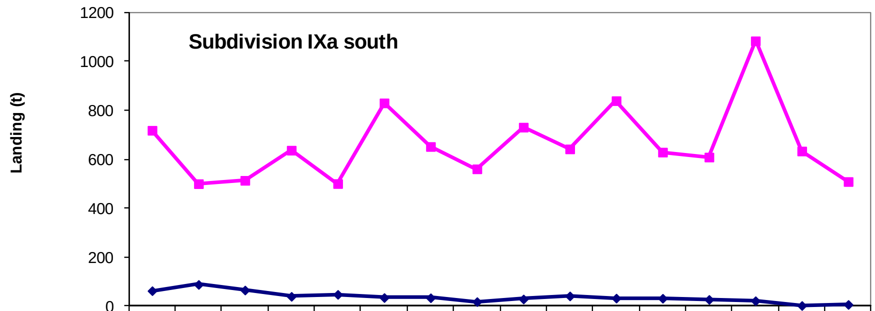
The cuttlefish annual landings trends by Subarea/Division is shown in Figure 5. Total landings ranged between 1985 t in 2013 and 1129 t in 2001. Since 2001, landings had been increasing until 2005 and 2007, when they reached the two new maximum values similar to those reached in 2000. Afterwards, landings decreased slightly up to 1224 t in 2010, reaching the highest values of the time-series in 2013, with an important decreasing trend in 2014 of 36% reduction in relation to the previous year. In 2015, the downward trend continued. Division IXa contributed with 70% of total cuttlefish landings by the Spanish fleet (1.021 t), with the 71% of landings in this Division corresponding to the Subdivision IXa-South (Gulf of Cadiz). Landings in Division VIIIc increased at the end of the analysed period, reaching 102 t in 2014, whereas in Division VIIIabd they showed a mean value of 170 t, with a marked drop in the last three years of the time-series, from 548 t in 2012 to 167 t in 2014. Landings in Subarea VII were below 20 t, and very scarce in the last three years, except in 2000 and 2010 with 110 t and 73 t, respectively, and they were almost absent in the Subarea VI.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	1609	1222	1147	1190	1389	1634	1459	1563	1402	1233	1473	1467	1742	1978	1261	1052
VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VII	110	18	3	6	11	12	9	9	19	11	73	29	1	8	4	17.99
VIIIabd	418	247	187	200	318	226	208	272	221	114	83	227	548	228	167	7.914
VIIIc	154	99	123	88	176	182	149	246	237	134	216	176	187	194	102	117.3
IXa	1037	765	820	899	889	1215	1090	1036	935	965	1164	991	978	1555	984	922.4

Figure 5. Spanish landings (in tons) of cuttlefish species (O. Sepioidea) by ICES Subarea/Division for the 2000-2015 period.

Cuttlefish (O. Sepioidea) landings from Subarea VII and Divisions VIIIabd mainly comprise common cuttlefish *Sepia officinalis* and, in a smaller amount, also elegant cuttlefish *Sepia elegans* and pink cuttlefish *Sepia orbignyana*. Bobtail squid *Sepiola* spp. hasn't been identified in most of the landings. Only *Sepia officinalis* and *Sepia elegans* are present in landings from Divisions IXa and VIIIc. Data on the proportion of each species is only available for Subdivision IXa-south, where *Sepia officinalis* makes up to 94% of cuttlefish landed (Figure 5). In this area, *Sepia elegans* and *Sepia orbignyana* appeared mixed in the landings, although the last specie is quite scarce. The commercial value of *Sepia elegans* is high, and for this reason is separated in the catch. During the 2014-2015 period, the landings of *Sepia elegans* in Subdivision IXa-South showed an important drop.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
S.elegans	63	89	66	40	48	35	34	19	29	42	33	32	28	22	3	7
S.officinalis	718	500	514	637	501	830	652	561	731	642	839	629	609	1084	634	509

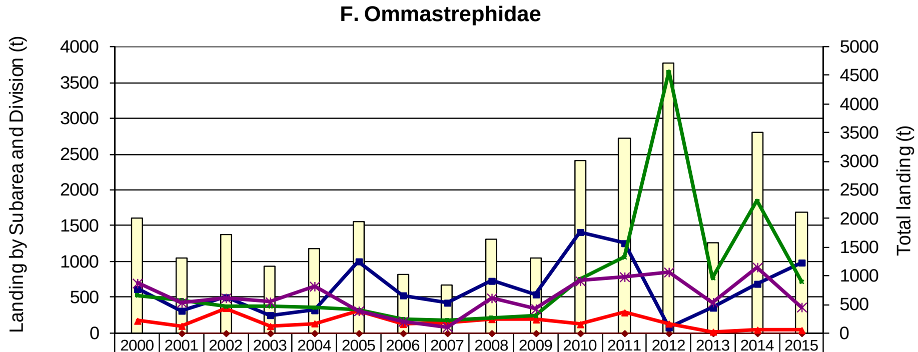
Figure 6. Sepiidae landings by species in Subdivision IXa south for the 2000-2015 period.

Ommastrephidae

Short-finned squid landings (Fam. *Ommastrephidae*) comprise mainly broad-tail short-finned squid *Illex coindetii* and lesser flying squid *Todaropsis eblanae*. European flying squid *Todarodes sagitattus* also appears in catches, but it is very scarce. Figure 7 illustrates the trends of both total landings of short-finned squids and by Subarea/Division. Total landings presented a mean value of 2020 t, with low values in the first half of the time interval. Afterwards, landings quickly dropped reaching a minimum of 834 t in 2007. In 2008, this value doubled in relation to the previous year, with a new decrease in 2009. In the last three years of the time-series a strong increase occurs, reaching the maximum values of 4718 tonnes in 2012, as in the rest of cephalopod groups. However, a sharp decrease is observed in 2013, with a decline of 3000 t in comparison to the previous year. It is possible that this decrease in landings is due to a change in the fisheries information source and the correct name assignment to each species landed. In 2014, an increase of 2000 t is observed in Figure 7, reaching the second maximum value in the time-series, followed by a drop of 1400 t in 2015.

The analysis by area shows scarce landings in Subarea VI throughout the time-series. From 2000 to 2004, the Division IXa contributed with the highest landings, ranging between 700 and 430 t. Since 2004, landings from Subarea VII increased, reaching two maximums in 2005 and 2008 of 1000 and 730 tons, respectively. The rest of Divisions showed decreased landings, sharing similar levels below 200 t, with only the División IXa experiencing a significant recovery in 2008. In 2010, all the Subareas and Divisions reached the maximum values, except Division VIIIabd which presented a slightly decrease in relation to the previous years. At the end of the time-series, both Division IXa and VIIIc showed considerable increases, mainly in Division VIII c, a value 300% greater than in 2011 (3651 t) was reached in 2012. Subdivision IXa–South accounts for the lowest values of the time-series with landings below 1% of the total short-finned squid species landings. In 2013, the landings decreased in all Divisions, except in Division VII, which showed a significant recovery. The decrease was most important in Division VIIIc, with a reduction of

80% in 2013. The reason has been described in the first paragraph. In 2014, all Divisions showed a significant increase of about 100% in relation to the previous year. However, only the Division VII showed an increase in 2015, with the rest of them showing an overall drop as it has been mentioned before.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	2017	1305	1718	1164	1471	1950	1018	834	1636	1314	3023	3397	4718	1580	3508	2115
VI		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
VII	616	313	501	252	320	1003	528	426	731	541	1413	1257	79	356	689	986
VIIIabd	172	101	351	98	136	315	127	141	196	190	124	289	133	20	48	42
VIIIc	530	462	373	377	359	319	199	180	219	240	756	1062	3651	771	1848	722
IXa	699	429	492	438	656	312	164	87	491	342	730	788	854	433	923	365

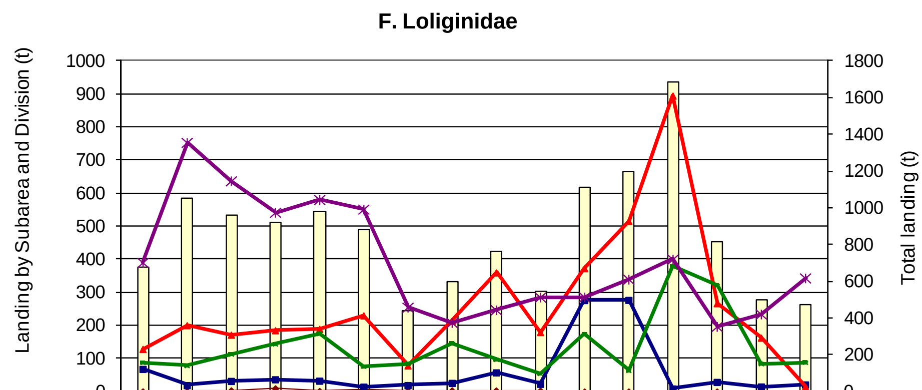
Figure 7. Spanish landings (in tons) of short-finned squid species (Fam. *Ommastrephidae*) by ICES Subarea/Division for the 2000-2015 period.

Loliginidae

Long-finned squid landings (F. *Loliginidae*) consists mainly of common European squid *Loligo vulgaris*. Three other species are present in unknown proportions. Of these, veined squid *Loligo forbesi* is currently thought to be very scarce, with variable presence in landings. Squids of the genus *Alloteuthis* (*Alloteuthis media* and *Alloteuthis subulata*) are mainly present in squid landings from Sub-Division IXa-South, showing low catch levels in Sub-Division IXa north during the same years.

Figure 8 shows the trend of total long-finned squid landings and by Subarea/Division. Total landings presented a maximum value of 1052 t in 2001, afterwards they remain more or less stable at around 900 t until 2006, when they showed a drop, reaching the minimum value in the time-series of 441 t. An increasing trend is observed from this year up to 2012, reaching the maximum value in this year of 1683 t, indicating a considerable recovery of landings. However, the landings decreased in all Divisions in 2013, with only a slight recovery in Division VII. This trend to decrease kept going in 2014. The reason could be the same as in the case of *Ommastrephidae*. In 2015, global landings remained stable although there was a strong drop in the subarea VIIIabd and an appreciable increase in the IXa.

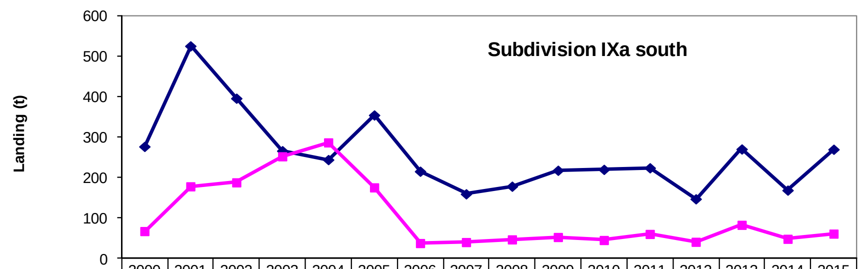
The analysis by Subarea/Division showed that the Division IXa recorded the highest landings from 2001 to 2005, with values ranging between 753 and 552 t, respectively. The 2007 landings fell to 200 t and remained stable during three years with an increasing trend up to 2012 when the maximum value is reached (401 t). In 2013, the landings decreased by 50% in relation to the previous year, with a slightly recover in 2014 that continued throughout the 2015, when the 343 t were reached. Landings in Division VIIIabd and VIIIc were lower than in IXa, except at the end of the time-series, oscillating between 128 t in 2000 and 895 t in 2012, and between 76 t in 2005 and 378 t in 2012, respectively. In 2015, the lowest value of the time-series which was only 15 t, was registered in the Division VIIIabd. Landings in Subarea VII were also very low as compared with other areas, with a mean value of the annual landings of only 30 t, but they showed a significant increase in 2010 and 2011, as also happened in Division VIIIc and VIIIabd. The Subarea VI showed very scarce landings, below 10 t, as it was also mentioned above for the other analysed groups of cephalopod species, without landings in the last years. Only 2 t were registered in 2015.



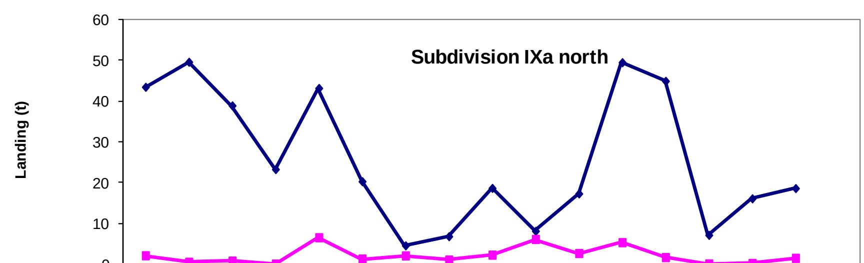
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	676	1052	958	917	980	880	441	598	765	546	1109	1196	1683	814	496	470
VI	0	1	3	10	2	8	2	3	3	3	0	0	0	0	0	2
VII	68	19	32	37	33	15	19	26	58	23	277	277	9	29	15	21
VIIIabd	129	201	172	185	190	230	79	214	360	180	373	516	895	267	163	15
VIIIc	88	78	113	144	175	76	85	146	97	55	173	63	378	321	84	88
IXa	390	753	637	542	581	552	255	209	247	286	286	340	401	197	234	343

Figure 8. Spanish landings (in tons) of long-finned squid species (Fam. *Loliginidae*) by ICES Subarea/Division for the 2000-2015 period.

Both in Sub-divisions IXa south and north, *Loligo spp* and *Alloteuthis* spp landings appear separated due to their high commercial importance. Figure 9 shows the proportion of each species group by Sub-Division. Both groups yielded higher landings in IXa south than in IXa north. *Alloteuthis* spp landings in IXa south ranged between 286 t in 2004 (i.e. higher landings than *Loligo* spp ones in this year) and 38 t in 2006, whereas in IXa north the highest record was 6.5 t in 2004. In both Subdivisions, the first half of the time-series in both Subdivisions recorded the highest landings, although *Loligo* spp. showed an important increase in 2011-2012 in Subdivision IXa-north, with landings of around 45 t. In 2013, the landings of these species decreased significantly in Subdivison IXa-north, while in IXa south there was a 100% increase in relation to the previous year. Lower values were recorded in 2014, followed by a 22% increase in 2015. Finally, it is worth mentioning that in the last few years *Alloteuthis africana* is also occasionally present in the Gulf of Cadiz (IXa-South) landings, mixed with the other *Alloteuthis* species (Silva *et al.*, 2011).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Loligo spp	276.8	524.8	395.8	266.3	244.4	354.4	215.6	159.9	178.7	218.0	220.2	224.1	147.6	270.5	169.1	269.9
Alloteuthis spp	68.0	178.4	188.2	252.5	286.8	175.8	38.5	40.9	47.5	53.4	46.0	60.9	41.6	83.4	49.0	61.8



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Loligo spp	43.4	49.5	38.8	23.2	43.1	20.3	4.5	6.8	18.6	8.1	17.3	49.4	44.9	7.1	16.1	18.6
Alloteuthis spp	2.1	0.5	0.8	0.1	6.5	1.3	2.1	1.0	2.3	6.1	2.6	5.3	1.7	0.1	0.2	1.5

Figure 9. Long finned squid landings by species in Sub-Division IXa south and north for the 2000-2015 period.

Discard ratio

The discarded fraction has been estimated with the information got form the sampling programs carried out by the observers aboard the fishing vessels in the several bottom trawl fleets. Table II shows the discarded fraction in relation to the total amount of landings by species or group of species, for the different trawling métiers, by Sub-area/Division. The Sub-areas VI-VII exhibits the higher estimates of discards, while the smaller values were registered in the Sub-Division IXa south. The most discarded species for the time period 2003-2015 were *Eledone cirrossa,* with mean values around 52% of the total catch along with the *Ommastrephidae* group, which accounted for 55% in the Sub-areas VI-VII. In the División VIIIc and Sub-Division IXa north, both species/group of species showed lower mean values (around 18% less). It's likely that this low commercial value is related to the high discarding rate.

The lowest discard estimates proceed from the bottom trawl metier of the Sub-Division IXa south (Table II). The estimates mentioned before have mean values for the period 2005-2015 which oscillated between 5 % for *Eledone sp* and *Octopus vulgaris* and less than 1% registered for *Loligo sp*, Ommastrephides and *Sepia oficinalis.* The highly multispecific nature of the OTB_MCD metier in the Sub-Division IXa, and that they take advantage of everything that is fished by the fleet makes the discards estimates to be low. The highest peaks observed for *O. vulgaris* between 2009-2011 occurred because of a high recruitment and also a tougher control by the fishing control. The last mentioned caused an increase in the discarding of octopus with less than 1 kg (Minimum capture weight: 1 kg; BOE nº 290, Orden de 22 de noviembre de 1996). (Santos *et al.*, 2012)

			% discard from total catches												
Gear	Area	Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
OTB	VI-VII	Eledone cirrhosa	59.0	34.2	50.8	46.0	66.5	59.9	72.3	38.7	71.2	96.6	12.7	52.8	23.8
		Loligo spp.	52.0	24.0	73.0	80.0	92.0	65.0	26.0	12.0	4.4	35.4	0.7	1.1	10.8
		Octopus vulgaris	0.0	100.0	100.0	91.0	0.0	0.0	0.0	37.0	0.0	0.0	10.3	0.0	0.0
		Ommastrephidae	90.1	79.2	68.7	71.4	79.5	74.3	77.3	29.4	10.7	74.4	32.7	18.0	12.4
		Sepia officinalis	77.4	8.7	5.9	76.6	4.6	21.7	2.4	0.0	0.5	94.6	21.8	0.7	0.0
OTB_MIX OTB_HOM OTB_MAC	VIIIc + IXa north	Eledone cirrhosa	8.0	26.0	8.2	23.0	18.6	5.9	36.7	5.2	24.2	14.0	35.7	22.4	11.7
		Loligo spp.	2.0	1.0	12.0	1.0	1.0	2.0	7.0	2.0	61.0	0.3	43.3	0.7	0.0
		Octopus vulgaris	6.0	4.4	34.0	7.0	39.0	0.8	12.0	3.1	25.3	1.3	0.0	0.0	0.9
		Ommastrephidae	10.8	26.7	18.7	11.4	20.6	19.4	13.9	6.5	27.0	6.1	73.0	3.8	6.5
		Sepia officinalis	60.8	0.9	13.1	60.5	1.2	1.2	17.7	5.9	33.6	11.4	0.0	3.3	0.0
PTB	VIIIc + IXa north	Eledone cirrhosa	0.0	0.0	64.0	63.0	94.0	31.6	90.3	95.5	36.8	0.6	0.0	94.6	100.0
		Loligo spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0
		Octopus vulgaris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Ommastrephidae	2.1	1.5	10.5	3.7	2.7	2.6	8.9	0.5	1.1	0.1	2.0	0.8	2.4
		Sepia officinalis	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	100.0	0.0	0.0	0.0	0.0
OTB	IXa - south	Alloteuthis spp	-	-	0.0	0.0	0.0	0.0	3.2	4.5	7.1	0.0	2.6	0.7	0.0
		Eledone spp	-	-	0.0	0.0	1.1	4.5	16.8	19.0	11.4	0.0	4.3	1.6	2.1
		Loligo vulgaris	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.1
		Octopus vulgaris	-	-	0.0	3.1	0.0	18.8	35.1	0.0	1.6	1.9	0.0	0.0	0.0
		Ommastrephidae	-	-	0.0	0.0	0.0	0.0	2.0	5.8	0.0	0.0	1.2	0.0	0.0
		Sepia elegans	-	-	0.0	0.0	0.0	2.1	9.0	2.7	1.2	0.0	21.1	5.1	0.0
		Sepia officinalis	-	-	0.2	4.0	0.0	0.0	0.0	0.5	0.0	3.2	0.7	0.0	0.0

Table II. Estimated discarded fraction of the total catch for the main species/groups of species by Sub-area/Division. 2003-2015 period.

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Working Document 2.

ICES Working Group on the Cephalopod Fisheries and Life History

Tenerife (Spain), 8–11 June 20154

UPDATE OF THE BASQUE CEPHALOPOD FISHERY IN THE NORTHEASTERN ATLANTIC WATERS DURING THE PERIOD 1994-2014

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1. INTRODUCTION

Up to 2014 AZTI-Tecnalia is monitoring monthly cephalopod landings, catch, and discards, and fishing effort by gear and sea area of the Basque Country ports. Compilation and updating of the cephalopods catches made by the Spanish and Basque fleets landed at the Basque Country ports is updated every year.

Cephalopod catches were considered as by-catches of other directed demersal fisheries operated by the Basque fleet, targeting hake, anglerfish and megrim and more than other 30 species until some years ago. These demersal fisheries operate in different sea areas – ICES Sub-areas VI, VII and Divisions VIIIa,b,d (Bay of Biscay) and VIIIc (eastern Cantabrian Sea)- and different gears: bottom trawl, pair-trawlers, longliners, purse-seiners, nets, artisanal hook and lines and traps or pots. However, in the last years cephalopods obtained in mixed fisheries (mainly "Baka" Otter trawls) are becoming more important in relation to the species composition of the catch and for some trips nowadays they are target species.

In this document, data of the Basque Country cephalopod landings from 1994 to 2014 are presented. Catch data correspond to groups of similar species comprising more than two or three species, with similar appreciation in the markets. Data available were compiled in the following commercial species groups according to local names:

- Squid: mainly *Loligo vulgaris* and also, *L.forbesi, Alloteuthis media* and *A.subulata.*

- Cuttlefish: mainly *Sepia officinalis* and also *S.elegans* and *S.orbignyana.*

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- Short-finned squid: mainly *Illex coindetii* and also *Todaropsis eblanae*, and European flying squid: *Todarodes sagitattus*,

-Octopus: mainly *Eledone cirrhosa* and also *Octopus vulgaris.*

Most of the large trawlers of the Basque Country catch cephalopods mainly in the Bay of Biscay (Div. VIIIa,b,d), but also in Sub-area VII (Celtic Sea and Porcupine Bank) and in Sub-area VI (both in the western part of Scotland and around Rockall Bank). Local trawls, artisanal gillneters and some pots or trap vessels working usually in the eastern Cantabrian Sea (Div. VIIIc) also catch some cephalopods.

The target species are usually mixed demersal fish, mainly hake, megrim or anglerfish, but together with those, variable quantities of cephalopods are caught. The proportion of these catches varies in relation to the sea area, the gear used and the distinct seasonality of these species. In the last years an important increase of cephalopod landings is observed in Basque trawling fleet.

2. RESULTS

2.1. Landings of cephalopods in Sub-areas VI, VII and Div. (VIIIa,b,d)

During 2014 and in Div. VIIIa,b,d, the largest landings of squids were recorded during November and December, reaching to 43 t in November. For cuttlefish landings reached a peak of around 42 t in February. Short-finned squid maximum landings occurred in December being around 13 t. Landings of octopus were higher in Div. VIIIa,b,d during January reaching around 14 t (Figure 1).

In Figure 2 percentage of landings by species groups and sea area in 2014 are presented. Landings from Div. VIIIa,b,d for squids comprise 96% and for cuttlefish 97%. In the case of short-finned squid 34% and for octopus the 90% of landings came from Div. VIIIa,b,d.

For 2014, each of the cephalopod groups contributed evenly to the total cephalopod catches, 29% squids, 35% cuttlefish, 14% short-finned squid and 22% octopus. 87% of total cephalopod landings came from Div. VIIIa,b,d (Figure 3).

Looking at the catch evolution of squid and cuttlefish during the period 1994-2014, the most remarkable feature is the continuous seasonality of the landings in all areas (Figure 4). The largest landings occur from October to February for all cephalopod species, and also a marked alternation of years of rather high and low landings is observed mainly in squids. For all data series, no cuttlefish, short finned squid and octopus landings were registered in Sub-area VI. The great fishery *reservoir* for all species groups appears to be the sea area comprises within Div. VIIIa,b,d. Catches evolution of short-finned squid does not present the marked seasonality described for the other species groups, however maxima landings are registered from March and April almost till June. Octopus higher landings are registered during autumn and winter months.

Cephalopod historical landings deployed by Basque vessels show an important decreasing trend from 1994 to 2001 (Figure 5). From 2002 onwards, the total landings of cephalopods remain quite stable but with inter-annual fluctuations. From 2009 and increasing trend is observed and in year 2012 landings are close to the maximum level of the time-series with the peak in 1994. For 2013 and 2014, an important decrease of cephalopod landings, mainly of squids, has been observed.

Focusing on fishing effort (Figure 6) it shows a decreasing trend from 1996 to 2013 which is caused by the disappearance of some Basque vessels in the last years due to regulation implementation and other different factors. In year 2014 a slight increase in Baka" otter trawler was observed in Division VIIIabd.

Nowadays, the most important Basque fleet targeting cephalopods are "Baka" bottom otter trawlers in the Division VIIIa,b,d. Within this fleet three different metiers have been defined following the criteria defined in the European Data Collection Framework:

-OTB_DEF_>=70 (otter trawlers targeting demersal fish).

-OTB_MCF_>=70 (otter trawlers targeting mixed cephalopod and demersal fish).

-OTB_MPD_>=70 (otter trawlers targeting mixed pelagic and demersal).

Landings of the different species have been included in one or other metier following the segmentation above. From 2009 to 2012, the metier targeting cephalopods OTB_MCF has increased its number of trips and its cephalopods catches but in the last year 2013 and 2014 it has decrease significantly (Figure 7). The decrease in the OTB_MCF metier seems to be related to the increase in OTB_DEF metier targeting demersal species like hake, megrim or anglerfish.

2.2. LPUE of cephalopods in Sub-areas VI, VII and Div. (VIIIa,b,d)

1. In the last years, fleet composition has changed in the Basque ports and nowadays there are mainly three fleets targeting cephalopods, which are:

2. . Baka-trawl-Ondarroa in Div. VIIIa,b,d

3. . Baka-trawl-Ondarroa in Sub-area VI

4. . VHVO Pair Trawl-Ondarroa in Div. VIIIa,b,d

5. All of them, together considered, represented close to 97% total cephalopod landings in the Basque Country ports in 2014.

6. In 2009 the Baka-trawl-Ondarroa in Sub-area VII did no effort and change its fishing area to Division VIIIa,b,d. So for the last years only 3 of them will be active and will provide effort information.

7. Effort for each fleet was obtained from the information provided yearly by the log books filled out by the skippers of most of vessels landing in Ondarroa and Pasajes, and processed by AZTI-Tecnalia. The effort unit used has been the fishing days.

8. When summing up all cephalopod landings and divided them by main fleets fishing efforts, the landing per unit of effort are obtained (LPUE) (Figure 8). This figure shows a stable situation in LPUE from 1995 till 2002 but important fluctuations with high and low abundances are observed in short fined squids data series. During the last period of the series, and in relation to Div. VIIIabd, LPUEs for squid and cuttlefish have markedly increasing whilst, octopus and short-finned squid have, in general, decreased. In Subarea VII, Octopus LPUEs have markedly decreased since 2007, mainly driven by the decrease in the effort deployed by the Basque fleet in that area. Octopus caught in this area is mainly *Eledone cirrhosa* catches of this species in the last year are nil. Short finned squids LPUEs are maintained at low levels along data series despite a sharp increase in 2010 due to a high catch in a unique trip deployed by “Baka” otter trawlers in Subarea VII. In year 2013 and 2014 an important decrease in LPUE of squids and cuttlefish is observed in Div. VIIIabd.

2.3. Discard estimation of cephalopods

Since 2001, a discard sampling program has been carried out by the AZTI-Tecnalia on the Basque fleet (North Spain). Sampling developed during 2001 and 2002 correspond to the Study Contract (98/039). From 2003 onwards, AZTI-Tecnalia has continued sampling discards onboard commercial fleet under the National Sampling program. Only the trawl fleet is considered in this study, since the rest of the segments of the Basque fleet in the North East Atlantic like purse seine, etc. (Ruiz, *et al.* 2009) have negligible levels of discard.

1. The sampling strategy and the estimation methodology used in the “Discard Sampling Programme” have been established following the “*Workshop on Discard Sampling Methodology and Raising Procedures*” guidelines (Anon., 2003). The observers-on-board programme is based on a stratified random sampling, considering the Fishery Unit as stratum and the trip as sampling unit.

2. Landings and effort are used in the raising procedure; nevertheless, only discard estimates using effort as raising procedure are presented in this document.

Although the sampling tried to cover all species retained and discarded in the different fleets, no length sampling was carried out for any of them. Thus, no length distribution and numbers of all discarded and retained cephalopod species were estimated whilst weights retained and discarded were obtained.

In Table 1 the amount of estimated cephalopods discarded (in percentage) during 2003-2014 series is presented.

In general terms, it can be said that:

- Short-finned squid mainly and curled octopus (*Eledone cirrhosa)* in a lesser extent are the most discarded species because of their low price in market.

- In Subarea VII, there is no effort deployed by the fleet from 2012-2014, so no discard information is available.

- A revision of discard from year 2012 has been presented. An important change in the exploitation pattern of cephalopods was observed as discards in all fleets of the Basque fleets have reduced their discards significantly.

- Data presented in this document has to be considered as very preliminary. Thus, discard data here presented has to be taken just as reflect of the discard practices carried out by these fleets and never as absolute numbers.

2.4. Prices of cephalopods in Basque ports

Cephalopod prices in Basque ports from 2001 to 2014 are presented in Figure 9. The price given is the mean value of both landing ports Ondarroa and Pasajes. It can be observed that the mean value has remained quite stable in the last eleven years. Squids have the best price of landed cephalopod that goes from 6 euro in 2001 to 9.37 euro in 2013. Cuttlefish is the second better paid which goes from 2.50 euro in 2001 to 4.38 euro in 2014. Octopus had the peak in price in 2003 but after that it has decrease some years and in 2009 it was around 3.10 euro. Finally, the short-finned squid, which is the cephalopod with lower prices in the time-series, shows a price of 1.53 euro in 2014.

In general terms, prices of cephalopods hardly have increased in the last fourteen years. Only in squids and cuttlefish is observed a slight increase in the last three years.

3. CONCLUSIONS

Cephalopod historical landings trend from 1994 to 2014 should be more in detail analyzed. A study should be desirable to define if changes in landings are due to changes in fisheries/metiers (fishing strategies due to market reasons), differences in fishing capacity or a real change in the abundance of these species. The comparison of the historical landings of cephalopods and LPUE data shows that LPUE data present in the last three years of the time-series the same decreasing trend as landing data. Therefore, one conclusion could be that landings decrease and the abundance indices (LPUE data) of the fleets analyzed do show this decreasing trend in the abundance of some cephalopods mainly squids and cuttlefish.

The contribution of the different cephalopods species groups to the total landing composition has been updated from 2005 to 2014. From previous studies, cephalopod proportion in the landings markedly increased from around 8% in 1997 to almost twice in 2001 in "Baka" otter trawls operating in Div. VIIIa,b,d (Santurtun *et al.*, 2005, WD), coinciding with the bad shape of the hake stock. In the last studied five years, the cephalopod proportion in landings is around 15% with a peak of 28% in year 2007.

Cephalopods appears to be an important accessory species for the baka trawlers in division VIIIa,b,d due to, specially, reduction of quotas of some traditional demersal species during the period 2002-2005, with apparent constant availability and relatively good market prices. In the period 2009-2012 effort of the mixed cephalopod metier (OTB_MCF) has yearly increased and landings of the metier have also increased but in the last two years 2013 and 2014 the effort has decreased significantly. This shows a change in the fishing exploitation pattern if the Basque trawlers having cephalopods as target species in some periods of the year due to the good price of these species and the lack of quota for them.

The analysis of prices shows that in the last twelve years there has been hardly increase in prices of cephalopods, as it has also occurred for the rest of the main demersal commercial species. The squids remain being the cephalopod with highest price with an increasing trend in the last two years and the short-finned squid and octopus are the ones with lowest price.

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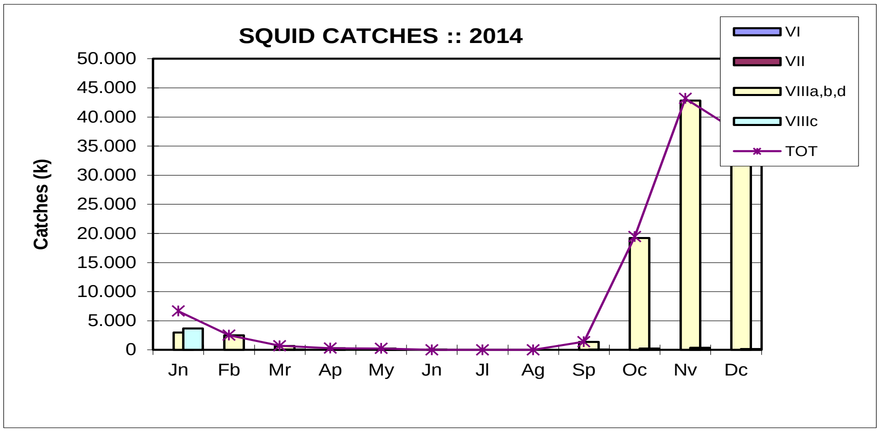

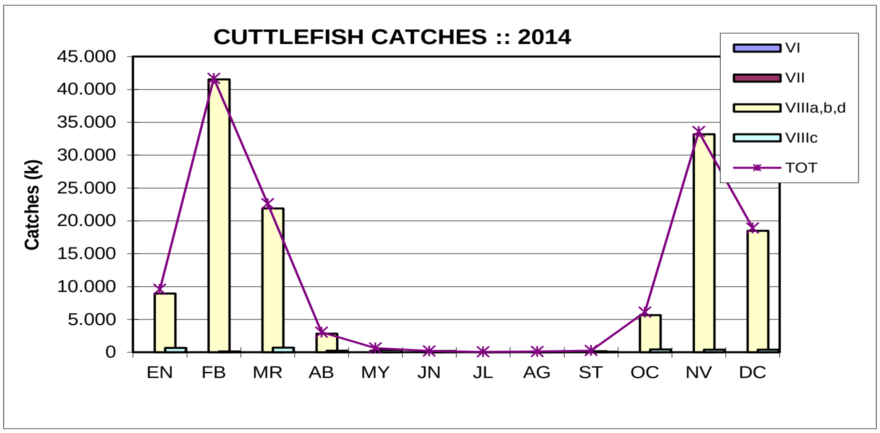

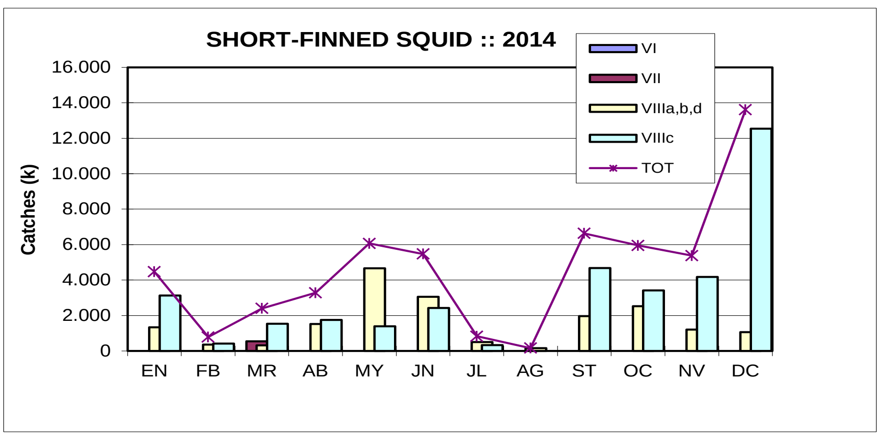

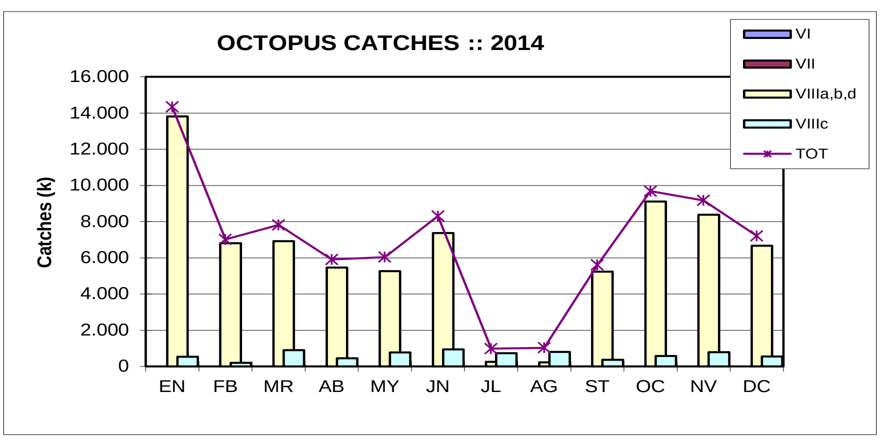

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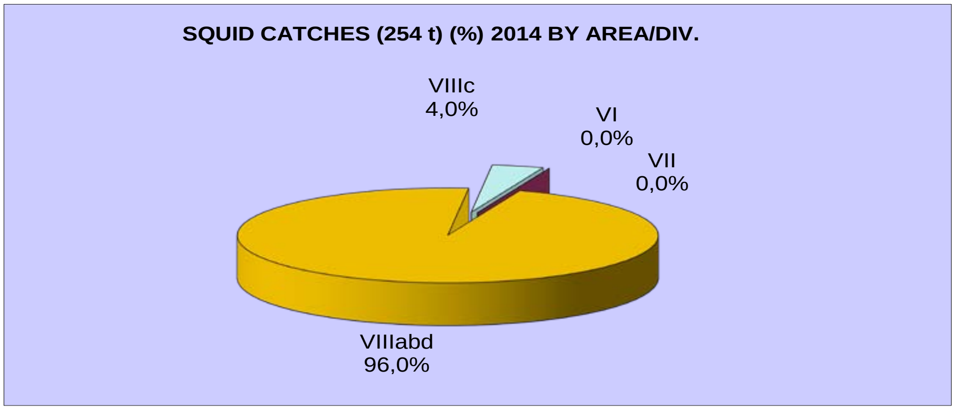
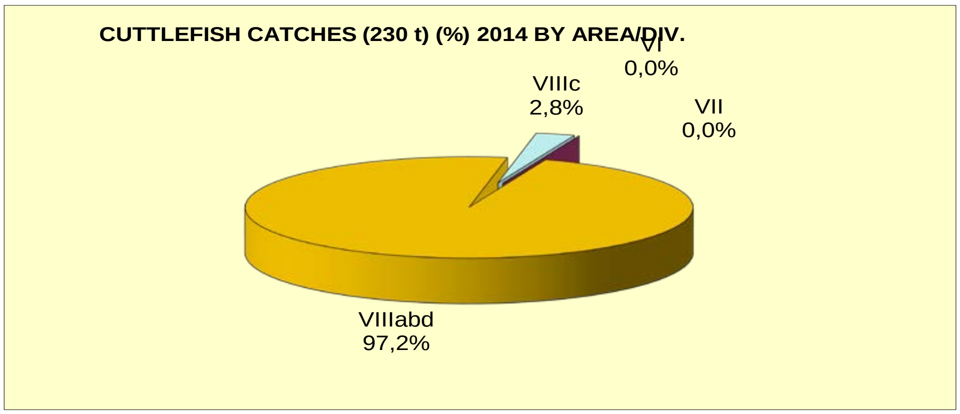
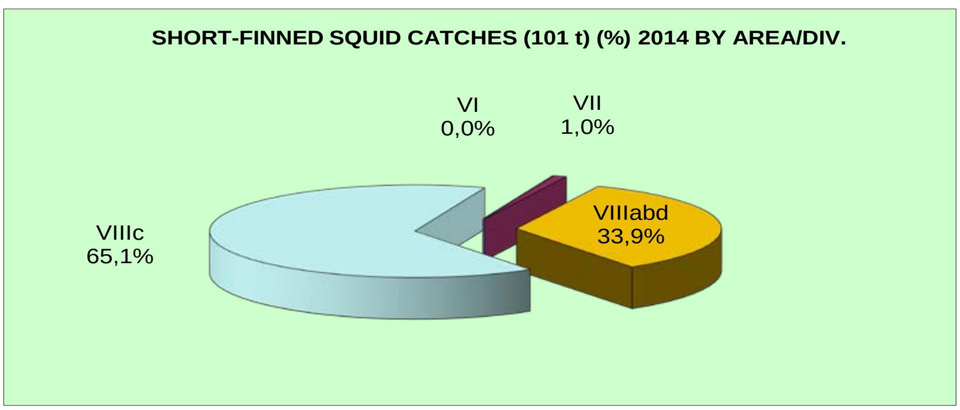
Figure 2. Monthly distribution of the Basque Country Catches (land-


SQUID CATCHES (254 t) (%) 2014 BY AREA/DIV.
VIIIc
4,0%
VI
0,0%
VII
0,0%
VIIIabd
96,0%


CUTTLEFISH CATCHES (230 t) (%) 2014 BY AREA/DIV.
VI
0,0%
VIIIc
2,8%
VII
0,0%
VIIIabd
97,2%


SHORT-FINNED SQUID CATCHES (101 t) (%) 2014 BY AREA/DIV.
VI
0,0%
VII
1,0%
VIIIc
65,1%
VIIIabd
33,9%

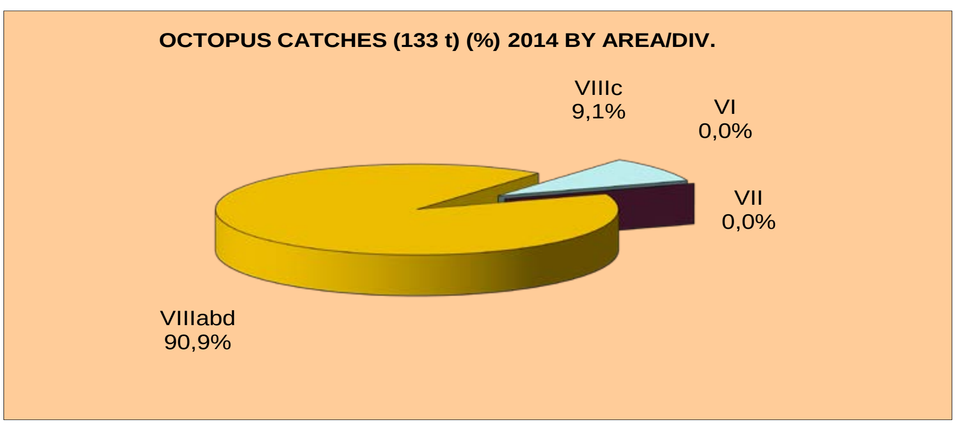
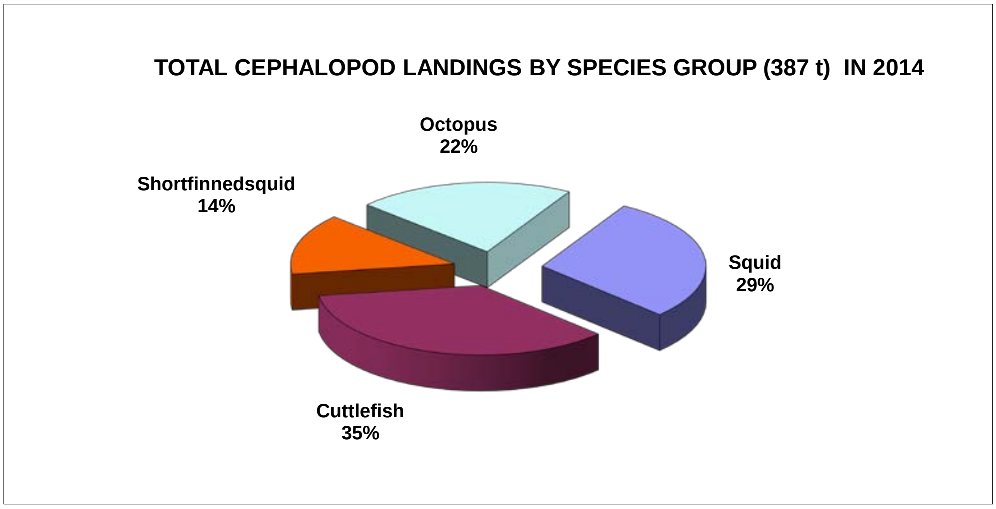

OCTOPUS CATCHES (133 t) (%) 2014 BY AREA/DIV.
VIIIc
9,1%
VI
0,0%
VII
0,0%
VIIIabd
90,9%

Figure 3. Percentage of the Basque Country landings of Squid, Cuttlefish, Short-finned squid and Octopus by sea area, in 2014.



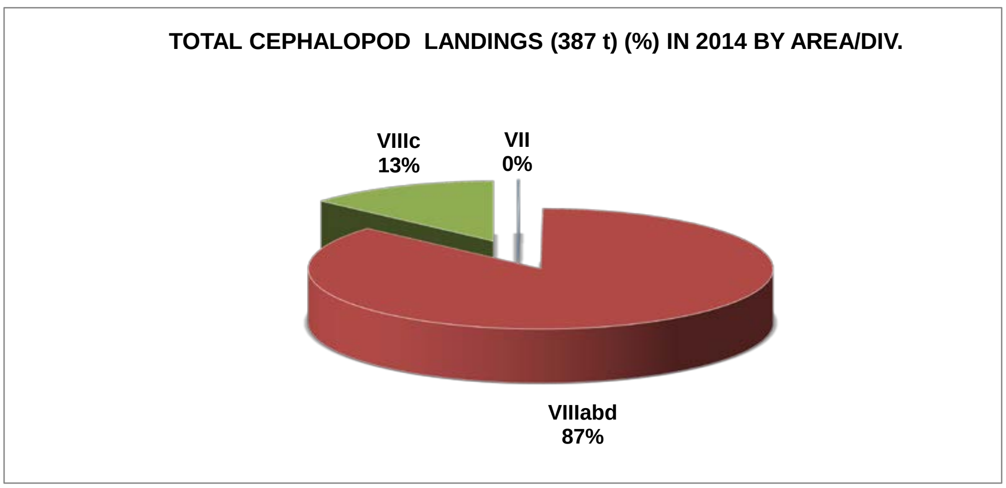


Figure 4. Total composition in percentage of the Basque Country landings. Above: By species group. Below: By sea area for 2014.

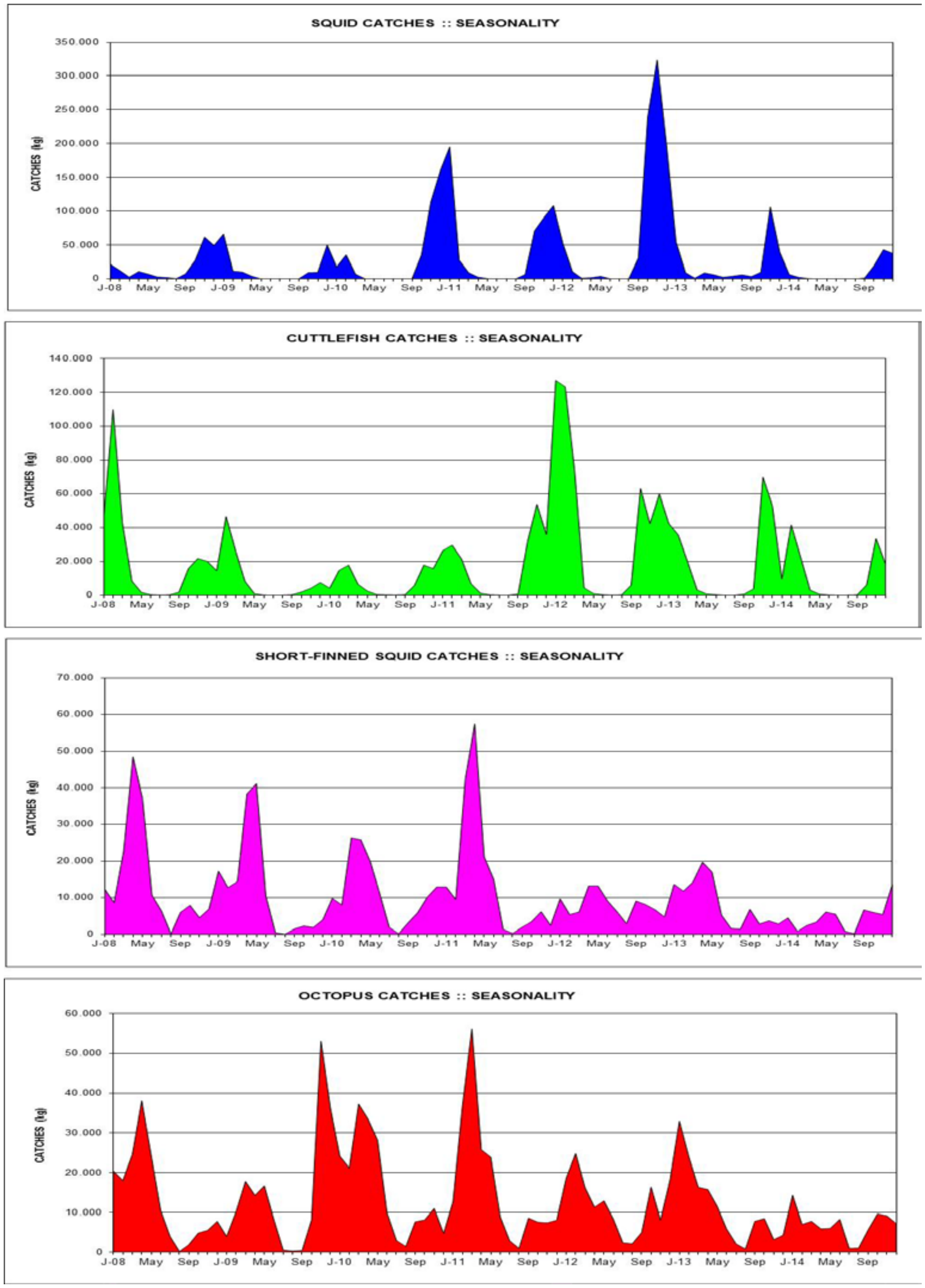


Figure 5. Cephalopods landing (in kg) evolution of the Basque Country by species group considering all areas together (VI, VII, VIIIabd and VIIIc) for the total period 1994-2014.

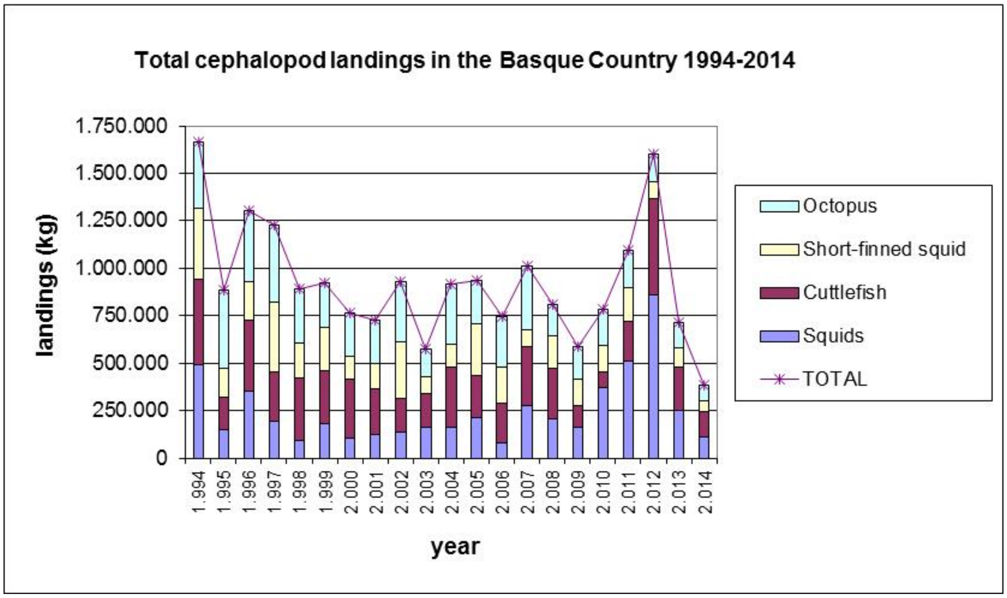


Figure 6. Cephalopods landing evolution of the Basque Country by species group for the total period 1994-2014.

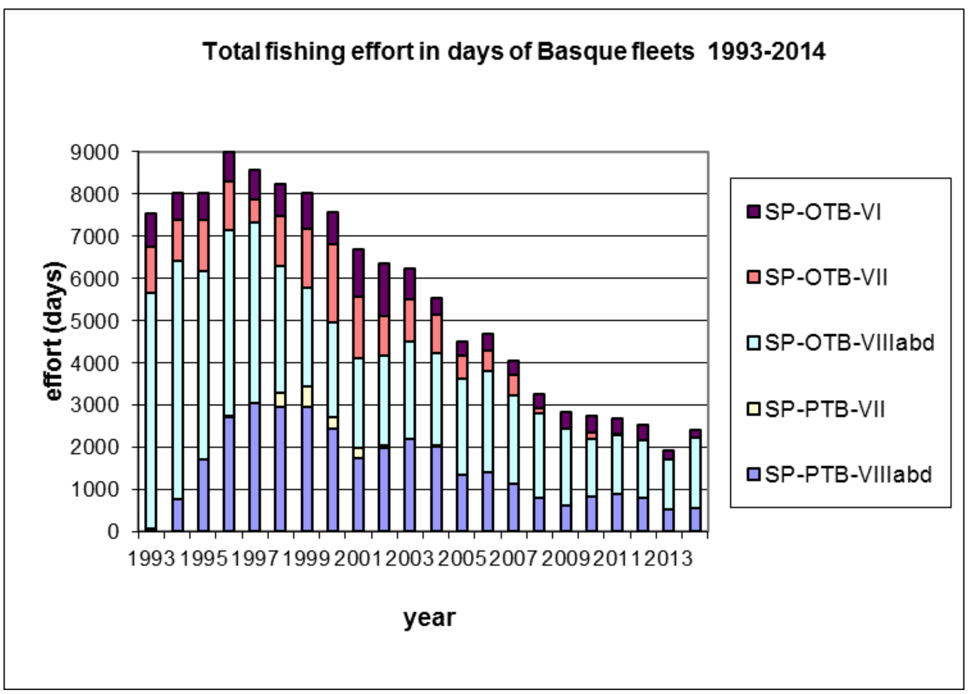


Figure 7. Total fishing effort of the Basque fleets from 1993 to 2014.

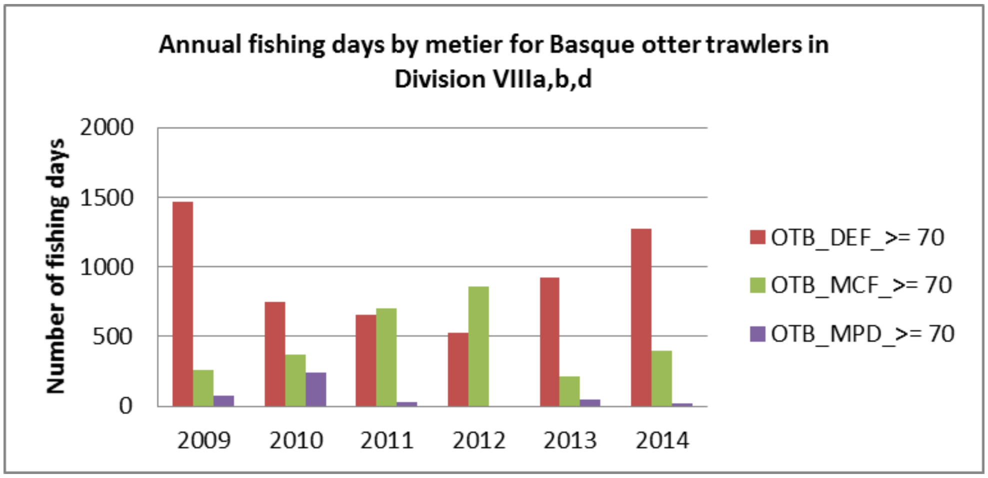


Figure 8. Annual fishing days by metier for Basque bottom otter trawlers operating in Division VIIIa,b,d during 2009 to 2014.

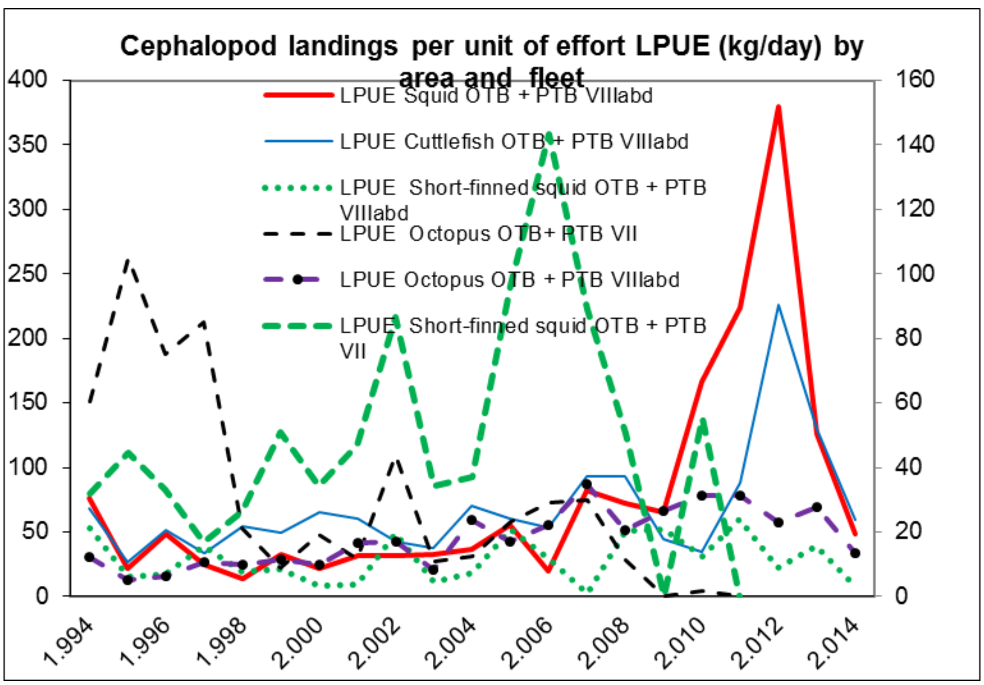


Figure 9. Cephalopod landings per unit of effort (kg/day) of the Basque fleet from 1994 to 2014.

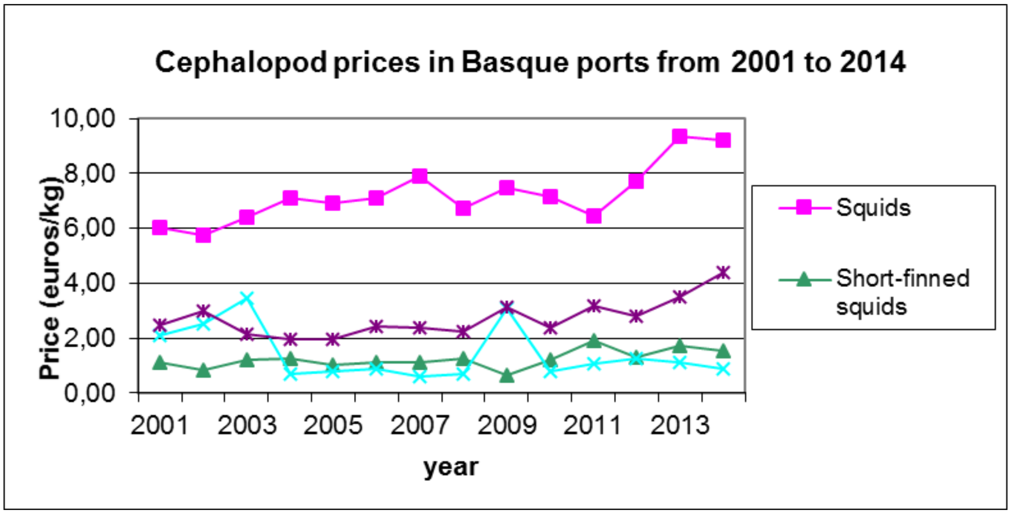


Figure 10. Cephalopod prices in Basque ports from 2001 to 2014.

Table 1. Estimated cephalopod discard (kg) during 2003-2014 series is presented.

Gear	Area	Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*	2013	2014
OTB	VI	Short finned squid	100 %	-	-	-	-	100 %	100 %	100 %	100 %	-	-	
		Curled octopus	-	-	-	-	-	-	-	-	-	-	-	
		Cuttlefish	-	-	-	-	-	-	-	-	-	-	-	
	VII	Short finned squid	61 %	77 %	19 %	4%	52 %	87 %	-	-	-	-	-	
		Curled octopus	33 %	1%	38 %	12 %	56 %	-	-	-	-	-	-	
		Cuttlefish	12 %	-	-	-	-	-	-	-	-	-	-	
	VIII abd	Short finned squid	59 %	57 %	17 %	35 %	38 %	12 %	15 %	31 %	87 %	16 %	31 %	67 %

		Curled octopus	28 %	5%	7%	0%	19 %	2%	14 %	5%	74 %	1%	1%	7%
		Cuttlefish	0%	1%	2%	-	1%	-	8%	-	3%	0%	3%	0%

*Updated in year 2013.

% discard from total catches.

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Update of the English Channel cuttlefish stock assessment with a Bayesian two-stage biomass model

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ABSTRACT

A two-stage biomass model is developed in the Bayesian framework that allows us to assimilate various sources of information. A method that makes use of ancillary length frequency data is developed to provide an informative prior distribution for the intrinsic biomass growth rate parameter and its annual variability. The new Bayesian model provides substantial improvement to the existing stock assessment method used by ICES. Considering a time-varying *g* parameter improves model fit and improves the ecological realisms of the model according to the sensitivity of the cuttlefish population dynamics to environmental fluctuations. We present results of the English Channel cuttlefish stock assessment updated with the new Bayesian model. The model also provides predictions of the unexploited biomass in winter based on survey data, and help managing the stock in case of strong depletion.

***Keywords**: stock assessment, short-lived species, data-limited, cuttlefish, Sepia officinalis, English Channel, two-stage biomass model, Bayesian*

INTRODUCTION

Most of cephalopods fisheries are only occasionally assessed, despite trials of various models (Pierce and Guerra 1994). There is no generalized method to conduct stock assessment for short-lived species, which makes it difficult to compare outputs of the assessments or to infer information from one stock to another. There is a need for a precautionary approach when no routine stock assessment is conducted (Rodhouse *et al.* 2014).

The cuttlefish stock in the English Channel has already been assessed occasionally with a Thomson and Bell model based on monthly catch-at-age data (Royer *et al.* 2006), but the method was too much data-demanding for a routine stock assessment. In order to achieve routine stock assessment, a two-stage biomass model (Roel and Butterworth 2000) was adapted to this stock (Gras *et al.* 2014). A simplification of cuttlefish life-cycle was used, assuming two different stages among the exploited population: recruitment and full exploitation. The model was fitted to time-series of catches and abundance indices by a least-square error method, and uncertainties were estimated by bootstrapping the estimates.

However, the model suffers several caveats. First, it is fitted to data sources using a classical least-square procedure that might not be adapted to fully quantify uncertainties in estimates and predictions and that suffers from a lack of flexibility to change model assumption and/or to assimilate other sources of available information or data.

Second, the model is based on a very strong hypothesis of a fixed biomass growth parameter that embeds a natural mortality and a mean growth coefficient both considered constant in time and known without uncertainty. An annual natural mortality rate of 1.2 was set, and a mean growth coefficient of 2.2 was calculated based on historical data (Medhioub 1986). However, a sensitivity analysis showed a high sensitivity of model outputs to this biomass growth rate parameter. Gras *et al.* (2014) advocate for the use of more recent data to provide a more accurate estimate of the biomass growth rate parameter. Moreover, using a constant biomass growth rate might not be suitable for short-lived species strongly sensitive to environmental factors.

Third, the initial two-stage biomass model represents the biomass of group 1+ individuals only, and basic assumptions are made on the data to fit this hypothesis. The model assumes that the exploited population can be observed at two different stages: recruitment and full exploitation. Recruited biomass (B_1) is estimated with abundance indices from the Bottom Trawl survey (BTS) and the Channel Ground Fish Survey (CGFS). Spawning stock biomass (B_2) is estimated with Landings Per Unit Effort (LPUE) from French and UK bottom trawl fisheries. In this initial model, CGFS time-series is assumed to be based mainly on group 1+ individuals, but regarding the length frequencies, this assumption could be criticized. Indeed, this survey occurs in October, when cuttlefish migrates offshore. Part of the group 0 individuals is 3 months old at this period of the year, forming the lower part of the survey length frequencies. The same assumption is made for BTS data, which is more acceptable, as this survey happens around July, at

hatching time. A monthly percentage is applied on French LPUE, based on commercial category information from sales data.
In this work, we elaborate on the two-stage biomass model adapted for cuttlefish, and we bring three substantive new contributions:

(i) First, the model is developed in a Bayesian framework (Gelman 2004), thus allowing for a comprehensive quantification of the different sources of uncertainty (Punt and Hilborn 1997, Parent and Rivot 2013) and for the use of informative prior on some key parameters (Hilborn and Liermann 1998).

(ii) Second, we develop a method to build an informative prior on the biomass growth rate that takes advantage of various sources of data. The method allows us to provide an informative prior for the average growth rate together with a credible range of variability among years.

(iii) Third, we improve the demographic realism of the model by explicitly considering that two separate age classes (0+ and 1+) can compose the exploited biomass.

We present results of the English Channel cuttlefish stock assessment updated with the new Bayesian two-stage biomass model. We also discuss the possible use of a model based only on survey data to predict the unexploited biomass in winter and help managing the stock.

MATERIALS AND METHODS

The model is written in a Bayesian state-space modelling framework (Gelman 2004) that integrates stochasticity in both the process equations for the population dynamics (process errors) and the observation equations (observation errors), hence the hierarchical framework of the modeling (Rivot *et al.* 2004, Buckland *et al.* 2007, Parent and Rivot 2013). We first describe the process equation for the biomass dynamic. Second, we describe the observations equations. Third, we provide details about the data processing and the method used to build an informative prior on the biomass growth rate parameter (denoted g in the following). Last, we detail our strategy to analyse the sensitivity of the results to the hypotheses made on the time-variations of critical parameters, to the age-structure and the data sources. All parameters used in the model are summarized in Table 4.

The two-stage biomass model

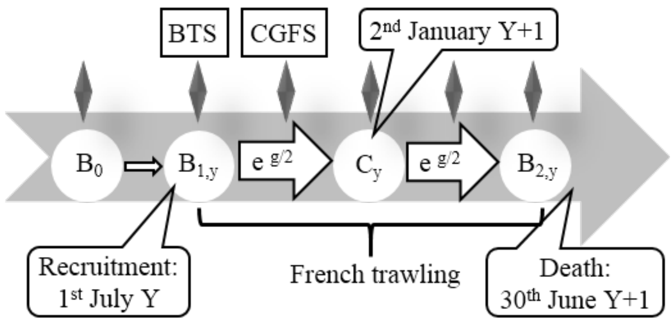

Figure 1: Simplified life cycle of the English Channel stock of cuttlefish.

The model is based on a simplification of cuttlefish life cycle: we consider an exclusive 2 years lifespan, with mass mortality occurring short after spawning in July. Each fishing season extends from 1st July (one year-old individuals are recruited to the fishery) to 30th June of the following year (one year later, remaining individuals are mature and have spawned). Total catch of cuttlefish (C_y) is assumed to happen as a pulse in the middle of the fishing season (on 2nd January). We use subscript y to refer to the fishing season.

Spawning stock biomass $B_{2,y}$ of fishing season y is expressed as:

$$B_{2,y} = \left[B_{1,y} e^{g_y} (1 - E_y)\right] e^{\varepsilon_{1,y} - 0.5 \times sigma\_B2}$$

(1)

where E_y is the exploitation rate, $B_{1,y}$ is the biomass at the beginning of the fishing season, g is the intrinsic biomass growth rate parameter and $\varepsilon_{1,y}$ the lognormal random noise term with variance *sigma_B2*.

The unexploited biomass estimated on 1st January ($B_{1.jan,y}$) without catch removals is calculated as follows:

$$B_{1.jan,y} = B_{1,y} e^{\frac{g_y}{2}}$$

(2)

Observation equations

Expected mean of the catches are calculated as the product of the biomass in the middle of the fishing season, $B_{1,y} e^{\frac{g_y}{2}}$ with the exploitation rate E_y. Catches are then considered observed with lognormal observation errors $\varepsilon_{2,y}$ with variance *sigma_C*.

$$C_y = E_y B_{1,y} e^{\frac{g_y}{2}} e^{\varepsilon_{2,y} - 0.5 \times sigma\_C}$$

(3)

BTS and CGFS survey index are considered as indirect observation of the biomass $B_{1,y}$ with catchabilities q_{bts} and q_{cgfs} and lognormal observation errors with unknown variance *sigma_AI*, drawn in a non-informative prior distribution (see Table 2):

$$\begin{cases} U_y^{bts} = q_{bts} B_{1,y} e^{\varepsilon_{3,y} - 0.5 \times sigma\_AI} \\ U_y^{cgfs} = q_{\mathrm{cgfs}} B_{1,y} e^{\frac{g_y}{4}} e^{\varepsilon_{4,y} - 0.5 \times sigma\_AI} \end{cases}$$

(4)

where U_y^{bts} is the BTS survey index for fishing season *y*, U_y^{cgfs} the CGFS survey index for fishing season *y*, $\varepsilon_{3,y}$ and $\varepsilon_{4,y}$ the lognormal observation errors with variance *sigma_AI*.

French standardized LPUE (U_y^{fr}) is modelled as follows:

$$U_y^{fr} = \frac{1}{2} q_{fr} \left[B_{1,y} + B_{1,y} e^{g_y} \left(1 - E_y\right) \right] e^{\varepsilon_{5,y} - 0.5 \times sigma\_AI}$$

(5)

where q_{fr} is the catchability of French trawlers and $\varepsilon_{5,y}$ the lognormal observation errors with variance *sigma_AI*. Setting the same variance for BTS, CGFS and French LPUE observation errors is a model hypothesis allowing to reduce the number of estimated parameters.

Both BTS abundance indices and UK catch data were obtained from the Center for Environment Fisheries and Aquaculture Science (CEFAS). French CGFS abundance indices, French catch and effort data, and length data were obtained from the French Research Institute for Exploitation of the Sea (IFREMER).

As BTS survey occurs around July, hatchlings are born very recently inshore, and should therefore represent a very small proportion in biomass. BTS abundance indices are therefore used to model both global biomass and 1+ biomass.

CGFS survey occurs each year on October. At this time of the year, part of the population of group 0 individuals is already 3 months old, meaning that the abundance indices time-series can't be directly used to infer information on group 1+ individuals. The following procedure was used to derive a CGFS abundance index of group 1+ individuals. The package mixdist was used on CGFS length frequency data to calculate mean length and percentage in number of individuals older than one year-old ($\%N_{1+}$). Mean length was converted into mean weight using Dunn (1999) length-weight relationship. Percentage in weight of 1+ individuals was calculated as follows:

$$\%w_{1+} = [\%N_{1+} * \overline{w}_{1+}]/[\overline{w}_{1+} * \%N_{1+} + \overline{w}_0 * (1 - \%N_{1+})]$$
(6)

where $\overline{w}_0$ and $\overline{w}_{1+}$ are the mean weight of group 0 and group 1+ individuals. $\%w_{1+}$ was then applied to CGFS catch data to calculate abundance indices for 1+ individuals. On average, 1+ individuals represented 91.5% of CGFS catch in weight, with a CV of 0.056. As length data for CGFS survey are available from 2005 only, we used this value to calculate previous abundance indexes for 1+ individuals.

To calculate French LPUE, commercial data were used to know the percentage in weight of one year-old cuttlefish (animals above 300g) by year and month, and a Delta-GLM was applied with ICES statistical rectangle, vessel power, year and month as factors. Percentages were also applied to total catch data (from both French and UK vessels) to select individuals older than one year-old (1+).

As we didn't have information on the proportion of one year-old cuttlefish among English catch, we couldn't calculate UK LPUE time-series specific to group 1+ individuals. Furthermore, French LPUE are considered to better capture spatial and temporal variability than UK LPUE for the English Channel stock. Indeed, French otter bottom trawlers operate almost every month in all ICES rectangles (Denis and Robin 2001), which is not the case for UK trawlers (Dunn 1999b). We chose to favour data quality rather than quantity, and decided therefore not to use UK LPUE.

We calculated Bayesian posterior predictive *p*-values to evaluate the fit of the posterior distribution of the model. The aim is to quantify the discrepancies between data and model, and assess whether they could have arisen by chance, under the model's own assumptions (Gelman *et al.*, 2014). *p*-values concentrating near 0 or 1 indicate that the observed pattern would be unlikely to be seen in replications of the data if the model were true.

<u>Building an informative prior distribution for the biomass growth rate parameter *g*</u>

The biomass growth rate parameter *g* is defined as the balance between the mean growth coefficient (*Gr*), and the natural mortality rate (*M*) as follows:

$$g = Gr - M$$
(7)

To build a prior for group 1+ individuals (prior_g_{1+}), we first calculate the mean growth coefficient for 1+ individuals (*Gr*). We apply the package mixdist on length frequency data obtained from the French Onboard Observer Program (ObsMer). Number of individuals sampled each year is indicated in Table 1. Mean length of 1+ individuals is calculated in October and December, as cohort split-up is of better quality for these months. Dunn (1999) length-weight relationship is used to convert mean length into mean weight ($\overline{w}_{1+}$). Variability of mean weight values is plotted on Figure 2. The goodness-of-fit is checked, and years where one of the cohort split-up model has a *p*-value above 0.05 are not used in the growth rate calculation.

Table 1: Number of individuals sampled in ObsMer. Years followed by "*" were not used for growth rate calculation.

Year	October	December
2005	277	252
2006	1035	186
2007*	245	138
2008	409	220
2009	526	161
2010*	1304	220
2011*	655	153
2012	755	796
2013	1035	334
2014	1001	1488

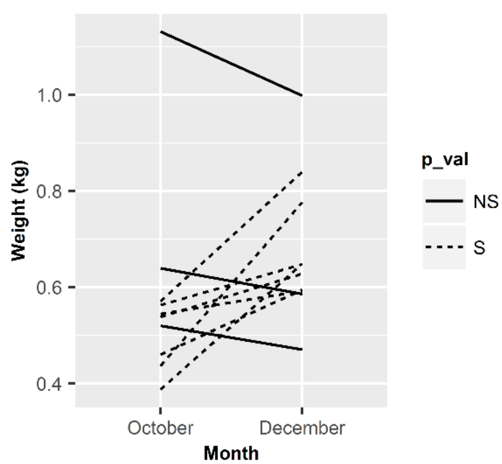

Figure 2: Variability of mean weight values of 1+ individuals after cohort split-up of ObsMer data. Full lines represent years where *p*-value of cohort split-up model was not significant, and dotted lines represent years used for growth rate calculation.

For each year where cohort split-up is reliable, the growth rate Gr_y is calculated (equation 8) and Gr is calculated as the median value of all Gr_y.

$$Gr_y = \log\left(\overline{w}_{1+,December} / \overline{w}_{1+,October}\right) * 6$$

(8)

To calculate the mean growth coefficient of 1+ individuals (*Gr*), ObsMer data were used. Cohort split-up was reliable for seven years from 2005 to 2014. Length data obtained from mixdist package had a CV of 0.058 in October and 0.054 in December. We found a value of 1.542 for *Gr*, with CV of 0.64.

Natural mortality (*M*) is calculated with Caddy (1996) gnomonic time division method. This method assumes that M is a simple function of mean lifespan and is constant. A vector of natural mortality at age is calculated: life-span is divided into several intervals whose duration increases proportionally to the age, and mortality is constant for each interval. The time-division is called gnomonic, and for each interval, a constant number (β) is obtained when multiplying the instantaneous mortality rate by the interval duration. Initial death rate is assumed to be high, and after a few months, a plateau is obtained. An initial number of individuals must be chosen, and 2 survivors must remain after 2 years to assure population replacement.

The mortality function is fitted with an initial number of hatchlings (N_1) derived from fecundity estimates. Previous studies on cuttlefish fecundity can help choosing values for the initial number of individuals. Mangold-Wirz (1963) reported that females *Sepia officinalis* may lay from about 150 to 4000 eggs depending on their size. Richard (1971) estimated numbers of 150 to 500 eggs by counting mature ova only, and a mean number of 2000 eggs was observed in laboratory culture (Hanley *et al.* 1998). Four values of N_1 are tested: 500, 1000, 1500 and 2000.

The two years life span are divided into a number *i* of smaller time intervals Δ_i. A value of 2/365 is set for the first interval Δ_1. For each interval:

$$N_{i+1} = N_i * \exp(-M_i * \Delta_i)$$

(9)

where M_i is the mortality rate for the interval of duration Δ_i.

$$M_i * \Delta_i = \beta$$

(10)

where β is a constant. To calculate *M*, the SOLVER routine of EXCEL is used.

To estimate natural mortality of 1+ individuals, we choose the number of time intervals such that the last time interval ends at t = 2 years and lasts approximately 12 months. After the division of the lifespan into 10 gnomonic time intervals, SOLVER is used to calculate the decline in numbers such that 2 spawners survive by two years of age.

We tested four possible values of initial number of individuals (N_1) for 10 gnomonic time-intervals (Table 2). With 10 time-intervals, the pre-spawning interval was 11.5 months, so the resulting mortality was related to 1+ individuals.

Table 2: Results of natural mortality for different values of N_1 and different pre-spawning intervals.

N_1	a	β	M	Pre-spawning interval (months)	Number of gnomonic time-intervals
500	0.926	0.552	0.574	11.5	10
1 000	0.926	0.621	0.646	11.5	10
1 500	0.926	0.662	0.688	11.5	10
2 000	0.926	0.691	0.718	11.5	10

Once mean growth coefficient and natural mortality were calculated, we could obtain mean value *g* used for the construction of prior on the *g* parameter (Table 3). The choice of the CV value of 0.4 used to build priors on *g* parameter was motivated by three considerations: the high CV of *Gr*, model convergence issues with a CV of 0.6 for prior construction, and density-dependent mortality which might balance the high CV and justify a choice of 0.4.

Table 3: Summary of natural mortality, mean growth coefficient and *g* parameter.

Age class	Mean mortality	Mean individual growth	*g* parameter mean value
1+	0.657	1.542	0.89

We use the mean *g* value obtained to construct an informative prior on the biomass growth rate:

$$\log(\text{prior\_}g_{1+,y}) \sim \mathrm{N}(\log(0.89), 6.74)$$
(11)

where the precision of 6.74 results from a CV of 0.4 (inter-annual variability), allowing a certain variability of *g* but keeping the prior informative enough for model fit.

Table 4: Summary of model parameters values and priors.

Parameter	Definition	Value/Prior
$\text{prior\_g}_{1+,y}$	*g* for 1+ individuals	$\text{Log}(\text{prior\_g}_{1+,y}) \sim \text{N}(0.89, 6.74)$
$B_{1,y}$	Initial biomass	$\text{Log}(B_{1,y}) \sim \text{N}(15\,000, 4.5)$
E_y	Exploitation rate	~ Beta(1.5, 1.5)

q.bts	BTS catchability	Log(q.bts) ~ Unif(-15, 3)
q.cgfs	CGFS catchability	Log(q.cgfs) ~ Unif(-15, 3)
q.fr	LPUE.FR catchability	Log(q.fr) ~ Unif(-15, 3)
sigma_B2	Precision for B_2	25.5 (for CV=0.2)
sigma_AI	Precision for all abundance indices	~ Gamma(0.05, 0.05)
sigma_C	Precision for total catch	2 500.5 (for CV=0.02)

Model construction

The model used to update the English Channel cuttlefish stock assessment (M1) is based on a time-varying *g* parameter and BTS, CGFS and LPUE.FR time-series, and captures the dynamics of 1+ individuals only. A second model is constructed (M2), based only on BTS and CGFS time-series. After comparing outputs of models M1 and M2, we run a retrospective analysis to evaluate model predictive capacity. We construct model M2r1 which is similar to M2, but catch of the last fishing season (2014) is replaced by the mean of the 5 previous years of catch. For model M2r2, all data from 2014 are deleted, and catch value used for 2013 is the mean of the 5 previous years of catch. Model M2r3 is constructed with the same logic, deleting data from 2013.

RESULTS

Results from the full model M1

Results are plotted with years at the beginning of the fishing seasons on the x-axis. Therefore, for a fishing year y, estimates of B_1 are on July y, estimates of $B_{1.jan}$ are on January y+1, and estimates of B_2 are on June y+1. Catch of group 1+ (Figure 3a) show high between-years variability with no clear trend until 2006. From 2006 to 2014, a decreasing trend can be identified.

All observed abundance indices are within the range of 95% Bayesian credible intervals for French LPUE (Figure 3b) and BTS (Figure 3c). For CGFS (Figure 3d), only 2011 observed abundance index is outside the Bayesian credible intervals.

Variability is greater for French LPUE than for the survey abundance indices. One possible explanation is that French LPUE abundance indices cover the entire fishing season, whereas the calculation for CGFS and BTS is based on data from a single month each year.

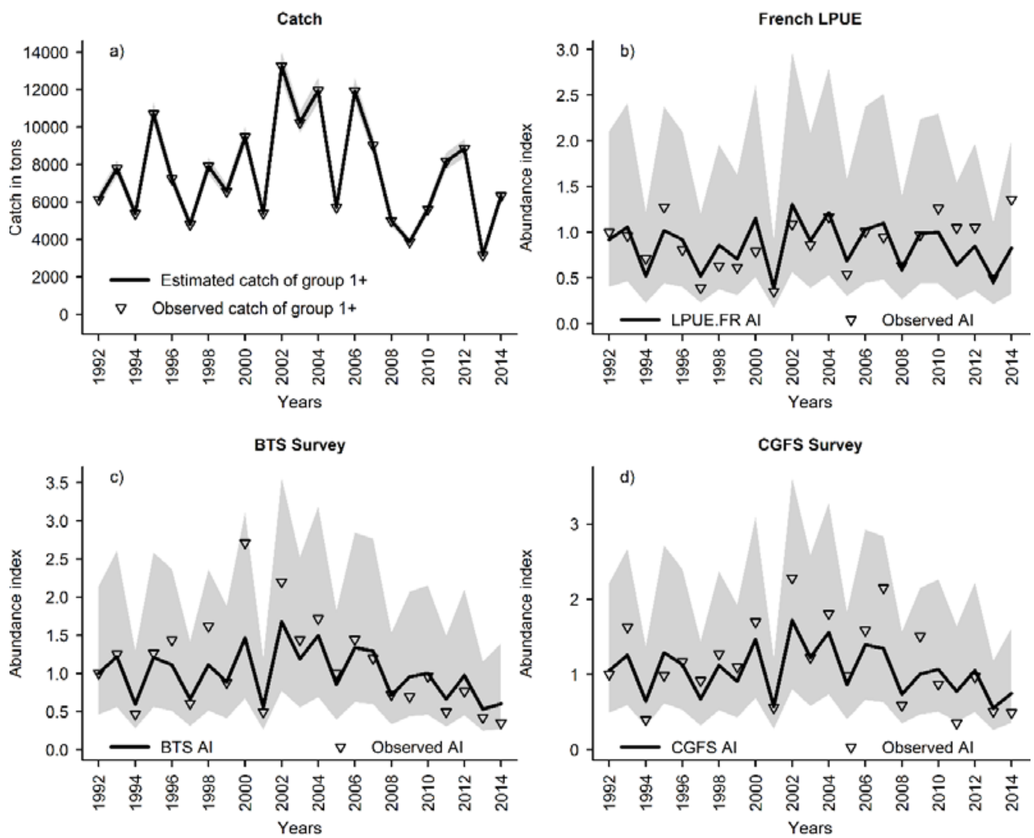

Figure 3: Comparison of posterior median estimates with observed values for catch (a) and LPUE (b), BTS (c) and CGFGS (d) abundance indices. Solid lines: posterior medians. Shaded areas: 95% Bayesian credible intervals.

Biomass estimates B_1 and $B_{1.jan}$ show a slight decreasing trend from 2002 to 2013 (Figure 4a). Biomass estimates of B2 show no clear trend (Figure 4b). Estimates of g from model M1 fluctuate between 0.63 and 0.92 from 1992 to 2008 with no particular trend. Median g estimate increases from 0.8 in 2009 to 1.2 in 2011. The highest value is estimated to 1.47 in 2014 (Figure 4c). Exploitation rate varies between 0.34 and 0.57 from 1992 to 2008, and a drop to 0.2 occurs in 2009 (Figure 4d). Highest values are obtained for years 2001 and 2011 (respectively 0.57 and 0.55) and are associated with low estimates of recruited biomass B_1 and spawning stock biomass B_2 in 2001, and high estimate of g in 2011.

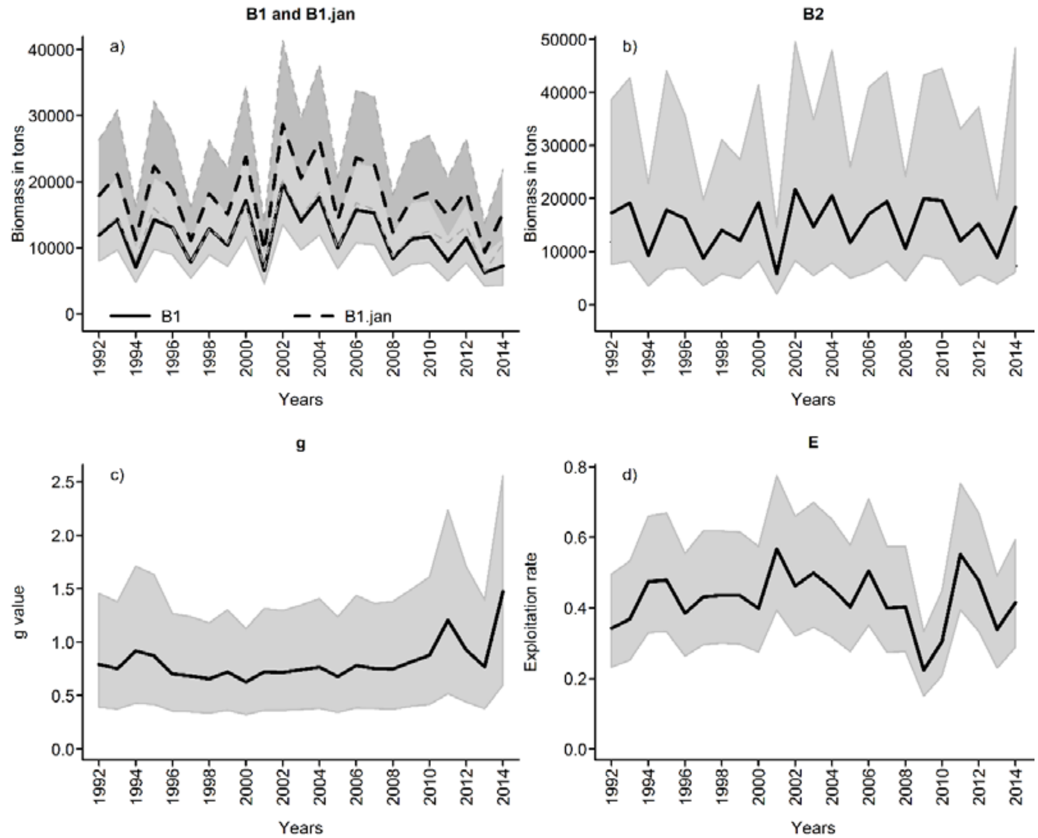

Figure 4: Posterior medians estimates of recruited biomass and unexploited biomass on 1st January (a), spawning stock biomass (b), growth rate (c) and exploitation rate (d) for model M1. Shaded areas: 95% Bayesian credible intervals.

Posterior predicted *p*-value for catch is 0.5, showing a good capacity of the model to reproduce similar results when data are replicated. This is explained by the small value of CV used for catch data. The model tends to slightly overestimate BTS abundance indices (*p*-value > 0.5) and slightly underestimates CGFS and LPUE.FR abundance indices (Table 5).

Table 5: Posterior predictive *p*-values for model M1.

	Catch	BTS	CGFS	LPUE.FR
Model M1	0.5	0.61	0.46	0.46

Results from model M2 and predictive capacity of the model

We compare results of the full model M1 and model M2 based only on survey abundance indices, to evaluate the impact of suppressing French LPUE abundance indices. Biomass estimates B1 and B1.jan (Figures 5a and 5b) follow the same trend for models M1 and M2, but model M2 outputs show a greater decreasing trend between 2002 and 2014 than model M1. This result is due to the French LPUE abundance indices which are higher than survey abundance indices for the five last fishing seasons (Figures 3b, 3c and 3d).

Estimates of biomass growth parameter (Figure 5c) and exploitation rate (Figure 5d) show that model M2 estimates less extreme values for g and more extreme values for E than model M1. In 2011 and 2014, g estimates are above 1.1 for model M1 and under 0.9 for model M2, whereas E estimates are above 0.7 for model M2 and under 0.6 for model M1. For these years, survey abundance indices are low, therefore the estimated biomass at the beginning of the fishing season is low. But as catches are not low, model M2 estimates high exploitation rate, whereas model M1 estimates higher g value thanks to the information brought by French LPUE.

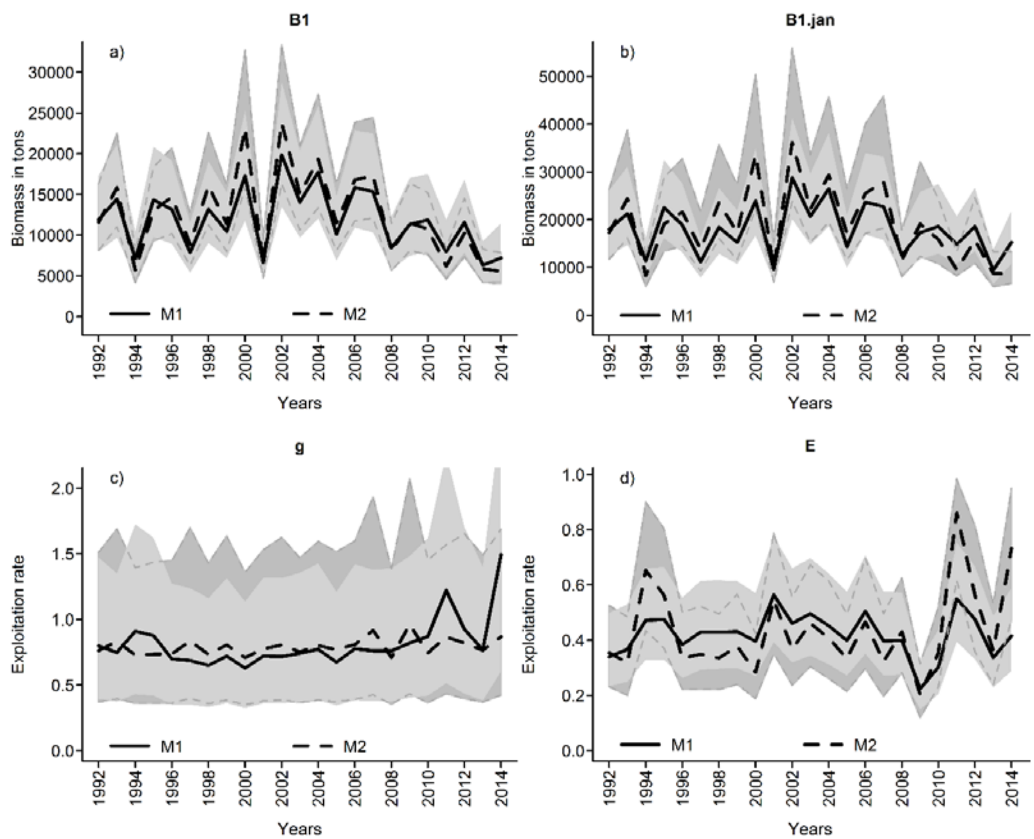

Figure 5: Comparison of B_1 (a), $B_{1.jan}$ (b), g (c) and E (d) for models M1 and M2. Solid lines: posterior medians for model M1. Dotted lines: posterior medians for model M2. Shaded areas: 95% Bayesian credible intervals (Light grey for model M1 and grey for model M2).

The retrospective analysis conducted on the unexploited biomass (Figure 6a) shows a good predictive capacity of model M2 for this variable. Results obtained for the exploitation rate (Figure 6b) are less conclusive, as 2013 exploitation rate estimates from M2 and M2r2 differ greatly.

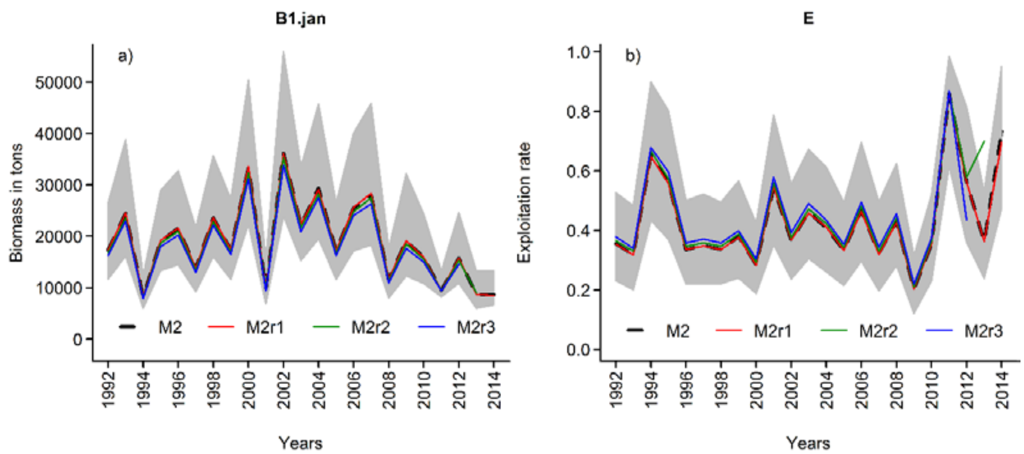

Figure 6: Retrospective analysis of $B_{1.jan}$ (a) and E (b) for model M2. Grey shaded areas: 95% Bayesian credible intervals.

Model M2 posterior predicted *p*-value is 0.5 for catch and 0.51 for CGFS abundance indices, showing a good capacity of the model to reproduce similar results when data are replicated. The model tends to slightly overestimate BTS abundance indices (*p*-value > 0.5), and this is amplified for models M2r1, M2r2 and M2r3. Models M2r2 and M2r3 tend to slightly underestimate CGFS abundance indices (Table 6).

Table 6: Posterior predictive *p*-values for models M2, M2r1, M2r2 and M2r3.

	Catch	BTS	CGFS
Model M2	0.5	0.56	0.51
Model M2r1	0.5	0.57	0.51
Model M2r2	0.5	0.6	0.48
Model M2r3	0.5	0.62	0.45

DISCUSSION

Quality and limits of the data and the model

We present a Bayesian implementation of a two-stage biomass model adapted to the English Channel stock of cuttlefish. The initial model (Gras *et al.*, 2014) was based on CGFS and BTS abundance indices, as well as LPUE from both French and UK trawlers. The model was sensitive to the fixed biomass growth parameter *g*, whose value was based on individual growth estimated with historical mean weight at age data and assumption of a natural mortality equals to 1.2. The first aim of the present study was to build an informative prior for the *g* parameter and to test a model with a time-varying *g*. For the stock used in this study, we had data available to calculate abundance indices time-series specific to 1+ individuals. We were also able to build a prior on *g* parameter specific to 1+ individuals, using ObsMer length frequency data. This data source contains a risk of bias because the sampling plan is not entirely achieved, and the percentage of achievement varies between years. But these data are only used to construct a prior on *g*, which is then updated during model runs.

Our choice to focus on 1+ individuals was based on two main arguments. A previous study (Royer *et al.* 2006) indicates the presence of two micro-cohorts of cuttlefish among the English Channel, with a first recruitment around October, and a second around April. But the presence of two micro-cohorts observed during the study is not always verified, which makes it difficult to use CGFS length data to calculate a mean growth coefficient. Furthermore, environmental conditions might have stronger impact on group 0 individuals than on group 1+ individuals. Indeed, temperature and nutrient availability are known to affect both growth and natural mortality of cuttlefish, particularly in the juvenile phase (Moltschaniwskyj and Martinez 1998).

Other stock assessment methods have already been used on the English Channel stock of cuttlefish. A Leslie-De Lury depletion model has been applied by Dunn (1999a) based on data from UK beam trawl fleet only. French landings were not taken into account, although higher than English landings. Trials with a monthly VPA have also been conducted by Royer *et al.* (2006). But because of the inconsistence of size structures, this stock assessment method could not be applied routinely. Using complex models requires more data, and human resources to gather data and run the model. The two main advantages of the two-stage biomass model are its simplicity, allowing a routine update of the stock assessment, and its suitability in case of short-lived species and lack of reliable age-data (Roel and Butterworth 2000, Roel *et al.* 2009, Giannoulaki *et al.* 2014). A Bayesian model allowing time-variability of the *g* parameter is closer to reality, and brings additional information about the biomass growth parameter.

Management implications

Following Gras *et al.* (2014) conclusions, we did not find any stock-recruitment relationship. In their work, they do not detect any trend in exploitation rates between 1992 and 2008. Our study adds 6 years of data, and results differ as we detect a decreasing trend of exploitation rate from 2001 to 2009. Our results show that the highest exploitation rates occur in 2001 and 2011, with a slightly higher exploitation rate in 2001. Exploitation level from 2001 should be a limit reference point for future management. This recommendation was also specified in (Gras *et al.* 2014).

Because of the short lifespan of cuttlefish and the strong effect of environmental conditions on recruitment, usual management applied to finfish cannot be considered. In-season assessment and management might be necessary to avoid overexploitation risk (Rosenberg *et al.* 1990, Pierce and Guerra 1994). In France, the minimum landing weight of cuttlefish is 100 g and otter trawl nets are not allowed to use mesh size <80mm. For pot fishery, there is also a limited number of fishing licenses. In Normandy, trawlers are allowed to fish cuttlefish spawners 6 weeks in spring inside the 3 nautical miles as an exemption which is decided each year around April. Another exemption allows them to target hatchlings 2 weeks in summer. BTS survey occurs in July/August and CGFS in October. It is therefore possible to have the abundance indices in winter and estimate the unexploited biomass $B_{1.jan}$ with model M2. Therefore, based on the prediction of $B_{1.jan}$, these exemptions could be avoided in case of very low biomass predicted for the fishing season considered. This would give adult cuttlefish better chances to spawn and would increase juveniles' survival chances.

Targeting juveniles leads to a loss in production for the following year, and discarding juveniles would still not be a solution. The survival rate of discarded cuttlefish has indeed been studied by (Revill *et al.* 2015). They found an immediate survival rate of 31% for cuttlefish smaller than 15 cm dorsal mantle length, and additional mortality occurred later. The exemption of the 3 nautical miles law is systematically granted in Normandy, which might result in a loss of production as well as a destruction of juvenile habitats.

In a context of global warming, we can fear a strong impact of sea temperature on cuttlefish growth and life cycle. Indeed, with the warming of the sea, we can expect higher growth rates and shorter life span (Forsythe *et al.* 1994). But at the same time there might be an effect of size at hatching on the resultant size-at-age. Due to the exponential nature of growth, the effect of hatchling size is more apparent at higher growth rates. There is a decrease in hatchling size as temperatures increase (Vidal *et al.* 2002), therefore the smaller initial size of cephalopods might balance the higher growth rates induced by increased temperatures (Pecl *et al.* 2004). These conclusions are valid for cephalopods in general, but more specific studies were conducted on *S. officinalis*. (Safi 2013) found an effect of incubation's environmental conditions on hatchling sizes, with larger juveniles obtained when eggs were incubated in colder waters. But the difference observed with different incubation temperatures was compensated when individuals grew in the same biotic and abiotic conditions. With the combined effect of sea temperature increase and pollution, changes in both growth and mortality could be expected. A time-varying g will bring additional information allowing to detect these changes.

<u>Applicability of the model on other stocks</u>

By using a Bayesian framework, we intended to incorporate uncertainty at different levels of the model, in order to propagate uncertainty to final outputs. We also intended to build a simple and general model which could be easily modified for an application on other stocks. We wanted to use the English Channel cuttlefish stock as a case study for this kind of stock assessment models. As some stocks suffer from a severe lack of data, it might not be possible to calculate abundance indices separated by age class, in which case both group 0 and 1+ individuals could be modelled as a single group. The issue remains the calculation of the *g* parameter. The use of a meta-analysis could help improving precision around this parameter and transfer information to stocks where no data are available for the calculation of *g*.

Some trials of stock assessment have been conducted on other cuttlefish stocks. An assessment of *S. officinalis* stock in the Bay of Biscay was conducted by (Gi Jeon 1982). He used a VPA with a monthly time-scale and two age groups, based on data from years 1978-1979. A Schaefer dynamic production model was implemented for the Dakhla (2001-2006), Cape Blanc (1990-2006) and Senegal-the Gambia stocks (1993-2006) (FAO/CECAF 2007). Results obtained for Cape Blanc stock were judged unreliable because of the bad model fit. Results obtained for the two other stocks showed a situation of overexploitation. As both catch and abundance indices from survey and CPUE are available, a two-stage biomass model can be applied on these stocks to estimate *g* parameter.

Other species of cuttlefish have also been subject to assessment trials in India (Nair *et al.* 1993, Rao *et al.* 1993), in the Arabian Sea coast of Oman (Mehanna *et al.* 2014), in the Gulf of Suez (Mehanna and Amin 2005, Mehanna and El-Gammal 2010). But these studies use length-based cohort analysis, which requires the assumption of a stable age-length relationship. Cephalopod growth rates are known to be highly variable (Pierce and Guerra 1994), and the use of Von Bertalanffy growth model for cephalopods might not be valid (Forsythe and Heukelem 1987, Saville 1987).

Some European cuttlefish stocks monitored by the International Council for the Exploration of the Sea Working Group on Cephalopod Fisheries and Life History have not been yet subject to an assessment, but data are available to try the two-stage biomass model. For the Bay of Biscay stock of *S. officinalis*, a series of French standardized LPUE can be calculated, and data are available from Ifremer EVHOE survey. But data from EVHOE survey might not be reliable abundance indices because it occurs offshore in November, therefore catching cuttlefish only if the migration already happened. Another stock of *S. officinalis* is found in ICES divisions VIIIc and IXa, exploited mainly by Spain and Portugal, with most of the catches occurring in division IXa. A time-series of Spanish trawlers LPUE is available, as well as a time-series of survey abundance indices in division IXa South. For stocks in warmer waters, we could expect a higher value of *Gr*. Indeed, cuttlefish seems to experience faster growth in warmer waters, even at small scale (Richard 1971). Cuttlefish experiences for example a slower growth rate in the English Channel than in South Brittany, and a water temperature effect is suspected (Le Goff and Daguzan 1991). The initial two-stage biomass model (Roel and Butterworth 2000) was developed for a squid with a one-year life cycle. Care must be taken when adapting the model to other stocks, as the assumption of an exclusive two-year life cycle is no longer valid. The model should be modified to take into account a proportion of the population experiencing a one-year life cycle.

For several cuttlefish stocks, there might be enough available data to apply a two-stage biomass model. For others, this model might not be appropriate, but as data are sometimes available to calculate growth, information could be extended to establish for example a relationship between growth, latitude of the stock and length of the life-cycle. But care should be taken to establish data reliability, and to distinguish parameters which can be assimilated to *Gr* or to *g*.

One of the consequences of overfishing is the decrease of many fish stocks, impacting the whole ecosystem. As cephalopod predators' abundance decrease, biotic changes might benefit cephalopods. At the same time, changes in environmental conditions as well as density-dependent mortality might impact these stocks. Doubleday *et al.* (2016) show that cephalopod populations have increased globally and may have benefited from a changing ocean environment. Using a model with a time-varying *g* parameter could allow the detection of long-term changes in either growth or natural mortality for the stock considered. It might not be possible to identify the role played by mortality or growth, or to know whether biotic or abiotic factors had the most impact. But it could help identifying a general tendency in the evolution of the ecosystem toward a favorable situation or an unfavorable situation for a specific stock.

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Annex 6: Coordination work for peer review paper on cephalopod trends

Main idea of paper:

1 Cephalopod trends along NorthAtlantic regions

2 Reason for the trends (environmental ? Fishing? Or else?)

To look in more detail:

1 Choosing the indices

Evaluate the indices available (are there appropiate for the species?) How to deal with commercial indices when cephalopod species are not the target of the fisheries?. Chossing subsets of trips tar

Data quality: reliability, appropiate for stock distribution …

How to deal with different periods in the time-series both for surveys and commercial series: initial evualion

Analyse trends for landings and surveys : compare betwen different species, areas, indices…

Depending on the results of the analysis, trends could be similar or different…this is something to be covered on the discussion

What is the population/stock status : for some species wealreadyhave some idea about levels of populations from assessments deployed in the last years.

IF TIME 2 **Environmental data to be used:**

Depending on the species but basically: SST (FROM EXISTING STELITE DATA (Maps) , NAO, Salinity (Ixa soth), rain fall, depth,

There are many other variables that could have an influence in the abundance but not analysed yet: Mediterranean oscillation, wind, chlorofile...

Check for environmental relationship/signals within index series

Comment from Daniel: For my trend analysis in the PhD I checked the German Survey (IBTS North Sea) data from the 60ties onwards, even if it was not possible at species level, trends are very impr

Some issues of concern:

Data quality

Methodology for producing standarised indices

Choose the most adequate stock in area/region

Availability for Environmental data

Area	**Species**	**Landings**	**Commercial CPUE**	**Years available**	**Surveys Indices**	**Years available**	**Environmental Variabl**
IV	*Loligo forbesi*	YES		~2000 - 2016	German IBTS	~2000 - 2016	CTD
IV	*Alloteuthis subulata*	YES		~2000 - 2016	German IBTS	~2000 - 2016	CTD
IXa (south)	*Octopus vulgaris*	YES	OTB > 55	1993-2015	ARSA	1993-2015	Rain
IXa (south)	*Sepia officinalis*	YES	OTB > 55	1993-2015	ARSA	1993-2015	Need to be identified
IXa (south)	*Loligo vulgaris*	YES	OTB > 55	1993-2015	ARSA	1993-2015	Need to be identified
IXa (south)	*Ommastrephidae*	YES	OTB > 55	1993-2015	ARSA	1993-2015	Need to be identified
IXa (south)	*Eledone spp.*	YES	OTB > 55	1993-2015	ARSA	1993-2015	Need to be identified
IXa	*Loligo vulgaris*	YES	OTB_DEF > 65	1993-2015	IBTS	1993-2015	CTD
IXa	*Loligo forbesi*	YES	OTB_DEF > 65	1993-2015	IBTS	1993-2015	CTD
IXa	*Octopus vulgaris*	YES	OTB_CRU >55	1993-2015	IBTS	1993-2015	CTD
IXa	*Octopus vulgaris*	YES	OTB_DEF > 65	1993-2015	IBTS	1993-2015	CTD
IXa	*Octopus vulgaris*	YES	Artisanal gear (traps) FPO	2009-2015	IBTS	1993-2015	CTD
IXa	*Sepia officinalis*	YES	nets (		IBTS	1993-2015	CTD
VIIIc&Ixa (north)	*Octopus vulgaris*	YES		2000-2015			
VIIIc&Ixa (north)	*Ommastrephidae*	YES	OTB_DEF > 55 & OTB_MPD >55	2000-2015	DEMERSAL	2000-2015	CTD
VIIIc&Ixa (north)	*Eledone cirrosa*	YES	OTB_DEF > 55 & OTB_MPD >55	2000-2015	DEMERSAL	2000-2015	CTD
VIIIab	*Loligo vulgaris & Loligo forbesi*	YES	OTB_DEF >70 & OTB_MCD >70 (Basque)	2009-2015	EVHOE	1992-2015	CTD

VIIIab		*Loligo vulgaris & Loligo forbesi*	YES	OTB_DEF	1990- 2015	EVHOE	1992-2015	CTD
VIIe& d		*Loligo spp*	YES	OTB_DEF	1990-2013	CGFS	1993-2015	CTD
VIIe& d		*Sepia officinalis*	YES	OTB_DEF	1990-2013	CGFS	1993-2015	CTD
VI & VII								
	7	*Eledone cirrhosa*	YES	OTB	2000-2015	PORCUPINE	2001-2015	SST
	7	*Loligo forbesii*	YES	OTB	2000-2015	PORCUPINE	2001-2015	SST
7		*Todaropsis eblanae*	YES	OTB	2000-2015	PORCUPINE	2001-2015	SST
7		*Illex coindetii*	YES	OTB	2000-2015	PORCUPINE	2001-2015	SST

Annex 7: References

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