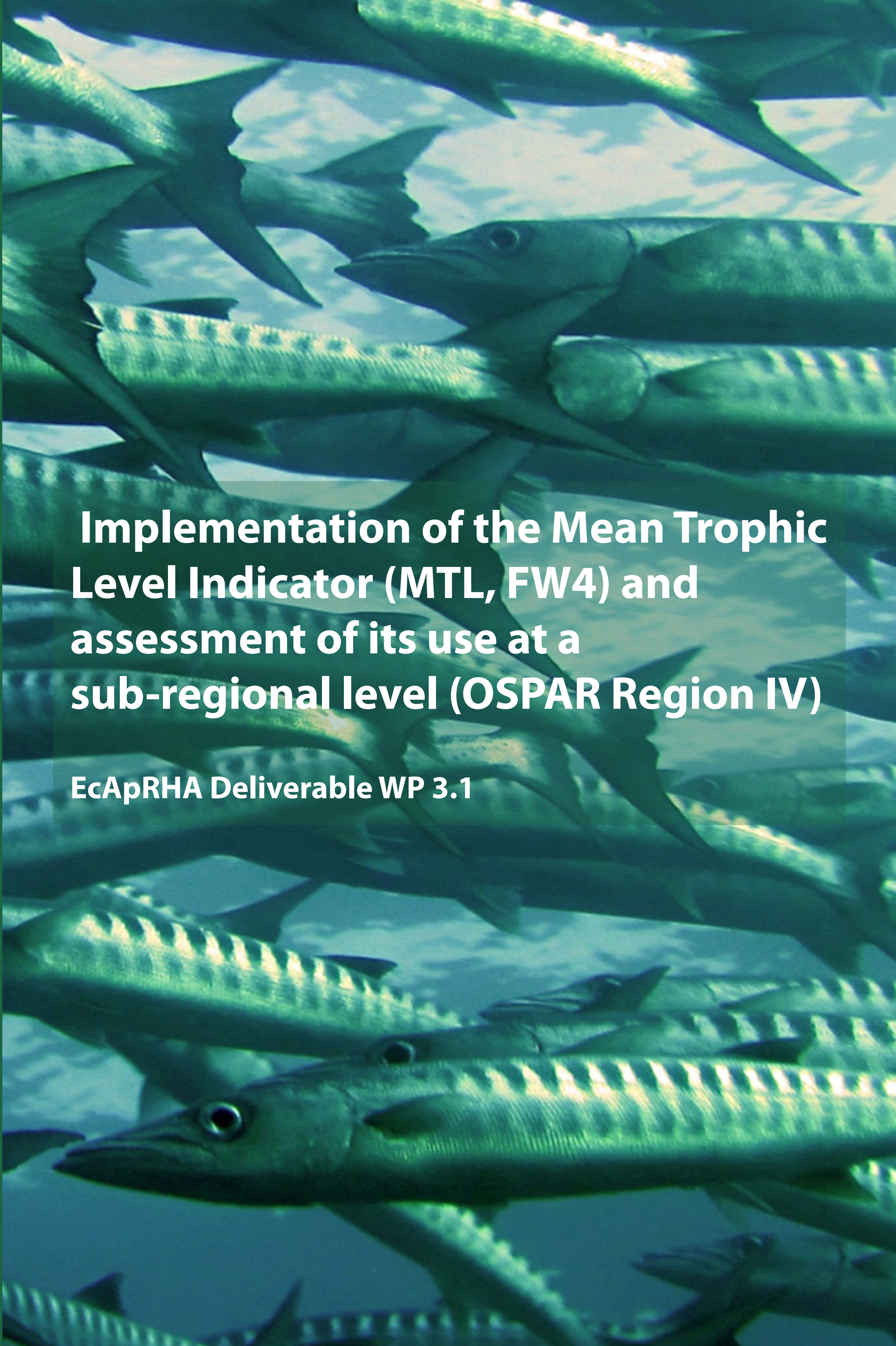

Implementation of the Mean Trophic Level Indicator (MTL, FW4) and assessment of its use at a sub-regional level (OSPAR Region IV)

EcApRHA Deliverable WP 3.1

Co-financed by the European Union

EcApRHA an Ecosystem Approach to Regional Habitat Assessments

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Contents

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EcApRHA

The EcApRHA project (Applying an Ecosystem Approach to (sub) Regional Habitat Assessment) aims to address gaps in the development of biodiversity indicators for the OSPAR Regions. In particular, the project aims to overcome challenges in the development of indicators relating to the MSFD (Marine Strategy Framework Directive 56/2008/EU), such as Descriptor D1 (Biodiversity), D4 (Food webs) and D6 (Seafloor integrity), and to deliver an action plan to OSPAR that will enable monitoring and assessment at the (sub) regional scale, to contribute to OSPAR Intermediate Assessment 2017.

Indicators related to the benthic and pelagic habitats, as well as food webs, are investigated within the project at different levels (from data to indicator; from indicator to habitat assessment; from habitat to ecosystem assessment).

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Executive Summary

The mean trophic level of marine assemblages has been extensively used as a measure of health of the marine communities. Used on landings data, it inspired the Marine Trophic Index, which was identified by the Conference of the Parties to the Convention on Biological Diversity (CBD) as a key indicator for measuring biodiversity changes. Since then, the index has been subsequently refined with the incorporation of different thresholds to account for variations in the biomass of specific compartments of the food webs. Despite its general use, the indicator has received criticisms mainly regarding the accuracy of the assignation of trophic levels and the influence of factors such as ontogenetic, seasonal or regional variations in its values, in its calculation. Moreover, the fact that it has been mainly used with the biomass obtained from landings data, has caused new criticisms regarding their representativity of the actual status of the marine food webs and the reliability of such data.

The mean trophic level of marine predators was adopted by OSPAR as a common indicator for region IV (Bay of Biscay), where efforts are being made to assess its operationality and consistence within the scope of coordinated regional assessments. The present document is an account of such efforts in the framework of the EcApRHA project.

LIST OF ACRONYMS

AIC	Akaike's Information Criteria
CBD	Conference of the Parties to the Convention on Biological Diversity
BH	Benthic Habitats, referring to Descriptor 1 Indicators within the MSFD
BH3	OSPAR Benthic Habitats indicator 3, Extent of physical damage to predominant and special habitats
DATRAS	The Database of Trawl Surveys
EC	European Commission
EMODNET	European Marine Observation and Data Network
EUNIS	European Nature Information System
EVHOE	French Groundfish survey in the Celtic Sea and Bay of Biscay, by its French Acronym
GAM	General Additive Model
GES	Good Environmental Status
GIS	Geographic Information System
IBTS	International Bottom Trawl Surveys
ICES	International Council for the Exploration of the Sea
IEO	Spanish Institute of Oceanography, by its Spanish Acronym
IFREMER	French Research Institute for Exploitation of the Sea, by its French acronym
SIH	Fisheries Information System of the IFREMER, by its French acronym
FW	Food webs, referring to Descriptor 4 Indicators within the MSFD
FW4	OSPAR Food Web Indicator 4, the Mean Trophic Level of Marine Predators
FW7	OSPAR Food Web Indicator 7, Biomass and abundance of functional groups / trophic guilds
FW9	OSPAR Food Web Indicator 9, Ecological Network Analysis (ENA)
MSFD	The EU Marine Strategy Framework Directive (2008/56/EC)
MTI	Mean Trophic Index
MTL	Mean Trophic Level
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic.
TL	Trophic Level
VIF	Variance Inflation Factor
VMS	Vessel Monitoring System
WoRMS	World Register of Marine Species

1 INTRODUCTION

The Conference of the Parties to the Convention on Biological Diversity (CBD) identified trophic level (TL)-based indicators as key indicators for measuring biodiversity changes, and listed the Mean Trophic Index - MTI (CBD, 2004) as one of its headline indicators (Butchart et al., 2010).The MTI, proposed by Pauly and Watson (2003), has been extensively used and successively refined, its concept serving as inspiration to subsequent indicators and metrics aimed at assessing the effects of (mainly) fisheries in ecosystems. The rationale behind this indicator (the "fishing down marine food webs" concept) is that when TL values begin to drop, it indicates that fishers are relying on ever smaller fish and that stocks of the larger predatory fish are beginning to collapse. Since large and slow-growing species with late maturity decline in abundance more rapidly and they typically feed at higher trophic levels, fishing is expected to reduce the mean trophic level of exploited fish communities. Pauly and Watson (2003) showed that overfishing had caused the complexity of food chains in important fisheries to drop by more than one trophic level between the years 1950 and 2000. If decline in mean trophic levels of fisheries landings continues, the resulting smaller food chains leave marine ecosystems increasingly vulnerable to natural and human induced stresses, and reduce the overall supply of fish for human consumption. Thus, the indicator is well suited to illustrate the focal area on ecosystem integrity and the provision of goods and services provided by biodiversity in support of human well-being, and should thus, in principle, be a good indicator of GES of food webs at a regional scale of relevance to MSFD implementation.

The indicator has been subsequently refined by applying different cut-off thresholds so as to better reflect changes in the upper TLs of individual ecosystems. Thus, while the MTI, used a minimum threshold of 3.25 (Pauly and Watson, 2005), to exclude planktivores, whose high biomass tends to vary widely in response to environmental conditions, further cut-off levels (i.e.: 3.5, 4) have been incorporated to account for variations in the mean trophic level of the apical and very top predators within food webs. The aim of a cut-off of TL at 4.0 is to examine changes within the apex predator community while excluding small and medium fish, some of which have TLs above 3.25 and which are still subject to large natural fluctuations in abundance. Several authors have stressed that concentrating on higher trophic levels may provide a better precautionary approach than lower ones, arguing that contrary to some criticisms, they don't provide a skewed or partial vision of the ecosystem since they represent functional information which reveals the energetic efficiency of an ecosystem, improving their stability (Odum, 1969).

In global comparisons, however, in order to accommodate ecosystems in which low TL species dominate catches or catch variability (e.g. upwelling systems), comparing trends in MTL of lower levels (MTL2), both for survey data and landings has been recommended, in order to provide a fuller picture of what is happening at the community level and capture combined effects of fishing and the environment more clearly (Shannon et al., 2014). Indeed, despite the probably stronger ability of higher cut-off levels to detect the effect of fisheries, they might not be able to detect situations in which targeted species are mainly or exclusively composed of low or intermediate trophic levels, indicating a misleading improvement of the ecosystem's health. Therefore, the inclusion of lower cut-off levels is also needed in order to obtain a broader vision of potential changes occurring in the respective ecosystems/areas.

The "fishing down marine food webs" process theory was complemented by other reported processes such as the "fishing through the food web" (Essington et al., 2006), the validity of using landings data to evaluate changes in trophic indicators being questioned due to the fact that variations in fishing strategies can bias them significantly. The shortcomings associated to using commercial landings data have been further and extensively documented (Branch et al., 2010; Shannon et al., 2014, Gascuel et al., 2016) and could be summarized in the fact that they are strongly linked to fishing strategy, and highly dependent on market demand and prizes, management regulations, and/or discarding practices, so they do not necessarily reflect what is happening at community / ecosystem level since non-targeted and discarded species are not considered. Moreover, catch based indicators are indicators of pressure, and respond sensitively to management action but are not specific indicators of change in state. Still, they provide a longterm perspective on exploitation history (Gascuel et al., 2016) and provide complementary information, which should not be overlooked when attempting to assess ecosystem health.

Thus, from a theoretical point of view, indicators based on surveys are preferred for an un-biased analysis of fishing-induced changes in ecosystem health. However, because in practice, surveys only consider a subset of the fish community (i.e. often demersal finfish) and cover a relatively short period, complementary indicators based on landings can be applied to put the survey-based information in a longer-term and broader perspective (Gascuel et al., 2014), and consider the contribution of non-surveyed species to MTL variations (Shannon et al., 2014). Therefore, using different data sources maximizes the possibilities of detecting trends at ecosystems level.

Despite the fact that the suitability of trophic indicators to detect patterns in ecosystems as a result of fishing pressure remains controversial (Branch et al., 2010), most comprehensive studies conclude that they can help to gain insight on the effects of these impacts at ecosystem level, especially if various data sources and cut-off levels are considered, and their results are interpreted at regional or local level, observing the particular impact and environmental history occurring at these levels (Shannon et al., 2014). However, there are still issues that need to be assessed and confirmed before their general use, and particularly that of the MTL, can be generalized for its implementation at MSFD level.

At this respect, the MTL indicator (indicator FW4 in OSPAR terminology) was proposed as a candidate indicator to assess GES of the North East Atlantic (OSPAR convention) in 2012, and adopted as common for OSPAR region IV in 2014. The indicator is still in candidate status for OSPAR regions II and III, and consideration of its validity for other European regions will very much depend on how its applicability and suitability as a pressure indicator is proved through subsequent analyses providing convincing results and setting the basis for a coherent set of recommendations validating its general use in GES assessments. In this respect, the aims and activities proposed within the EcApRHA project are very much directed at contributing to these goals.

2 Relevance of the EcApRHA Approach

In its recommendation to the EU (ICES Advice 2015, Book 1), ICES advised on the roadmap to be followed to further implement Descriptor 4 of MSFD (foodwebs), implying that cooperation among Member States was essential in order to pursue actions along the roadmap, especially within relevant regional or sub-regional Seas.

In this context, and as a first step, Member States should identify indicators that represent the range of foodweb components including their structural and functional properties and their resilience (an emergent property of structure and function). Member states should select a minimum of two indicators; one related to “structure” (revised criterion 4.1), and one related to “function” (revised criterion 4.2. of the Commission Decision (EC, 2010), as suggested by ICES, 2014). The recommendation also indicated that empirical data should be used rather than modelled information and that the indicators used should have broad geographic coverage of (sub-) regional seas, so that they are coherent and representative across (sub-) regional seas.

To improve coherence, the European Commission report (EU, 2014) suggested that further scientific and methodological developments should occur at the regional level to improve the possibilities for setting GES and environmental targets, and also to consider a more holistic setting of GES through integrating Descriptor 4 with other descriptors, particularly D1 and D6.

The objectives of the EcApRHA project were to further develop and refine methodologies of food web indicators, relevant for habitats, and more specifically concentrate these efforts in FW4 (Action 3.1), which is adopted as an OSPAR common indicator in OSPAR region IV and candidate indicator in OSPAR regions II and III. These efforts will facilitate the contribution of this indicator to the OSPAR intermediate assessment 2017, providing the resources needed to finaliseits testing and make proposals to make the *indicator fully operational at the (sub) regional scale* (OSPAR regions II, III, and IV), addressing OSPAR and MSFD assessment issues with an automated method for further assessment.

The aim is that this work will directly contribute to the improvement of implementation in the next steps of the MSFD (i.e. 2018 assessment to be achieved by member states), and can be used directly by all OSPAR Contracting Parties who are EU member states in the studied sub-regions for the 2017 Intermediate assessment as input to the 2018 update of EU MSFD Article 8. It will also give important information for a better coordination of monitoring programmes (article 11) using the actual and future cooperation between experts from different member states (e.g. FR and ES for FW4).

The guidelines for the implementation of Action 3.1., were summarized in the technical proposal as follows:

1) Focus on the Bay of Biscay sub-regional habitat
2) Propose an ameliorated methodology for the assessment, including:
    a. Considering the influence of species length structure in the calculation of the indicator
    b. Extend "average trophic level" computations to all nektonic predators (combining fin fish and cephalopods in which length structure is not applicable)
    c. Applying an analysis (e.g. Jack-knife) to detect species that could be driving the indicator evolution
    d. Use an “R script” to automate the assessment

3) Assessment of Bay of Biscay using the indicator in a coherent way (ES/FR collaboration
4) Investigate on a smaller scale the interactions between fishing pressure and the indicator trends
5) Test the indicator with new methodology on other OSPAR regions
    a. Collating local trophic level estimations of sampled species for all studied OSPAR regions

The aim of the work is that the assessment outputs will be taken up directly and reported in the OSPAR 2017 intermediate assessment. National reporting, which will include the common OSPAR assessment on these indicators, will thus create opportunities for consistency and coherence in Member States’ developments under Article 9 and 10 related to these descriptors. The particular part of the regional plan to be delivered by the project are the short and medium term goals and actions under the section; Common indicators, assessment and determination of GES (Art. 8 and 9 MSFD).

3 STATUS OF TASKS COMPLETED

3.1 Focus on the Bay of Biscay sub-regional habitat

All analyses and case studies are based on the Bay of Biscay, however many methodological conclusions are exportable to other OSPAR regions.

3.2 Propose an improved methodology for the assessment

This task has been completed and the results are included in Annex 1 to this deliverable. The ameliorated methodology has been approached:

a. Considering the influence of species length structure or ontogenetic variationsin the calculation of the indicator. Preliminary results are shown in Annex 2.

b. Extending "average trophic level" computations to all nektonic predators (combining fin fish and cephalopods in which length structure is not applicable).

Cephalopods represent an important molluscan class that is present in the North-East Atlantic waters and are part of the main species, in terms of biomass, exploited in these regions. Our analysis showed that several cephalopods (e.g. *Sepia officinalis*, *Loligo forbesii*) are in the list of the main species that have an influence on the indicator trend which highlights the importance of considering them in the indicator analysis. This is true in both survey-based and landing-based data.

In addition to that, our investigations indicate that other invertebrate species (e.g. the pelagic crab *Polybius henslowi*) with a high biomass, and an important role as prey species as revealed by stomach content analysis, may have a bearing in the development of the indicator and the GES of the Bay of Biscay food web and should thus, be considered to evaluate it. In order to incorporate them and understand the importance their inclusion may have in the trends observed in FW4, three different cut-off levels have been established throughout our analyses: MTL2 (including all species appearing in each data set and thus all invertebrates), MTL3.25 (including only species with a trophic level equal or higher to 3.25, which comprises most predators, including some carnivore invertebrates), and MTL4 (including species with a TL equal or higher to 4, and which gathers only high predators included in each data set).

c. Applying an analysis (e.g. Jack-knife) to detect species that could be driving the indicator evolution

Different scenarios were tested on the MTL indicators; e.g. using different data sources for TL estimations and applying different cut-offs. For each scenario described, the list of the main species representing 95% of total biomass was established. The influence of this species list on the MTL trend was observed by computing a bootstrap script methodology including one species at a time with a decreasing order in species' biomass (*i.e.* species with highest biomass were included first then the others in decreasing order).

The influence of specific species on the indicator evolution was thus based on the species representing the most important biomass. Our approach showed that these species were sufficient in order to get an estimate of the indicator trend. Depending on the scenario tested, three to eleven species formed the main list driving the indicator in the Northern part of the Bay of Biscay. For more details, see detailed results in Annex 1.

d. Use an "R script" to automate the assessment.

The script is ready. It allows the inclusion of the uncertainty around the TL values when plotting the indicator trend.

Uncertainty exists around each TL value which is related to spatio-temporal variability. This uncertainty was reported as a standard error for each TL value. In order to include uncertainty in the MTL model, a bootstrap methodology was developed using the R software (R version 3.1.0). A random sampling was applied on TL values and their standard error performing 500 MTL computations per studied year. The model was then fitted as a mean value of the 500 MTL generated with an uncertainty related to its standard deviation. The uncertainty around the MTL model is thus linked to the uncertainty of the TL estimations. For more details, see detailed results in Annex 1.

3.2.1 Assessment of Bay of Biscay using the indicator in a coherent way (ES/FR collaboration), – i.e., Applying the same methodology in Southern (ES) and Northern (FR) Bay of Biscay.

The methodology (Annex 1) was tested in the Northern Part of the Bay of Biscay (using EVHOE survey data). For a coherent application of the indicator between the French and Spanish parts of the Bay, the same methodology was used to conduct a global assessment of the Bay of Biscay (Annex 3).

3.2.2 Investigate on a smaller scale the interactions between fishing pressure and the indicator trends

An overview of the methodology and analyses conducted to date can be found in Annex 3. Moreover, an update on advances made in the integration of BH (benthic habitats) and FW (food web) indicators, to better understand the spatial dimension of MTL variations in relation with fishing pressure is provided in Annex 4.

3.2.3 Test the indicator with new methodology on other OSPAR regions

This task was not possible given delays in the start of the project and contracting of the affected post-doc.

4 SUMMARY OF RESULTS

Overall, most of the objectives set forth when defining the project have been accomplished. The results obtained confirm the adequacy of the MTL indicator at its various thresholds as a good tool to evaluate the state of marine food webs.

Preliminary results on the effect of ontogenetic variations show that the effect on global MTL values is not apparent when considering all variations together. However, these results can’t be considered definitive since it would be necessary to conduct further assessments in which more species and their ontogenetic variations are included. However, the ones used are those representing the highest biomasses and their influence should be determinant.The fact that it was not so, indicates that ontogenetic variations in diet and trophic level do not pose a problem in global values and in the use of MTL as an indicator.

Our results confirm the appropriateness of using both landings and survey data and several sources (ideally, the longest standardized time series available should be used) when conducting the evaluation, as well as the use of several cut-offs and species combinations in order to extract the utmost information from the variations in composition and functionality of the food web.

They also confirm the tight association between MTL values and variations in fishing pressure, thus confirming the suitability of the indicator as one of fishing pressure, as well as the information it may provide regarding state of the community under analysis. The first results analysing the integration between this indicator and the OSPAR benthic habitat indicator, BH3 (Extent of physical damage to predominant and special habitats), and particularly the first step, in which MTL values are crossed with VMS (vessel mentoring system) values at accurate spatial levels, further confirm this suitability, suggesting that the combination of these two information sources may be very useful to identify areas of high impact within those of severe fishing pressure. The management implications of such a tool are many and should be further explored.

The main gaps identified concerning the development of the indicator and its use in regional MSFD assessments are those associated with data availability and accuracy and the fact that it is as yet difficult to establish reference, target or threshold values to define GES. However, our results indicate that MTL (FW4) has a good potential of being a pressure indicator (as well as a surveillance one), and complies with MSFD requirements to assess the GES of marine ecosystems.

5 RECOMMENDATIONS

5.1 Regarding species biomass data sources

1. In agreement with other authors (Guénette and Gascuel, 2012; Gascuel et al., 2016), we conclude that whenever this is possible and in order to draw valid conclusions, the **longest time-series available** (comprising standardised and reliable data) should be considered, rather than stickingto more uniform but maybe less complete data sets such as ICES DATRAS/MSFD data product. This may change, of course if data are further incorporated and standardized in these official data repositories, which would then probably provide the most accurate and quality assured data sources.
2. In a first approach, it is important to assess the environmental status using the most reliable data which is the **scientific survey data** in our case. In a second approach, the **other data sources** (e.g. landings) could be investigated as complementary information in the ecosystem assessment.
3. As regards inclusion of all life compartments (e.g. using databases where no invertebrates are considered), our recommendation is that **as much information regarding the communities inhabiting specific environments should be incorporated** as long as it is comparable throughout the time series, which is not always the case. The upper cut-off levels used already seemingly disregard lower trophic levels were most invertebrates are gathered, but some invertebrates, as for instance squid and other cephalopods, have high trophic levels and play a major role as predators. They should thus not be ignored, especially if we consider it is the GES of food webs that is trying to be elucidated. Additionally, there are many invertebrates, such as polychaetes, which feed mainly on other animals and bear a much higher trophic level than is normally assigned to them. Our work emphasized **the need to consider invertebrate species** (including cephalopods) in the indicator analysis as (1) they represent an important biomass in the Bay of Biscay food web, (2) they are important prey-items with a fundamental role in the food web; and (3) they influence the indicator trends.
4. Landings and survey data provide complementary information which should be used combined with a **good knowledge of the fisheries history** of the (sub)region under analysis when interpreting the observed trends.

5.2 Regarding TL estimations

Several TL estimation methods are used currently: gut content analyses, mass balance models, SIA approaches (and their combination). In general, modelled and isotopic trophic values agree, although sometimes discrepancies occur (e.g.: Navarro et al., 2011), and species feeding on detritus or other food items whose TL has not been established accurately should be treated carefully. Other authors have cautioned on the use of estimates based on gut content analyses, arguing that they only provide a snapshot of the diet of particular species in time and space and therefore offer a poor basis for establishing trophic levels (Pinnegar et al., 2002). They also reasoned that gut content analysis often neglects certain dietary elements such as gelatinous plankton and/or detritus which may sometimes be an important component of the diet of particular species, and that the technique is especially unsuitable when estimating the trophic level of high predators, that feed intermittently and often regurgitate their food upon capture. Despite of these, a priori, inconvenients, gut content analyses can provide an overall view of food web interactions giving the opportunity to know who eats whom, which is a relevant information to understand food web structure and functioning.

1. Better to use **regional data** rather than worldwide data (e.g. fishbase data or model data), which reduces uncertainty. This has been substantiated by other studies (Branch et al., 2010, 2011), though others, such as Gascuel et al., (2016), found that trophic indicators based on landings appeared little sensitive to the uncertainty regarding values of trophic level per species.
2. The importance of **defining accurate trophic levels** has been highlighted before (Bourdaud et al., 2016, and references therein) and may have a strong bearing, especially when limiting analyses to higher trophic levels. The reliability of data sources, especially if modelling TLs are used is paramount and our **recommendation of using a hierarchical and regionally prioritized TL data** base is very well framed in these ideas.
3. One of the main concerns regarding TL assignation is also the possible **influence of ontogenetic changes** in TL values that may affect the final MTL trends. Our results indicate that such influence if buffered by overall mean trophic level trends and interspecific variations in TL, and that the effort and resources needed to incorporate ontogenetic variations in the MTL estimations may not be justified (see Annex 2 for further explanations regarding this issue).
4. Surveys are conducted during the same season every year. Accordingly, the effects of **seasonal variations in TL** reported by some authors (eg. Vinagre et al., 2012) should not have a bearing if the trend is evaluated using the same data over time. Fluctuations in the mean trophic level would reflect changes in that system during that season.
5. The **miss-assignation of TLs** (as referred to above), **is a major concern** and may as a matter of fact, force to recommend not including taxa whose TL is not well established by means of isotopic analysis or gut contents. This is especially true for species with very high biomasses who will then have a strong influence in driving the indicator trends.

5.3 Regarding compliance with MSFD Descriptor Criteria

In its consultative recommendation, ICES (2015) suggested that the Decision (EU, 2010) text for Descriptor 4 should be changed from 3 Criteria of GES to the following two:

Criterion 4.1. "Food web Structure" – Abundance/biomass of, and size distribution within trophic guilds.

Criterion 4.2. "Food web function" – Productivity of trophic guilds.

This revision has already been adopted in the Revised Commision Decision (2016), member states being urged to establish a list of trophic guilds through regional or subregional cooperation and use them in the assessment of ecosystems. The new established criteria for D4 are:

D4C1 (considered Primary): **the diversity** (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures.

D4C2 (considered Primary): **the balance of total abundance** between trophic guilds is not adversely affected due to anthropogenic pressures.

D4C3 (considered secondary): the **size distribution of individuals** across trophic guild is not adversely affected due to anthropogenic pressures.

D4C4 (considered secondary, to be used in support of crierion D4C2, where necessary): **Productivity** of the trophic guild is not adversely affected due to anthropogenic pressures.

In this new criteria context, FW4 informs mainly Criterion D4C2, giving an indication of the balance in the biomasses of the main species conforming a particular ecosystem, while at the same time apprising details on the maintenance of the functionality of food webs through the preservation of balanced amounts of individuals from higher trophic levels.

5.4 Regarding targets

According to ICES recommendation (ICES, 2015), the majority of FW indicators are surveillance indicators that are unlikely to respond unequivocally to management or support target setting but help to track the impact of human activity and natural change at a high level in food webs, and provide valuable contextual information for an informed assessment of ecosystem change, as well as broad insight into changes that may affect our ability to achieve specific targets. The majority of food web indicators are still candidate indicators for the assessment of GES within the MSFD and are difficult to assimilate to pressure levels. Notably, the MTL (FW4, in MSFD terms) has been proposed as an indicator of fishing pressure and has shown a good ability to reflect the impacts of overfishing worldwide.

Despite this, it is still difficult to identify values of the indicator that are desirable or undesirable in relation to fishing pressure in particular and other pressures in general, and what is more often sought for is a balanced state in which neither very high nor very low values are attained. Reference values are difficult to obtain since most surveyed areas and most data on landings already proceed from times when systems were under severe exploitation, and no pristine reference level is available for most of them.

Therefore, it is still difficult to establish targets to be met at regional level and these should be set at regional/sub-regional level following detailed studies on the evolution of the indicator based on landings and survey data and on the fishing/exploitation history occurring there.

In the specific case of the Bay of Biscay, our analyses are awaiting a common assessment of the whole Bay of Biscay using the MSFD DATRAS product which will permit a joint assessment of the northern and southern areas of the Bay based on standardised and quality assured data for both zones. The MTL values and trends obtained for the northern and southern sub-areas still don't allow establishing specific targets for each of the regions and further studies on the range of values adopted by the MTL at its various cut-off thresholds, and under specific pressures are obtained, **we recommend that only trends at the various cut-off levels are examined**. In this way, **a non-varying trend or an increasing one should be considered as signs of increasing GES, while a decreasing trend should be further investigated in order to determine its possible causes**. These variations in trend should be examined during each MSFD cycle, six years being a sufficient time frame for variations in trend within the time series (provided it is around 20 years long) to be observed.

For the purpose of the use of the integration tool defined in deliverable 3.5 ("the NEAT tool"), the assessment was based on MTL 3.25. A decrease in MTL 3.25 is typically interpreted as a loss of higher trophic levels, often due to fishing. From a sustainability perspective, a decrease in MTL 3.25 is therefore considered as bad, and an increase or a non-significant trend as good. If a change is detected, further investigation of the underlying reason is important, which can be done by looking at the species that are driving the MTL 3.25 in each case (Annex 1).

The definition of definitive targets and thresholds for the Bay of Biscay subregions is thus, still underway, a preliminary proposal being part of the aims of the project, as a result of the integration of the MTL indicator within the NEAT tool.

5.5 Regarding interpretation and uncertainty of results

Interpretation of results should be made separately in each ecosystem and based on scientific knowledge and expertise regarding it. Our work showed that the MTL trend can be influenced by data availability and completeness, which is often dependent also on survey design. Data comparability is thus the first step to be conductedbefore exploring thecommon assessment of any given region.

It is fundamental that results be interpreted in the light of the fisheries and exploitation history of the area under study, since some oscillations in the trends observed can be easily explained knowing the fluctuations in fishing effort/species targeted in a specific area. This will also help to extract better conclusions regarding the accuracy of FW4 as an indicator of fishing pressure in specific areas.

For now, the levels of uncertainty implicit in the assessment include uncertainty regarding the correct limit level, and regarding the precision of the indicator estimated from the data (mainly due to the uncertainty associated with TL values and in the case of landings data, with their reliability).

As for uncertainty about the effects of pressures on the indicator, and despite the fact that as a Food Web indicator, it is mainly considered a state indicator, our results show that FW4 is relatively sensitive to the effects of fishing pressure, both from a temporal and spatial perspective. Our conclusion is that it can be very well used in the adoption of management measures, since, especially when combined with measures of fishing effort (such as VMS, see Annex 4) data, it provides a good illustration of the main areas affected and the degree in which indicator values are reduced as a function of it.

Further studies on the variation of indicator values under different degrees of fishing pressure will probably enable the establishment of limits, which will help in the definition of acceptable risks related with the fishing impact caused in specific areas.

5.6 Regarding monitoring/scientific surveys

1) The IBTS surveys in which our results are based give a seasonal snapshot of (mainly) the existing demersal assemblages, where the pelagic compartment is not well sampled. Pelagic surveys are also carried out yearly but during different seasons, so it is not possible to aggregate the data in order to obtain a global vision of the ecosystem that can be compared on an annual basis. It would be interesting to conduct surveys which are inclusive of all compartments during a same period of time, or to somehow better sample the pelagic compartments during IBTS surveys.

2) Similarly, and in order to be able to conduct regional assessments in a homogeneous way, our recommendation is that the methods and procedures between scientific surveys (e.g.: EVHOE and Demersales for the Bay of Biscay) are standardized.

3) In this regard, one of the standards we recommend should be implemented is the **systematic analysis of stomach contents and/or stable isotope for food web analyses**. Both are valuable sources of information for this indicator (trophic level estimations) but also for other indicators and models (e.g.: FW7, FW8 and FW9).

5.7. Regarding management

As mentioned earlier, despite the difficulty in identifying clear limits beyond which the indicator might be showing failure to attain GES, the clear relationship shown between its trends and values and increasing fishing pressure, indicate that MTL has a good ability to describe a pressure – state relationship, and thus can be considered a management indicator.

The preliminary results obtained when integrating FW4 with the benthic habitats indicator BH3, and more particularly when modelling the response of the evolution of mean trophic level in relation with fishing pressure (VMS data, see Annex 4) clearly show a direct relationship between increasing fishing pressure and the decline in the mean trophic level of the affected communities, with a strikingly high level of spatial precision.

These results suggest that with this methodology, the FW4 indicator could be used for management purposes, by identifying areas of high fishing impact within commonly trawled grounds.

6 Gaps and Shortcomings

1. Trophic level data are still not complete and in many instances global values have to be used. In the case of invertebrates, very crude estimations are made, often not representing the real values they would attain (i.e.: some carnivorous and scavenger invertebrates may reach quite high TL values and they are often given a common “2” of secondary consumers).

2. The recorded biomass in most regions is restricted to commercial fish biomass and this is not representative of the whole food web. Food web indicators are supposed to be the most holistic and integrative ones and they should (when possible) include as many elements of the food web as possible. Many standardized surveys do not include invertebrates in their sampling schemes and this is a shortcoming when the evolution of the indicator at low trophic values is to be examined. In these cases, only MTL3.25 (with a limited approach to the food web) and MTL4 can be assessed.

3. A better understanding of the spatial variations of the various cut-off levels depending on the fishing pressure exerted in specific areas would help to understand the sensitivity and temporal frame in which the indicator may identify critical levels. This approach has been partly assessed during WP4, as a synergy between Benthic habitats and Food web indicators within EcApRHA and the results are shown in Annex 4. Still further analyses at sub-regional level are required to make this approach fully operational and be able to fully implement it in coherent assessments.

4. Finally, another gap is the limited temporal range of current surveys, which are usually undertaken during a single season every year. Since the diet of most predators changes seasonally and some environmental events (i.e. upwelling) or fishing-related changes (closure periods, seasonal fisheries) have also a seasonal periodicity, and may have a bearing on their evolution, more exhaustive demersal surveys taking place during different seasons would give a broader picture of the responses of the community and help in the establishment of target values and thresholds.

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8 ANNEXES 1 to 6

Annex 1: Draft of Methodology paper by Safi et al. used for the Mean Trophic Level indicator application in the Bay of Biscay (OSPAR region IV)

1.INTRODUCTION

The MTL is an ecosystem indicator based on two metrics, trophic level and biomass of species, each representing an important concept of the food webs. The trophic level (TL) reflects the position of species in a food web catching energy transfer between prey and predator (Lindeman 1942). It describes the position of each element in the food chain from the larger fishes feeding on smaller fishes, themselves feeding on zooplankton; all these animals resting upon primary producers (Pauly and Watson, 2005). TL can be derived from dietary analyses of guts or stomach contents (Velasco et al., 2003), stable isotope analysis of nitrogen in tissues (Le Loch' et al., 2008; Jennings and Molen, 2015) and models (Lassale et al., 2011). Biomass represents the mass of living organisms in a certain area.The sum of species biomass multiplied by theirrespective TL is divided by the total species biomasses giving the MTL value for a given year (Pauly and Palomares, 2005).

The MTL indicator was firstly introduced by Pauly et al. (1998) with the concept of "fishing down marine food webs". A decline in the MTL of catches is a sign of a gradual transition in fisheries landings from long-lived, high trophic level, piscivorous fish toward short-lived, low trophic level, invertebrates and planktivorous fish. The decrease in MTL may imply major changes in the structure of the marine food webs and indirectly, their functioning.The resulting shorter food chain leaves the ecosystems increasingly vulnerable to natural and human-induced stresses (CBD, 2004). Thus, the indicatoraims to highlight the likely unsustainable practices of fisheries from past decades and this indicator is commonly used in the ecosystem approach of fisheries management as a measure of ecosystem integrity, (CBD, 2004, Shin et al., 2012).

However, MTL metrics are prone to several improvements. Indeed, the sources of biomass data (*i.e.* landings, survey and models data) are subject to various constraints as described by Shannon et al. (2014). First, landings are influenced by fishers' behaviours, management strategies and market forces which makes them not always representative of the ecosystem status. Landings are also often restricted to exploited communities with declarations partly incomplete, not taking into account discards and by-catch. This data source was traditionally used to compute the MTL indicator from the establishment of the concept (Pauly et al., 1998) until recent years (Shannon et al., 2014, Gascuel et al., 2016). Notwithstanding, some authors are very sceptic about the usefulness of this indicator based on landings data for the description of marine biodiversity changes (Branch et al., 2010) and the "fishing down marine food webs" concept (Pauly et al., 1998) is not always applicable with landings data (Essington et al., 2006, Stergiou and Tsikliras, 2011, Foley, 2013). Secondly, survey data, are often on short time series, limited to one or two seasons of the year and targeting demersal communities due to survey design. Thirdly,food web models (such as Ecopath with Ecosim)depend on data availability and parameterization of species groups, understanding prey-predator interactions and model assumptions.In parallel, TL of most of the species have been estimated and can be easily collected from online database (*e.g.* Fishbase and Sealifebase). Those values are worldwide averaged of trophic level estimations gathered on different ecosystems often leading to a misrepresentation of the particularities of a given region and its specific trophic interactions between species linked to environmental or human-induced conditions.

The MTL indicator is an original concept based on important metrics of the food webs. If European marine public policies have implemented numerous biodiversity indicators through scientific advisory bodies to assess the fishing pressure on ecosystems (e.g. STECF, ICES, GFCM), the implementation of food web indicators to appraise the impacts associated is relatively recent and challenging from a scientific point of view.The MTL indicator is expected to be used in a marine policy context (OSPAR 2014) as an ecosystemic indicator describing the fishing impact on food webs. As the application of MTL focuses generally on high predators by excluding low trophic level species (Pauly and Watson, 2005), it is necessary to explore the potential of this indicator in describing the food webs with a holistic approach.

In this study, the choice of survey as only source of biomass data used was made because it reflects the actual changes in communities including non-targeted species (Shannon et al., 2014). This allows the proposition of a standardised protocol for computing MTL applicable in all European regions where surveys exist.The use of different TL sources is also tested in order to evaluate the importance of using local TL estimations.

The objectives of this work are to (1) propose a standardised and improved methodology for the computation of MTL indicator taking into account the main criticisms, (2) apply the methodology for the assessment of the evolution of food webs in the Bay of Biscay continental shelf as a case study and (3) propose recommendations for management use of MTL indicator to assess the food web status

2. MATERIAL AND METHODS

2.1 Study area and biomass data used

The area considered in this study is the continental shelf of the Bay of Biscay (BoB), a North-East Atlantic Ocean gulf located off the west coast of France and the northern coast of Spain (**Fig. 1**).

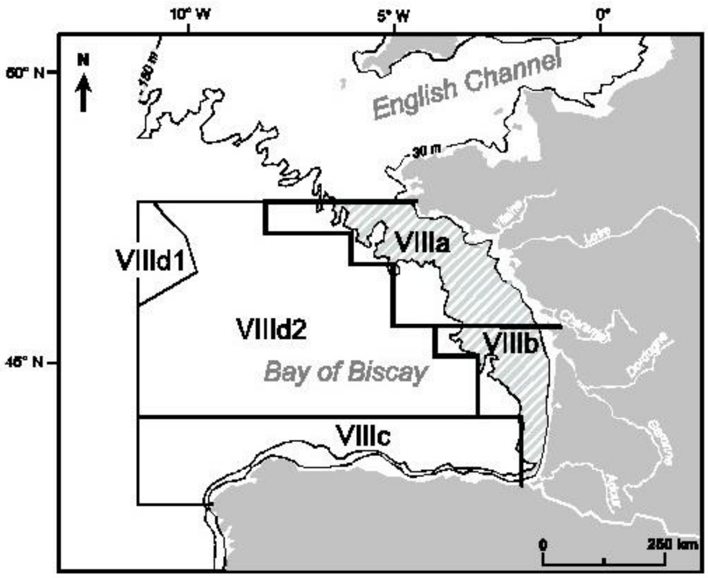


Figure 1: Study area of the Bay of Biscay continental shelf corresponding to the ICES divisions VIIIa and VIIIb. The striped blue area corresponds to the continental shelf with < 200m depth and used in this study. This figure is modified from Lassalle et al., 2011

The area corresponds to the ICES divisions VIIIa and VIIIb (ICES; www.ices.dk), for a total surface area of 102.585 km² (between 50 m and 200 m depth). The area is about 140 km wide in the northern BoB narrowing to 50 km in the south. From coast to offshore, the shelf is mainly flat and its depth increases almost regularly down to 200 m (ICES, 2008). In the BoB, species diversity is high where temperate-water species occur together with boreal and southern lusitanian species with relative abundances following latitudinal gradients (ICES 2008; Rochet et al., 2012). Fishing activity on the continental shelf is important and most aspects of the demersal fish community of the French continental shelf are in a poorer state than in the mid- to late 1980s (OSPAR, 2010). This activity impacts commercial stocks, threatened and declining fish species, seabirds and marine mammals and food-webs (ICES Advice Book 7, 2016).

2.2 Data used

Biomass data

The annual biomass per species collected from 1997 to 2014 in ICES subdivisions VIIIa and VIIIb were downloaded from DATRAS database for bottom trawl scientific survey EVHOE (EValuation des ressources Halieutiques de l'Ouest Europe)(http://www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx)

Trophic level assigned to species

In order to calculate the mean trophic level (MTL) of the community, a trophic level (TL) was assigned to each species. Two TL dataframes were used in this work.

Dataframe A where TL values and standard errors were exclusively collated from online database [*i.e.* Fishbase (http://www.fishbase.org/) and Sealifebase (http://www.sealifebase.org/)].

DataframeB where TL values and standard errors were collated from various sources with a prioritisation applied in order to favour, when possible, local TL estimates in BoB.These TL values were selectively prioritized following this order : (1) Local TL estimations from stomach content and stable isotope analyses (representing 48% of total TL used for species in BOB), (2) Non local TL estimations from stomach content and stable isotopes analyses from surrounding regions (representing 6% of total TL used), (3) TL mean values from online database [*i.e.* Fishbase (http://www.fishbase.org/) and Sealifebase (http://www.sealifebase.org/)] (representing 46% of total TL used). The local TL estimates from stomach content analyses came mainly from a private analysis of the Instituto Español de Oceanografia (IEO) conducted from 1990 to 2014 during the "Demersales survey" in the Spanish part of the Bay of Biscay. The other TL estimates from stomach content analysis and stable isotope analysis were collated from literature for local and non-local areas (Pinnegar et al 2002; Le Loc'h and Hily 2005; Chouvelon et al. 2012; Lassalle et al. 2014).

2.3 MTL ecosystem indicator

The MTLis calculated as the mean trophic position of species in relation to their relative biomass in BoB continental shelf following the equation:

$$MTL_k = \sum_i (TL_i) \times (Y_{ik}) / \sum_i Y_{ik}$$

TLi is the trophic level of species i and, Yik refers to the biomass of the species in year *k*.

MTL is assessed using two metrics which are species biomass data (ICES DATRAS and EVHOE survey) and species TL (Dataframe A and B) (**Fig. 2**). Three different scenarios were applied to these metrics: **(1)** including all the species' biomass available in EVHOE survey with species TL collated exclusively from online datasets (*i.e.*section 2.2, **Dataframe A**), **(2)** including all the species' biomass available in EVHOE survey with species TL collated from regional estimations (*i.e.*section 2.2, **DataframeB**) and **(3)** excluding pelagic species' biomass from the analysis with species TL collated from regional estimations (*i.e.*section 2.2, **DataframeB**) (**Fig. 2**).

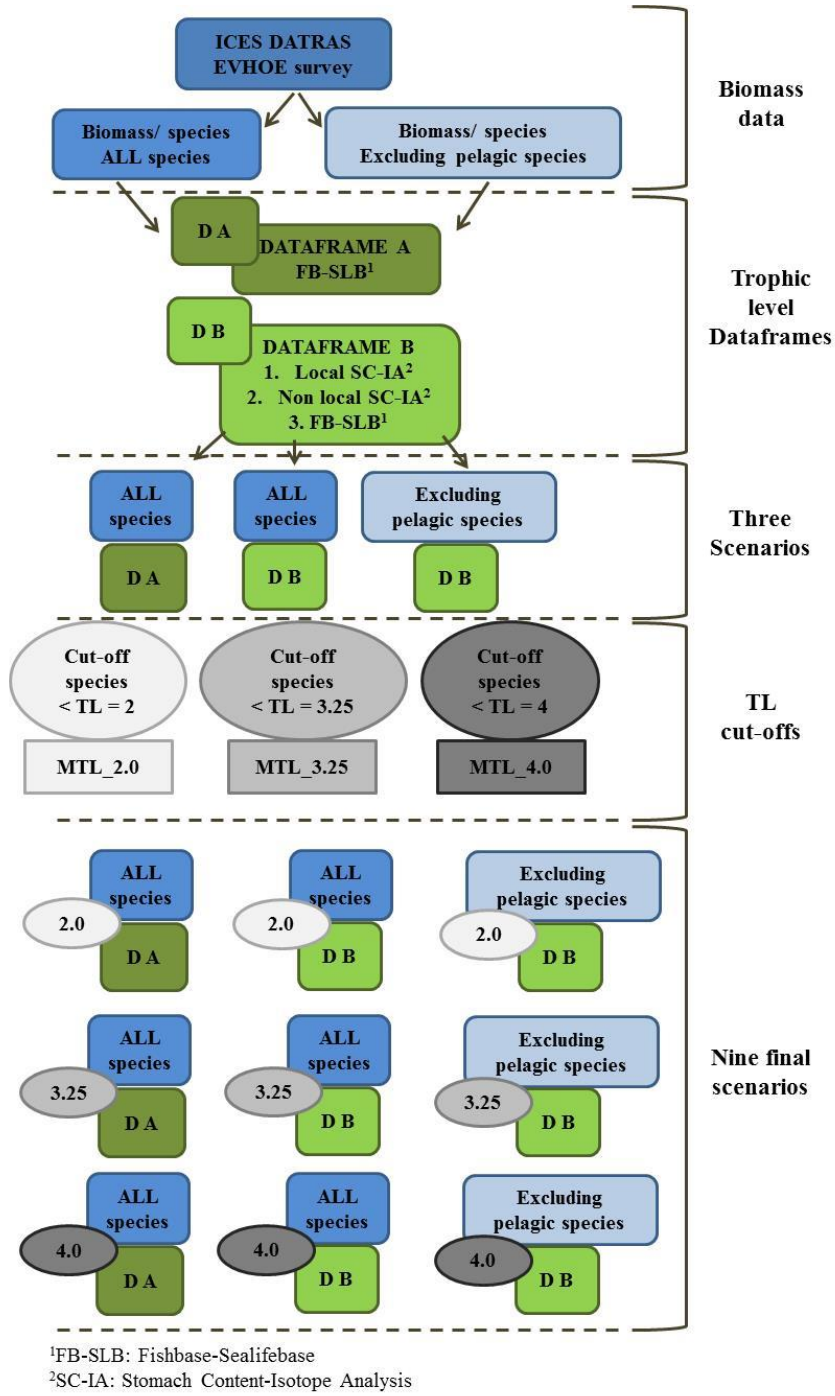


Fig. 2 Various steps in processing data (*i.e*. biomass and trophic level data) for testing nine different scenarios on MTL indicator in Bay of Biscay continental shelf.

For each of the three scenarios, three TL cut-offs were applied to MTL: **(i)** MTL_2.0 describing the entire consumers' community in the ecosystem, **(ii)** MTL_3.25 with a cut-off of all species with a TL<3.25 and **(iii)** MTL_4.0 with a cut-off of all species with a TL< 4.0.The TL cut-offat 3.25 was first described by Pauly and Watson (2005) applied on landings data (known as the Marine Trophic Index, MTI). In this study, the MTL_3.25 is similar to MTI indicator at the exception that we used survey data rather than landings. The aim of the higher cut-offs (*i.e.* 3.25 and 4.0) was to examine changes within the predators' community while excluding small and medium TL species.

At the end, 9 scenarios were generated for MTL indicator in the BoB continental shelf (**Fig. 2**) based on three combinations of datasets (**1,2 and 3**) and three cut-offs in species TL (**i,ii,iii**).

Uncertainty exists around each TL value which is related to spatio-temporal variability. This uncertainty was reported as a standard error in the Dataframes A and B. In order to include uncertainty in the MTL model, a bootstrap methodology was developed using the R software (R version 3.1.0). A random sampling was applied on TL values and their standard error performing 500 MTL computations per studied year. The model was then fitted as a mean value of the 500 MTL generated with an uncertainty related to its standard deviation. The uncertainty around the MTL model is thus linked to the uncertainty of the TL estimations.

2.4 Main species and the ecosystem structure evolution in BoB

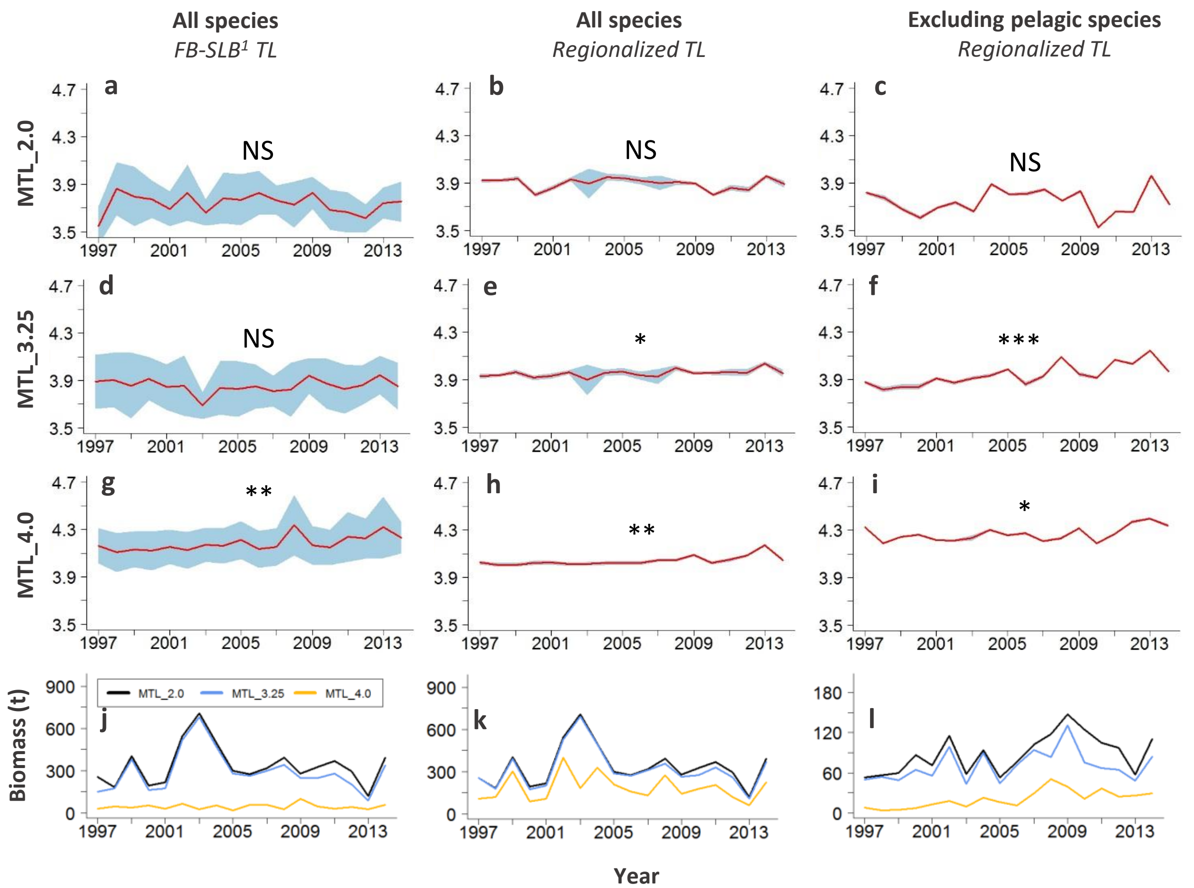
For each of the 9 scenarios described before, the list of the main species representing 95% of total biomass was established. The biomass of species was cumulated over the studied period (*i.e.* between 1997 and 2014) and listed in decreasing order of biomass. The influence of this species list on the MTL trend was observed by computing the same previous bootstrap methodology including one species at a time with a decreasing order in species' biomass (*i.e.* species with highest biomass were included first then the others in decreasing order). Afterwards, MTL mean values were zero-centered in order to have a normal distribution within an interval of (-0.2, 0.2) for all scenarios.

The ecosystem structure evolution was investigated by looking at the main species list (*i.e.*representing 95% of total biomass) evolution. For each species, the percentage of total biomass per year was calculated. The structure evolution in the ecosystem was explored with species proportion change over time.

RESULTS

3.1 Testing different scenarios for MTL indicator in the Bay of Biscay continental shelf

Nine different scenarios were applied to the MTL indicator using EVHOE survey data from Bay of Biscay continental shelf ecosystem (**Fig. 3**). These scenarios were driven by the choice of trophic level (TL) utilized for species (*i.e.* online database vs regionalized estimations) and by cut-off of some compartments of the ecosystem (*e.g.* pelagic species or low TL species). The list of the main species (*i.e*. representing 95% of total biomass) included in each scenario also differed according to the equation used (*i.e.* TL choice x cut-off practiced) (**Table 1**).



[1]FB-SLB: Fishbase and Sealifebase websites

Fig.3: Trends in Mean Trophic Level (MTL) from Bay of Biscay continental shelf ecosystem based on EVHOE survey biomass. Results are mean MTL values (red model) with the uncertainty (in blue) around the model. Three different scenarios were applied to MTL: (**a,d,g**) including all the species' biomass with species TL collated from online datasets (*i.e.*fishbase/sealifebase), (**b,e,h**) including all the species' biomass with species TL collated from regional estimations and (**c,f,i**) excluding pelagic species' biomass from the analysis with species TL collated from regional estimations. For each scenario, three TL cut-offs were applied to MTL: (i) MTL_2.0 describing the whole consumers' community in the ecosystem, (ii) MTL_3.25 with a cut-off of all species with a TL under 3.25 and (iii) MTL_4.0 with a cut-off of all species with a TL under 4.0. Total biomass (t) of species included in each scenario are represented (**j,k,l**). NS: Not significant and '***' $p<0.001$ '**' $p<0.01$ '*' $p<0.05$

Table 1: Main species lists (*i.e.* species representing 95% of total biomassbased on EVHOE survey) in Mean Trophic Level (MTL) according to different scenarios: (**a,d,g**) including all the species' biomass with species trophic level (TL) collated from online datasets (*i.e.*fishbase/sealifebase), (**b,e,h**) including all the species' biomass with species TL collated from regional estimations and (**c,f,i**) excluding pelagic species' biomass from the analysis with species TL collated from regional estimations. For each scenario, three TL cut-off were applied to MTL (*i.e.* MTL_2.0, MTL_3.25, MTL_4.0).

		All species FB/SLB TL				All species Regionalized TL				Excluding pelagic species Regionalized TL		
		Species 95% total biomass	Percentage of total biomass (%)	TL ± se		Species 95% total biomass	Percentage of total biomass (%)	TL ± se		Species 95% total biomass	Percentage of total biomass (%)	TL ± se
MTL_2.0	a	*T. trachurus*	48,8	3.84 ± 0.59	b	*T. trachurus*	48,8	4.00 ± 0.03	c	*M. poutassou*	37,9	3.77 ± 0.05
		S. scombrus	17,4	3.60 ± 0.20		*S. scombrus*	17,4	3.86 ± 0.32		***C. aper***	**19,7**	**2.94 ± 0.03**
		M. poutassou	9,9	4.10 ± 0.30		*M. poutassou*	9,9	3.77 ± 0.05		*T. minutus*	11,6	3.90 ± 0.02
		C. aper	**5,1**	**3.10 ± 0.30**		***C. aper***	**5,1**	**2.94 ± 0.03**		*S. canicula*	9,3	4.08 ± 0.02
		S. pilchardus	3,7	3.10 ± 0.10		*S. pilchardus*	3,7	3.80 ± 0.06		***M. merluccius***	**8,3**	**4.56 ± 0.02**
		E. encrasicolus	3,6	3.10 ± 0.45		*E. encrasicolus*	3,6	3.90 ± 0.09		*T. luscus*	2,5	4.00 ± 0.03
		T. minutus	3,0	3.80 ± 0.50		*T. minutus*	3,0	3.90 ± 0.02		*A. sphyraena*	1,7	3.80 ± 0.09
		S. canicula	2,4	3.70 ± 0.60		*S. canicula*	2,4	4.08 ± 0.02		*C. cuculus*	1,4	3.86 ± 0.02
		M. merluccius	**2,2**	**4.40 ± 0.80**		***M. merluccius***	**2,2**	**4.56 ± 0.02**		*Z. faber*	1,2	4.47 ± 0.19
										I. coindetii	0,8	3.91 ± 0.02
										L. naevus	0,8	3.87 ± 0.04
MTL_3.25	d	*T. trachurus*	55,9	3.84 ± 0.59	e	*T. trachurus*	51,5	4.00 ± 0.03	f	*M. poutassou*	47,3	3.77 ± 0.05
		S. scombrus	20,0	3.60 ± 0.20		*S. scombrus*	18,4	3.86 ± 0.32		*T. minutus*	14,4	3.90 ± 0.02
		M. poutassou	11,3	4.10 ± 0.30		*M. poutassou*	10,4	3.77 ± 0.05		*S. canicula*	11,6	4.08 ± 0.02
		T. minutus	3,5	3.80 ± 0.50		*S. pilchardus*	3,9	3.80 ± 0.06		***M. merluccius***	**10,4**	**4.56 ± 0.02**
		S. canicula	2,8	3.70 ± 0.60		*E. encrasicolus*	3,8	3.90 ± 0.09		*T. luscus*	3,1	4.00 ± 0.03
		M. merluccius	**2,5**	**4.40 ± 0.80**		*T. minutus*	3,2	3.90 ± 0.02		*A. sphyraena*	2,1	3.80 ± 0.09
						S. canicula	2,6	4.08 ± 0.02		*C. cuculus*	1,8	3.86 ± 0.02
						M. merluccius	**2,3**	**4.56 ± 0.02**		*Z. faber*	1,5	4.47 ± 0.19
										I. coindetii	1,0	3.91 ± 0.02
										L. naevus	1,0	3.87 ± 0.04
										L. forbesii	0,7	4.00 ± 0.03
MTL_4.0	g	*M. poutassou*	73,9	4.10 ± 0.30	h	*T. trachurus*	88,58	4.00 ± 0.03	i	*S. canicula*	39,9	4.08 ± 0.02
		M. merluccius	**16,2**	**4.40 ± 0.80**		*S. canicula*	4,41	4.08 ± 0.02		***M. merluccius***	**35,7**	**4.56 ± 0.02**
		Z. faber	2,3	4.50 ± 0.80		***M. merluccius***	**3,94**	**4.56 ± 0.02**		*T. luscus*	10,5	4.00 ± 0.03
		I. coindetii	1,6	4.11 ± 0.85						*Z. faber*	5,1	4.47 ± 0.19
		L. forbesii	1,1	4.29 ± 0.82						*L. forbesii*	2,4	4.00 ± 0.03
										L. whiffiagonis	1,7	4.26 ± 0.02

The use of the online database (*i.e*. fishbase/ sealifebase) exhibited high uncertainty around the MTL model whereas this uncertainty was reduced when using regionalized estimations (**Fig. 3**). Furthermore, in some cases (*e.g.***Fig. 3a vs 3b**) the MTL model was shaped at a lower MTL level when using online TL estimations compared to regionalized estimations. This was related to the difference in TL values applied to the MTL model (**Table 1a and 1b**). The opposite situation was observed when using MTL_4.0. Indeed, the MTL model using fishbase/sealifebase (**Fig. 3g**) was shaped at a higher mean trophic level compared to MTL model with regionalized estimations of TL (**Fig. 3h**). In this case, the difference between the two approaches was related to the difference in TL values applied to MTL model, but also to the structure of the main species considered (**Table 1g and 1h**).

The cut-off of low TL species has increased the significance of the trend observed for MTL models (*i.e.* MTL_3.25 and MTL_4.0) (**Fig. 3e to 3i**). Also, when increasing the cut-off (*i.e.* from MTL_3.25 to MTL_4.0), biomass of species included in the analysis was reduced (**Fig. 3j, 3k and 3l**) as we focused on higher predators. The most significant increase of the model was registered for MTL_3.25 when excluding pelagic species from the analysis (**Fig. 3f**). However, the cut-off of the pelagic compartment highly reduced the biomass of species included to run the MTL model (**Fig. 3kand 3l**). Pelagic species had indeed the highest biomass over the whole studied period (*i.e.* 1997-2014) representing more than 70% of the total biomass in consideration of only the four main species (*i.e*. *Trachurus trachurus*, *Scomber scombrus, Sardina pilchardus* and *Engraulis encrasicolus*) (**Table 1a and 1b**). On the other hand, excluding pelagic species has enlarged the list of the main species representing 95% of total biomass (**Table 1c, 1f and 1i**).

3.2 Species driving the MTL indicatorin the Bay of Biscay continental shelf

Species influence on the MTL indicator trend was assessed by integrating one species at a time following a decreasing order of biomass (*i.e.* species with highest biomass were included first than the others in decreasing order) (**Fig. 4**). In all scenarios tested, the list of the main species (*i.e.* representing 95% of total biomass) was sufficient to obtain the trend of the MTL indicator. This main species list was reduced when the TL cut-off was increased (*i.e.* passing from MTL_2.0 to MTL_4.0). A list of 11 species was observed for example with MTL_2.0 when excluding the pelagic compartment (**Table 1c**). While 3 species represented 95% of total biomass when looking at MTL_4.0 (**Table 1h**).

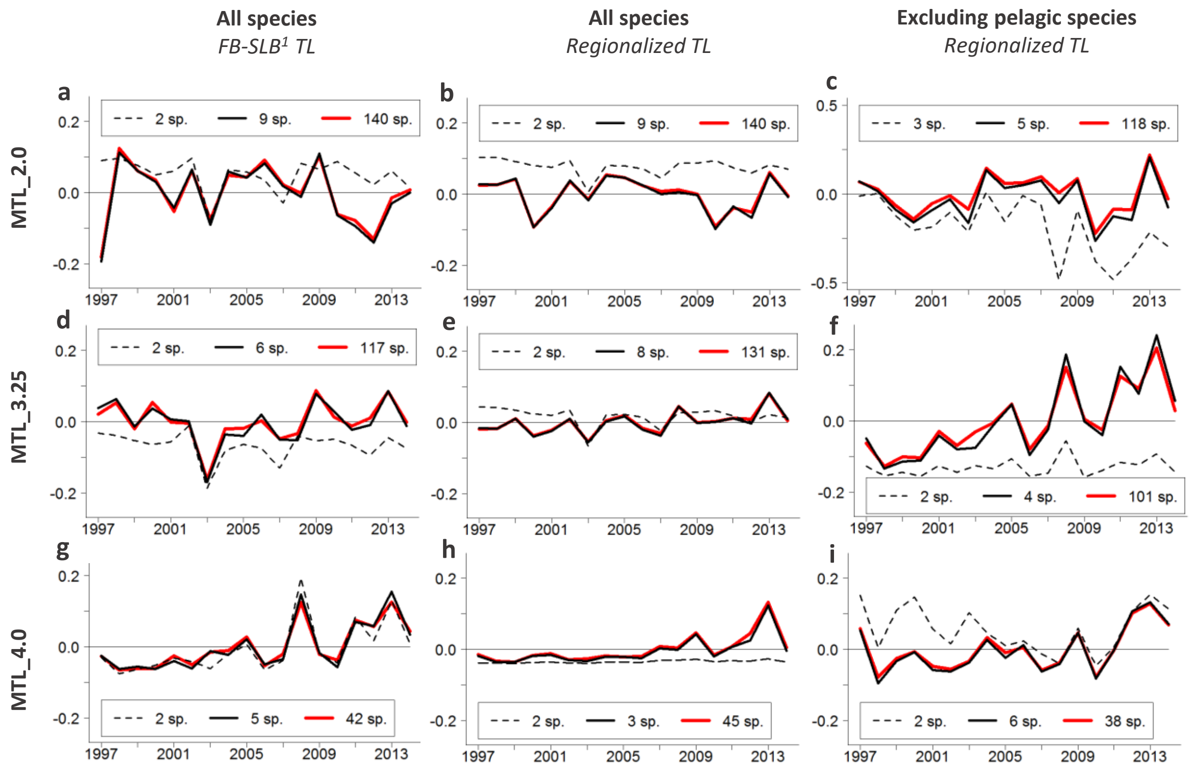


Fig.4: Number of species driving the Mean Trophic Level (MTL) from the Bay of Biscay's continental shelf based on EVHOE surveys according to different scenarios: (**a,d,g**) including all the species' biomass with species trophic level (TL) collated from online datasets (*i.e.*fishbase/sealifebase), (**b,e,h**) including all the species' biomass with species TL collated from regional estimations and (**c,f,i**) excluding pelagic species' biomass from the analysis with species TL collated from regional estimations. For each scenario, the cumulated biomass (%) and the number of species included for each model were detailed below(**a' to i'**). Three TL cut-off were also applied to MTL indicator (*i.e.* MTL_2.0, MTL_3.25, MTL_4.0).

Two species should be highlighted for their influence on the indicator trend. First, *Capros aper* which is a low TL species exerting its influence only on MTL with the lowest cut-off (*i.e*. MTL_2.0). Indeed, this species is the only one that is excluded from the list of the main species (**Table 1**) when establishing a higher TL cut-off (*e.g.* MTL_3.25). The exclusion of *C. aper* showed a change in the indicator trend passing from a non-significant trend at MTL_2.0 to a significant increasing trend at MTL_3.25 (**Fig. 3e and 3f**). Thus, the biomass of this species broke off the trends in all scenarios tested on MTL indicator (**Fig. 3a, 3b and 3c**). The second species, *Merluccius merluccius* is a structuring high TL species playing a major role in the MTL trend for all scenarios tested. The clearest example is the MTL_3.25 after excluding pelagic species (**Fig. 4f**). Indeed, after including the 4th species to run the indicator, the curve obtained followed perfectly the trend of the MTL indicator (red model) based on all species (*i.e*. 101 species considered in the indicator after applying the TL cut-off and the pelagic species exclusion). The 4th species being *M. merluccius* (see **Table 1**). In the same way, the 9th species was needed to obtain the trend in MTL_2.0 without pelagic exclusion (**Fig. 4a and 4b**), the 2nd species was needed for MTL_4.0 using fishbase/sealifebase TL estimations (**Fig. 4g**) and the 3rd species for MTL_4.0 using regionalized TL estimations (**Fig. 4h**). In all of these cases, the requested species was *M. merluccius* (**Table 1**) and this was observed in all scenarios.

Howbeit, the influence of *M. merluccius* on the MTL indicator trend was mainly marked in the latest years (after 2005). This is very clear if we observe the MTL_4.0 when using regionalized TL estimations (**Fig. 4h and 4i**). In the **Fig. 4h**, we can note that when including only 2 species to run the indicator (*i.e., T. trachurus* and *Scyliorhinus canicula*), the dashed curve followed the red model trend before 2005. After 2005, the 3rd species (*i.e., M. merluccius*) was needed to have a match between the black and the red models. In parallel, the **Fig. 4i** shows that the inclusion of *M. merluccius* (*i.e.* 2nd species) before 2005 was not sufficient to have the dashed curve matching the red model. But after 2005, the dashed curve had a better match with the red model. The increasing influence of *M. merluccius* in this same period was also marked with MTL_2.0 (**Fig. 4a and 4b**) and MTL_3.25 (**Fig. 4d and 4e**).

3.3 Evolution of the ecosystem structure in the Bay of Biscay continental shelf

The structure of the main population sampled in the Bay of Biscay continental shelf ecosystem has evolved between 1997 and 2014, which affected the trend of the MTL indicator. *T. trachurus* was the only pelagic species to show an important constant decrease of its biomass between 2002 (381.7 t) and 2013 (33.8 t) (**Fig. S1**) and this was reflected in its relative biomass (**Fig. 5a**). After excluding all pelagic species, *Micromesistius poutassou's* relative biomass decreased over time with a maximum of 75 % of total biomass registered in 1998 and a minimum of 2 % in 2008 (**Fig. 5b**). This decrease of *M. poutassou* proportion has heightened the influence of *M. merluccius* and *C. aper* on the indicator. Indeed, the increase of *M. merluccius* and *C. aper* relative biomasses over the time strenghtened their influence on the MTL indicator (**Fig. 5a, 5b**). *M. merluccius* biomass has almost quadrupled between 1997 (3.8 t) and 2014 (12.5 t) with a constant increase during this period (**Fig. S1**). In parallel, the biomass of *C. aper*, showed two peaks of biomass, one in the year 2000 and the second one in 2010. The second peak being almost twice as high as the first one (**Fig. S1**). In parallel, *S. canicula* was more represented in the main population structure after 2005 while an inverse trend was registered for *Trisopterus minutus* (**Fig. 5b**). Several high TL species (*i.e. Zeus faber, Chelidonichthys cuculus* and *Lepidorhombus whiffiagonis*) have also increased their biomass (**Fig. S1**). However, their relative biomass was smaller than that of *M. merluccius*' (**Fig. 5b**).

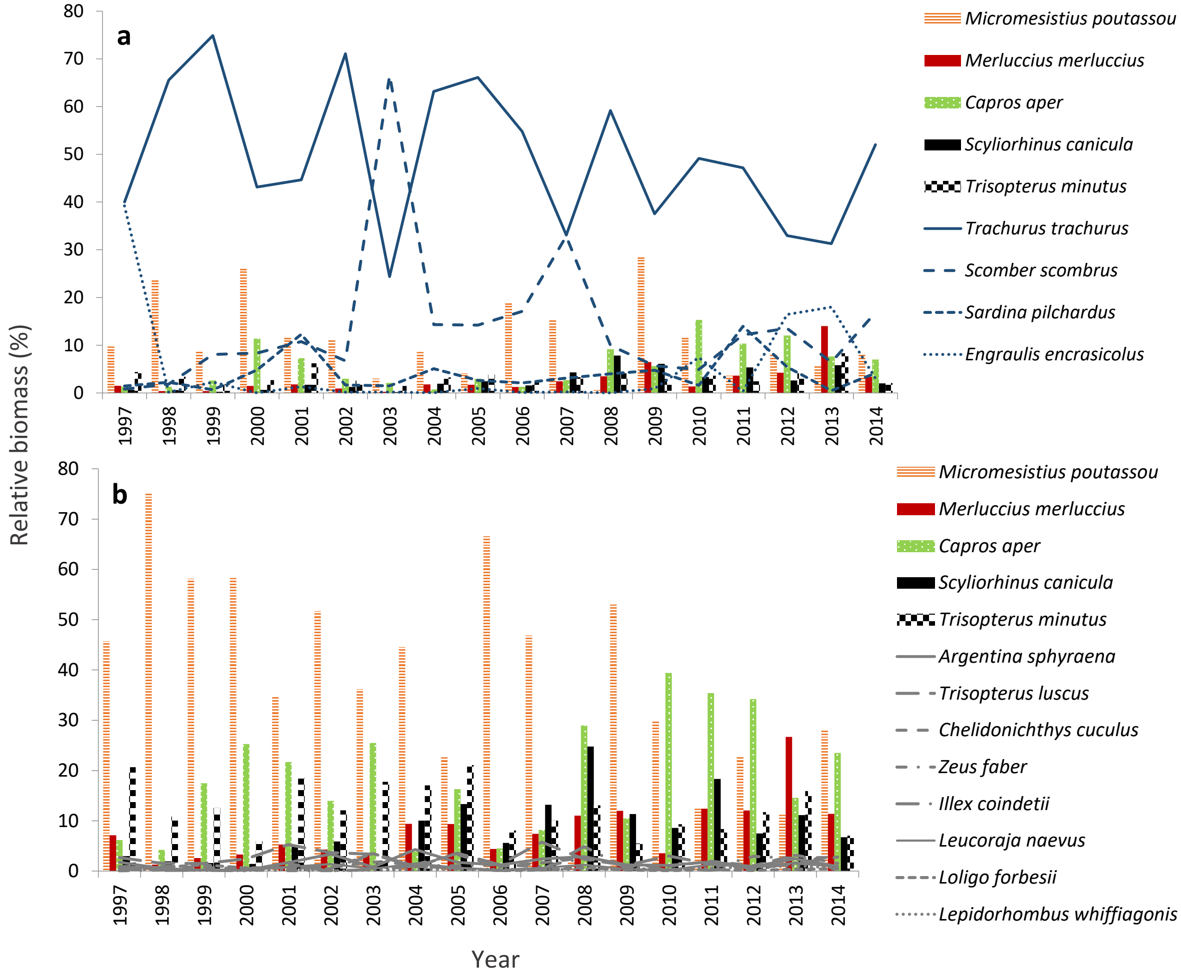
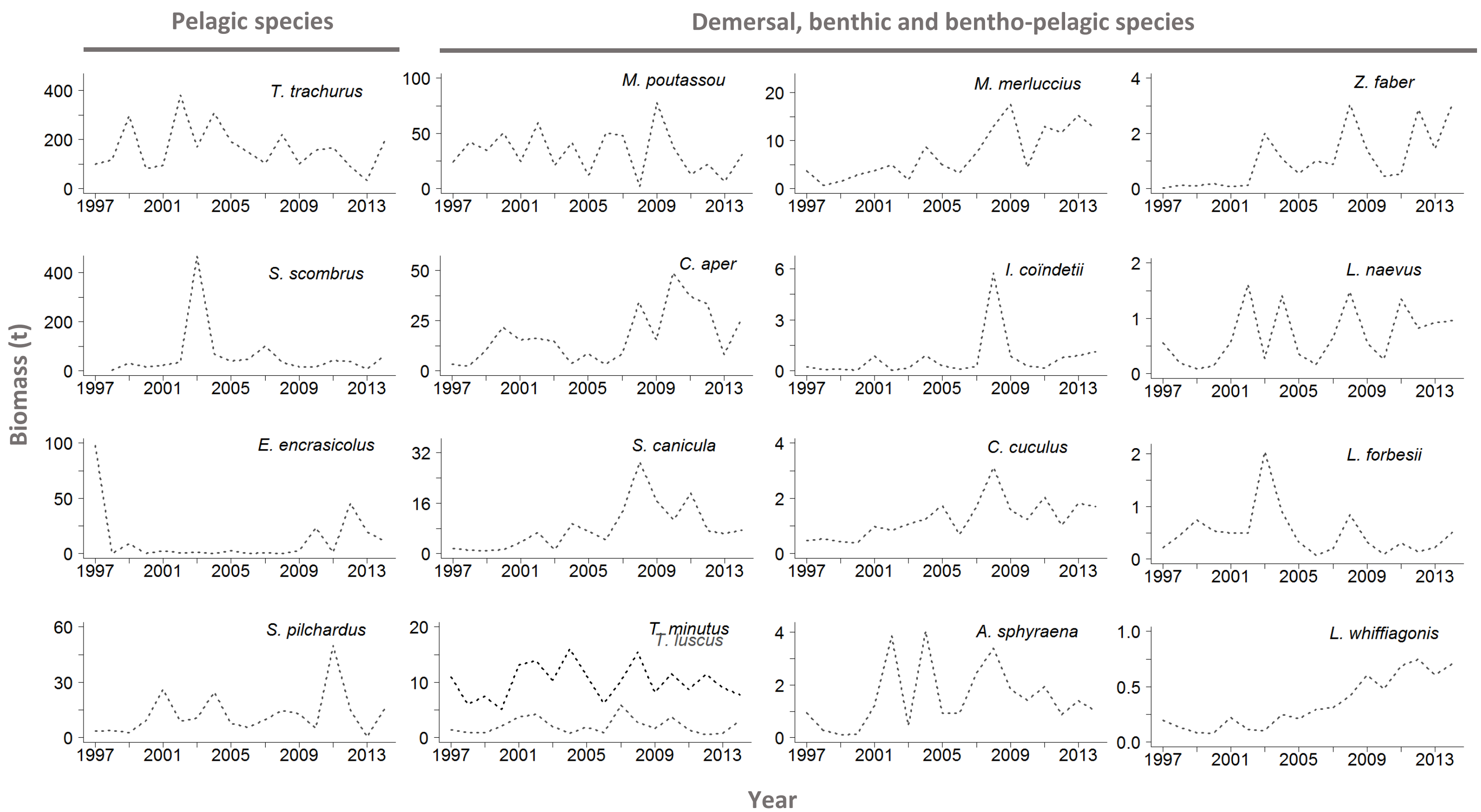


Fig. 5: Relative biomass (percentage of total biomass) of the main species within each year in the EVHOE survey. The species list is related to the MTL indicator where regionalized trophic levels of the various species were applied (**Dataframe B**). Plot (a) considers pelagic and bentho-pelagic species. Plot (b) excludes pelagic species from the list

Supplementary material



Supplementary Material Fig.S1: Trends in annual biomass (tonnes) of species sampled during EVHOE survey in the Bay of Biscay continental shelf. Species selected are those who represent 95% of total biomass collated between 1997 and 2014.

CONCLUSION

This work proposes the use of a methodology for the MTL indicator which reinforces the accuracy of the MTL indicator for its application in marine policies as a food web indicator. This methodology consists at:

- Using the most reliable data sources to run the MTL indicator: (1)Scientific survey to be used for species biomass data to describe the food web evolution on a sub-regional level. (2) Local trophic level estimates to be applied in order to reduce the uncertainty around the MTL trend evolution.
- Applying a Monte Carlo analysis considering TL estimation variability which allows the estimation of an uncertainty around the MTL indicator
- Running the MTL indicator considering all species and in parallel, excluding pelagic species. Indeed, the exclusion of pelagic species increased the significance of the indicator. The high pelagic species biomass and its interannual variability may mask a part of the indicator's signal. EVHOE survey mainly targeting demersal species, the exclusion of the pelagic compartment helped to increase the signal force.
- Considering a combined use of cut-offs on the MTL indicator for a more holistic description of ecosystem structure evolution. Indeed, when considering all consumers (i.e. MTL_2.0), a low trophic level species (*Capros aper*) was driving the indicator trend. While the use of higher cut-offs (i.e. MTL_3.25 and MTL_4.0) were driven by a high predator (*Merluccius merluccius*).

The work described in this report allowed also the assessment of the environmental status of the Bay of Biscay continental shelf food web. When applying local TL estimations to the indicator, all cut-offs superior to 3.25 showed a significant increase of the indicator trends. This reflected an evolution of the ecosystem structure of the Bay of Biscay continental shelf, from the late nineties until recent years, towards a state where the biomass of higher predators was increased reflecting an ameliorated food web state.

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Annex 2: Influence of ontogenetic variations in trophic level in global MTL trends at various cut-off levels.

INFLUENCE OF ONTOGENICAL DIET CHANGES ON THE TROPHIC LEVEL OF SPECIES AND ON MTL VALUES

The TL of species varies with size and can vary in time and space (Jennings et al., 2002; Vinagre et al., 2012), and this has caused scientists to recommend caution when using TL-based indicators in monitoring assessments (Caddy et al., 1998). However, the effect of ontogenetic changes in the TL of species was found to be negligible within-species in comparison with between-species effects (i.e. changes in the relative abundance of species) in landings data (Pauly et al., 2000).

Shannon et al., (2014) highlighted that these differences might be important to consider in community indicators based on survey data, and that model-based Tl indicators could be better equipped to handle ontogenetic changes in TL, since they are defined within the model.

Material and Methods

We used data from stomach contents gathered during the Demersales surveys from 1990 – 2013 to determine the trophic level of the different fish size classes over time.

We evaluated ontogenic changes in 8 demersal species which appear frequently and in large quantities during these surveys (Table 1), and which are characteristic and representative species within the demersal assemblages of the Southern Bay of Biscay, with biomasses which may have a bearing on the evolution of MTL indicators. The species comprised four gurnards, two megrims, a monkfish and hake, probably the most representative and abundant of the demersal large predators in the area.

We defined size classes following López-López et al. (2011) in the case of gurnards (*Aspitrigla cuculus*, *Chelidonichthys lucerna, Eutrigla gurnardus and Trigla lyra*); Preciado et al. (2006) for black anglerfish (*Lophius budegassa*), and Velasco (2007) for hake (*Merluccius merluccius*). Megrim size classes were defined attending to the same type of multivariate analyses conducted for the other species (Preciado, unpublished data). The various size classes established are shown in Table 1.

Statistical analyses

First, we analysed whether there were significant variations in the trophic level of each of the size classes established for each species over time using Mann Kendall trend analyses for uncorrelated and correlated data, as appropriate.

Next, we evaluated whether there were significant differences in trophic level among the various size classes for each species, by means of Kruskal- Wallis rank sum tests or Wilcoxon rank sum tests, on the mean trophic level per size class, based on the whole data series of trophic levels calculated on stomach content data (i.e.: 24 years).

Finally, we assessed whether the incorporation of TLs adding ontogenetic variability would have a bearing on the average MTL values and MTL evolution at various thresholds, over time. This we analysed by comparing the average trophic level obtained along the time series using a single mean trophic level for each species, or incorporating the size-based ones for each case, by means of the Welch two sample t-test analyses. The different threshold examined coincided with those selected to analyse variations in the trend of the indicator to assess GES of marine communities, i.e.: MTL2, MTL3.25 (MTI, Pauly and Watson, 2005), MTL3.5 and MTL4.

All analyses were conducted using R.

Results

Variations in TL among size classes

A summary of results regarding variations in TL of the different size classes is included in Table 1. In general, there were less intraspecific TL levels than dietary ontogenetic levels among size classes for the various species. *Aspitrigla cuculus* showed significant variations among size classes 1 and 2 and 3, that is, between the smaller size and the two subsequent ones, which "shared" trophic levels. *Lepidorhombus whiffiagonis* showed only 3 TL classes, instead of the 4 dietary classes established by dietary analyses. In this case, the smaller size classes showed no significant variations in Tl between them. *L. boscii* and hake also showed significant variations between size 1 and 2 and 3, respectively, which did not differ between them, indicating that once a mainly piscivorous diet is reached, variations in TL are negligible. *Eutrigla gurnardus* showed no variations between size classes, but there were several years in which there were no specimens of size 2. The same happened with *Chelidonichthys lucerna*, whose size class 1 specimens were not well represented throughout the time series.

Table 1. Mean trophic level (st. dev and st. error) calculated for the different size classes established for the eight demersal fish species analysed, based on stomach content analyses, and results of Kruskal-Wallis or Wilcoxon rank sum tests to identify significant variations among them.

Species	**mean**	**st.dev**	**st.error**			
Aspitrigla cuculus, Kruskal-Wallis chi-squared = 13.0391, df = 2, p-value = 0.001474				***Size 1***	***Size 2***	***Size 3***
Size 1 (≤17 cm)	3.76995153	0.1482824	0.03026802			
Size 2 (18 – 31) cm	3.89608553	0.10073467	0.02056238	**		
Size 3 (≥32 cm)	3.98887014	0.31056139	0.06339308	***	*n.s.*	
Chelidonichthys lucerna Kruskal-Wallis chi-squared = 4.0689, df = 2, p-value = 0.1307						
Size 1 (=<20 cm)	3.9561153	0.19318295	0.03943331			
Size 2 (21-39 cm)	3.77731485	0.29963402	0.06116254			
Size 3 (>=40 cm)	3.84706514	0.36645091	0.07480148			

Eutrigla gurnardus W = 105, p-value = 0.0008588						
Size 1 (=<27 cm)	3.87453392	0.13705571	0.02797638			
Size 2 (=>28 cm)	4.21902546	0.35415131	0.07229083	***		
Trigla lyra W = 81, p-value = 0.6674						
Size 1 (<=29 cm)	3.45911517	0.11438256	0.02334824			
Size 2 (>30 cm)	3.5806172	0.51270457	0.10465538	*n.s.*		
Lepidorhombus whiffiagonis Kruskal-Wallis chi-squared = 55.1276, df = 3, p-value = 6.449e-12						
Size 1 (<15 cm)	3.74314072	0.26653761	0.05440676			
Size 2 (16-23 cm)	4.05482307	0.19616478	0.04004197	*n.s.*		
Size 3 (24-36 cm)	4.26866767	0.14867302	0.03034775	***	**	
Size 4 (>37 cm)	4.54993986	0.18922218	0.03862482	***	***	**
Lepidorhombus boscii Kruskal-Wallis chi-squared = 29.0002, df = 2, p-value = 5.043e-07						
Size 1 (<=17 cm)	3.67729846	0.08700735	0.0177603			
Size 2 (18-32 cm)	3.82378189	0.07234809	0.01476799	***		
Size 3 (>33 cm)	3.94460764	0.21868772	0.04463944	***	*n.s.*	
Merluccius merluccius Kruskal-Wallis chi-squared = 42.9066, df = 2, p-value = 4.819e-10						
Size 1 (<17 cm)	4.10620798	0.16145914	0.03295771			
Size 2 (18-34 cm)	4.62939093	0.14249339	0.02908634	***		
Size 3 (35-69 cm)	4.55408724	0.17600693	0.03592727	***	*n.s*	
Lophius budegassa Kruskal-Wallis chi-squared = 3.0495, df = 2, p-value = 0.2177						
Size 1 (<25 cm)	4.49151562	0.16294246	0.03326049			
Size 2 (26-44 cm)	4.59008908	0.14646352	0.02989674			

Size 3 (>45 cm)	4.51976059	0.25670929	0.05240056			

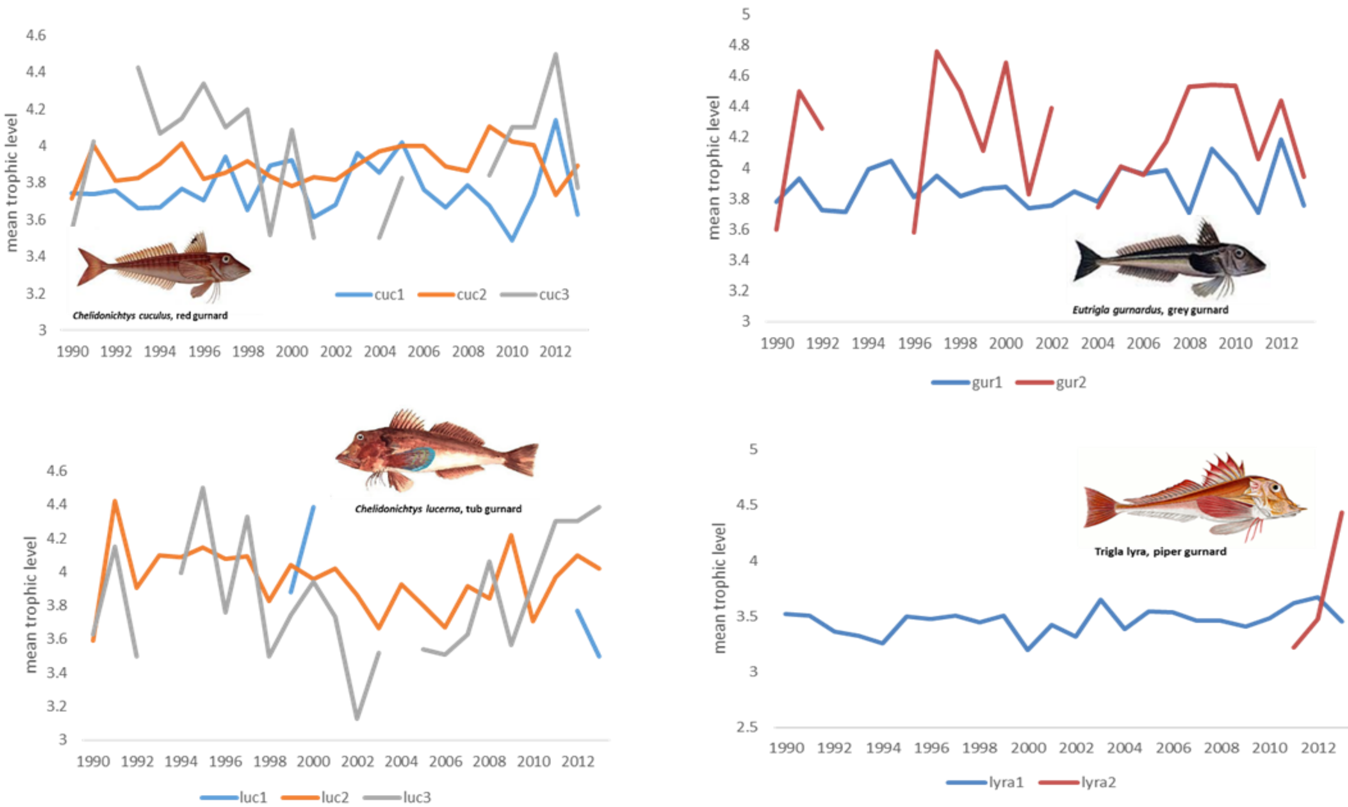
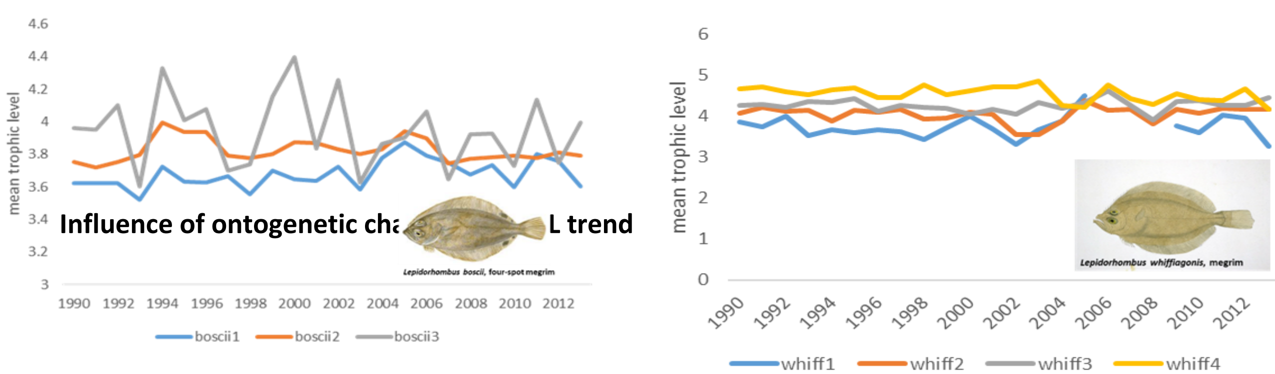


Figure 1. Trends in mean trophic level of the various size classes defined for the 4 species of gurnards analysed, based on the assessment of their food items.

Chelidonichthys lucerna, *Trigla lyra* and *Lophius budegassa* showed no significant differences among the different ontogenetic shift size classes established for them.

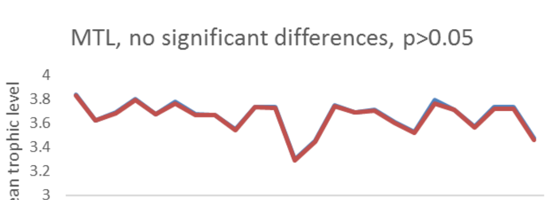


Influence of ontogenetic cha **L trend**

Results of the Welch two sample t-test analyses showed no significant variations between trends using the data considering ontogenetic variations in trophic level of the 8 species or when these variations weren't considered (Table 2, Figure 3). However, differences between trends were more acute when the trend using the higher cut-off levels were examined, indicating that ontogenetic variations in TL might have a bearing on global trends at these levels if more species or a different set of them is considered. Similarly, different results may appear when examining other geographic regions or specific temporal scenarios (our data are from autumn surveys), when for instance higher recruitment of particular species and thus higher relative proportions of low trophic levels are present. In fact, seasonal changes in diet have been reported for these species in the study area (Velasco and Olaso, 1998; Preciado et al., 2006) which would imply differences in TL. Further studies in more areas and at different times are thus necessary before firm conclusions regarding this issue can be extracted.

Table 2. Results of Welch two sample t-test analyses on differences between trends analysed considering ontogenetic variations in TL estimations and single species values for the various cut-off levels analysed.

MTL	**t**	**df**	**p-value**
MTL2	0.2148	45.99	0.8309
MTL3.25	1.1281	45.396	0.2652
MTL3.5	1.7813	42.151	0.08207
MTL4	0.4397	29.3	0.6634



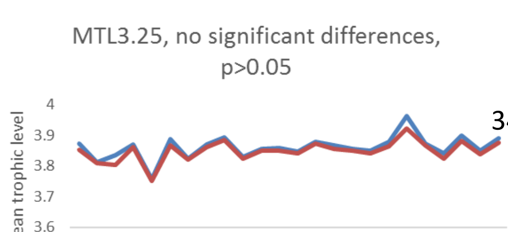


Figure 3. Trends in MTL of the Southern Bay of Biscay assemblage (based on Demersales IBTS data) considering variations in trophic levels of the various size classes of the 8 species analysed (MTLsize) and applying a single trophic level to each of them.

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Annex 3: Assessment of the status of the Bay of Biscay's demersal food web status using the MTL indicator.

CONTENT

1. INTRODUCTION

In Europe, a decrease in the mean trophic level of landings was reported by various authors in the Bay of Biscay (Guenette and Gascuel, 2012), the Celtic Sea (Pinnegar et al., 2002) or the North Sea (Heath, 2005; Jennings et al., 2002). More generally, Gascuel et al., (2016) observed a generalized decrease in the mean trophic level of both landings and survey data across European seas.

These reportings contrast with the encouraging news of relative recovery of fish stocks reported in various studies (Cardinale et al., 2013; Fernandes and Cook, 2013; Gascuel et al., 2016), which should, in theory, be mirrored in an increase in the mean trophic level of the assessed assemblages.

The Bay of Biscay has been subjected to high fishing pressure (mainly trawling, but also purse seine and longline) for many decades, several stocks experiencing severe depletion over the years, which has called for regulations and fishing limitations being imposed since the late 90's. The result has been an apparent recovery of the fish populations, and more particularly of the demersal realm, including many of the most representative large predators.

The aim of this assessment is twofold:

1- On the one hand, to try to validate the FW4 common OSPAR indicator as an operational and valid indicator of the status of marine food webs in the Bay of Biscay;

2- On the other, to assess the accordance of the trends observed in the Bay of Biscay, with the reported trends of fish recovery in the area, confirming the suitability of the indicator as an efficient one of both ecosystem status and fishing pressure.

2. MATERIAL AND METHODS

2.1. Study area

The Bay of Biscay- (included in OSPAR REGION IV)

The Bay of Biscay as regarded in this document, comprises regions VIIIa, b, c and IXa-north of ICES subdivisions. Two subdivisions have been made, considering on the one hand the northern Bay of Biscay (French part, VIIIa and VIIIb) and on the other, the southern part, comprising the Cantabrian Sea including the Atlantic part of Galicia (subdivision VIIIc and IXa-north).

In these areas the topography from the continental shelf to the abyssal plain is very variable, and characterized by the presence of seamounts, banks and canyons and a diversified coastline where estuaries, rías and wetlands hold highly productive ecosystems.Specifically, the northern and southern Bay of Biscay differ notably in the structure of their continental platforms, the French one being much broader and uniform in terms of depth and types of substrate, while the Spanish one, comprising the Cantabrian sea and the Atlantic coast of Galicia, is much narrower and varied as to the topography and depth ranges.

The main human activities in the region include tourism, fishing and aquaculture, shipping, sand and gravel extraction, and new development of wave, tide and wind power generation. The coastal strip has an increasing high population density. Industries of various types, agriculture and land based activities are located along the coasts.

The Bay of Biscay and Iberian Coast region is situated in temperate latitudes with a climate that is strongly influenced by the inflow of oceanic water from the Atlantic Ocean and by the large scale westerly air circulation which frequently contains low pressure system. Large storms occur in the Bay of Biscay, especially during the winter months.

Region IV is highly diverse, having many different types of coastal habitats, such as rocky cliffs, shingles, rocky shores, sandy and muddy shores, coastal lagoons and estuaries. A large variety of marine mammal's species, both boreal and temperate, have been reported in the region, including 30 species of cetaceans and 7 species of seals. Even if the seabird community is dominated by sea gulls, the Iberian Peninsula is at a strategic geographical position regarding the migratory behaviour of other seabird species. The nesting seabird community is very poor in comparison with other European Atlantic areas, but it improves appreciably during migrations and winter. The autumn passage of species such as Balearic shearwater or great cormorant is particularly important in the region. As for fish, 700 described species are present in Region IV. Due to oceanographic conditions, many species reach their southern or northern limits of distribution in the Bay of Biscay such as the Albacore or the bluefin tuna which live in subtropical areas of the western Atlantic and make annual migrations to the Bay of Biscay. The majority of fish in Region IV are species living near the bottom of the sea (for example sole, dogfish or blue whiting) with limited geographical range, unless they are deep-water species. Pelagic fish such as sardine or mackerel have wide geographic distribution from Africa to Northern Europe.

2.2. Monitoring surveys

Demersales Surveys

In the Southern Bay of Biscay, the survey follows a stratified semi-random design. Stratification involves five geographical zones between the Portuguese border at the Miño river and the French border at the Bidasoa river, followed by further bathymetric depth stratification. The depth strata considered are 70–120m, 121–200m, 201–500m. The number of stations per stratum is allocated *pro rata* with stratum area, with an approximate sampling effort of 5.4 hauls for every 1000 km², based on achieving approximately 120 hauls per survey. When time permits, further stations are sampled to cover two additional depth strata between 30–70 m and between 500 and 800 m. Surveyed depthstherefore range from 30 to 800 m.The semi-random design of the survey is intended to ensure adequate coverage of hake nursery areas in different parts of the northern Spanish shelf. Samples taken from water shallower than 70 m and deeper than 500 m, were not included in the stratified abundance estimates used in stock assessments (ICES 2013b).

Evhoe Surveys

The French fourth quarter EVHOE survey data series starts in 1987. For the 1987 to 1996 period, the Survey EVHOE has been conducted by the Thallassa I vessel in the Bay of Biscay on an annual basis with exception of the years 1993 and 1996. The Celtic Sea was surveyed from 1990 to 1994 but the sampling was restricted to a small geographic area. Since 1997, the protocol was modified and standardized to cover Bay of Biscay and Celtic Seas.The RV Thallassa II was used for the entire period and only the GOV trawl was used. The periodstarting from 1997 was used in the current work for the Northern Bay of Biscay.

The Northern Bay of Biscay EVHOE survey follows a stratified semi-random design. The stratification scheme adopted defines 6 depth strata according to the following depth ranges: 0-30m, 31-80m, 81-120m, 121-160m, 161-200m, 201-400m. The sampling strategy is of a stratified random allocation, the number of set per stratum being optimizedby a Neyman allocation on numbers variance averaged on the 4 most important commercial species (hake, monkfishes and megrim) leaving of course at least two stations per stratum. One hundred and forty sets are planned every year which are adjusted according to the time at sea available.

3. MEAN TROPHIC LEVEL TREND ANALYSES

3.1. Data Sources

3.1.1. Southern Bay of Biscay - Cantabrian Sea

3.1.1.1. Landings data

Two data sets were used in order to examine the evolution of mean trophic level values from landings data:

1) Data compiled by the Spanish Institute of Oceanography (IEO, by its Spanish acronym), based on log-book informationgathered for areas VIIIc and IXa north (corresponding to the Galicia coast). In this case data covered the temporal range 1994 – 2015.

2) Data from ICES catch Statistics. In this case two different data sets were analysed:
    i. Official nominal catches, from 2006 -2014,
    ii. Historical landings, from 1989 – 2010.

    For these analyses, only region 27.8c was considered since region 27.9a includes also Portugal and the southern part of the Spanish North Atlantic coast (corresponding to Cadiz), and data are not segregated in the various north, centre and south regions as is the case with IEO data. Analyses were conducted considering all landings declared (corresponding to all countries operating in the area, i.e.: Denmark, France, Portugal, and Great Britain). Catches reported from GB and Denmark were practically negligible, but were still included in the analyses. Analyses were conducted first on all data identified to Family, Genus or Species level, and then excluding the pelagic species from this data set.

Regarding historical landings, only the period 1989 – 2010 was examined, given that the only data available prior to that date corresponded to the years 1976 – 1980, and didn´t seem to be equivalent in terms of species and quantities declared to those of the subsequent period.

Mussels and oysters were excluded from the database since most of the reported biomass came from aquaculture facilities rather than from landed material. Algal landings were excluded from all analyses.

3.1.1.2. Survey data

In this case, three data sets were examined:

1) The ICES DATRAS data base;
2) The IEO IBTS Demersales database; and
3) The Groundfish survey monitoring and assessment data product

Since IBT surveys target demersal species, the indicator was applied using all species surveyed and also excluding pelagic species, which are not well sampled by these surveys and whose high biomass may mask the actual status of the demersal communities. By excluding pelagic species, a focus is being made on demersal communities.

The groundfish survey monitoring and assessment data product was specifically developed to assess the status of fish communities across the Northeast Atlantic region. Benthic invertebrate data were not consistently sampled and the fishing gears used in the surveys were not considered to be good samplers of either infauna or epibenthos (ref. MSFD). Hence, all records that did not relate to fish were excluded from the database during screening. This was primarily achieved by selecting WoRMS identification codes related to the phylum Chordata, but excluding the subphylum Tunicata.

3.1.2. Northern Bay of Biscay

3.1.2.1. Landings data

Data coming from ICES catch statistics were used in order to examine the evolution of mean trophic level values from landings data. Two data sets were combined together to conduct this analysis on a longer time series.

i. Official nominal catches, from 2006 -2014,
ii. Historical landings, from 1989 – 2010.

All landings declared in regions 27.8a and 27.8b were considered (corresponding to all countries operating in the area, i.e.: France, Spain, Belgium, Netherlands, Denmark, Germany, Ireland, Lithuania, Portugal, and United Kingdom). Except for France, Spain and Belgium, catches were practically negligible, but were still included in the analyses.

Some data aggregation was made after the combination of the two datasets (historical + officialcatches) to solve evolution's problems in the accuracy of the identification level. The catches of Sepiidae/Sepiolidae were merged with those of *Sepia officinalis* (based on data and cephalopod expert validation), as well as the catches of Loliginidae/Ommastrephidae with those of Loliginidae. *Alosa* spp and *Alosa alosa*/*A. fallax* were also united as only two species exist in the Genus.

Analyses were conducted first on all data identified to Family, Genus or Species level (removed), and then excluding the pelagic species from this data set.

Mussels and oysters were excluded from the database since most of the reported biomass came from aquaculture facilities rather than from landed material. Algal landings were also removed from all analyses, as well as high taxonomic ranks (for which one trophic level value is not relevant).

Only the period 1997–2014 was examined to have the same starting date in the time series as that of the surveys. Data for the year 1999 were excluded of the analysis because France, which is the main country fishing in the area, did not declare landings that year.

3.1.2.2. Survey data

In this case, three data sets were examined:

1) The Ifremer SIH EVHOE database;
2) The ICES DATRAS data base; and
3) The Groundfish survey monitoring and assessment data product

Since IBT surveys target demersal species, the indicator was applied using all species surveyed and also excluding pelagic species, which are not well sampled by these surveys and whose high biomass may mask the actual status of the demersal communities. By excluding pelagic species, a focus was made on demersal communities.

The Ifremer SIH data are available on the Ifremer website and cover the period from 1987 until 2012. For the work achieved in this report and for comparison reasons, only the period from 1997 until 2012 was kept for analysing Ifremer SIH data series. This data series includes fish and invertebrates' data.

The ICES DATRAS data base covers the period 1997 to 2014. This data series includes fish and invertebrates' data and is very similar to the data format available in the Ifremer SIH data base.

The groundfish survey monitoring and assessment data product was specifically developed to assess the status of fish communities across the Northeast Atlantic region. Benthic invertebrate data were not consistently sampled and the fishing gears used in the surveys were not considered to be good samplers of either infauna or epibenthos (ref. MSFD).

Hence, all records that did not relate to fish were excluded from the database during screening.

3.1.3. Trophic level data

The trophic level of species included in Table 1 was calculated using stomach content data collected during the "Demersales" surveys over the period 1990-2013. For each fish species, the percentage contribution of each prey item during each year was calculated and used to derive the trophic level using the formula:

$$TL_i = \sum_j TLj \cdot DCij$$

Where TLj is the fractional TL of prey j, and DCij represents the fraction of j in the diet of i.

Trophic levels for species/groups for which no stomach content data were available, were obtained from estimations made in relevant publications from the same or similar habitats in the area (Lassalle et al., 2011, 2014; LeLoch et al., 2008; Chouvelon et al., 2013), or from the Sea Around us Project (www.fishbase.org). When different TLs based on isotopic data were obtained by the various studies, we used those values pertaining to studies in which a wider area (higher prey variability) was prospected, as follows: Lasalle et al., 2014 > Le Loc'h et al., 2008 > Lasalle et al., 2011. A list of the compiled TL values and their sources is shown in Annex 5.

3.2. Mean trophic level calculation

Mean TLs for each year k were calculated using the formula:

$$TLk = \sum_i (TLi) \cdot (Yik) / \sum_i Yik$$

Where Yi refers to the biomass of species (group) i in year k, as included in landings data or in survey data, respectively.

An R script was developed in order to calculate the mean trophic level of the assemblages per year, as well as the uncertainty around this mean trophic level based on the assigned TLs per species. Uncertainty exists around each TL value which is related to spatio-temporal variability. This uncertainty was reported as a standard error for each TL value. In order to include uncertainty in the MTL model, a bootstrap methodology was developed using the R software (R version 3.1.0). A random sampling was applied on TL values and their standard error performing 500 MTL computations per studied year. The model was then fitted as a mean value of the 500 MTL generated with an uncertainty related to its standard deviation. The uncertainty around the MTL model is thus linked to the uncertainty of the TL estimations.

Table 1. Trophic level (mean, standard deviation and standard error) calculated from stomach contents data on several species collected during IBTS surveys (Demersales) in the Southern Bay of Biscay. The number of years in which the TL calculation is based is also indicated.

	years	Mean TL	st.dev	se
C.conger	24	4.24788309	0.09689168	0.01977793
C.cuculus	24	3.86429729	0.0964238	0.01968243
C.gurnardus	24	3.93603621	0.1781817	0.03637119
C.lucerna	24	3.92008487	0.20748397	0.04235249
C.lyra	24	3.44469311	0.11742608	0.0239695
C.obscurus	24	3.55294601	0.22836613	0.04661504
D.calcea	24	4.42131959	1.52371643	0.31102731
G.macrophtalmus	24	3.73034917	0.24184158	0.04936571
G.melastomus	24	4.04487488	0.22300067	0.04551982
H.dactylopterus	24	3.99376678	0.2534664	0.05173861
L.boscii	24	3.75051907	0.20999391	0.04286483
L.budegassa	24	4.53868746	0.17052609	0.03480849
L.naevus	24	3.86840818	0.22696424	0.04632888
L.piscatorius	24	4.56786258	0.15602952	0.03184939
L.whiffiagonis	24	4.26549479	0.12386719	0.02528429
M.macrophtalma	24	4.50327567	1.87075042	0.38186533
M.merluccius >20	24	4.60160548	0.14051186	0.02868186
M.merlucius <20	24	4.2074104	0.20191441	0.04121561
M.poutassou	24	3.77432305	0.25794616	0.05265304
M.surmulletus	24	3.27187455	0.09645928	0.01968967
P.acarne	24	3.54639268	0.21366348	0.04361387
P.blennoides	24	3.72463021	0.18953409	0.03868848
P.erythrinus	24	3.49224856	0.25850435	0.05276698
R.clavata	24	3.77126351	0.12240304	0.02498541
R.montagui	24	3.92686009	0.22586075	0.04610363
S.canicula	24	4.0760768	0.10605293	0.02164796
S.scombrus	24	3.85716124	1.57460849	0.32141561
T.luscus	24	3.76169534	0.150894	0.03080111
T.minutus	24	3.66520082	0.09951307	0.02031302
Z.faber	24	4.46983516	0.92845214	0.1895195
E.spinax	22	3.93219831	1.16069565	0.23692601
D.calcea	21	4.42131959	0.3229315	0.07046943
S.cantharus	21	3.57853072	0.46347967	0.10113956
T.draco	20	3.97836673	0.45842429	0.10250679
S.cabrilla	18	3.65272752	0.21436046	0.05052524
S.lopei	18	3.75943136	0.26615154	0.06273252
L.cavillone	14	3.61902307	0.23445405	0.06266048
S.ringens	14	4.52999043	0.25616655	0.06846339
S.scrofa	14	4.42866456	0.27378831	0.073173
S.stellaris	13	4.02661365	0.25956626	0.07199073
L.circularis	11	3.90615152	0.43043565	0.12978123
S.notata	11	3.73738876	0.30178888	0.09099277

T.cristulata	11	4.0702337	0.57933824	0.17467705
H.mediterraneus	10	3.56388554	0.16485212	0.05213082
L.mormyrus	10	3.18094679	0.23970498	0.07580137
L.eques	9	3.58828427	0.07803412	0.02601137
G.atlanticus	6	3.99234674	0.34390767	0.14039972
D.profundorum	5	4.28024674	0.53840465	0.24078188
B.ocellaris	4	3.45464063	0.38031026	0.19015513
L.dieuzeidei	4	3.55999412	0.07324869	0.03662434
R.brachyura	3	3.94682199	0.21885087	0.12635361

3.3. Trend analyses

Data were analysed using linear regression except in those cases in which the assumptions of normality (Shapiro-Wilkins tests), homoscedasticity (Harrison McCabe test) and/or independence (Durbin-Watson test) were not met, in which case Mann Kendall trend analyses for non-correlated and/or correlated data were conveniently conducted. significances of observed trends over time were examined by using a modified version of the Mann-Kendall trend test for autocorrelated data based on Hamed and Rao, 1998, and developed by the Santander Meteorology Group <http://www.meteo.unican.es> (https://cran.r-project.org/src/contrib/Archive/fume/). This package provides both the uncorrected (Z) and corrected (Zc) statistic, calculates the slope according to Sen's (1968) test, and allows to determine whether any autocorrelation has a clear effect on the significance of the Mann-Kendall correlation by providing the adjusted sample size after the correction. Trends were judged significant when $p<0.05$.

All statistical analyses were conducted using R software (R Core Team, 2015), except where otherwise specified.

3.4. Relationship with fishing mortality

To analyse whether there was any relationship between mean trophic level values and Fishing mortality, we conducted Spearman rank correlations between Fcom and the various mean trophic level values (MTL, MTI3.25, MTI3.5).

Estimates of assemblage-averaged fishing mortality (Fcom) were generated using data from the five main commercial demersal species, i.e.: hake (*Merluccius merluccius*), angler (*Lophius piscatorius*), black-bellied angler (*Lophius budegassa*), and the two megrim species (*Lepidorhombus boscii* and *Lepidorhombus whiffiagonis*), using Fs, msy as reference point (Modica et al., 2014), and calculated as:

$$F_{com,Y} = \frac{\sum_{s=1}^{4} Fs, Y / Fs, msy}{5}$$

Where $F_{s,Y}$ is the annual fishing mortality for each species in each year. Values of $F_{s,Y}$, and $F_{s,msy}$ were obtained from stock assessment data at the ICES data portal.

Comparisons were made between the Fcom and MTL3.25 levels including and excluding pelagic species, respectively. This cut-off level was chosen since it was deemed the most appropriate to include most predators in the calculation.

4. RESULTS

4.1.Trend Analyses

4. 1.1. Southern Bay of Biscay – Cantabrian Sea

4. 1.1.1. Landings

SPANISH OCEANOGRAPHIC INSTITUTE (IEO) DATA SET (1994 – 2015)

The biomass of nominal catches (kg of live weight equivalent landed biomass) has been increasing over the time series analysed (Figure 1). Landings declined markedly in 2003 and there was an outstanding peak in 2009, following changes in the landed biomass of mackerel (*Scomber scombrus*), which accounted for almost 25% of the global biomass over time. Altogether, 6 species, namely mackerel, horse mackerel (*Trachurus trachurus,* 18.6%), blue whiting (*Micromesistius poutassou*, 13.8%), sardine (*Sardina pilchardus*, 12.7%), Atlantic chub mackerel (*Scomber colias*, 5.6%), and hake (*Merluccius merluccius*, 4.7%) accounted for 80% of the total landed biomass over the analysed time period.

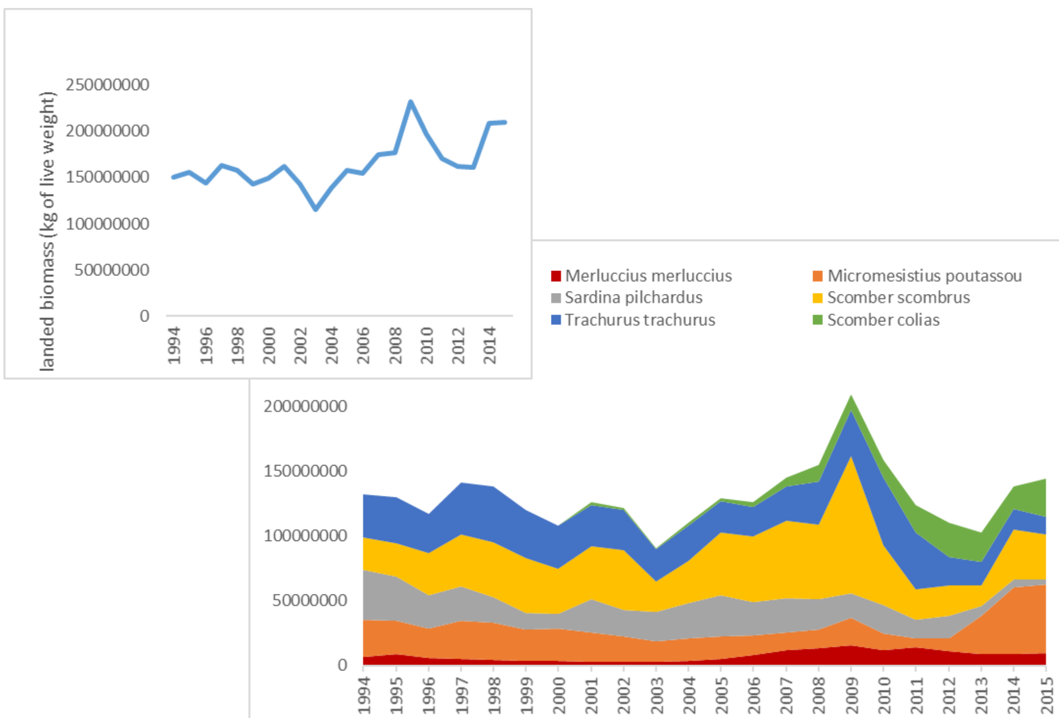


Figure 1. Trend in landed biomass over time and trend in the biomass of species accounting for 80% of the landed biomass over the studied period.

In this case, results of the Mann Kendall test analysis for auto-correlated data showed no significant trend of the data for cut off-levels MTL2 (MK, Zc= - 0.92; pc>0.05) or 3.25 (MK, Zc= 0.70; pc>0.05). However, a significant increasing trend was obtained when using the cut-off level of 4 (Zc =2.20, pc <0.05, Figure 2).

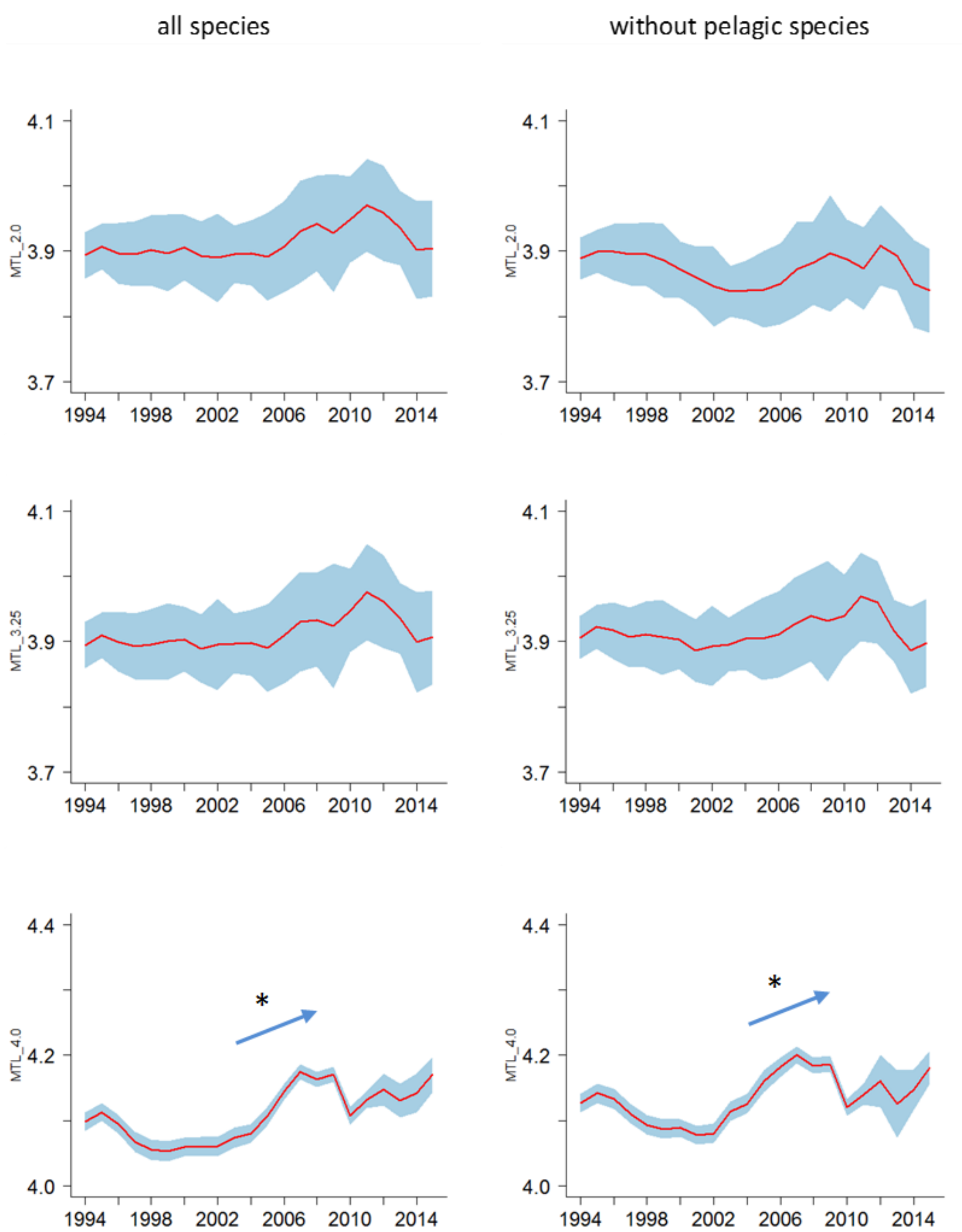
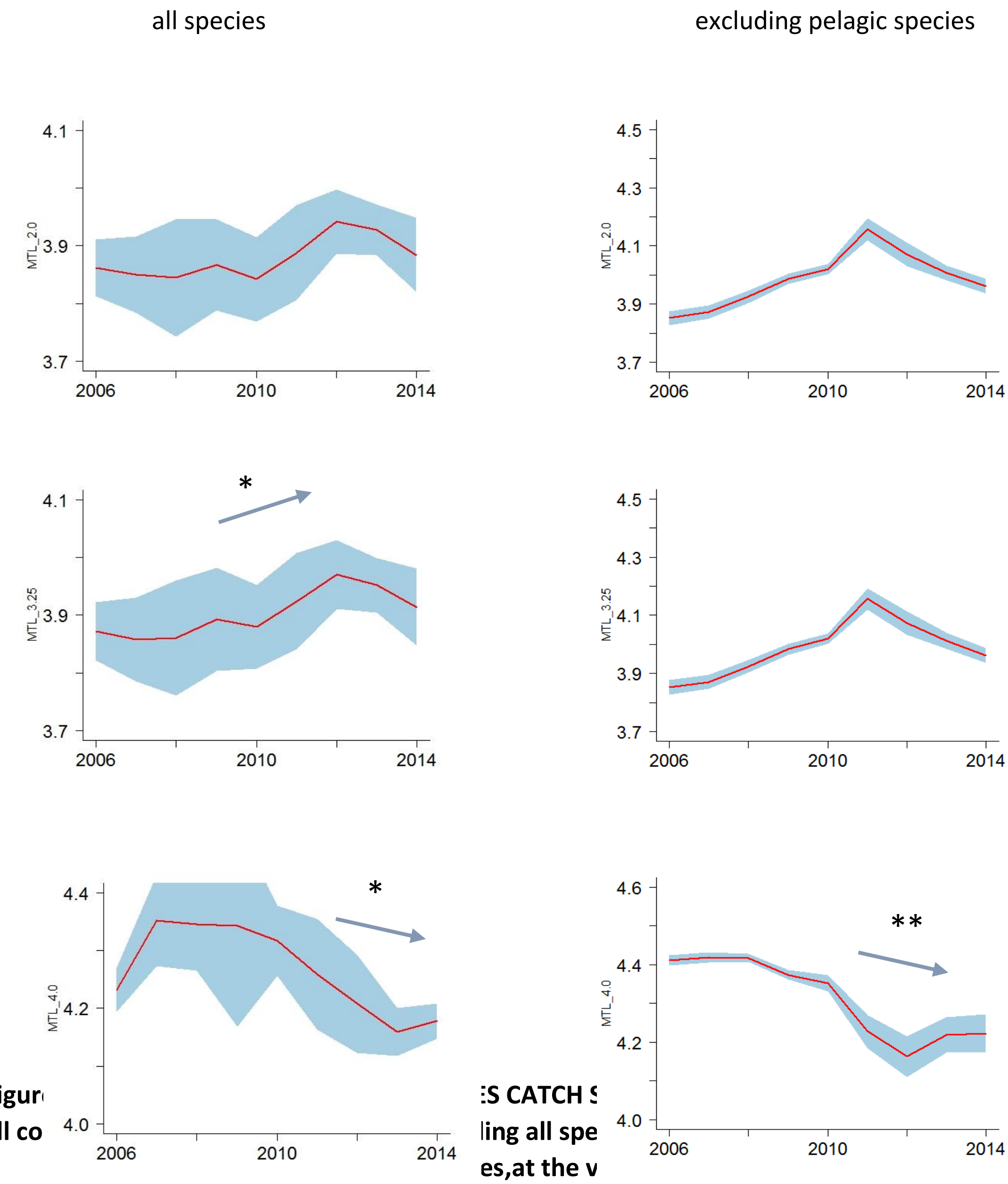


Figure 2. Trends in mean trophic level of landings IEO data (1994 – 2014), at the various cut-off levels analysed including all species and excluding pelagic ones from the analyses.

When pelagic species were excluded from the analyses, the trend was of a non-significant decrease and increase in MTL 2 ($Zc= - 1.01$, $p>0.05$) and MTL 3.25 ($Zc= 0.83$, $p>0.05$), respectively, and a significant increase in MTL4 ($Zc = 2.01$, $p<0.05$), as shown in Figure 2.

ICES CATCH STATISTICS (2006 – 2014)

When all specimens identified to family, genus or species level were included in the data matrix, significant trends were detected both for cut-offs 3.25 (lm, $R^2 = 0.56$, F-statistic = 11.12, $p<0.05$) and 4 ($Z = -2.19$, $p<0.05$, Sen's slope = 0.028), with an increasing and a decreasing trend, respectively (Figure 3). When pelagic species were excluded from the analyses, only MTL4 ($Z = -2.60$, $p<0.01$, Sen's slope = - 0.033) showed a significantly negative trend (Figure 3).



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These plots seem to indicate an increasing trend of intermediate trophic level species mainly driven by pelagic species, but a decrease in top predators with TLs above 4, which are probably comprised mainly of demersal species. These trends were detected in the last years of landings data, and may be masked by global trends observed in the longer term. Therefore the trends observed and the interpretation of these results should be taken with caution

ICES HISTORICAL LANDINGS DATA (1989 – 2010)

In fact, no significant trends were detected when analysing historical landings data from the ICES database.

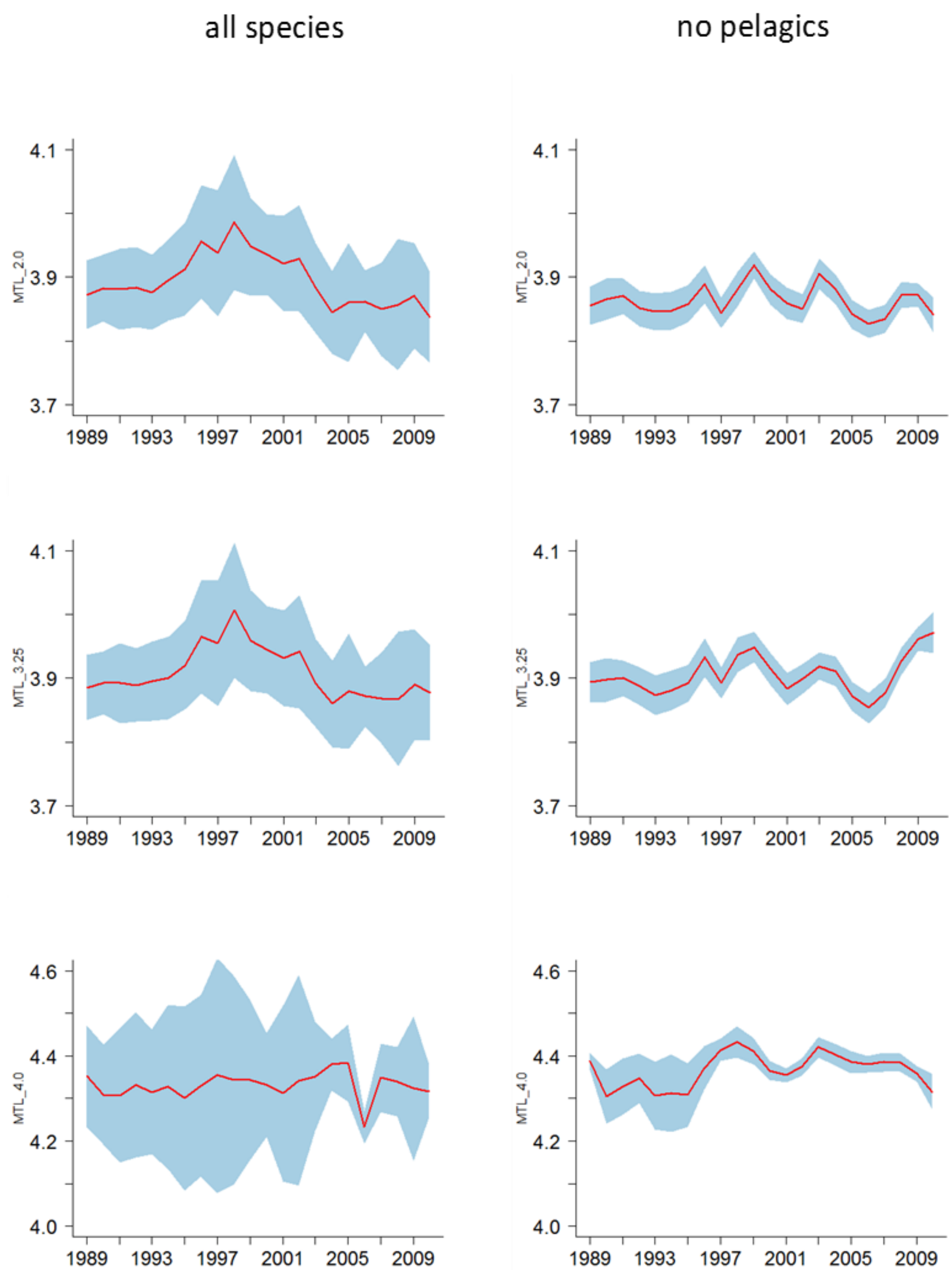


Figure 4. Trends in mean trophic level of ICES HISTORICAL LANDINGS DATA (a) including all species identified to family, genus or species level at the various cut-off levels analysed, (b) excluding pelagic species from the former data base.

Indeed, when examining historical landings data it seems the trend has not changed from years in which a strong fishing pressure was exerted in the area (80´s – 90´s) and more recent values. However, the decreasing trend found for higher trophic levels both considering pelagic species and not could be indicating a decrease in the amount of large predators being landed and should be looked further into, comparing the data with those from surveys. Overall, the length of the historical series is a key factor when observing the trends and trying to interpret what is occurring at ecosystem level.

4.1.1.2. Surveys

IEO DEMERSALES DATA (1992 – 2015)

The Demersales IBTS surveys have been ongoing since the early 80's, 1983 being the first year for which a complete data set was compiled. However, these surveys have been progressively made more holistic as regards the species being followed and it was not until 1992 that the whole set of species (invertebrates + fish) being collected was systematically identified and incorporated into the data set. Thus, our analyses include the period from 1992 to 2015, comprising a total of 23 years.

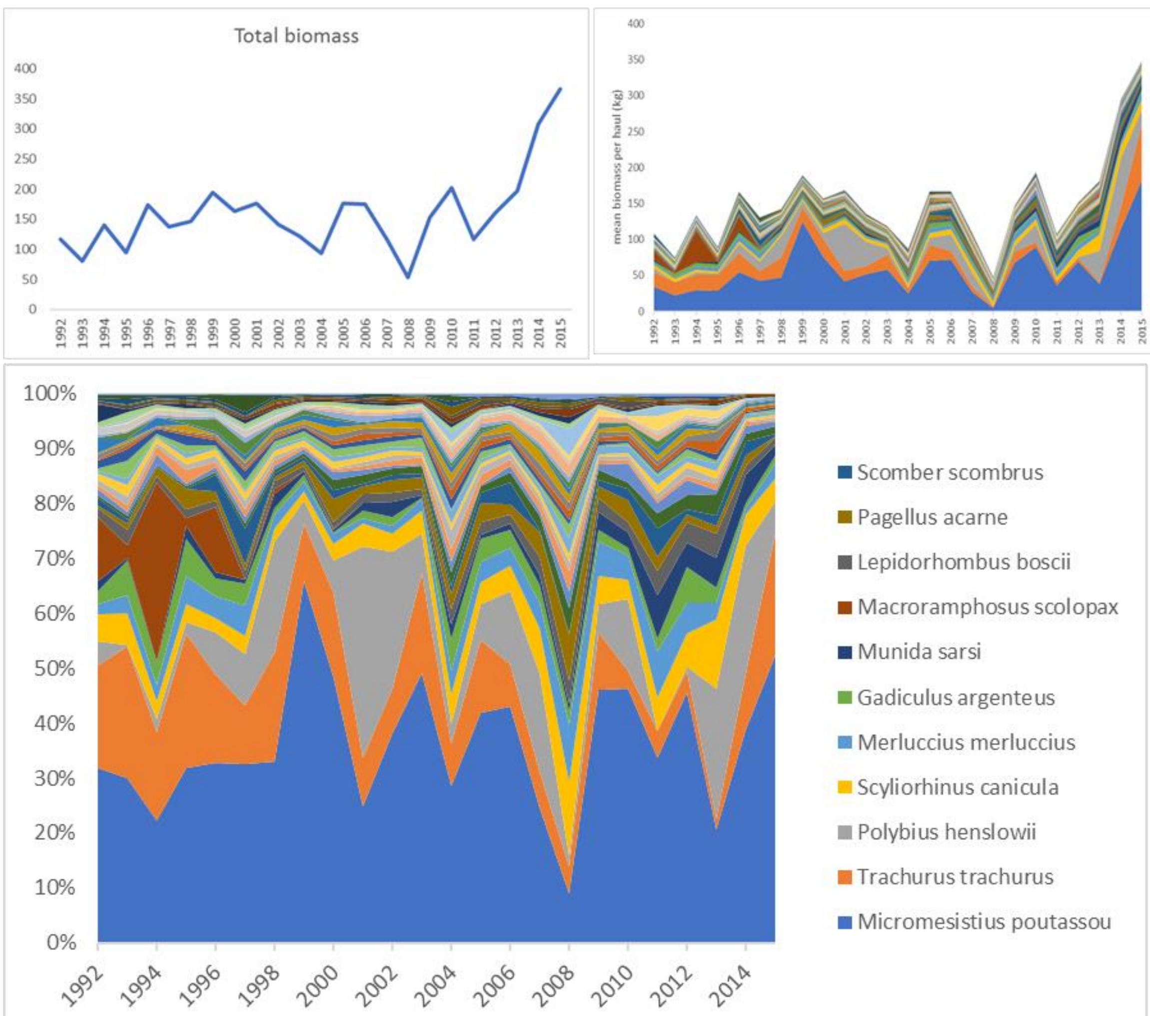


Figure 5. Trends in IEO Demersales survey data global biomass and that of the dominant species (accounting for 95%of global biomass), over time.

These data show that the main species contributing to the biomass over time (Figure 4), were *Micromesistius poutassou* (blue whiting), *Trachurus trachurus*, and the pelagic crab *Polybius henslowii*, followed by *Scyliorhinus canicula* and hake (*Merluccius merluccius*). The biomass of the surveys has been increasing over time, with a notable increase over the last years, and significant oscillations in the abundance of particular species (e.g.: *Macrorhamphosus scolopax* and *Capros aper* were very abundant during the first years of study but practically disappeared afterwards).

The analysis of trends in mean trophic level revealed significant trends only when MTL3.25 without considering pelagic species was analysed ($F=4.7$, $t=2.2$, $p<0.05$), indicating no major variation in mean trophic levels over time (Figure 5). Actually, the significant trend observed could respond to the influence of the aforementioned high biomass of *Macrorhamphosus scolopax* during the early part of the time series, which were not present thereafter. The elimination of this species under MTL4.0 yielded no significant results, showing that despite the apparent increase in biomass, the mean trophic level has remained more or less stable and only subject to fluctuations in the biomass of the main contributors.

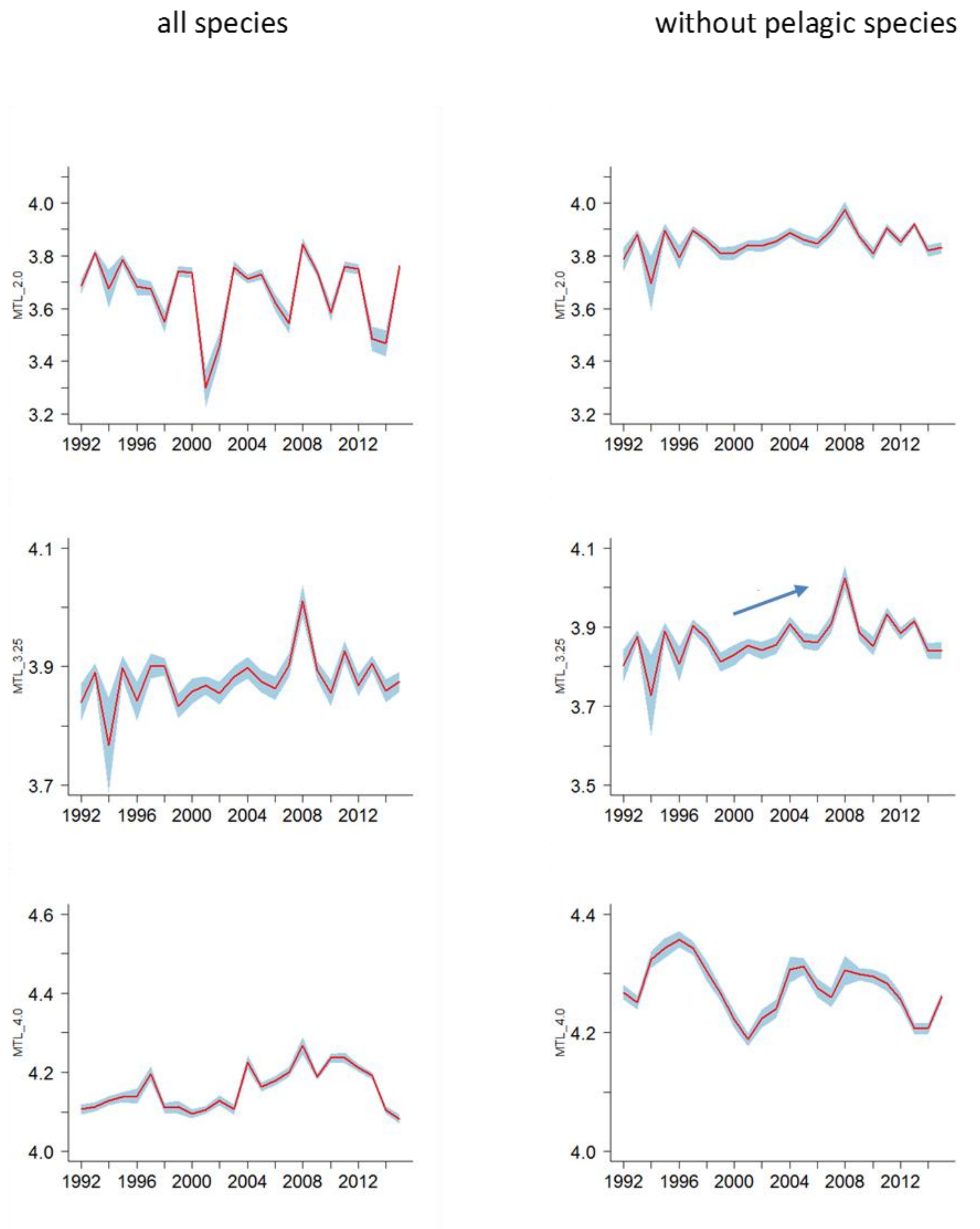


Figure 5. Trends in mean trophic level of IEO Demersales surveys data (a) including all species identified to family, genus or species level at the various cut-off levels analysed, (b) excluding pelagic species from the former data base.

DATRAS DATA (2001 – 2014)

The period included in this data set (where only commercial fish and invertebrates – represented solely by *Nephrops norvegicus*- are included), corresponded to that of the enforcement of fisheries regulations and the observed recovery of demersal populations in the Southern Bay of Biscay, shown by the IEO Demersales data (Figure 6). It showed two declines in biomass (one in 2004 and the steepest one in 2008), corresponding mainly to declines in *Micromesistius poutassou*, and *Trachurus trachurus* during those years.

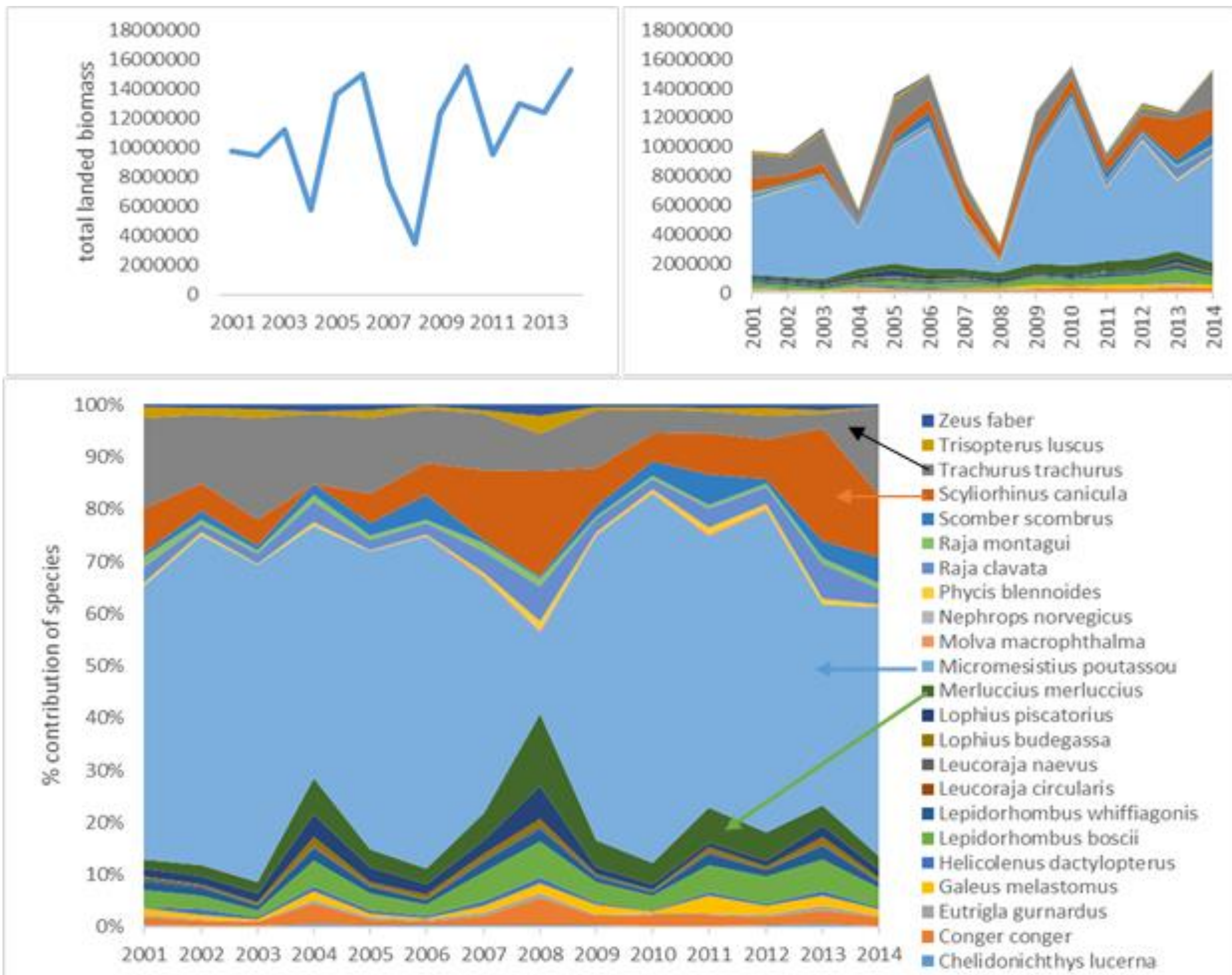


Figure 6. Trends in IBTS DATRAS survey data global biomass and that of the dominant species, over time.

None of the MTL cut-off levels showed a significant trend when analysed using the DATRAS data set (Figure 7). Only 23 species are included in these analyses (14 make up for 95% of the global biomass analysed), all of them, except for *Nephrops norvegicus* showing mean TL levels higher than 3.5. This explains the fact that the trends observed are exactly the same between MTL2.0 and MTL3.25

(Figure 7). Moreover, the only pelagic species in this data set were*Trachurus trachurus*and *Scomber scombrus*.

In any case, these analyses indicate that there have not been major changes in the indicator over the past decade when it comes to the main commercial species.

The 2008 peak corresponds to the decline in *Micromesistius poutassou* biomass that year noted with other data sets, and other than that event, no major variations were detected with these data during the available time series.

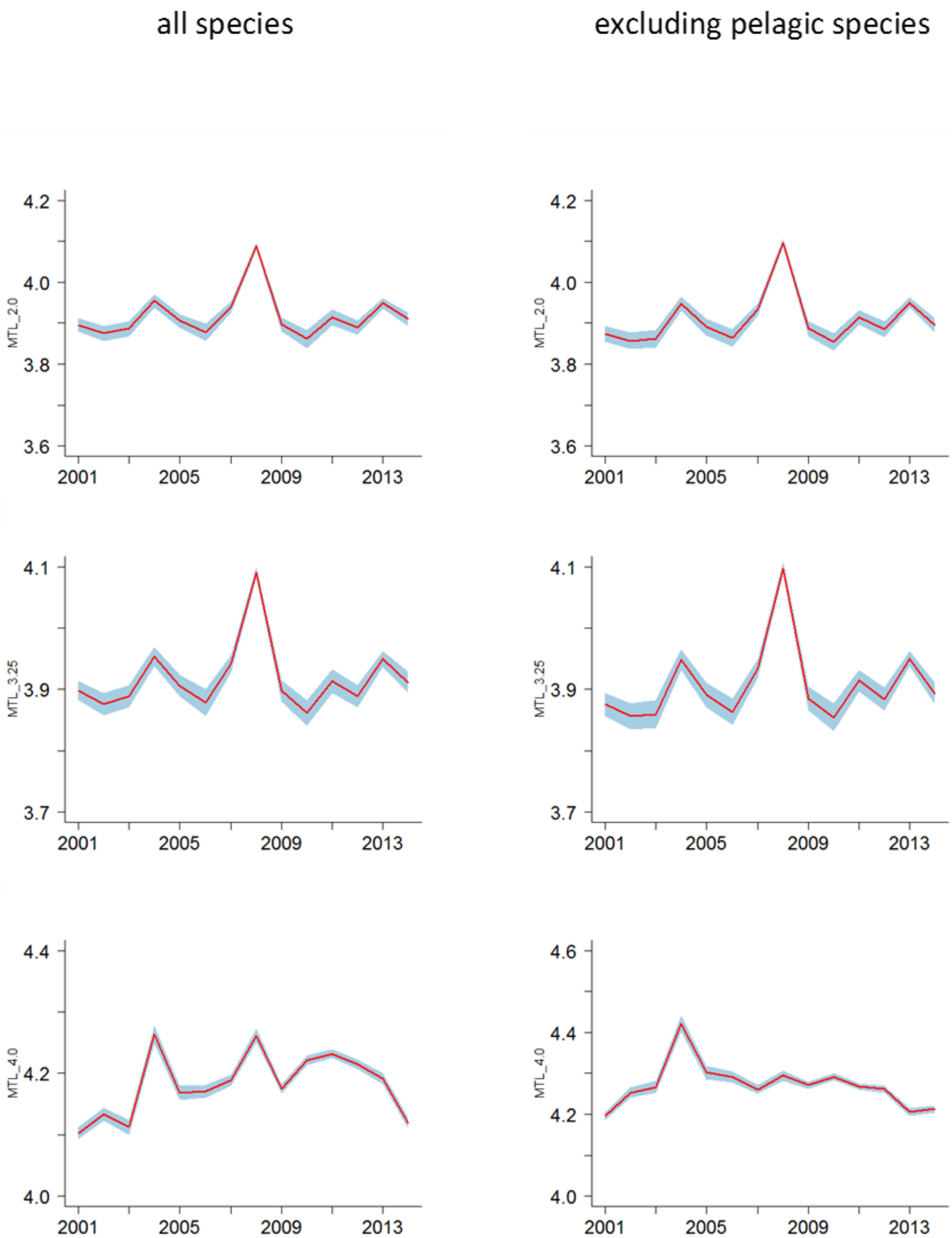


Figure 7. Trends in MTL levels at the different cut-off levels observed using the DATRAS IBTS survey data series for the Southern Bay of Biscay.

MSFD DATA PRODUCT

Unfortunately, it was not possible to use the MSFD data product for Southern Bay of Biscay. Several inconsistencies in the data and the accompanying documents were detected which prevented conducting the analyses with this data set. When these issues are clarified and the data set is ready for use in this area, the complete assessment of the Bay of Biscay will be conducted using this standardised data. For now, only the French part could be assessed.

In any case, this data product only considers fish and disregards invertebrates as a whole, and should hence modify the species considered when calculating the indicator, substantially when compared with IEO data.

4.1.2. Northern Bay of Biscay

4.1.2.1. Landings

The main species landed in the northern Bay of Biscay over time have been hake, sardine, horse mackerel and anchovy (Figure 8). The biomass of anchovy declined dramatically around the year 2005 and regulations were set forth on subsequent years which caused banning of the fishery until 2009. This anchovy crisis appeared because the European Commission ignored the multiple warnings of the scientific advisors (e.g. ICES), which alerted on the bad state of the anchovy stocks and recommended to decrease drastically the TAC (total allowable catches), of this species. From 2010 onwards, landings seem to have reached values close to those prior to the banning. The anchovy stock in the Bay of Biscay was estimated to have recovered due to its life history traits, which allow a quick collapse but also a rapid recovery of the population (low life expectancy, high fecundity but recruitment highly sensitive to environmental conditions variation. On the other hand, the biomass of horse mackerel (*Trachurus trachurus*) has been declining during the time series, as was observed in the Cantabrian Sea. The peak of mackerels (*Scomber* spp) observed around the year 2006 is due to unusually high Spanish catches that year.

Despite these fluctuations, there wasn´t a significant trend in the landed biomass over the period studied.

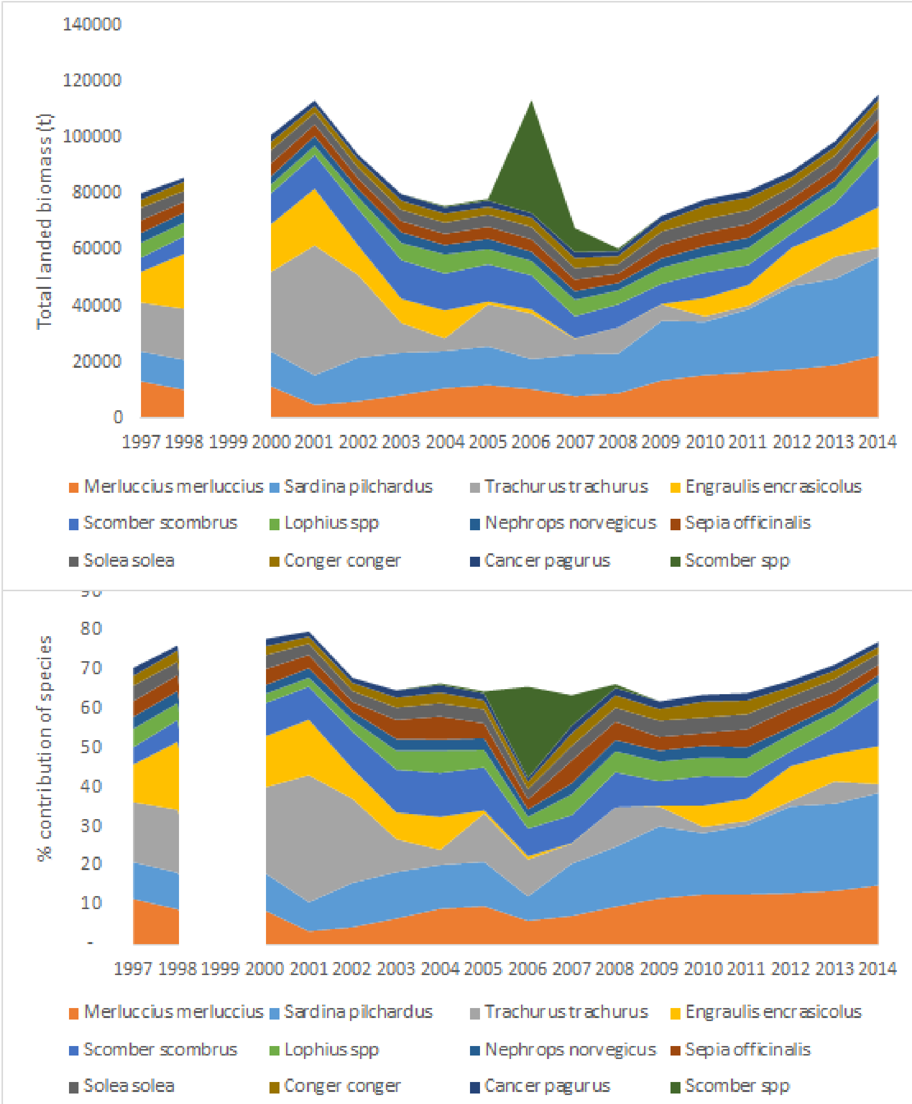
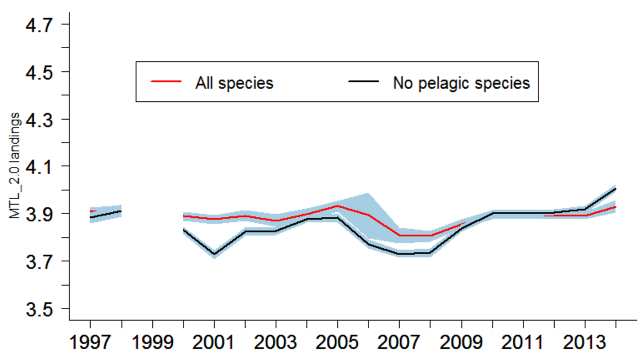


Figure 8. Trend in landed biomass over time and trend in the biomass of species accounting for 80% of the landed biomass over the studied period.

Landings data from the northern part of the BoB also indicated an apparent increase in MTLs, especially when concentrating on higher trophic levels: cut-off 3.25, excluding pelagic species ($F=11.78$, MannKendall: $tau=0.56$, $p<0.05$), and cut-off 4 both when excluding pelagic species ($F=12.18$, MannKendall: $tau=0.51$, $p<0.05$) or not ($F=26.88$, MannKendall: $tau=0.73$, $p<0.05$) (Figure 9).



All species
No pelagic species
MTL_2.0 landings
4.7
4.5
4.3
4.1
3.9
3.7
3.5
1997
1999
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2005
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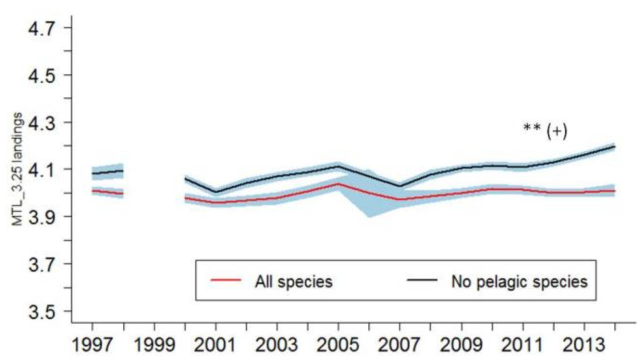

** (+)
All species
No pelagic species
MTL_3.25 landings
4.7
4.5
4.3
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1997
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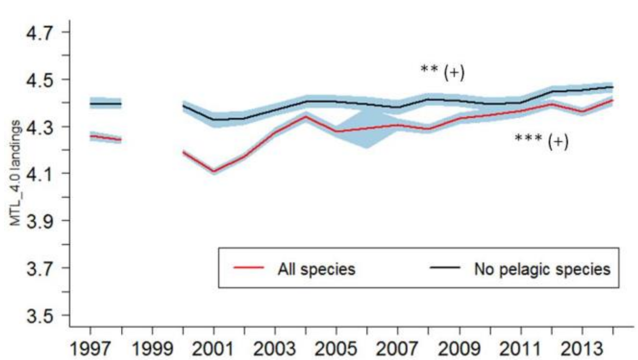


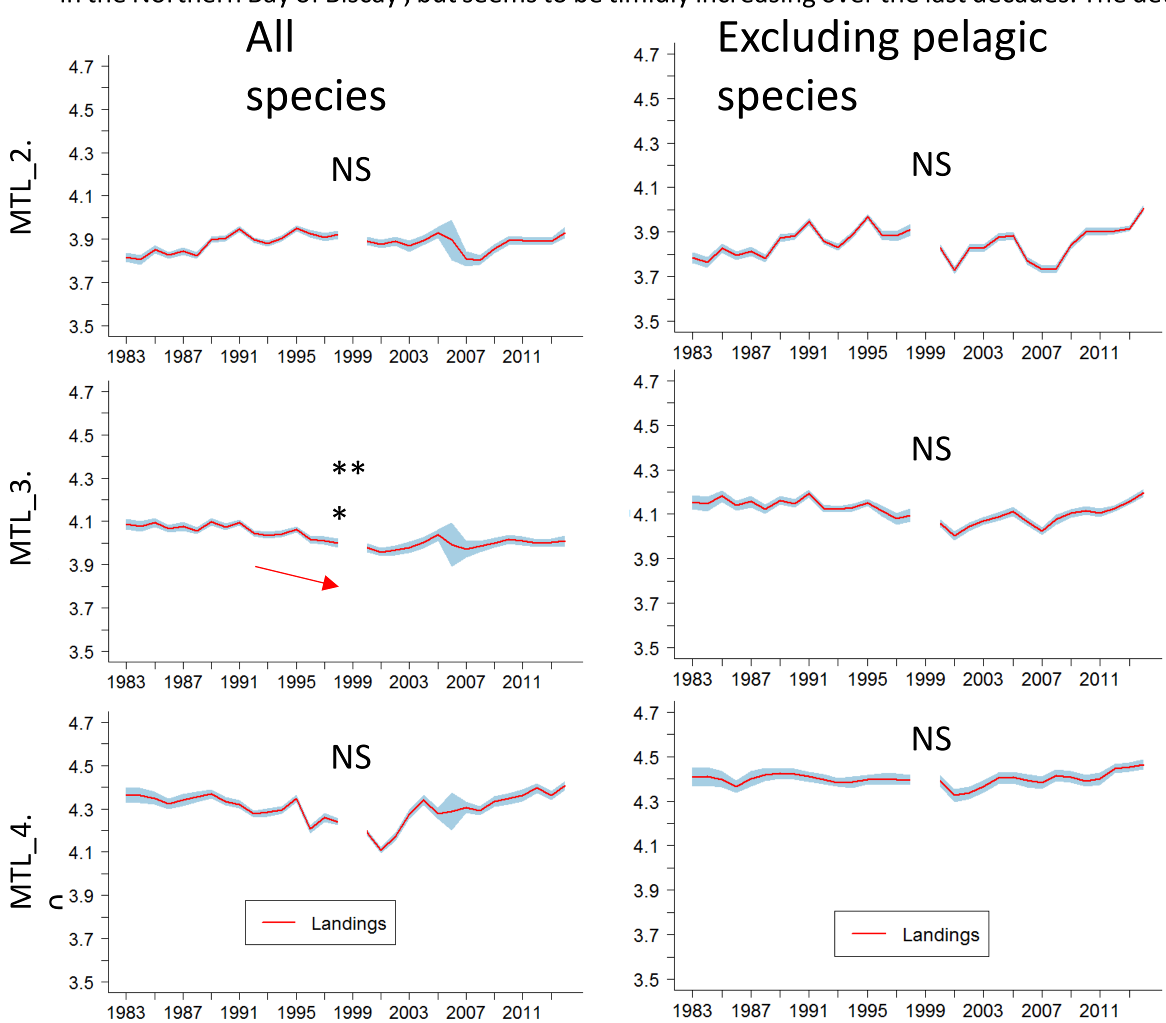
** (+)
*** (+)
All species
No pelagic species
MTL_4.0 landings
4.7
4.5
4.3
4.1
3.9
3.7
3.5
1997
1999
2001
2003
2005
2007
2009
2011
2013

Figure 9.Trends in mean trophic level of ICES OFFICIAL CATCHES data (1997 – 2014), at the various cut-off levels analysed including all species and excluding pelagic ones from the analyses. Data from 1999 are missing due to the absence of French datadeclared this year.

These results confirm the apparent progressive recovery of demersal predators in this region from the beginning of the 21st century onwards, in accordance with the rise in the amount of allowed fishing quotas for the main species, such as *Merluccius merluccius*, which took place as of the year 2000.

The analysis of the trend including the early 80's, from 1983 onwards (ICES historical landings combined with official nominal catches), on the other hand, showed no significant trend except in the case of MTL3.25, which showed a significant decrease (F=43.19, MannKendall: tau=-0.52, p<0.05, Figure 10). It seems, therefore, that results depend on the temporal context on which the data is set, longer time series providing a broader view of the actual trends in the indicator at its various thresholds.

In general then, and combining results from both data sets, the trends observed don't show any increase or decrease of the indicator when excluding pelagic species, indicating that the TL of landed bentho-demersal species in principle hasn't experienced any dramatic decline over the past 30 years in the Northern Bay of Biscay , but seems to be timidly increasing over the last decades. The detected



decrease in MTL3.25 when analysing all species together might be an indication of the reduction in the landed biomass of certain pelagic species such as *Trachurus trachurus* (decrease of the fishing quotas since the end of the 90's due partly to a low recruitment) and the increase in lower trophic level ones such as *Scomber scombrus* (for which fishing quotas increased these recent years in the area), which is a general trend observed in the Bay of Biscay (ICES advices 2014.

Figure 10.Trends in mean trophic level of ICES HISTORICAL LANDINGS DATA plus OFFICIAL CATCHES in the Northern Bay of Biscay (a) including all species identified to family, genus or species level at the various cut-off levels analysed, (b) excluding pelagic species from the former data base.

<u>4.1.2.2. Surveys</u>

EVHOE DATRAS data

The total biomass (g) from the DATRAS EVHOE survey data showed no specific trend during the studied period (i.e. 1997 – 2014) (Figure 11). An important peak was observed in 2003 which was mainly due to an important catch of Mackerel (*Scomber scombrus*) that year. Pelagic species had the highest relative biomass compared to demersal species. Two main species, the European Mackerel (*S. scombrus*) and the horse Mackerel (*Trachurus trachurus*), were representing more than 60% of total biomass surveyed.

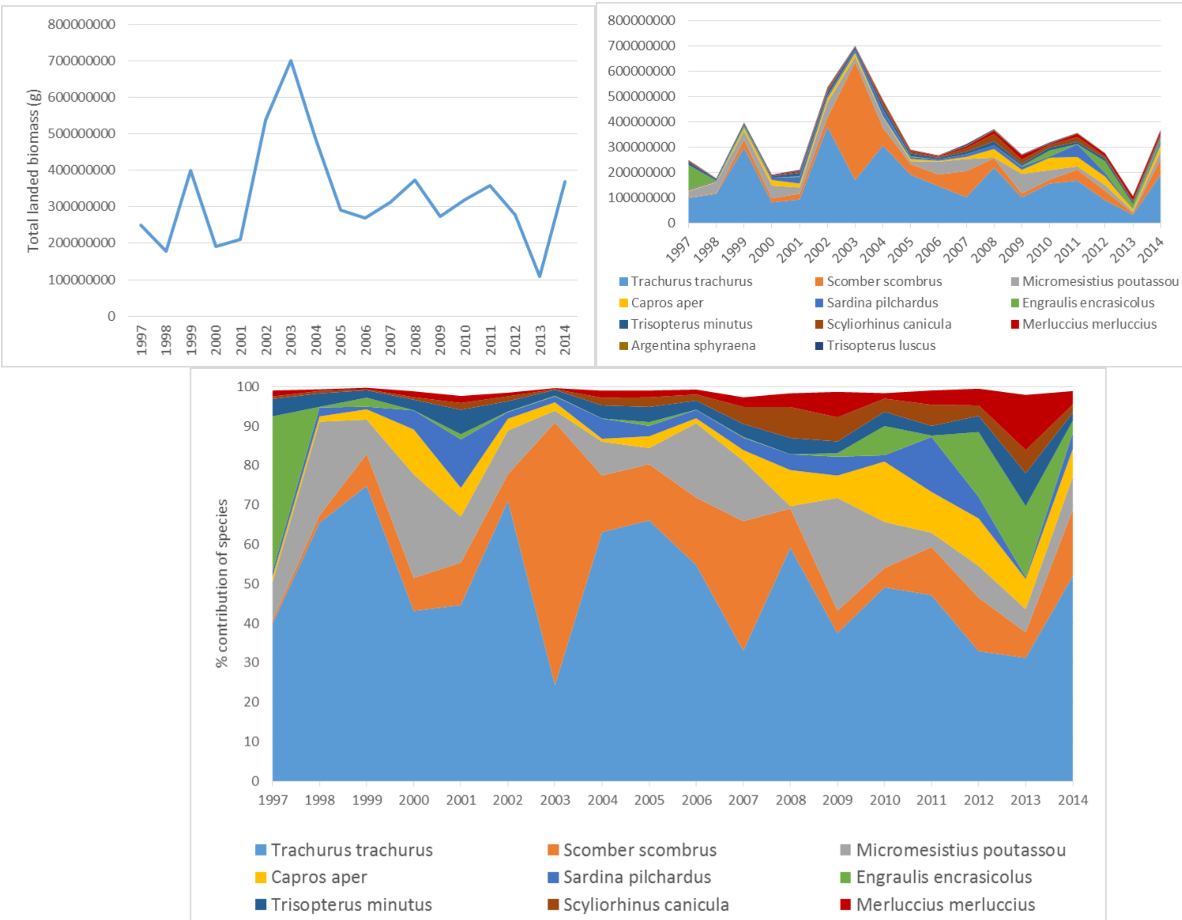


Figure 11. Trends in EVHOE DATRAS survey data global biomass and that of the dominant species, over time.

The trends analysis revealed that when all species with a trophic level lower than 3.25 (i.e. MTL with a cut-off of 3.25 and higher) were excluded, the MTL indicator showed significant increasing trends (Figure 12).

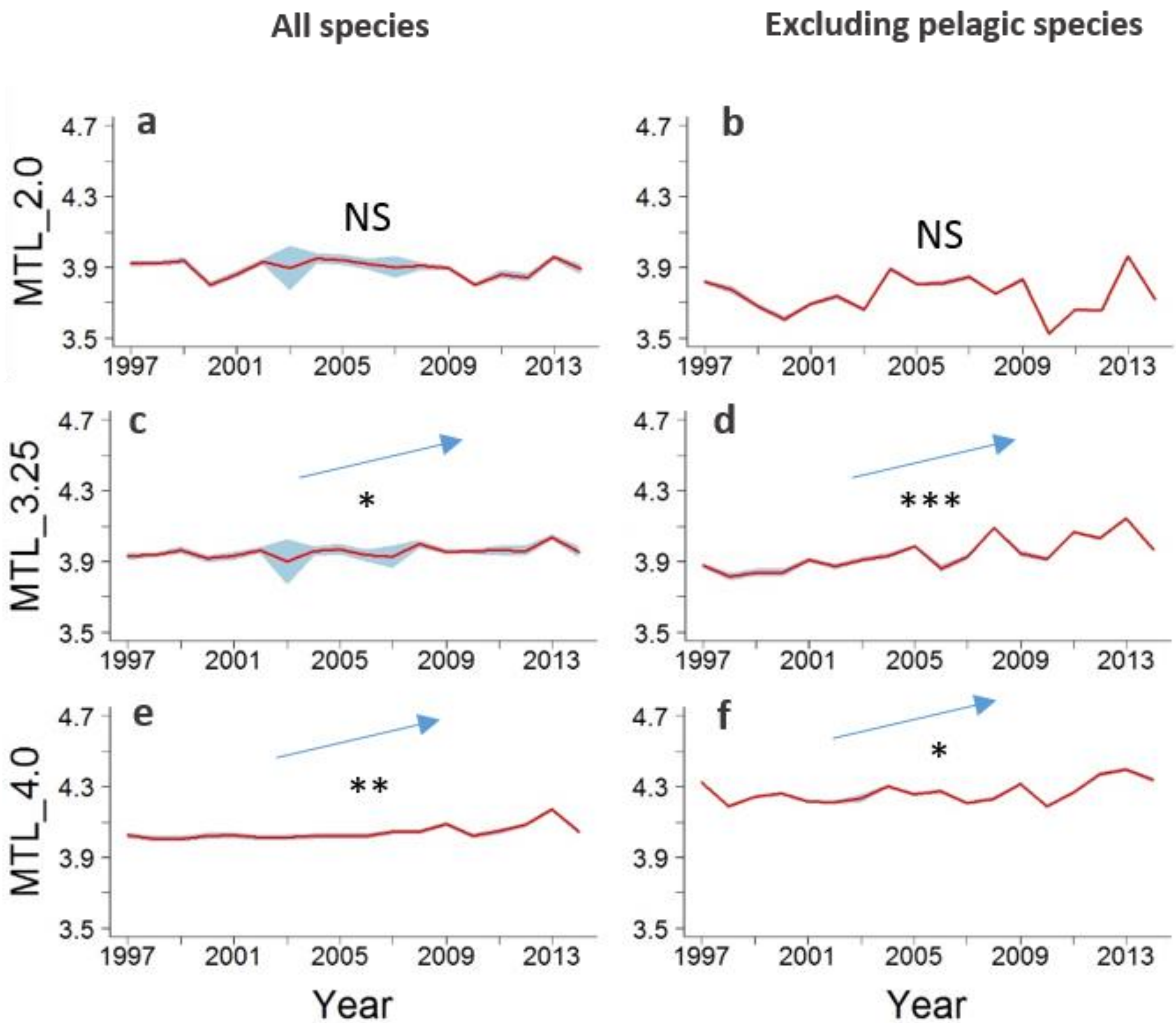


Figure 12. Trends in MTL levels at the different cut-off levels observed using the DATRAS EVHOE survey data series for the Bay of Biscay continental shelf.

Trends in theMTL_2.0 (with all species or excluding pelagic species) were highly influenced by the biomass of boarfish (*Capros aper*), which is a low trophic level species (Safi et al.-in prep, Annex 1). The high interannual variation in boarfish biomass induced a non-significant trend in the MTL_2.0. When applying a mid or high cut-off (i.e. MTL_3.25 and MTL_4.0), boarfish were excluded from the analyses, which allowed the detection of significant trends. These significant trends were mainly driven by the biomass of European hake (*Merluccius merluccius*) which has significantly increased in the last decade in the Bay of Biscay continental shelf (Safi et al.-in prep, Annex 1).

IFREMER SIH DATA

The total surveyed biomass (g) from the IFREMER SIH (EVHOE survey) data showed similar trends to the ones observed in DATRAS (Figure 13) with no significant differences between them. IFREMER SIH data are however limited to the period (1997-2012) and no update has been available on their site (http://sih.ifremer.fr/) since 2012. It is worth noting, however, that global biomass values arelower in the IFREMER SIH (e.g. peak in 2003 is at 600000000 g) compared to the DATRAS (e.g. peak in 2003 is at 700000000 g). This might be related to adjustments/corrections made by IFREMER when declaring/submitting biomass data to DATRAS.

In both data sources, the main species surveyed in terms of biomass along the time series are, as in the southern part of the BoB, *Trachurus trachurus*, *Scomber scombrus*, and *Micromesistius poutassou*, the peak in 2003 being mainly related to a high biomass of mackerel during those years. This peak caused a slight decline in MTL 2 and 3.25 during that year which wasn't discernible when applying the MTL4 or when excluding pelagic species, where *S.scomber* is included. In general, the MTL trends analysis (Figure 14) showed only slightly different trends compared to the ones observed when using DATRAS data. Indeed, the MTL_2.0 with all species showed an overall significant decrease while no significant trend was observed with DATRAS. This could be due to the smaller time series available for SIH data (i.e. until 2012) which have influenced the global trend for MTL_2.0. Furthermore, some species appearing in the IFREMER SIH data base are excluded when data are compiled in the DATRAS database, which could have influenced the MTL trends during specific years.

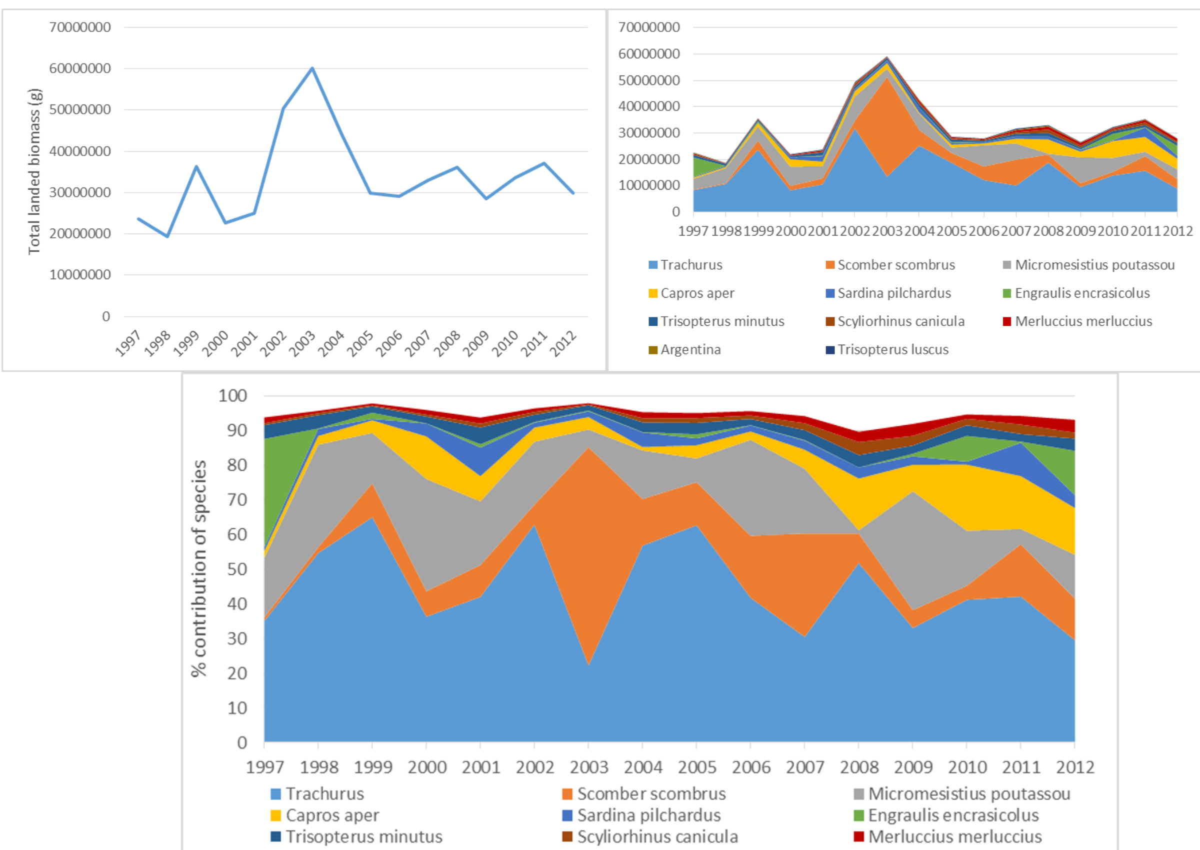


Figure 13. Trends in EVHOE DATRAS survey data global biomass and that of the dominant species, over time.

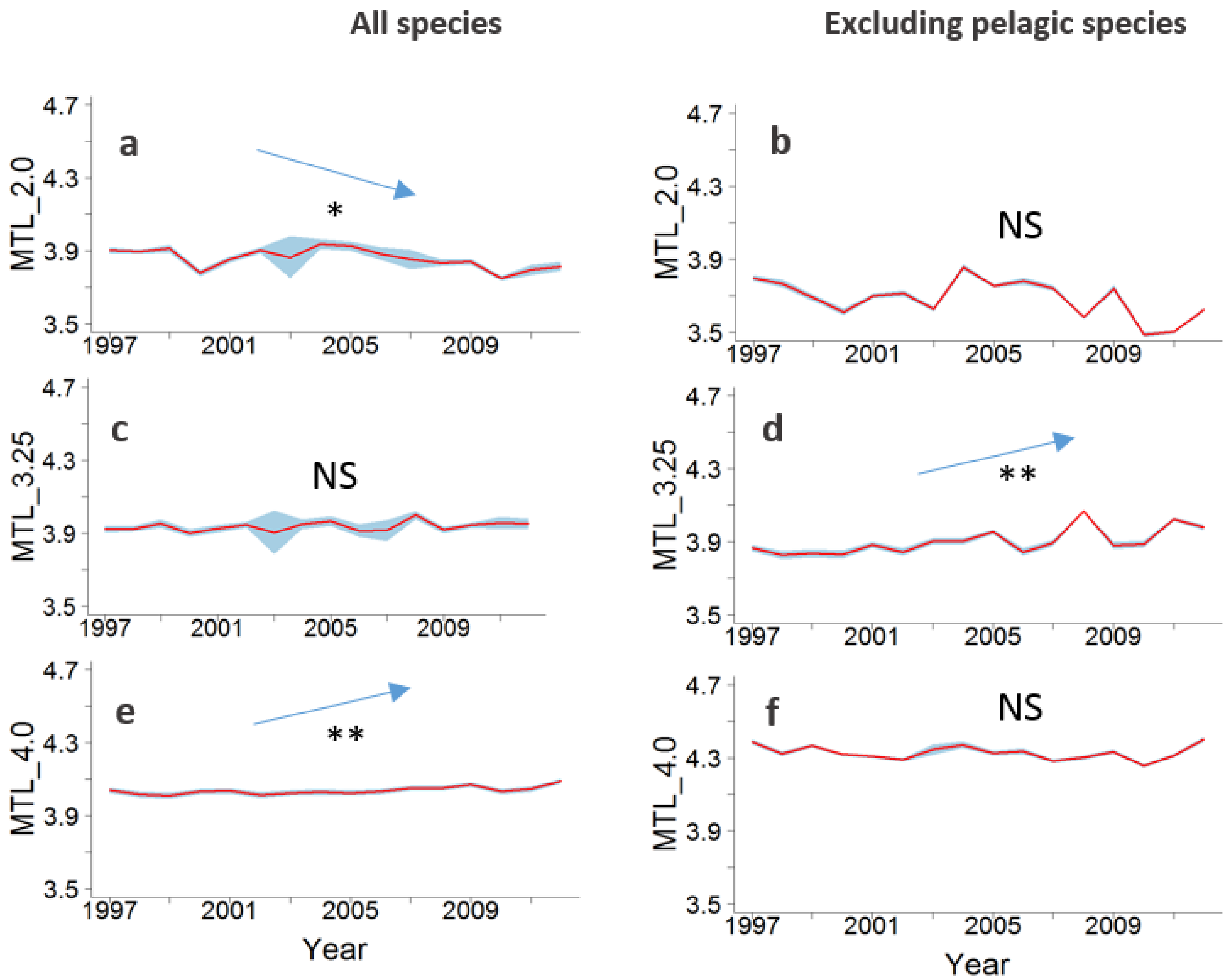


Figure 14. Trends in MTL levels at the different cut-off levels observed using the IFREMER SIHEVHOE survey data series for the Bay of Biscay continental shelf.

MSFD DATA PRODUCT

In general, the species biomass trends (Figure 15) and the MTL trends (Figure 16) observed with MSFD data product are similar to those observed with DATRAS and SIH data bases. MTL trends indicate an apparent increase in the mean trophic level at the thresholds involving top predators (MTL3.25 and MTL4).

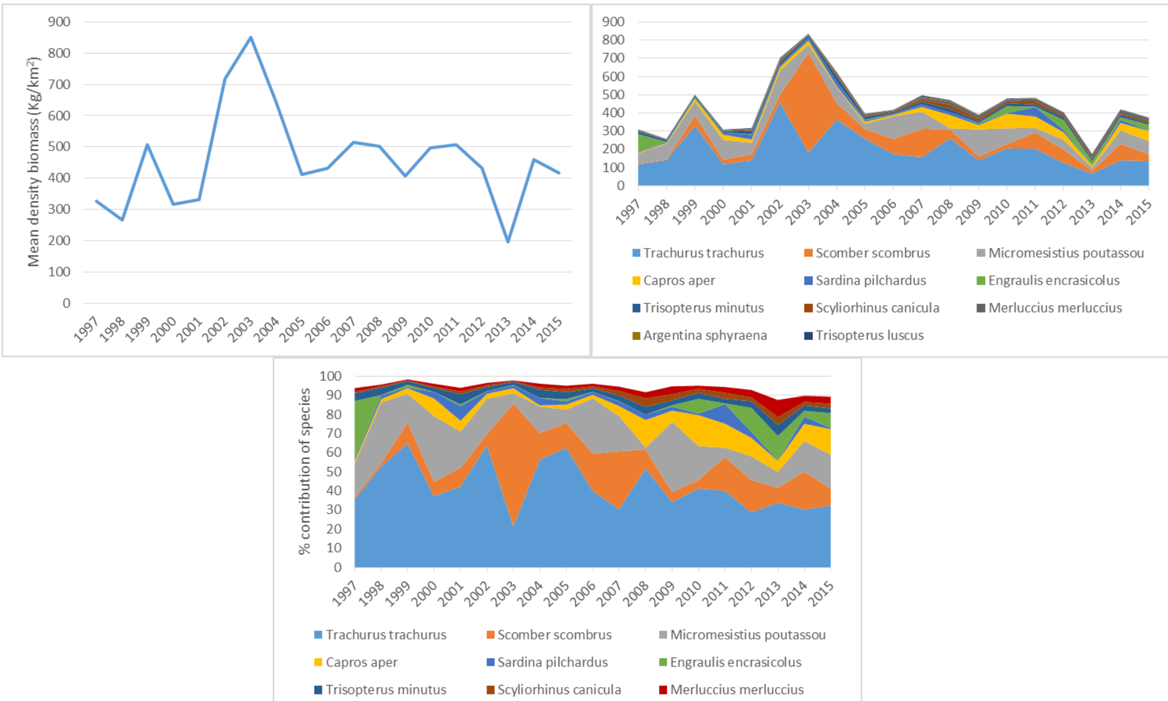


Figure15: Trends in global biomass and that of the dominant species, over time using EVHOE MSFD data product survey data.

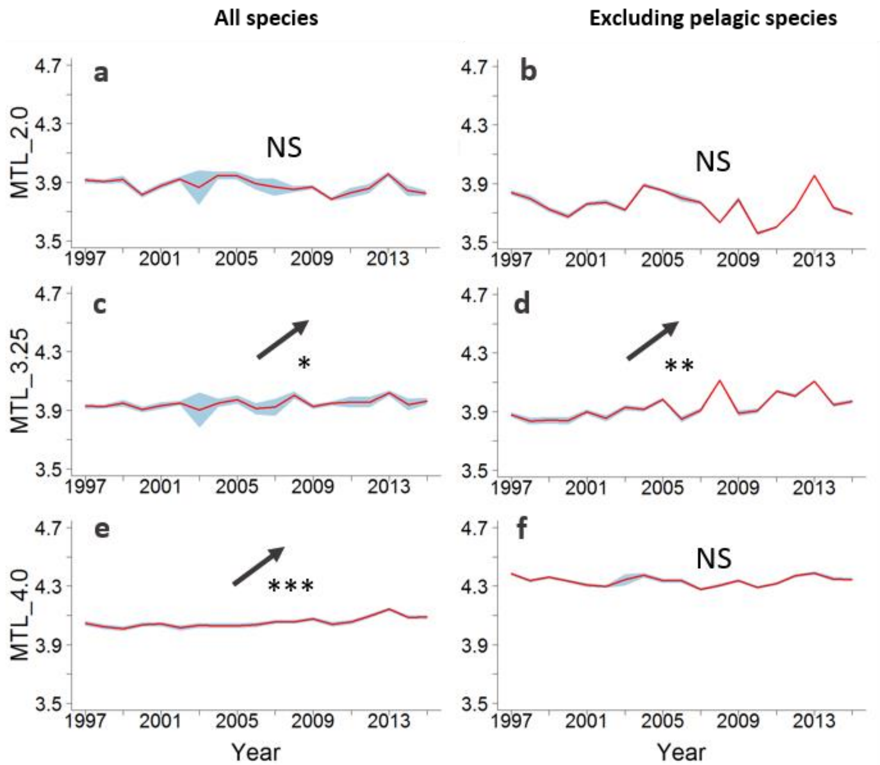


Figure 16: Trends in MTL levels at the different cut-off levels observed using the MSFD product data series for the Bay of Biscay continental shelf.

4.2.RELATIONSHIP WITH FISHING MORTALITY

These comparisons were only conducted for the Southern Bay of Biscay, where a composite mortality value can be calculated based on ICES stock assessment data. For now, it is not possible to conduct a similar analysis for the French Bay of Biscay continental shelf.

Landings data

No significant correlation was found between Fcom and the MTL3.25 of ICES historical landings or IEO landings data, whether including or not pelagic species ($p>0.05$). However, when the same analysis was conducted using ICES CATCH STATISTICS, on a much shorter data time series, there was a significant negative correlation (Spearman rho= - 0.85, $p<0.01$) between the MTL values at cut-off levels 2 and 3.25 (essentially the same species were included here), but a positive one (Spearman rho = 0.7, $p<0.05$), when considering MTL4 and the Fcom when excluding pelagic species (Figure 17), although no such relationship was found when the whole species assemblage was analysed. This makes sense, given that the combined mortality was calculated using that of the main commercial demersal species.

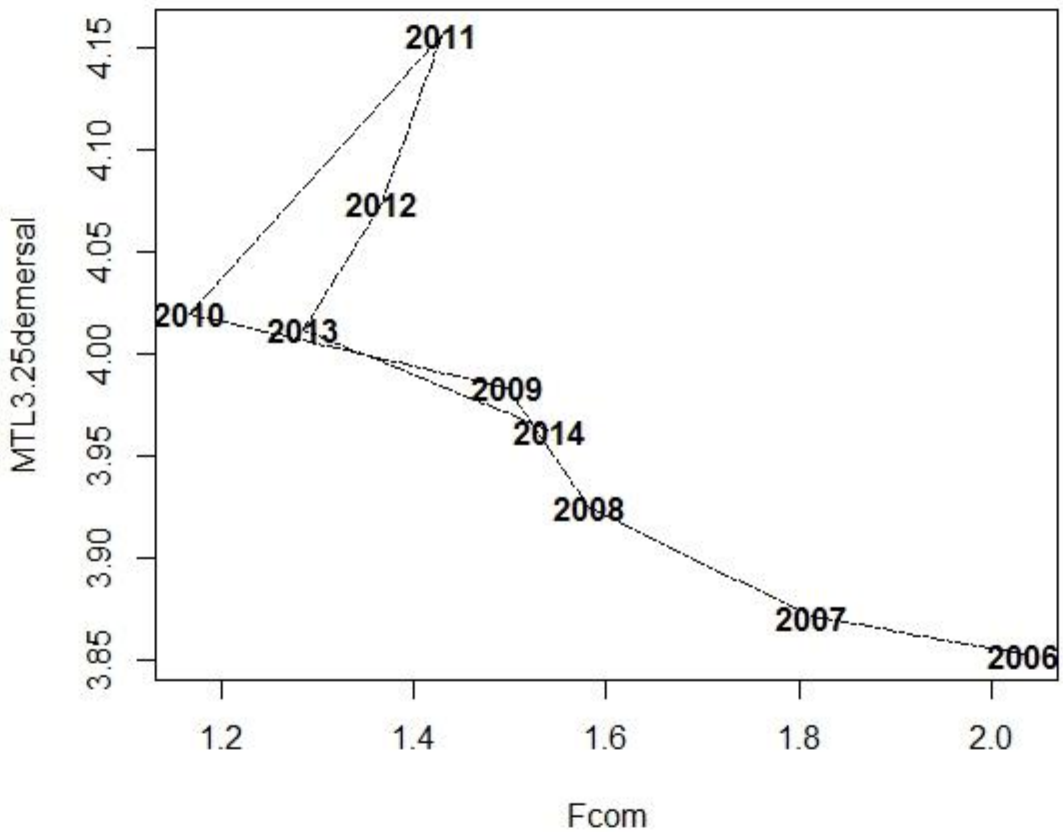


Figure 17. Relationship between MTL3.25 of ICES landings for demersal species and the combined mortality (Fcom) over time.

SURVEY DATA

No correlation between fishing mortality (Fcom) and trends observed for the various cut-offs, whether considering pelagic species or not, where observed with data from IEO demersales data, or DATRAS data (p>0.05). However, the relationship was always a negative one (decreasing mortalities were coupled with increasing MTLs), except for demersal MTL4, which showed a positive correlation with Fcom values, as recorded with landings. This is an interesting result which should be looked further into.

5. DISCUSSION AND CONCLUSIONS RELATIVE TO THE USE OF THE INDICATOR

Landings –In general, trends reflected by the mean trophic level of landings were only significant when high predators were considered. In the Southern Bay of Biscay, the MTL2 cut-off level showed no significant trend for any of the data-bases/time-series considered, while the cut-off level 3.25 showed a significant increasing trend only in the period between 2006 – 2014. As regards cut-off level 4, it seems the trend was positive in the long data series (increasing from 1994 – 2015 and 1989 – 2009), but decreasing significantly (especially when only demersal and benthic species were considered), in the recent ICES data series (2006 – 2014). This may mean either that high predator populations are recovering in the fished areas or that new (further from the coast or deeper) areas have been exploited in the latter years, where large predators are still abundant (Essington et al., 2006; Shannon et al., 2014).

As regards the northern Bay of Biscay, again, significant trends were only observed when higher trophic levels were examined, showing an increasing trend in MTL3.25 and MTL4 (also when pelagic species were eliminated), when the EVHOE (1997 -2015) database was analysed, and decreasing one for MTL3.25 when ICES historical data (1983 – 2013), based on the main commercial species were analysed.

One explanation for increase in MTL could be the fact that new areas are being exploited and larger fish taken from for instance, deeper areas, but Gascuel et al. (2016), reported a generalized decrease in MML across Europe, which should be due to a predominance of smaller species and lower trophic levels among landed biomasses.In the Southern Bay of Biscay, exploitation of deeper or further off-shore areas has only been punctual and hence would not explain the increases in MTL observed, which would more probably be attributable to the relative recovery of demersal stocks already shown elsewhere.

The apparent higher sensitivity of the indicator at higher trophic levels when using landings data can be due to their intrinsic nature, since they are based on catches normally focusing on high TL species. This was also found by Bourdaud et al., (2016), who using two new indicators, the HTI (percentage of consumers with a trophic level equal or higher than 4), and the API (percentage of top or apex predators, on the total of predators excluding planktivores), also found them to show a stronger sensitivity to fishing pressure compared to mean trophic level (our cut-off level 2) and the MTI (our cut-off level 3.25).

This makes sense given their higher sensitivity to fishing due to their lower productivity and turn-over rates.

It seems pelagic species are responsible for most of the uncertainty at all cut-off levels, which confirms the need to analyse the demersal assemblage separately. This is especially true considering that IBT surveys in which the assessments are based do not properly sample pelagic elements and that the abundances of pelagic species are more environmentally conditioned than demersal ones. Nevertheless, they constitute the majority of the fished biomass in the Bay of Biscay and their relevance in the evolution of the MTL should not be overlooked.

Surveys – As regards results obtained using survey data, the main trend observed is also an increasing one, whatever the data base observed, which should be in accordance with recent stock recovery trends observed in the Bay of Biscay (Modica et al., 2014; Punzón et al., 2016; Arroyo et al., 2017) and the Northeast Atlantic (Fernandes and Cook, 2013), but which contradict former reported trends in the Northern Bay of Biscay (Gascuel et al., 2016), where the mean trophic level was found to decrease. The latter, were however based on the short time series available in DATRAS data, and where therefore cautioned to be interpreted carefully. Our analyses of all the available data series and for Northern and Southern areas in the Bay of Biscay reflect an apparent recovery and stabilization of mean trophic level values which should be interpreted as the reflection of the recovery of (especially), the vast majority of predators in the area, though trends found in some cases for demersal top predators should be further looked into before extracting any definitive conclusions.

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Annex 4: Investigating interactions between fishing pressure and the indicator trends: Towards Integration of benthic (BH3) and food webs (FW4) indicators.

INTEGRATION APPROACH

According to ICES recommendations (ICES Advice, 2015): *the challenges when considering state (including biodiversity) and function need to be considered across Descriptors 1, 3, 4, and 6. The concepts of trophic guild, taxonomic grouping, habitat type, and fish stock need to be combined in a way that accounts for the functional requirements of the state descriptors to ensure efficient implementation of the MSFD.*

Within the EcApRHA project, an attempt has been made to integrate benthic and food webs indicators. An attempt for full integration of FW4 and BH3 indicators has been tested, the results indicating that still further refinement of the indicators is needed before they can be used for integration purposes.

Specifically, the following gaps were identified and have been incorporated into the EcApRHA deliverable 5.6 - Action plan:

Gap 1: BH3 is represented using the actual assemblage of species present in a certain area, while the outcome of the crossing of MTL and VMS values is a representation of the results of the model comparing MTL values under the specific fishing pressure levels taking place in a particular area with a scenario of no fishing pressure at all. This comparison may introduce bias due to the different nature of the represented elements.

Solution: Maybe a better representation/crossing of the indicators would be obtained if the sensitivity of the habitats/areas was also modeled in the same way as FW4, and a prediction of the potential habitat loss as a function of fishing pressure was obtained.

Gap 2: BH3 has different spatial scales incorporated in its development, i.e.: gridded area around survey data 0.05 x 0.05 degrees, where you select the highest sensitivity value, EUNIS polygons with survey data (median value), and EUNIS polygons without survey data, which are not contemplated in FW4. This produces a patchy distribution of BH3 values that is not observed in FW4, which hampers comparisons.

Solution: A further refinement of the indicators is necessary in order to conduct indicator integrations in general, and this one in particular.

Thus, this annex only deals with the first steps of such integration, concerning the crossing between MTL and VMS values and the modelling of their responses to derive a relationship between mean trophic level of the assemblages and fishing pressure exerted by trawling vessels.

Further details on the possibilities of this integration and specific recommendations as to its use and implementation, as well as discussions on its management implications at OSPAR level, are provided in deliverable 4.1. - Working towards an ecosystem perspective: Proposals for the integration of pelagic, benthic and food web indicators

Preliminary results on the integration of BH3 (Physical damage) and FW4 (Mean trophic level of marine predators) OSPAR indicators

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INTRODUCTION

The health and sustainability of fisheries can be assessed by monitoring the trends in average trophic levels (Pauly & Watson, 2003). When TL values begin to drop, it indicates that fisheries are relying on ever smaller fish and that stocks of the larger predatory fish are beginning to collapse. TL-based indicators have already been established as food web indicators capturing fishing impacts at community level of marine ecosystems (Shannon et al., 2014). Many studies have been conducted using landings, surveys and model estimations to capture the changes observed on mean trophic level of demersal communities in the last decades (Navarro et al., 2011; Bourdaud et al., 2016; Reed et al., 2016). Data sources and TL cut-offs arise as the main key questions on the trends observed in all TL-based indicators (Shannon et al., 2014). But, while all these studies prioritized a temporal approach, the spatial scale of these variations has hardly been considered, the relationship between fishing pressure and changes in the TL of demersal and benthic communities at specific and localized pressure being virtually unknown. The present work is the first attempt to explore the direct impact of trawling on the mean trophic level of demersal communities using a spatial approach at local scale.

In the last years the way we locate fishing effort in the seabed has experienced a remarkable improvement with the implementation in fishing vessels longer than 12 m of the BlueTraker Vessel Monitoring System (VMS). This system provides information on the location and activity of each fishing vessel in the study area with a periodicity of 2 hours, giving a high level of detail regarding where fishing vessels are acting/impacting the seafloor. Since most of the hauls carried out during Spanish IBT surveys (Demersales) match those fishing grounds used by the Spanish fleet (otter trawl) there is a good opportunity to analyse, at a local scale, the direct impact of fishing vessels on the trophic level of the demersal assemblages.

The rationale of the present work was to discern whether there is a direct link, between fishing pressure and trophic levels of the benthic and demersal communities. The first results on MTL trends in the Bay of Biscay (Safi et al., in prep.), using a temporal approach, seemed to indicate an increasing trend from the 80's until now. These trends were observed both in the French and Spanish continental shelves, and seem to indicate a recovery of the demersal communities during the last decade. Here, we want to check if this recovery is taking place homogenously across the study area or on the contrary, if there is heterogeneity in the ecosystem recovery caused by the varying location/concentration of trawling efforts.

MATERIAL AND METHODS

Mean Trophic Level (MTL)

Data come from IBTS bottom trawl surveys carried out every autumn in the southern Bay of Biscay. Although the Demersales time series covered between 1983 and 2015, VMS data were restricted to years 2007 – 2010, so in the present work we only used data from 2007 to 2010 in order to be consistent with the VMS data. To calculate the metric, the biomass and trophic level of each species were used. Trophic levels (TL) of all species were calculated using stomach contents sampled for demersal fish species, combined with data from Fishbase and local references for those species which lacked empirical data (see Safi et al., in prep, for further details on TL assignation). First we assigned the trophic levels to each species and then calculated the Mean Trophic Level by haul. The MTL was calculated using three different cut-offs (2.0, 3.25 and 4.0), although only the MTL 2 and 3.25 cut-offs are shown in these preliminary results.

Vessel Monitoring System (VMS)

VMS data were calculated as the number of fishing days by haul (only otter trawl vessels were taken into account). In this study, the following processing technique was used:

- the time interval and the Euclidean distance between successive signals of the BlueTraker VMS were obtained. Each of these values were associated with the first signal of each corresponding pair. The VMS and logbook data were provided by the Spanish Ministry of Agriculture, Fisheries, Food and Environment (MAPAMA, by its Spanish acronym).

- when the time interval between signals was longer than four hours, the beginning and end of each fishing expedition was determined

- the average speed of the ship was calculated using the interval between successive signals (pings)

Each signal coinciding with a fishing trip registered in the logbooks (according to the ship code and the date of capture) was associated with a fishing gear and a fishing tactic. Vessels for which less than ten signals in a year were available were removed. Signals recorded within a distance of three miles or less from the closest fishing harbour were also eliminated. Based on the distribution of frequencies of average speeds, a working range for each fishing gear was defined, and all signals with associated velocities out of the working range were eliminated.

The frequency distribution of the average velocities was used to determine the average speed ranges at which we considered fishing activity to be carried out. The determination of these ranges can be achieved by either locating changes in the tendency through the use of regression models (segmented regression) or using available information from the fleet and observers aboard. In the case of dynamic fisheries (trawling), both methods are used jointly.

Thresholds were applied to determine if the filtered data from VMS corresponded to real fishing activities. Thus, each effort value was assigned to the corresponding point where the presence of fishing was detected. Subsequently, it was necessary to set a threshold for the effort value below which fishing activity was considered to be negligible or non-existent, for which there are numerous techniques (Liu et al, 2005, Jiménez-Valverde and Lobo, 2007; Freeman and Moisen, 2008). The techniques that provided the best outcomes were based on applying quartile thresholds. Points at which the presence of fishing was detected were eliminated according to the distribution of effort frequencies. Thresholds can be applied to fishing tactics or to fishing gear. If the relative importance of thresholds is small, it is better to apply them to fishing tactics; otherwise, it is more effective to apply them to fishing gear. In any case, 0.2 was considered to be an optimum threshold value.

Statistical analyses

The relationship between MTL by haul and fishing disturbance was analyzed using General Additive Models (GAMs) and the implementation gam in the package "mgcv" (Wood, 2011). Sediment type and depth were also included as explanatory variables in the model. These two variables are according to several studies key factors defining biological communities and therefore it is expected that they can affect TLs (Serrano et al., 2006, 2008; González-Irusta et al., 2012). Before starting the analysis, the correlation between the explanatory variables was checked for colinearity using Spearman rank correlations and Variance Inflation Factors (VIFs) (Zuur et al., 2009). Since the data were normally distributed we used a GAM with a Gaussian distribution and a log link function. To avoid overfitting, all the smoothers were constrained to 4 knots. This limitation reduced the potential complexity of the smoothers by limiting the maximum degrees of freedom of the smoothers to 3. The full binomial model was the same for the 3 different TLs tested:

$$MTL = \beta + s(VMS) + s(Depth) + f(Sediment\ type) + \mathcal{E}$$

Where β is the intercept, s is an isotropic smoothing function (thin plate regression splines, one for each variable and model), f indicates the variables which were included as factors in the formula and Ɛ is the error term. Selection of explanatory variables for each model was carried out using a backwards/forwards stepwise selection process based on the Akaike's Information Criteria (AIC).

All the response variables were in a raster format which allows projecting the GAM results in a map and therefore predict the MTLs in space. Sediment types were derived from EMODNET (2012) and comprised five levels: mud - sandy mud (e.g. < 1% coarser than 2 mm, and at least 20.1% <63µm), sand - muddy sand, coarse sand, mixed sediment (including diamicton) and rock. Since rocky areas are not sampled in the IBTS, they were not included in the models. The Depth layer was supplied by the Spanish Institute of Oceanography in a GIS raster with an original resolution of 200 m and resampled to the final resolution of 3000 m using bilinear interpolation.

The final maps were computed using the real scenario (with real fishing effort values) and a no fishing scenario, where all the values in the VMS map were substituted by 0. Then the differences between both maps were computed and the percentage of change in the MTL produced by fishing was computed as follows:

% Change in MTL= ΔMTL between scenarios/MTL in real scenario.

RESULTS

MTL>2.0

The resulting GAM using VMS, depth and sediment type as explanatory variables explained 11.18 % of the variance for MTL>2. The three variables were independent since no colinearity existed. There was a clear and negative relationship between MTL and VMS, showing a significant decrease in the mean trophic level with increasing fishing effort (Figure 1). This trend seemed to change in the highest fishing efforts (showing an increasing mean trophic level with increasing fishing effort), however this result should be taken with caution since very few data were available in this section (confidence intervals also increased here).

The relationship between MTL and Depth was positively correlated with increasing trophic levels with depth (Fig.1). This result was in accordance with the larger fish sizes and the increased abundances of deep-sea sharks dwelling at deeper waters.

Differences between GAM predictions of MTL in the map in a non-fishing scenario and a fishing scenario are shown in Figure 2. The model is predicting a MTL value of 3.5, in a certain area, with fishing pressure and 3.9 in a non-fishing scenario, which would mean that the mean trophic level in that specific area was 10 % lower than it would be expected without fishing. The high resolution of this map, will allow detecting specific areas of high fishing pressure "hotspots of anthropogenic pressure" where a significant decrease in MTL was observed.

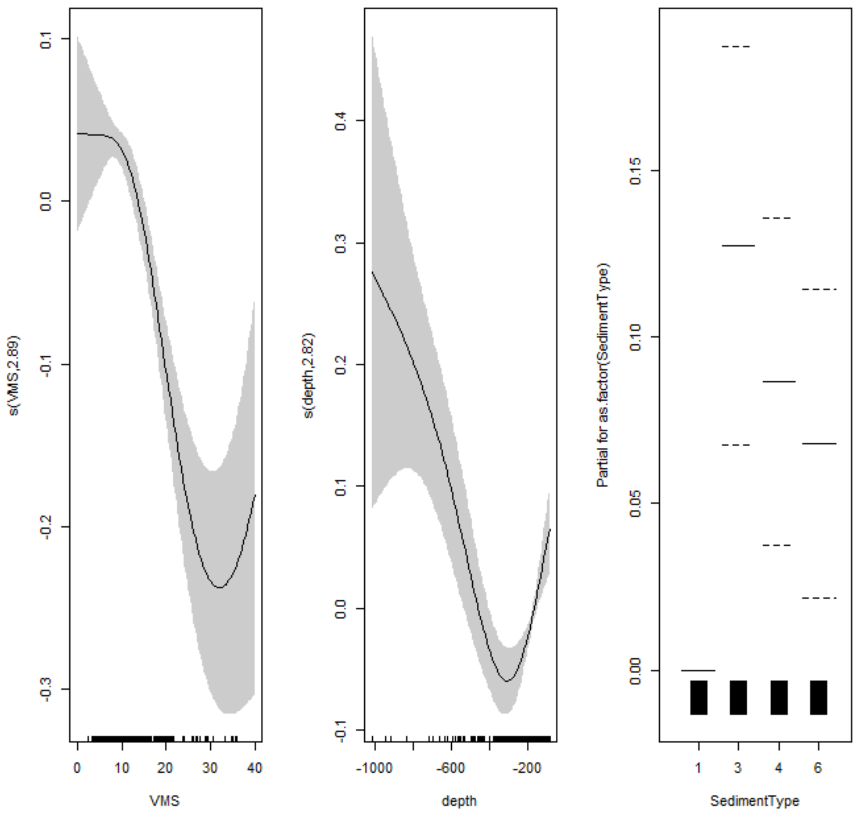

Figure 1. Results of the GAM performed using VMS, depth and sediment type as explanatory variables of changes observed in MTLs (TL> 2).

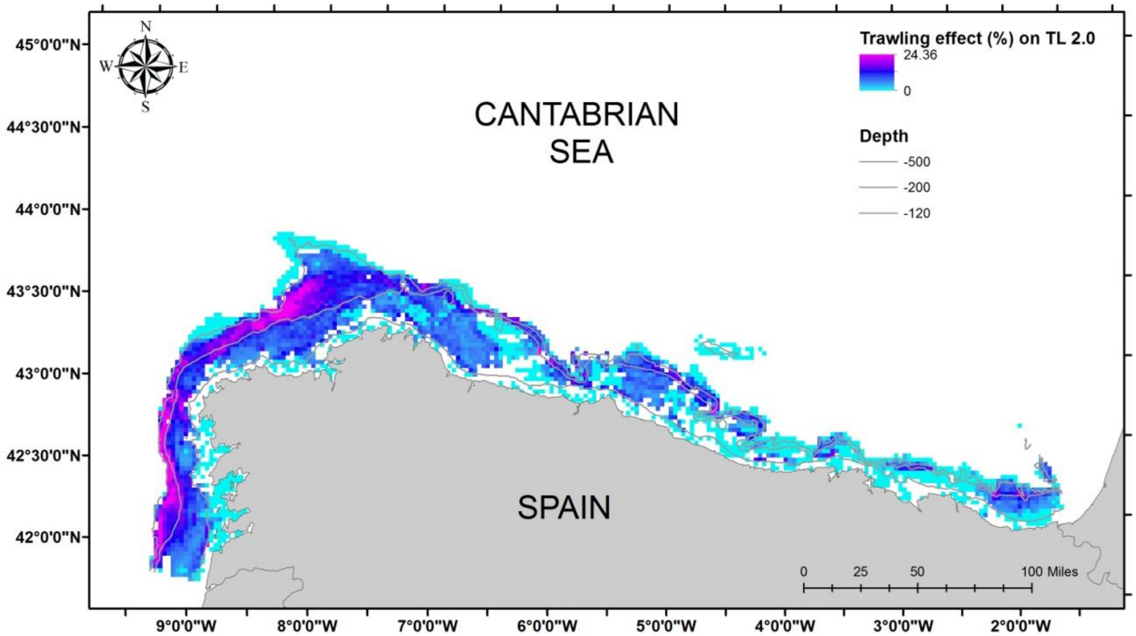

Figure 2. Map showing the decrease in MTL (TL>2) between fishing and non-fishing MTL scenarios.

MTL>3.25

The resulting GAM using MTL>3.25 explained 12.1 % of variance, very similar results to those observed for the 2.0 cut-off level. The three explanatory variables were also independent (no colinearity). There was also a clear and negative relationship between MTL and VMS, showing a significant decrease in the mean trophic level with increasing fishing effort (Figure 3). The relationship between MTL and Depth was also positively correlated with increasing trophic levels with depth, similarly to that found with TL>2 (larger fish sizes and the highest abundances of deep-sea sharks dwelling at deeper waters).

Differences in GAM predictions of MTL in a non-fishing and fishing scenario are also shown in Figure 4. The results look quite similar to those found for TLs >2.0, although with lower percentages.

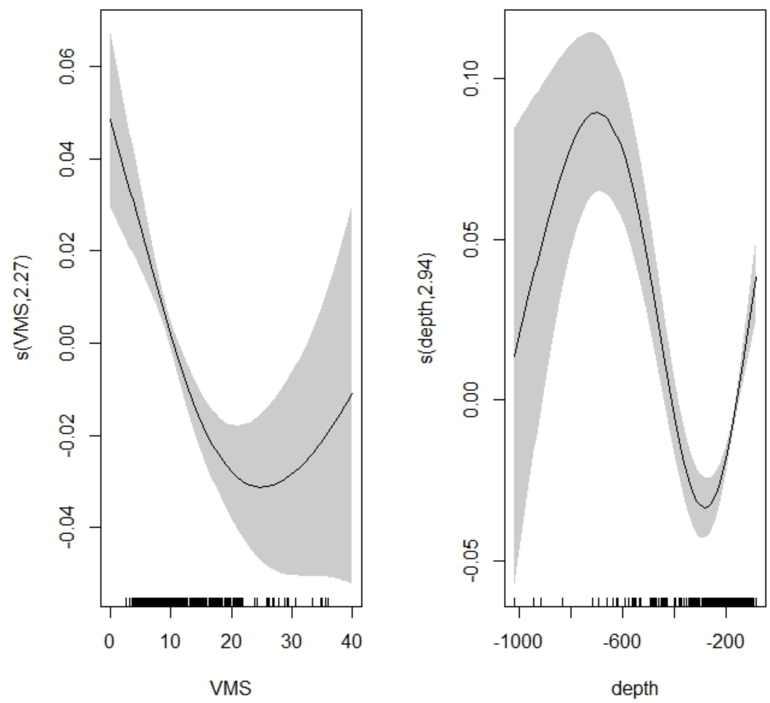

Figure 3. Results of the GAM performed using VMS and depth as explanatory variables of changes observed in MTLs (TL> 3.25).

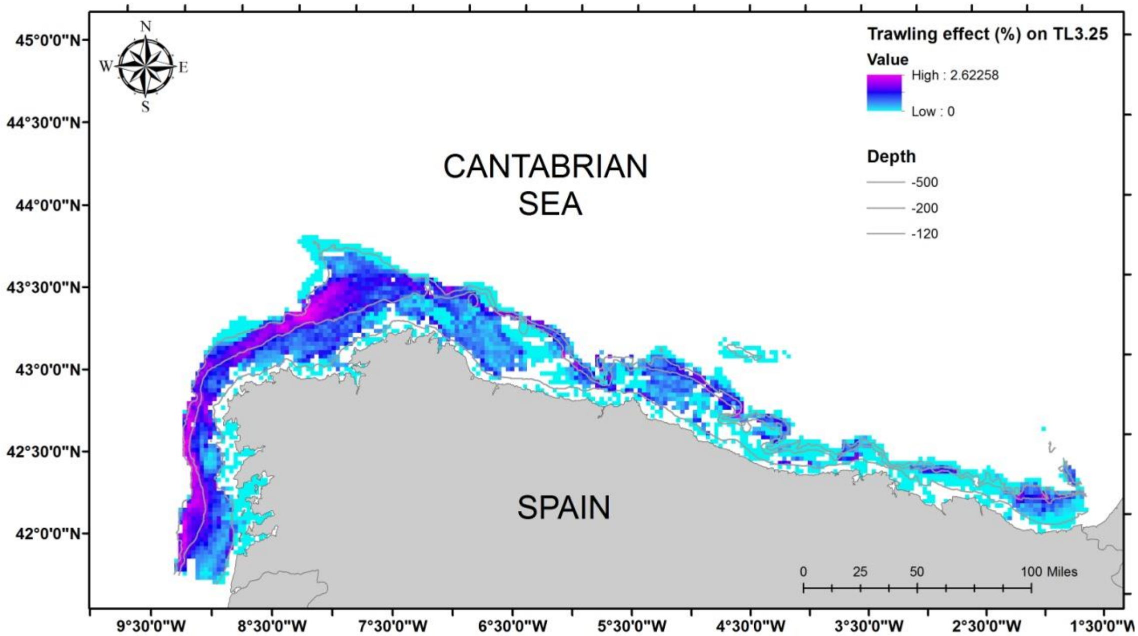

Figure 4. Map showing the decrease in MTL (TL>3.25) between fishing and non-fishing MTL scenarios.

MAIN CONCLUSIONS

- By combining trophic levels of the community with fishing pressure the usefulness of MTL as a pressure indicator is reinforced.
- Using the spatial approach, the most impacted areas (from a food web perspective) can be identified.
- The results of the present work could be used in a future scenario as a tool to establish restricted areas to fishing.

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Annex 5: Trophic levels for OSPAR region IV (Bay of Biscay) collated

The table presented here corresponds to the collation of TL values for species found in the various sources of landings and survey data corresponding to OSPAR region IV (Bay of Biscay).

Species	TL	SE	analysis	source
Abudefduf spp	3	0.33	FB/SLB	www.fishbase.org
Acantephyra eximia	2.5	0.35	labtroph	
Acantephyra pelagica	2.5	0.35	labtroph	
Acantephyra purpurea	2.5	0.35	labtroph	
Acantephyra spp	2.5	0.35	labtroph	
Acanthocardia aculeata	2.5	0.35	labtroph	
Acanthocardia echinata	2.1	0.35	labtroph	
Acanthocardia paucicostata	2.1	0.35	labtroph	
Acanthocybium solandri	4.3	0.2	FB/SLB	www.fishbase.org
Acantholabrus palloni	3.5	0.37	FB/SLB	www.fishbase.org
Acipenser spp	3.5	0.51		
Acipenser sturio	3.5	0.51	FB/SLB	www.fishbase.org
Acipenseridae	3.5	0.51		
Actinauge richardi	2.34	0.35	labtroph	
Actinia roja	2.34	0.35	labtroph	
Actinopterigios	3.5	0.5		
Adamsia carcinopados	2.7	0.35		
Adamsia palliata	2.7	0.35		
Aequipecten opercularis	2.2	0.04	Local IA	Chouvelon et al. 2012
Alcionum palmatum	2.34	0.35		
Alcyonium spp	2.34	0.35		
Alepocephalidae	3.7	0.2		
Alepocephalus rostratus	3.7	0.2	fishbase	
Algae	1	0.01		
Alloteuthis africana	3.71	0.35		
Alloteuthis media	4.45	0.35		
Alloteuthis spp	4.45	0.35		
Alloteuthis subulata	3.66	0.22	Non local IA	Navarro et al. 2011
Alopias spp	4.5	0.8	FB/SLB	www.fishbase.org
Alopias superciliosus	4.5	0.01	FB/SLB	
Alopias vulpinus	4.5	0.8	FB/SLB	www.fishbase.org
Alosa alosa	3.6	0.53	FB/SLB	www.fishbase.org
Alosa alosa, A. fallax	3.6	0.6	FB/SLB	www.fishbase.org
Alosa fallax	3.6	0.6	FB/SLB	www.fishbase.org
Alosa spp	3.6	0.6	FB/SLB	www.fishbase.org

Alpheus dentipes	2.4	0.35		
Alpheus glaber	2.4	0.35		LeLoc'h et al., 2008
Ammodytes marinus	2.7	0.3	FB/SLB	www.fishbase.org
Ammodytes spp	3.7	0.04	Local IA	Chouvelon et al. 2012
Ammodytes tobianus	3.7	0.04	Local IA	Chouvelon et al. 2012
Ammodytidae	3.7	0.04		
Ampelisca aequicornis	3.1	0.35		
Ampelisca spp	2	0.35	labtroph	
Ampeliscidae	2	0.35		
Amphipoda	2.3	0.35		
Amphiura filiformis	2.2	0.35	labtroph	
Anacanthini	3.5	0.35		
Anapagurus laevis	2	0.35	local IA	LeLoc'h et al., 2008
Anapagurus spp	2.5	0.35	labtroph	
Anarhichas lupus	4	0.35	Non local IA	Jennings et al. 2002
Anarhichas spp	3.6	0.01		
Anemona	2.5	0.35		
Anemonia sulcata	2.34	0.35		
Anguiliforme	3.5	0.35		
Anguilla anguilla	3.47	0.77	FB/SLB	www.fishbase.org
Anguilla spp	3.47	0.77	FB/SLB	www.fishbase.org
Anilocra physoides	0	0	parasite	
Anomura	2.5	0.35		
Anotopterus pharao	4.3	0.76	fishbase	
Anseropoda membranacea	2.2	0.35	labtroph	
Anseropoda placenta	2.2	0.35	labtroph	
Anthozoa	2.5	0.35		
Anthuridae	2.34	0.35		
Aphanopus carbo	4.2	0.04	Local IA	Chouvelon et al. 2012
Aphia minuta	3.1	0.28	FB/SLB	www.fishbase.org
Aphrodita aculeata	2.061	0.35	labtroph	
Aphrodite aculeata	2.061	0.35	labtroph	
Aphroditidae	2.061	0.35	labtroph	
Apodes	3.2	0.35	?	
Apogon imberbis	3.8	0.56		
Aporrhais pespelicani	2.37	0.35	labtroph	
Aporrhais serresianus	2.37	0.35	labtroph	
Arabella iricolor	2.061	0.35	labtroph	
Arculfia spp	2.285	0.35		

Arenicola marina	2.061	0.35		
Argentina silus	3.6	0.04	Local IA	Chouvelon et al. 2012
Argentina sphyraena	3.8	0.09	Local IA	Chouvelon et al. 2012
Argentina spp	3.7	0.09	Local IA	Chouvelon et al. 2012
Argissa hamatipes	2.285	0.35	labtroph	
Argobuccinum olearium	2.37	0.35	labtroph	
Argyropelecus spp	3.1	0.14		
Argyrosomus regius	4.3	0.75	FB/SLB	www.fishbase.org
Aristaeomorpha foliacea	3.8	0.59		
Aristeidae	3.3	0.47		
Aristeus antennatus	3.3	0.47		
Armina maculata	2.6	0.35	labtroph	
Arminia tigrina	2.6	0.35	labtroph	
Arnoglossus imperialis	3.8	0.6	FB/SLB	www.fishbase.org
Arnoglossus laterna	3.6	0.3	FB/SLB	www.fishbase.org
Arnoglossus spp	3.6	0.5		
Arrhis mediterraneus	2.285	0.35		
Ascophyllum nodosum	1	0.01		
Aspitrigla cuculus	3.86	0.02	Local SC	
Astacilla longicornis	2.285	0.35		
Asteroidea	2.2	0.35	labtroph	
Asteronys loveni	2.2	0.35	labtroph	
Astropecten irregularis	2.2	0.35	labtroph	
Atelecyclus rotundatus	2.8	0.35	local IA	LeLoc'h et al., 2008
Atelecyclus undecimdentatus	2.5	0.35	labtroph	
Atherina boyeri	3.2	0.36	FB/SLB	
Atherina presbyter	4.2	0.04	Local IA	Chouvelon et al. 2012
Atherina spp	3.7	0.43		
Atherinidae	3.53	0.36	FB/SLB & Local IA	
Atrina fragilis	2.1	0.35	labtroph	
Atrina pectinata	2.1	0.35	labtroph	
Auxis rochei	4.3	0.67	FB/SLB	www.fishbase.org
Auxis thazard	4.4	0.4	FB/SLB	www.fishbase.org
Auxis thazard, A. rochei	4.35	0.67	FB/SLB	www.fishbase.org
Balistes capriscus	3.6	0.5	FB/SLB	www.fishbase.org
Balistes carolinensis	4.1	0.2	FB/SLB	www.fishbase.org
Balistidae	3.85	0.35	FB/SLB	www.fishbase.org
Bathymedon spp	2.285	0.35	labtroph	

Bathynectes maravigna	2.5	0.35	labtroph	
Bathypathes patula	2.34	0.35	labtroph	
Bathypolipus arcticus	3.5	0.35	labtroph	
Bathypolipus spp	3.5	0.35	labtroph	
Bathypolipus sponsalis	3.5	0.35	labtroph	
Bathyraja spp	4	0.7		
Batrachoides spp	4	0.64	FB/SLB	
Belone belone	4.2	0.7	FB/SLB	www.fishbase.org
Berycidae	4.15	0.2	FB/SLB & Local IA	
Beryx decadactylus	4	0.08	Local IA	Chouvelon et al. 2012
Beryx splendens	4.3	0.2	FB/SLB	www.fishbase.org
Beryx spp	4.15	0.2	FB/SLB & Local IA	
Bivalvia	2.1	0.35		
Blenniidae	3.5	0.43		
Blennius ocellaris	3.5	0.43	FB/SLB	www.fishbase.org
Bolinus brandaris	3.23	0.45	FB/SLB	www.sealifebase.org
Bonnierella abyssorum	2.285	0.35	labtroph	
Boops boops	4	0.18	Local IA	Chouvelon et al. 2012
Bothidae	3.7	0.6	FB/SLB	www.fishbase.org
Bothus podas	3.4	0.4	FB/SLB	
Brachyura	2.5	0.35		
Brama brama	4.1	0.64	FB/SLB	www.fishbase.org
Brama spp	4.1	0.64		
Brosme brosme	4	0.4	FB/SLB	www.fishbase.org
Bruzelia typica	2.285	0.35	labtroph	
Buccinum undatum	2.2	0.09	Local IA	Chouvelon et al. 2012
Buenia jeffreysii	3.6	0.54	FB/SLB	www.fishbase.org
Buglossidium luteum	3.3	0.42	FB/SLB	www.fishbase.org
Calanoida	2	0.35	labtroph	
Calappa granulata	2.5	0.35		
Caliopsis parasitica	0	0	parasite	
Callianassa spp	2.2	0.35		
Callianassa tyrrhena	2	0.01	sealifebase	
Callionymus lyra	3.44	0.02	Local SC	
Callionymus maculatus	3.3	0.4	FB/SLB	www.fishbase.org
Callionymus reticulatus	3.3	0.39	FB/SLB	www.fishbase.org
Callionymus spp	3.3	0.35		
Calliostoma granulatum	3	0.35	local IA	LeLoc'h et al., 2008

Callista chione	2	0.35	Local modelling	Lassalle et al. 2011
Calocaris maecandrae	2.5	0.35	labtroph	
Campogramma glaycos	4.5	0.8		
Cancer bellianus	2.6	0.35		
Cancer pagurus	2.9	0.06	Local IA	Chouvelon et al. 2012
Caprellidae	2.285	0.35	labtroph	
Caproidae	2.94	0.03	Non local IA	Pinnegar et al. 2002
Capros aper	2.94	0.03	Non local IA	Pinnegar et al. 2002
Carangidae	4.14	0.8	FB/SLB & Local IA	
Carangolia barnardi	2.285	0.35	labtroph	
Caranx hippos	3.6	0.4		
Caranx rhonchus	3.6	0.59		
Carapidae	3.7	0.35		
Carcharhinidae	4.5	0.01		
Carcharhinus brachyurus	4.5	0.01		
Carcharias taurus	4.5	0.4		
Carcinus maenas	3.5	0.53	FB/SLB	www.sealifebase.org
Cardiidae	2	0.35	Local modelling	Lassalle et al. 2011
Cardioidea	2.1	0.35	labtroph	
Cardium spp	2.1	0.35	labtroph	
Caridea	2.6	0.35	labtroph	
Cavolinia inflexa	2.4	0.35	labtroph	
Cavolinia spp	2.4	0.35	labtroph	
Centrolophidae	3.9	0.38		
Centrolophus niger	3.9	0.38		
Centrophorus granulosus	4.1	0.4		
Centrophorus squamosus	4.2	0.6	FB/SLB	www.fishbase.org
Centroscymnus coelolepis	4.5	0.1	FB/SLB	www.fishbase.org
Centroscymnus crepidater	4.2	0.4		
Cephalopoda	3.5	0.35		
Cepola macrophthalma	4.1	0.04	Local IA	Chouvelon et al. 2012
Cepola rubescens	3.1	0.23	fishbase	
Cerastoderma edule	2	0.35	Local modelling	Lassalle et al. 2011
Cerastoderma spp	2	0.35	labtroph	
Cetorhinus maximus	3.2	0.3	FB/SLB	www.fishbase.org
Chaceon affinis	3.23	0.35	Local modelling	Lassalle et al. 2011

Chaceon quinquedens	3.23	0.35	Local modelling	Lassalle et al. 2011
Chaceon spp	3.09	0.35		
Charonia rubicunda	2.37	0.35	labtroph	
Chaetognata	2.4	0.35		
Chamelea gallina	2.1	0.35		
Charonia lampas	2.37	0.35		
Charonia lampax	2.37	0.35		
Chelidonichthys cuculus	3.86	0.02	Local SC	
Chelidonichthys lastoviza	3.4	0.5	FB/SLB	www.fishbase.org
Chelidonichthys lucerna	3.92	0.21	Local SC	
Chelidonichthys lucerna (≤ 20 cm)	3.77	0.06	Local SC	IEO Analysis
Chelidonichthys lucerna (≤ 21 ≥39 cm)	3.95	0.04	Local SC	IEO Analysis
Chelidonichthys lucerna (≥40 cm)	3.85	0.07	Local SC	IEO Analysis
Chelidonichthys obscurus	3.55	0.04	Local SC	
Chelidonichthys spp	3.5	0.5		
Chelidonichtys cuculus (≤17 cm)	3.77	0.03	Local SC	IEO Analysis
Chelidonichtys cuculus (≤18 ≥32 cm)	3.89	0.02	Local SC	IEO Analysis
Chelidonychtys cuculus (≥33 cm)	3.98	0.06	Local SC	IEO Analysis
Chelon labrosus	2.6	0.32	FB/SLB	www.fishbase.org
Chimaera monstrosa	4.1	0.08	Local IA	Chouvelon et al. 2012
Chlamys islandica	2	0.35		
Chlamys varia	2	0.35	Local modelling	Lassalle et al. 2011
Chloeia venusta	2.061	0.35		
Chlorophyceae	1	0.01		
Chlorotocus crassicornis	2.7	0.35		
Chondrichthyes	4	0.35		
Chondrus crispus	1	0.01		
Chromis chromis	3	0.2	FB/SLB	www.fishbase.org
Cidaris cidaris	2	0.35	labtroph	
Circomphalus casinus	2	0.35	Local modelling	Lassalle et al. 2011
Cirolanidae	2.285	0.35	labtroph	
Citharus linguatula	4	0.65	FB/SLB	www.fishbase.org
Clio pyramidata	2.4	0.35		
Clupea harengus	3.79	0.04	Non local IA	Pinnegar et al. 2002

Clupeidae	3.68	0.6	FB/SLB & Local IA & Non local IA	
Clupeoidei	3.79	0.04		
Cnidaria	2.34	0.35		
Codium tomentosum	1	0.01		
Coelorinchus caelorhincus	3.5	0.2	FB/SLB	www.fishbase.org
Colus spp	2	0.35		
Conger conger	4.25	0.02	Local SC	
Congridae	4.25	0.02		
Copepoda	2	0.35		
Corallium rubrum	2.34	0.35	Local modelling	Lassalle et al. 2011
Corallium spp	2.34	0.35		
Coris julis	3.2	0.5		
Coristes cassivelanus	2.5	0.35	labtroph	
Corophiidea	2.285	0.35		
Coryphaena hippurus	4.4	0.01		
Coryphaenoides rupestris	4.1	0.15	Local IA	Chouvelon et al. 2012
Crangon crangon	2.9	0.09	Local IA	Chouvelon et al. 2012
Crangonidae	2.95	0.09	Local IA	Chouvelon et al. 2012
Crassostrea gigas	2	0.01		
Crassostrea spp	2	0.35	Local modelling	Lassalle et al. 2011
Crepidula fornicata	2	0.35	Local modelling	Lassalle et al. 2011
Crinoidea	2.4	0.35		
Crustacea	2.5	0.35		
Crystallogobius linearis	3.4	0.45	fishbase	
Ctenolabrus rupestris	3.4	0.5	FB/SLB	www.fishbase.org
Cumacea	2.5	0.35		
Cyclothone spp	3.6	0.53	fishbase	
Cymbulia peronii	2.4	0.35	labtroph	
Cynoscion regalis	3.8	0.2	FB/SLB	www.fishbase.org
Cyprinus carpio	3	0.3	FB/SLB	www.fishbase.org
Cyttopsis rosea	4	0.66	FB/SLB	www.fishbase.org
Dalatias licha	4.2	0.7	FB/SLB	www.fishbase.org
Dasyatidae	3.87	0.63		
Dasyatis pastinaca	4.1	0.63	FB/SLB	www.fishbase.org
Dasyatis spp	3.87	0.63	FB/SLB	www.fishbase.org

Dasyatis violacea	4.4	0.54	FB/SLB	www.fishbase.org
Deania calcea	4.42	0.31	Local SC	
Deania profundorum	4.28	stomach contents		
Decabrachia	3.5	0.35		
Decapoda	2.5	0.35		
Decapterus punctatus	4	0.01		
Delectopecten vitreus	2.1	0.35	labtroph	
Deltentosteus quadrimaculatus	3.1	0.2	fishbase	
Dendrobranchiata	3.8	0.59		
Dendrophyllia ramea	2.34	0.35	labtroph	
Dendrophyllia spp	2.34	0.35	labtroph	
Dentalium spp	2	0.35	labtroph	
Dentex canariensis	3.6	0.59		
Dentex dentex	4.5	0.7	FB/SLB	www.fishbase.org
Dentex gibbosus	4.1	0.59		
Dentex macrophthalmus	3.5	0.44		
Dentex maroccanus	3.9	0.61		
Dentex spp	4	0.7	FB/SLB	www.fishbase.org
Dicentrarchus labrax	4.2	0.04	Local IA	Chouvelon et al. 2012
Dicentrarchus labrax (< 40 cm)	3.6	0.04	Local IA	Chouvelon et al. 2012
Dicentrarchus labrax (> 40 cm)	4.2	0.04	Local IA	Chouvelon et al. 2012
Dicentrarchus punctatus	4	0.1	Local IA	Chouvelon et al. 2012
Dicentrarchus spp	4.1	0.1	Local IA	Chouvelon et al. 2012
Dichelopandalus bonnieri	2.6	0.35	labtroph	
Dicologlossa cuneata	3.8	0.09	Local IA	Chouvelon et al. 2012
Diogenes pugilator	2.5	0.35	labtroph	
Diplodus annularis	3.4	0.4		
Diplodus cervinus	3	0.37	FB/SLB	www.fishbase.org
Diplodus puntazzo	3.2	0.01	FB/SLB	www.fishbase.org
Diplodus sargus	3.4	0.1	FB/SLB	www.fishbase.org
Diplodus spp	3.3	0.45	FB/SLB	www.fishbase.org
Diplodus vulgaris	3.5	0.1	FB/SLB	www.fishbase.org
Dipturus batis	4.2	0.6	FB/SLB	www.fishbase.org
Donax spp	2	0.35	Local modelling	Lassalle et al. 2011
Donax trunculus	2	0.35		
Dosinia exoleta	2.1	0.35	labtroph	

Dosinia spp	2.1	0.35	labtroph	
Ebalia spp	3.2	0.35		
Ebalia tuberosa	3.2	0.35		
Echiichthys vipera	3.9	0.04	Local IA	Chouvelon et al. 2012
Echinidae	2	0.35	labtroph	
Echinocyamus puxillus	2	0.35	labtroph	
Echinodermata	2	0.35	labtroph	
Echinoidea	2	0.35	labtroph	
Echiodon dentatus	3.7	0.6	fishbase	
Echiodon drummondii	4	0.65	FB/SLB	www.fishbase.org
Elasmobranchii	4	0.35		
Elasmobranchios	4	0.35		
Eledone cirrosa	3.3	0.04	Local IA	Chouvelon et al. 2012
Eledone moschata	3.7	0.35		
Eledone spp	3.48	0.58	FB/SLB & Local IA	
Enchelyopus cimbrius	3.5	0.2	FB/SLB	www.fishbase.org
Engraulis encrasicolus	3.9	0.09	Local IA	Chouvelon et al. 2012
Ensis ensis	2.1	0.01	labtroph	
Ensis magnus	2.1	0.35	labtroph	
Ensis siliqua	2.1	0.35	labtroph	
Entelurus aequoreus	3.5	0.44	FB/SLB	www.fishbase.org
Ephyrina figueirai	2.6	0.35	labtroph	
Ephyrina spp	2.6	0.35	labtroph	
Epigonus telescopus	3.3	0.5	FB/SLB	www.fishbase.org
Epinephelus caninus	3.8	0.55	FB/SLB	
Epinephelus marginatus	4.4	0.01	FB/SLB	www.fishbase.org
Epinephelus spp	4.4	0.01		
Epizoanthidae	2.34	0.35	labtroph	
Epizoanthus spp	2.34	0.35	labtroph	
Erythrops neapolitana	2.2	0.35	labtroph	
Erythrops spp	2.2	0.35	labtroph	
Etmopterus spinax	3.8	0.5	FB/SLB	3.932198308
Etmopterus spp	4.38	0.63	FB/SLB & Local IA	
Eucarida	2.2	0.35	labtroph	
Eunicidae	3.5	0.35	labtroph	
Euphasia krohni	2.2	0.35	labtroph	
Euphasia spp	2.2	0.35	labtroph	
Euphausia couchii	2.2	0.35	labtroph	

Euphausiacea	2.2	0.35	labtroph	
Eurynome aspera	2.5	0.35	labtroph	
Eusirus spp	2.285	0.35	labtroph	
Euthynnus alletteratus	4.5	0.01	FB/SLB	www.fishbase.org
Eutrigla gurnardus	3.9	0.02	Local IA	Chouvelon et al. 2012
Eutrigla gurnardus (≤27 cm)	3.87	0.03	Local SC	IEO Analysis
Eutrigla gurnardus (≥28 cm)	4.22	0.07	Local SC	IEO Analysis
Fucus spp	1	0.01		
Fucus vesiculosus	1	0.01		
Gadiculus argenteus	3.6	0.3	FB/SLB	www.fishbase.org
Gadidae	3.5	0.35		
Gadiformes	4.2	0.45		
Gadus macrocephalus	4.2	0.1	FB/SLB	www.fishbase.org
Gadus morhua	4.35	0.13	Non local IA	Pinnegar et al. 2002
Gaidropsarus biscayensis	3.6	0.3	FB/SLB	www.fishbase.org
Gaidropsarus macrophthalmus	3.73	0.05	Local SC	
Gaidropsarus mediterraneus	3.4	0.5	FB/SLB	www.fishbase.org
Gaidropsarus spp	3.44	0.5	FB/SLB	www.fishbase.org
Gaidropsarus vulgaris	3.3	0.5	FB/SLB	www.fishbase.org
Galathea dispersa	2.6	0.35	local IA	LeLoc'h et al., 2008
Galathea spp	2.5	0.35		
Galathea strigosa	3.09	0.35		
Galatheidae	2.3	0.35	FB/SLB & Local IA	
Galeocerdo cuvier	4.5	0.01		
Galeorhinus galeus	4.88	0.14	Non local IA	Pinnegar et al. 2002
Galeus atlanticus	4	0.2	FB/SLB	www.fishbase.org
Galeus melastomus	4.04	0.04	Local SC	
Galeus spp	4.04	0.04		
Gammaridae	2.285	0.35		
Gammaropsis spp	2.285	0.35		
Gastropoda	3.09	0.35		
Gastrosaccus spp	2.2	0.35		
Gelidium spp	1	0.01		
Gempylidae	4.25	0.71	FB/SLB	www.fishbase.org
Geryon longipes	2.6	0.35		
Geryon trispinosus	2.6	0.35		
Geryonidae	2.6	0.35		
Gibbula spp	3.2	0.35		
Gibbula umbilicalis	2.37	0.35		
Glycera spp	3.7	0.35		

Glycymeris glycymeris	2	0.35	Local modelling	Lassalle et al. 2011
Glycymeris spp	2.1	0.35		
Glyptocephalus cynoglossus	3.88	0.09	Non local IA	Pinnegar et al. 2002
Gnatophausia zoea	2.2	0.35	labtroph	
Gobiidae	3.1	0.35		
Gobioidei	3.1	0.35		
Gobioidei+Callionymoidei ind.	3.1	0.35		
Gobius niger	3.2	0.4		
Gobius spp	3.2	0.45	FB/SLB	www.fishbase.org
Gobiusculus flavescens	3.2	0.34		
Goneplax rhomboides	2.9	0.35	local IA	LeLoc'h et al., 2008
Gymnammodytes semisquamatus	2.7	0.3	FB/SLB	www.fishbase.org
Gymnura altavela	4.5	0.1	FB/SLB	www.fishbase.org
Haemulidae(=Pomadasyidae)	3.63	0.52	FB/SLB	www.fishbase.org
Halice spp	2.285	0.35		
Haliotis tuberculata	2	0.01	FB/SLB	www.sealifebase.org
Halobatrachus didactylus	4.0	0.64		
Harpinia antennaria	2.285	0.35		
Helicolenus dactylopterus	3.99	0.05	Local SC	
Heptranchias perlo	4.2	0.4		
Hexanchus griseus	4.3	0.5	FB/SLB	www.fishbase.org
Hidroides norvegica	2.061	0.35	labtroph	
Himanthalia elongata	1	0.01		
Hinia reticulata	2.37	0.35	labtroph	
Hippocampus hippocampus	3.2	0.4	FB/SLB	www.fishbase.org
Hippoglossoides platessoides	4.03	0.03	Non local IA	Pinnegar et al. 2002
Hippoglossus hippoglossus	4	0.5	FB/SLB	www.fishbase.org
Hirundichthys rondeletii	3	0.1	FB/SLB	www.fisbase.org
Histioteuthis reversa	3.5	0.35	labtroph	
Holothuria forskali	2	0.35	labtroph	
Holothuroidea	2.9	0.35	local IA	LeLoc'h et al., 2008
Homarus gammarus	3.7	0.23	FB/SLB	www.sealifebase.org
Homarus spp	3.7	0.23		
Hoplostethus atlanticus	4.5	0.04	Local IA	Chouvelon et al. 2012
Hoplostethus mediterraneus	3.5	0.53	FB/SLB	www.fishbase.org
Hydrolagus spp	3.88	0.61	FB/SLB	www.fishbase.org
Hydromedusa	3	0.35	labtroph	
Hydrozoa	3	0.35	labtroph	
Hyperoplus immaculatus	3.47	0.15	Non local IA	Pinnegar et al. 2002

Hyperoplus lanceolatus	4	0.04	Local IA	Chouvelon et al. 2012
Hypperiidae	2.285	0.35	labtroph	
Illex coindetii	3.91	0.02	Local IA	Lassalle et al. 2014
Illex illecebrosus	3.98	0.65	FB/SLB	www.sealifebase.org
Illex spp	3.95	0.65	FB/SLB & Local IA	
Inachiidae	3.5	0.35	labtroph	
Inachus dorsettensis	3.5	0.35	labtroph	
Inachus leptochirus	3.5	0.35	labtroph	
Invertebrata	2.5	0.35	labtroph	
Irregularia	2	0.35	labtroph	
Isopoda	2.285	0.35	labtroph	
Istiophoridae	4.48	0.4	FB/SLB	www.fishbase.org
Istiophorus albicans	4.5	0.4	FB/SLB	www.fishbase.org
Istiophorus spp	4.5	0.4	FB/SLB	www.fishbase.org
Isurus oxyrinchus	4.5	0.01	FB/SLB	www.fishbase.org
Isurus paucus	4.5	0.01	FB/SLB	www.fishbase.org
Isurus spp	4.5	0.01		
Jaxea nocturna	2.6	0.35	labtroph	
Jujubinus exasperatus	2.37	0.35	labtroph	
Katsuwonus pelamis	4.4	0.5	FB/SLB	www.fishbase.org
Kyphosidae	3.5	0.35		
L. boscii (≤17 cm)	3.67	0.02	Local SC	IEO Analysis
L. boscii (≤18 - ≥32 cm)	3.82	0.01	Local SC	IEO Analysis
L. boscii (≥33 cm)	3.94	0.04	Local SC	IEO Analysis
L. whiffiagonis (≤15 cm)	3.74	0.05	local SC	IEO Analysis
L. whiffiagonis (≤16- ≥23 cm)	4.05	0.04	local SC	IEO Analysis
L. whiffiagonis (≤24- ≥36 cm)	4.27	0.03	local SC	IEO Analysis
L. whiffiagonis (≥37 cm)	4.55	0.04	local SC	IEO Analysis
Labridae	3.53	0.62	FB/SLB & Local IA	
Labrus bergylta	4.3	0.01	Local IA	Chouvelon et al. 2012
Labrus bimaculatus	3.9	0.62	FB/SLB	
Labrus merula	3.6	0.5	FB/SLB	
Labrus mixtus	3.9	0.62	FB/SLB	www.fishbase.org
Labrus spp	3.9	0.6	mean	
Labrus viridis	3.9	0.4	FB/SLB	
Lamna nasus	4.6	0.01	FB/SLB	www.fishbase.org
Lamnidae	4.53	0.4	FB/SLB	www.fishbase.org
Lampanyctus crocodilus	3.8	0.04	Local IA	Chouvelon et al. 2012

Lampris guttatus	4.2	0.62	FB/SLB	www.fishbase.org
Lepas spp	2.1	0.35	labtroph	
Lepechinella manco	2.285	0.35	labtroph	
Lepidion eques	3.2	0.37	FB/SLB	www.fihbase.org
Lepidocybium flavobrunneum	4.3	0.67	FB/SLB	www.fishbase.org
Lepidopus caudatus	3.8	0.3	FB/SLB	www.fishbase.org
Lepidorhombus boscii	3.75	0.04	Local SC	
Lepidorhombus spp	4.01	0.04	Local SC	
Lepidorhombus whiffiagonis	4.26	0.02	Local SC	
Lepidotrigla cavillone	3.3	0.2	FB/SLB	www.fishbase.org
Lepidotrigla dieuzeidei	3.7	0.52	FB/SLB	www.fishbase.org
Leptometra celtica	2.4	0.35	labtroph	
Lesueurigobius friesii	4	0.04	Local IA	Chouvelon et al. 2012
Leucoraja circularis	3.9	0.01	Local SC	
Leucoraja fullonica	3.5	0.35	FB/SLB	www.fishbase.org
Leucoraja naevus	3.87	0.04	Local SC	
Lichia amia	4.5	0.8		
Limanda limanda	4.2	0.28	Non local IA	Pinnegar et al. 2002
Liocarcinus corrugatus	2.5	0.35		
Liocarcinus depurator	3.2	0.35	Local IA	Le Loc'h et al. 2008
Liocarcinus holsatus	2.5	0.35	labtroph	
Liocarcinus maculatus	2.5	0.35		
Liocarcinus marmoreus	2.5	0.35	labtroph	
Liocarcinus puber	2.5	0.35		
Liocarcinus pusillus	3.7	0.35		
Liocarcinus spp	2.5	0.35	labtroph	
Lithodes maja	2.5	0.35	labtroph	
Lithodes spp	2.5	0.35	labtroph	
Lithognathus mormyrus	3.4	0.5	FB/SLB	www.fishbase.org
Littorina littorea	2	0.35	Local modelling	Lassalle et al. 2011
Liza aurata	2.8	0.33	FB/SLB	www.fishbase.org
Liza ramada	2.2	0.1	FB/SLB	www.fishbase.org
Liza saliens	2.9	0.38	FB/SLB	www.fishbase.org
Loliginidae	3.92	0.03	Local IA	
Loligo forbesii	4	0.03	Local IA	Chouvelon et al. 2012
Loligo spp	3.95	0.03	Local IA	Chouvelon et al. 2012
Loligo vulgaris	3.9	0.02	Local IA	Chouvelon et al. 2012
Lophiidae	4.55	0.17	Local SC	

Lophius budegassa	4.54	0.17	Local SC	
Lophius budegassa (≤20 - ≥25 cm)	4.49	0.03	Local SC	IEO Analysis
Lophius budegassa (≤26 - ≥44 cm)	4.59	0.03	Local SC	IEO Analysis
Lophius budegassa (≥45 cm)	4.51	0.05	Local SC	IEO Analysis
Lophius piscatorius	4.57	0.16	Local SC	
Lophius piscatorius (>70cm)	4.2	0.03	Local IA	Chouvelon et al. 2012
Lophius piscatorius (40-70cm)	4.1	0.02	Local IA	Chouvelon et al. 2012
Lophius spp	4.55	0.17	Local SC	
M. merluccius (≥ 35 cm)	4.55	0.03592727	Local SC	IEO Analysis
M. merluccius (≤ 17 cm)	4.11	0.03295771	Local SC	IEO Analysis
M. merluccius (≤18 ≥ 34cm)	4.63	0.02908634	Local SC	IEO Analysis
Macropipus tuberculatus	2.6	0.35	local IA	Le Loc'h et al. 2008
Macroramphosus gracilis	3.4	0.5	FB/SLB	www.fishbase.org
Macroramphosus scolopax	3.5	0.4	FB/SLB	www.fishbase.org
Macrourus berglax	4.5	0.8	FB/SLB	www.fishbase.org
Macrourus spp	4.5	0.8	FB/SLB	www.fishbase.org
Mactridae	2	0.35	Local modelling	Lassalle et al. 2011
Maja squinado	2.94	0.45	FB/SLB	www.sealifebase.org
Makaira indica	4.5	0.4	FB/SLB	www.fishbase.org
Makaira nigricans	4.5	0.3	FB/SLB	www.fishbase.org
Malacocephalus laevis	3.9	0.04	Local IA	Chouvelon et al. 2012
Mallotus villosus	3.2	0.1	FB/SLB	www.fishbase.org
Maurolicus muelleri	3	0.1	FB/SLB	www.fishbase.org
Meganyctiphanes norvegica	2.2	0.35	labtroph	
Melanocharacidium blennioides	3.3	0.5	FB/SLB	www.fishbase.org
Melanogrammus aeglefinus	3.9	0.18	Local IA	Chouvelon et al. 2012
Mercenaria mercenaria	2	0.35	Local modelling	Lassalle et al. 2011
Meretrix spp	2	0.35	Local modelling	Lassalle et al. 2011
Merlangius merlangus	4.1	0.03	Local IA	Chouvelon et al. 2012
Merluccius merluccius	4.56	0.02	Local SC	
Merluccius merluccius (clase 0) juveniles	2.7	LeLoch		
Merluccius merluccius (clase 1)	4.2074104	stomach contents		3.3
Merluccius merluccius (clase 2+)	4.60160548	stomach contents		

Merluccius merluccius <20cm	4.21	0.04	Local SC	
Merluccius merluccius >20cm	4.56	0.03	Local SC	
Merluccius senegalensis	4.5	0.8	FB	
Merluccius spp	4.3	0.35	mean	
Microchirus azevia	3.2	0.41	FB/SLB	www.fishbase.org
Microchirus spp	3.43	0.41	FB/SLB & Local IA	
Microchirus variegatus	3.8	0.04	Local IA	Chouvelon et al. 2012
Micromesistius poutassou	3.77	0.05	Local SC	
Micromesistius poutassou (< 30 cm)	3.9	0.03	Local IA	Chouvelon et al. 2012
Micromesistius poutassou (> 30 cm)	3.8	0.04	Local IA	Chouvelon et al. 2012
Microstomus kitt	3.67	0.34	Non local IA	Pinnegar et al. 2002
Molva dypterygia	4.5	0.8	FB/SLB	www.fishbase.org
Molva macrophthalma	4.1	0.04	Local IA	Chouvelon et al. 2012
Molva molva	4.6	0.05	Local IA	Chouvelon et al. 2012
Molva spp	4.4	0.8	FB/SLB & Local IA	
Monadeus couchii	2.5	0.35		
Monoculodes spp	2.285	0.35		
Monodaeus couchii	2.5	0.35		
Monodaeus spp	2.5	0.35		
Mora moro	4	0.04	Local IA	Chouvelon et al. 2012
Moridae	3.48	0.55	FB/SLB	www.fishbase.org
Morone saxatilis	4.7	0.2	FB/SLB	www.fishbase.org
Mugil cephalus	2.5	0.17	FB/SLB	www.fishbase.org
Mugil spp	2.5	0.17	FB/SLB	www.fishbase.org
Mugilidae	2.54	0.38	FB/SLB	www.fishbase.org
Mullidae	3.24	0.4		
Mullus barbatus	3.2	0.4	FB/SLB	www.fishbase.org
Mullus spp	3.24	0.4	FB/SLB & Local SC	
Mullus surmuletus	3.27	0.02	Local SC	
Munida intermedia	3.09	0.35		
Munida iris	3.09	0.35		
Munida perarmata	3.09	0.35		
Munida sarsi	2.5	0.35	LeLoc'h et al. 2008	
Munida spp	3.09	0.35		
Munnopsidae	2.285	0.35		

Munnopsis beddardi	2.285	0.35		
Munnopsurus atlanticus	2.285	0.35		
Muraena helena	4.2	0.61	FB/SLB	www.fishbase.org
Muraenidae	4.2	0.61		
Murex spp	2	0.35		
Mustelus asterias	3.8	0.09	Local IA	Chouvelon et al. 2012
Mustelus mustelus	4	0.15	Local IA	Chouvelon et al. 2012
Mustelus spp	3.9	0.15	Local IA	Chouvelon et al. 2012
Mycteroperca rubra	4.1	0.58		
Myctophoidei	3.4	0.35		
Myliobatidae	3.65	0.54	FB/SLB	www.fishbase.org
Myliobatis aquila	3.6	0.54	FB/SLB	www.fishbase.org
Mysidacea	2.2	0.35	labtroph	
Mysideis parva	2.2	0.35	labtroph	
Mytilidae	2	0.35	Local modelling	Lassalle et al. 2011
Mytilus edulis	2	0.35	Local modelling	Lassalle et al. 2011
Mytilus galloprovincialis	2	0.35		
Mytilus spp	2	0.35	Local modelling	Lassalle et al. 2011
Nassarius spp	2.37	0.35		
Natantia	2.6	0.35		
Natatolana borealis	3.3	0.35	Local IA	LeLoc'h et al., 2008
Natica spp	2.37	0.35		
Necora puber	3.7	0.35	Non local IA	Bodin et al. 2008
Nematoscelis megalops	2.6	0.35		
Nemertini	2.061	0.35		
Nemichthyidae	3.5	0.35		
Neorossia caroli	3.5	0.35		
Neoscopelus spp	3.7	0.35		
Nephropidae	3.67	0.31	FB/SLB & Local IA	
Nephrops norvegicus	2.8	0.04	Local IA	Chouvelon et al. 2012
Nephrops norvegicus (14-17 mm)	2.9	NA	Local IA	Le Loch and Hily 2005
Nephrops norvegicus (22-34 mm)	3	NA	Local IA	Le Loch and Hily 2005
Nephrops norvegicus (39-42 mm)	3.1	NA	Local IA	Le Loch and Hily 2005

Neptunea contraria	2.37	0.35		
Nezumia aequalis	3.3	0.1	FB/SLB	www.fishbase.org
Nicippe tumida	2.285	0.35		
Nictyphanes couchii	2.2	0.35	labtroph	
Notacanthus bonaparte	3.9	0.1	FB/SLB	www.fishbase.org
Nudibranchia	2.6	0.35		
Oblada melanura	3.4	0.35	FB/SLB	www.fishbase.org
Ocinebrina spp	2	0.35		
Octopoda	3.46	0.58		
Octopodidae	3.46	0.58	FB/SLB & Local IA	
Octopus defilippi	3.5	0.6		
Octopus salutii	3.5	0.6		
Octopus spp	3.3	0.13	Local IA	Chouvelon et al. 2012
Octopus vulgaris	3.1	0.13	Local IA	Chouvelon et al. 2012
Oedalechilus labeo	2.5	0.2	FB/SLB	www.fishbase.org
Oedicerotidae	2.285	0.35		
Ommastrephes spp	4.01	0.68		
Ommastrephidae	4.02	0.65	FB/SLB & Local IA	
Oncorhynchus mykiss	4.1	0.3		
Ophidion barbatum	3.6	0.6	FB/SLB	www.fishbase.org
Ophiotrix fragilis	2.2	0.35		
Ophiura ophiura	2.2	0.35		
Ophiuroidea	2.2	0.35		
Opistobranchia	2.6	0.35		
Oplophoridae	2.6	0.35		
Oplophorus spinosus	2.6	0.35		
Orcynopsis unicolor	4.5	0.8		
Osmerus eperlanus	3.5	0.42	FB/SLB	www.fishbase.org
Osteichthyes1	3.5	0.35		
Osteichthyes2	3.5	0.35		
Osteichthyes3	3.5	0.35		
Osteichthyes4	3.5	0.35		
Ostrea edulis	2	0.35	Local modelling	Lassalle et al. 2011
Ostrea spp	2	0.35	Local modelling	Lassalle et al. 2011
Ostreidae	2	0.35	Local modelling	Lassalle et al. 2011
Oxynotus centrina	3.1	0.26		

Pagellus acarne	3.54639268	stomach contents		
Pagellus bellottii	3.6	0.59	FB/SLB	www.fishbase.org
Pagellus bogaraveo	3.7	0.56	FB/SLB	www.fishbase.org
Pagellus erythrinus	3.49	0.05	Local SC	
Pagellus spp	3.56	0.56	FB/SLB & Local SC	
Pagrus auriga	3.4	0.5	FB/SLB	www.fishbase.org
Pagrus caeruleostictus	3.7	0.54	FB/SLB	www.fishbase.org
Pagrus pagrus	3.7	0.6	FB/SLB	www.fishbase.org
Pagrus spp	3.63	0.6	FB/SLB	www.fishbase.org
Paguridae	2.7	0.35		
Pagurus alatus	2.5	0.35	labtroph	
Pagurus bernhardus	2.5	0.35	labtroph	
Pagurus excavatus	2.5	0.35	labtroph	
Pagurus prideaux	2.7	0.35	local IA	LeLoc'h et al., 2008
Palaemon elegans	3.1	0.35		
Palaemon longirostris	2.6	0.35	SeaAroundUs	
Palaemon serratus	2.69	0.32	FB/SLB	www.sealifebase.org
Palaemon spp	3.1	0.35		
Palaemonidae	3.1	0.35		
Palinuridae	3.14	0.35	SeaAroundUs	
Palinurus elephas	3.34	0.66	FB/SLB	www.sealifebase.org
Palinurus gilchristi	2.6	0.35	SeaAroundUs	
Palinurus mauritanicus	3.54	0.38	FB/SLB	www.sealifebase.org
Palinurus spp	3.44	0.66	FB/SLB	www.sealifebase.org
Pandalidae	2.7	0.35		
Pandalina brevirostris	2.7	0.35		
Pandalina profunda	2.7	0.35		
Pandalina spp	2.7	0.35		
Pandalus borealis	3.07	0.35		
Paphia aurea	2.1	0.35		
Paphia rhomboides	2.1	0.35		
Paracentrotus lividus	2.34	0.35	Local modelling	Lassalle et al. 2011
Paralepididae	3.2	0.35		
Paralepis coregonoides	4.1	0.7	FB/SLB	www.sealifebase.org
Paralepis spp	4.1	0.7		
Paraliparis spp	3.7	0.35	FB/SLB	www.sealifebae.org
Paralithodes spp	3.7	0.43	FB/SLB	www.sealifebase.org
Paramblyops rostrata	2.2	0.35	labtroph	
Parapagurus pilosimanus	2.5	0.35		
Parapasiphaea sulcatifrons	2.6	0.35		

Parapenaeus longirostris	3.3	0.44	FB/SLB	www.sealifebase.org
Parapseudomma calloplura	2.2	0.35		
Pardaliscidae	2.285	0.35		
Parerythrops obesa	2.2	0.35		
Parvipalpus major	2.285	0.35		
Pasiphaea multidentata	2.6	0.35		
Pasiphaea sivado	2.6	0.35		
Pasiphaea spp	2.6	0.35		
Patella spp	2	0.35	Local modelling	Lassalle et al. 2011
Patella vulgata	2	0.35		
Patellidae	2	0.35		
Patina pellicida	2.37	0.35		
Pecten maximus	2	0.07	Local IA	Chouvelon et al. 2012
Pectinaria koreni	2.061	0.35		
Pectinidae	2	0.35	Local modelling	Lassalle et al. 2011
Pegusa lascaris	3.3	0.1	FB/SLB	www.fishbase.org
Pelagia noctiluca	3	0.35	labtroph	
Penaeidae	3.3	0.35		
Penaeus brasiliensis	2.7	0.35	SeaAroundUs	
Penaeus spp	3.3	0.35		
Pennatula rubra	2.34	0.35		
Pennatula spp	2.34	0.35		
Perciforme	3.5	0.35		
Perciformes1	3.5	0.35		
Perciformes2	3.5	0.35		
Percoidei	4.4	0.01		
Perinereis diversicolor	2.061	0.35	labtroph	
Peristedion cataphractum	3.6	0.3	FB/SLB	www.fishbase.org
Petromyzon marinus	4.4	0.85	FB/SLB	www.fishbase.org
Petromyzontidae	4.33	0.85	FB/SLB	www.fishbase.org
Pharidae	2.1	0.35	labtroph	
Philocheras bispinosus	3.2	0.35		
Philocheras echinolatus	2.6	0.35		
Philocheras echinulatus	2.6	0.35		
Philocheras sculptus	3.2	0.35		
Philocheras spp	3.2	0.35		
Phoxocephalidae	2.285	0.35		
Phronima sedentaria	2.285	0.35		
Phrynorhombus norvegicus	4	0.6	FB/SLB	www.fishbase.org

Phtisica marina	2.285	0.35		
Phycis blennoides	3.72	0.04	Local SC	
Phycis phycis	4.3	0.3	FB/SLB	www.fishbase.org
Phycis spp	4.01	0.3	FB/SLB & Local SC	
Pirimela denticulata	2.5	0.35		
Pisces	3.5	0.35		
Platichthys flesus	3.85	0.2	Non local IA	Pinnegar et al. 2002
Plectorhinchus mediterraneus	3.5	0.52		
Plesionika edwardsi	2.7	0.35		
Plesionika heterocarpus	2.7	0.35		
Plesionika martia	2.6	0.35		
Plesionika spp	2.7	0.35		
Plesiopenaeus edwardsianus	2.6	0.36		
Pleuronectes platessa	3.67	0.17	Non local IA	Pinnegar et al. 2002
Pleuronectidae	3.9	0.5	FB/SLB & Non local IA	
Pleuronectiformes	3.7	0.5		
Pleuronectoidei	3.5	0.5		
Pollachius pollachius	4.2	0.7	FB/SLB	www.fishbase.org
Pollachius spp	4.2	0.7		
Pollachius virens	4.11	0.1	Non local IA	Pinnegar et al. 2002
Pollicipes pollicipes	3.23	0.35	Local modelling	Lassalle et al. 2011
Pollicipedidae	3.23	0.35		
Polybius henslowi	2.5	0.35		
Polychaeta	2.061	0.35		
Polycheles typhlops	3.2	0.35		
Polyprion americanus	4.1	0.64	FB/SLB	www.fishbase.org
Polyprion oxygeneios	4.5	0.77	FB/SLB	www.fishbase.org
Pomadasys incisus	3.8	0.52		
Pomadasys jubelini	3.3	0.5	FB/SLB	www.fishbase.org
Pomadasys spp	3.8	0.52		
Pomatochistus spp	3.43	0.25	mean	www.fishbase.org
Pomatomus saltatrix	4.5	0.3	FB/SLB	www.fishbase.org
Pomatoschistus lozanoi	3.1	0.34	FB/SLB	www.fishbase.org
Pomatoschistus minutus	4.1	0.04	Local IA	Chouvelon et al. 2012
Pomatoschistus pictus	3.1	0.33	FB/SLB	www.fishbase.org
Pontinus kuhlii	4.1	0.7	FB/SLB	www.fishbase.org
Pontophilus norvegicus	3.2	0.35		
Pontophilus spinosus	3.2	0.35		

Pontophilus spp	3.2	0.35		
Porphyra umbilicalis	1	0.01		
Portunidae	2.5	0.35		
Portunus spp	3.23	0.35	Local modelling	Lassalle et al. 2011
Priapulida	2.5	0.35		
Prionace glauca	4.2	0.7	FB/SLB	www.fishbase.org
Processa canaliculata	2.5	0.35		
Processa nouveli	2.5	0.35		
Processa spp	2.5	0.35		
Psathyrocaris infirma	2.6	0.35		
Psetta maxima	4.4	0.01	FB/SLB	www.fishbase.org
Psettodes bennettii	4.2	0.5	FB/SLB	
Pseudomma affine	2.2	0.35	labtroph	
Pseudomma spp	2.2	0.35	labtroph	
Pseudotiron bouvieri	2.285	0.35		
Pteroeides spinosum	2.34	0.35	labtroph	
Pteromylaeus bovinus	3.8	0.57	FB/SLB	www.fishbase.org
Pteropoda	2.4	0.35		
Rachotropis spp	2.285	0.35		
Raja alba	4.4	0.83	FB/SLB	www.fishbase.org
Raja asterias	3.5	0.37	FB/SLB	www.fishbase.org
Raja batis	3.5	0.6	FB/SLB	www.fishbase.org
Raja brachyura	3.8	0.61	FB/SLB	www.fishbase.org
Raja circularis	3.5	0.37	FB/SLB	www.fishbase.org
Raja clavata	3.77	0.02	Local SC	
Raja fullonica	3.5	0.35	FB/SLB	www.fishbase.org
Raja georgiana	4.2	0.3	FB/SLB	www.fishbase.org
Raja hyperborea	4.3	0.5	FB/SLB	www.fishbase.org
Raja leopardus	3.9	0.63	FB/SLB	www.fishbase.org
Raja lintea	3.6	0.5	FB/SLB	www.fishbase.org
Raja microocellata	3.6	0.04	Local IA	Chouvelon et al. 2012
Raja montagui	3.92	0.05	Local SC	
Raja naevus	3.87	0.04	Local SC	
Raja oxyrinchus	3.5	0.35	FB/SLB	www.fishbase.org
Raja spp	3.73	0.74	FB/SLB & Local SC & Local IA	
Raja undulata	3.5	0.37	FB/SLB	www.fishbase.org
Rajidae	3.77	0.83	FB/SLB & Local SC & Local IA	
Rajiformes	3.8	0.6		

Raniceps raninus	3.8	0.56	FB/SLB	www.fishbase.org
Reptantia	2.5	0.35		
Rhachotropis caeca	2.285	0.35		
Rhodophyceae	1	0.01		
Rissoidae	2.37	0.35		
Rissoides desmaresti	3.2	0.35		
Rochinia carpenteri	2.5	0.35		
Rondeletiola minor	3.5	0.35		
Rossia macrosoma	4.04	0.53	SLB	www.sealifebase.org
Ruditapes decussatus	2	0.35	Local modelling	Lassalle et al. 2011
Ruditapes philippinarum	2	0.35	Local modelling	Lassalle et al. 2011
Ruditapes spp	2	0.35	Local modelling	Lassalle et al. 2011
Ruvettus pretiosus	4.2	0.57	FB/SLB	www.fishbase.org
Sabella spallanzani	2.061	0.35	labtroph	
Saccorhiza polyschides	1	0.01		
Salmo salar	4.5	0.3	FB/SLB	www.fishbase.org
Salmo trutta	3.4	0.1	FB/SLB	www.fishbase.org
Sander lucioperca	4	0.78	FB/SLB	www.fishbase.org
Sarda sarda	4.5	0.7	FB/SLB	www.fishbase.org
Sarda spp	4.5	0.7	FB/SLB	www.fishbase.org
Sardina pilchardus	3.8	0.06	Local IA	Chouvelon et al. 2012
Sardinella spp	3.4	0.5		
Sarpa salpa	2	0.01	FB/SLB	www.fishbase.org
Scaphander lignarius	2.4	0.35	local IA	LeLoch et al., 2008
Scaphopoda	2.6	0.35		
Schedophilus ovalis	3.5	0.47	FB/SLB	www.fishbase.org
Sciaena umbra	3.8	0.5	FB/SLB	www.fishbase.org
Sciaenidae	3.72	0.75	FB/SLB	www.fishbase.org
Scomber colias	3.9	0.63	FB/SLB	www.fishbase.org
Scomber japonicus	3.7	0.04	Local IA	Chouvelon et al. 2012
Scomber scombrus	3.86	0.32	Local SC	
Scomber spp	3.82	0.63	FB/SLB & Local SC & Local IA	
Scomberesocidae	3.8	0.45	FB/SLB	www.fishbase.org
Scomberesox saurus	3.6	0.3	FB/SLB	www.fishbase.org
Scomberomorus maculatus	4.5	0.5	FB/SLB	www.fishbase.org
Scomberomorus spp	4.5	0.5	FB/SLB	www.fishbase.org

Scombridae	4.34	0.8	FB/SLB & Local SC & Local IA	
Scombroidei	4.34	0.8		
Scophthalmidae	4.2	0.4	mean	
Scophthalmus maximus	4	0.63	FB/SLB	www.fishbase.org
Scophthalmus rhombus	4.4	0.1	FB/SLB	www.fishbase.org
Scophthalmus spp	4.2	0.4	mean	
Scorpaena loppei	3.5	0.5	FB/SLB	www.fishbase.org
Scorpaena notata	3.5	0.5	FB/SLB	www.fishbase.org
Scorpaena porcus	3.9	0.7	FB/SLB	www.fishbase.org
Scorpaena scrofa	4.3	0.05	Local IA	Chouvelon et al. 2012
Scorpaena spp	3.82	0.7	FB/SLB & Local IA	
Scorpaenidae	3.82	0.7	FB/SLB & Local IA	
Scorpaeniformes	3.82	0.7		
Scyliorhinidae	3.93	0.5	FB/SLB & Local SC	
Scyliorhinus canicula	4.08	0.02	Local SC	
Scyliorhinus spp	4.04	0.5	FB/SLB & Local SC	
Scyliorhinus stellaris	4	0.5	FB/SLB	www.fishbase.org
Scyllaridae	2.98	0.35		
Scyllarus arctus	2.98	0.35		
Scyllarus spp	2.98	0.35		
Scymnodon ringens	3.9	0.6	FB/SLB	www.fishbase.org
Sebastes marinus	4	0.67	FB/SLB	www.fishbase.org
Sebastes mentella	4.1	0.66	FB/SLB	www.fishbase.org
Sebastes spp	4	0.68	FB/SLB	www.fishbase.org
Selachimorpha(Pleurotremata)	4.04	0.34		
Sepia elegans	3.7	0.35		
Sepia officinalis	3.6	0.05	Local IA	Chouvelon et al. 2012
Sepia orbignyana	3.35	0.03	Local IA	Lassalle et al. 2014
Sepia spp	3.7	0.35		
Sepietta oweniana	3.5	0.35		
Sepiidae	3.5	0.35		
Sepiidae, Sepiolidae	3.5	0.35		
Sepiola rondeleti	3.5	0.35		
Sepiola spp	3.5	0.35		
Sepiolidae	3.5	0.35		
Sergestes arcticus	2.6	0.35	labtroph	

Sergia robusta	2.6	0.35	labtroph	
Seriola dumerili	4.5	0.8	FB/SLB	www.fishbase.org
Seriola lalandi	4.2	0.1	FB/SLB	www.fishbase.org
Serpulidae	2.061	0.35	labtroph	
Serranidae	3.89	0.61	FB/SLB	www.fishbase.org
Serranus atricauda	4.3	0.6	FB/SLB	www.fishbase.org
Serranus cabrilla	3.4	0.5	FB/SLB	www.fishbase.org
Serranus hepatus	3.5	0.6	FB/SLB	www.fishbase.org
Serranus scriba	3.8	0.6	FB/SLB	www.fishbase.org
Serranus spp	3.57	0.6	FB/SLB	www.fishbase.org
Sigalionidae	2.061	0.35	labtroph	
Sinónimo de Histioteuthis r.	3.5	0.35	labtroph	
Sipunculida	2.5	0.35	labtroph	
Sipunculida notacanto	2.5	0.35	labtroph	
Sipunculus nudus	2.5	0.35	labtroph	
Solea lascaris	3.3	0.1	FB/SLB	www.fishbase.org
Solea senegalensis	3.1	0.3	FB/SLB	www.fishbase.org
Solea solea	3.31	0.06	Local IA	
Solea spp	3.2	0.3	FB/SLB & Local IA	
Soleidae	3.49	0.42	FB/SLB & Local IA	
Solen marginatus	2.1	0.35	labtroph	
Solen spp	2	0.35	Local modelling	Lassalle et al. 2011
Solenidae	2	0.35	Local modelling	Lassalle et al. 2011
Solenocera membranacea	2.6	0.35	labtroph	
Somniosus rostratus	4.2	0.4	FB/SLB	www.fishbase.org
Sparidae	3.49	0.7	FB/SLB & Local SC & Local IA	
Sparus aurata	3.3	0.5	FB/SLB	www.fishbase.org
Spatangoidea	2	0.35	labtroph	
Spatangus purpureus	2	0.35	labtroph	
Sphyraena sphyraena	4	0.51	FB/SLB	www.fishbase.org
Sphyraena spp	4	0.51	FB/SLB	www.fishbase.org
Sphyrna lewini	4.1	0.5	FB/SLB	www.fishbase.org
Sphyrna mokarran	4.3	0.5	FB/SLB	www.fishbase.org
Sphyrna spp	4.43	0.5	FB/SLB	www.fishbase.org
Sphyrna zygaena	4.9	0.5	FB/SLB	www.fishbase.org
Spicara maena	4.2	0.6	FB/SLB	www.fishbase.org
Spicara smaris	3	0.01	FB/SLB	www.fishbase.org
Spicara spp	4.2	0.6	FB/SLB	www.fishbase.org

Spisula ovalis	2	0.35	Local modelling	Lassalle et al. 2011
Spisula solida	2	0.35	Local modelling	Lassalle et al. 2011
Spondyliosoma cantharus	4.3	0.11	Local IA	Chouvelon et al. 2012
Sprattus sprattus	4	0.09	Local IA	Chouvelon et al. 2012
Squalidae	3.7	0.4	FB/SLB & Non local IA	
Squalidae, Scyliorhinidae	3.81	0.5	FB/SLB & Local SC & Non local IA	
Squaliformes	3.81	0.5		
Squalus acanthias	3.41	0.1	Non local IA	Pinnegar et al. 2002
Squalus blainville	4.0	0.6		
Squalus spp	3.7	0.4	FB/SLB & Non local IA	
Squatina spp	4.5	0.6		
Squatina squatina	4.1	0.5	FB/SLB	www.fishbase.org
Squilla mantis	2.6	0.35		
Squillidae	3.23	0.35	Local modelling	Lassalle et al. 2011
Stegocephalidae	2.285	0.35	labtroph	
Stenothoidae	2.285	0.35	labtroph	
Sternaspis scutata	2.061	0.35	labtroph	
Stichopus regalis	2.9	0.35	LeLoch et al., 2008	LeLoch et al., 2008
Stomias boa	4	0.64	FB/SLB	www.fishbase.org
Stomiatoidei	3.5	0.35		
Stromateidae	4	0.5		
Stromateus fiatola	4	0.5	FB/SLB	www.fishbase.org
Strongylocentrotus spp	2.34	0.35	labtroph	
Symphodus cinereus	3.5	0.1	FB/SLB	www.fishbase.org
Symphodus melops	3.4	0.1	FB/SLB	www.fishbase.org
Symphodus spp	3.45	0.1	mean	
Symphurus nigrescens	3.5	0.01	FB/SLB	www.fishbase.org
Synaphobranchus kaupii	4.1	0.4	FB/SLB	www.fishbase.org
Synaptura lusitanica	3.5	0.5	FB/SLB	www.fishbase.org
Syngnathidae	3.7	0.35		
Syrrhoe affinis	2.285	0.35	labtroph	
Systellaspis debilis	2.6	0.35	labtroph	
Tanaidacea	2.5	0.35	labtroph	

Tapes decussata	2.1	0.35		
Tapes philippinarum	2.1	0.35		
Tellina spp	2	0.35	Local modelling	Lassalle et al. 2011
Tetraodontidae	3.7	0.2		
Tetrapturus albidus	4.5	0.4		
Tetrapturus audax	4.5	0.77	FB/SLB	www.fishbase.org
Tetrapturus spp	4.6	0.3		
Thecosomata	2.4	0.35		
Thia scutellata	2.5	0.35		
Thunnini	4.41	0.8	FB/SLB	www.fishbase.org
Thunnus alalunga	4.3	0.2	FB/SLB	www.fishbase.org
Thunnus albacares	4.4	0.4	FB/SLB	www.fishbase.org
Thunnus atlanticus	4.4	0.3	FB/SLB	www.fishbase.org
Thunnus maccoyii	3.9	0.53	FB/SLB	www.fishbase.org
Thunnus obesus	4.5	0.01	FB/SLB	www.fishbase.org
Thunnus spp	4.5	0.5		
Thunnus thynnus	4.5	0.8	FB/SLB	www.fishbase.org
Thyrsites atun	3.6	0.3		
Thyssanoessa spp	2.2	0.35	labtroph	
Todarodes sagittatus	3.9	0.02	Local IA	Chouvelon et al. 2012
Todarodes spp	3.9	0.02		
Todaropsis eblanae	4.08	0.35		4.05
Torpedinidae	4.67	0.6		
Torpedo marmorata	5	0.29	Local IA	Chouvelon et al. 2012
Torpedo nobiliana	4.5	0.8	FB/SLB	www.fishbase.org
Torpedo spp	4.67	0.6	FB/SLB & Local IA	
Trachichthyidae	4	0.53	FB/SLB & Local IA	
Trachinidae	4.1	0.71	FB/SLB & Local IA	
Trachinotus ovatus	3.7	0.58		
Trachinotus spp	3.7	0.58		
Trachinus draco	3.8	0.03	Local IA	Chouvelon et al. 2012
Trachinus spp	4.2	0.71		
Trachipterus arcticus	4.5	0.62		
Trachipterus spp	4.5	0.62		
Trachurus mediterraneus	3.8	0.3	FB/SLB	www.fishbase.org
Trachurus picturatus	3.3	0.42	FB/SLB	www.fishbase.org

Trachurus spp	3.7	0.42	FB/SLB & Local IA	
Trachurus trachurus	4	0.03	Local IA	Chouvelon et al. 2012
Trachyrincus scabrus	3.6	0.3		
Trachyscorpia cristulata	4.4	0.04	Local IA	Chouvelon et al. 2012
Triakidae	3.5	0.4		
Trichiuridae	4.13	0.4	FB/SLB & Local IA	
Trichiurus lepturus	4.4	0.4	FB/SLB	www.fishbase.org
Trichiurus spp	4.4	0.4		
Trigla lyra	3.7	0.01	FB/SLB	www.fishbase.org
Trigla lyra (≤29 cm)	3.46	0.02	Local SC	IEO Analysis
Trigla lyra (≥30 cm)	3.58	0.1	Local SC	IEO Analysis
Trigla spp	3.7	0.01	FB/SLB	www.fishbase.org
Triglidae	3.72	0.5	FB/SLB & Local SC	
Trigloporus lastoviza	3.4	0.5	FB/SLB	www.fishbase.org
Trisopterus esmarkii	3.91	0.17	Non local IA	Pinnegar et al. 2002
Trisopterus luscus	4.04	0.03	Local IA	Chouvelon et al. 2012
Trisopterus minutus	3.94	0.02	Local IA	Chouvelon et al. 2012
Trisopterus spp	3.8	0.5		
Tryphosella caecula	2.285	0.35	labtroph	
Tryphosites alleni	2.285	0.35	labtroph	
Tubicola	2.061	0.35	labtroph	
Tunicata	2	0.35	labtroph	
Turritellidae	2.37	0.35	labtroph	
Umbrina canariensis	3.4	0.44	FB/SLB	www.fishbase.org
Umbrina cirrosa	3.5	0.6	FB/SLB	www.fishbase.org
Umbrina spp	3.5	0.52		
Undaria pinnatifida	1	0.01		
Upogebia spp	2.5	0.35		
Uranoscopus scaber	4.4	0.7		
Urophycis tenuis	4.3	0.5		
Urothoidae	2.285	0.35		
Veneridae	2	0.35	Local modelling	Lassalle et al. 2011
Venerupis aurea	2.09	0.35		
Venerupis pullastra	2	0.35	Local modelling	Lassalle et al. 2011

Venerupis rhomboides	2	0.35	Local modelling	Lassalle et al. 2011
Venerupis spp	2.09	0.35		
Venus verrucosa	2	0.35	Local modelling	Lassalle et al. 2011
Xanthidae	2.5	0.35		
Xantho pilipes	2.5	0.35		
Xenodermichthys copei	3.2	0.35	FB/SLB	www.fishbase.org
Xiphias gladius	4.5	0.2	FB/SLB	www.fishbase.org
Zeidae	4.47	0.19		
Zenopsis conchifer	4.5	0.8		
Zeugopterus punctatus	4	0.66	FB/SLB	www.fishbase.org
Zeus faber	4.47	0.19	Local SC	

Annex 6: Compartments assigned to Bay of Biscay species collated.

Table 1. Compartment assigned to species appearing in surveys or landings in the Bay of Biscay. B= benthic, D= demersal, BD = bentho-demersal, BP= bentho-pelagic, BaP= Bathypelagic, BaD= Bathydemersal, R = reef associated, P= pelagic, NB = nektobenthic.

Species	
Acanthocardia echinata	B
Acanthocybium solandri	P
Acantholabrus palloni	D
Acipenser spp	D
Acipenser sturio	D
Acipenseridae	D
Aequipecten opercularis	B
Alloteuthis media	B
Alloteuthis spp	B
Alopias spp	P
Alopias vulpinus	P
Alosa alosa	P
Alosa alosa, A. fallax	P
Alosa fallax	P
Alosa spp	P
Ammodytes marinus	BP
Ammodytes spp	D
Ammodytes tobianus	D
Anarhichas spp	BP
Anemonia sulcata	B
Anguilla anguilla	D
Anguilla spp	D
Aphanopus carbo	BaP
Aphia minuta	P
Apogon imberbis	R
Aristeidae	D
Argentina silus	D
Argentina sphyraena	D
Argentina spp	D
Argyrosomus regius	BP
Arnoglossus imperialis	D
Arnoglossus laterna	D
Arnoglossus spp	D
Aspitrigla cuculus	D
Atherina presbyter	P
Atherina spp	P
Atherinidae	P
Atrina fragilis	B
Auxis rochei	P
Auxis thazard	P
Auxis thazard, A. rochei	P
Balistes capriscus	D
Balistes carolinensis	R
Balistidae	D
Bathyraja spp	D
Batrachoides spp	D
Belone belone	P
Berycidae	BP
Beryx decadactylus	BaD
Beryx splendens	BP
Beryx spp	BP
Blenniidae	D
Blennius ocellaris	D
Bolinus brandaris	B
Boops boops	D
Bothidae	D
Bothus podas	D
Brama brama	BaP
Brosme brosme	D
Buccinum undatum	B
Buenia jeffreysii	D
Buglossidium luteum	D
Callionymus lyra	D
Callionymus maculatus	D
Callionymus reticulatus	D
Callista chione	D
Campogramma glaycos	BP
Cancer pagurus	B
Capros aper	D
Carangidae	R
Caranx hippos	R
Caranx rhonchus	BP
Carcharhinus brachyurus	R

Carcharhinidae	P
Carcharias taurus	R
Carcinus maenas	B
Centrolophidae	BaP
Centrolophus niger	BaP
Centrophorus granulosus	BaD
Centrophorus squamosus	BaD
Centroscymnus coelolepis	BaD
Centroscymnus crepidater	BaD
Cepola macrophthalma	D
Cepola macrophthalma	D
Cephalopoda	B
Cerastoderma edule	B
Chaceon affinis	B
Chaceon quinquedens	B
Chaceon spp	B
Chamelea gallina	B
Charonia lampas	B
Charonia rubicunda	B
Chelidonichthys cuculus	D
Chelidonichthys lastoviza	D
Chelidonichthys lucerna	D
Chelidonichthys lucerna	D
Chelidonichthys obscurus	D
Chelidonichthys obscurus	D
Chelidonichthys spp	D
Chelon labrosus	B
Chimaera monstrosa	BaD
Chlamys islandica	B
Chlamys varia	B
Citharus linguatula	D
Clupea harengus	BP
Coelorinchus caelorhincus	BP
Conger conger	D
Congridae	D
Corallium spp	B
Coris julis	R
Coryphaena hippurus	P
Coryphaenoides rupestris	BaP
Crangon crangon	B

Crangonidae	B
Ctenolabrus rupestris	D
Cynoscion regalis	D
Cyprinus carpio	BP
Cyttopsis rosea	P
Dalatias licha	BaD
Dasyatidae	D
Dasyatis pastinaca	D
Dasyatis spp	D
Deania calcea	BaD
Decapterus punctatus	R
Dentex dentex	BP
Dentex gibbosus	BP
Dentex macrophthalmus	BP
Dentex maroccanus	D
Dentex spp	BP
Donax spp	B
Dicentrarchus labrax	D
Dicentrarchus punctatus	P
Dicentrarchus spp	D
Dicologlossa cuneata	D
Diplodus annularis	BP
Diplodus cervinus	R
Diplodus puntazzo	BP
Diplodus sargus	D
Diplodus spp	D
Diplodus vulgaris	D
Dipturus batis	D
Donax trunculus	B
Dosinia exoleta	B
Dosinia spp	B
Echiichthys vipera	D
Echinidae	B
Echiodon drummondii	D
Eledone cirrosa	D
Eledone cirrhosa	D
Eledone spp	D
Enchelyopus cimbrius	D
Engraulis encrasicolus	P
Ensis ensis	B
Ensis magnus	B

Ensis siliqua	B
Entelurus aequoreus	D
Epigonus telescopus	BaD
Epinephelus caninus	D
Epinephelus marginatus	R
Epinephelus spp	R
Epizoanthidae	B
Etmopterus spinax	BaD
Etmopterus spp	BaD
Euthynnus alletteratus	R
Eutrigla gurnardus	D
Gadiculus argenteus	P
Gadus macrocephalus	D
Gadus morhua	BP
Gaidropsarus biscayensis	BP
Gaidropsarus macrophthalmus	D
Gaidropsarus mediterraneus	D
Gaidropsarus vulgaris	D
Gaidropsarus spp	D
Galeorhinus galeus	BP
Galeus melastomus	D
Galeus spp	D
Gempylidae	BP
Geryon longipes	B
Geryonidae	B
Glycymeris glycymeris	B
Glycymeris spp	B
Glyptocephalus cynoglossus	D
Gobiidae	D
Gobiusculus flavescens	D
Gobius niger	D
Gymnammodytes semisquamatus	D
Gymnura altavela	D
Haemulidae(=Pomadasyidae)	D
Haliotis tuberculata	B
Halobatrachus didactylus	D
Helicolenus dactylopterus	D
Heptranchias perlo	BaD

Hexanchus griseus	D
Hippocampus hippocampus	D
Hippoglossoides platessoides	D
Hippoglossus hippoglossus	D
Hirundichthys rondeletii	P
Homarus gammarus	B
Homarus spp	B
Hoplostethus atlanticus	BaP
Hoplostethus mediterraneus	BP
Hyperoplus lanceolatus	D
Illex coindetii	B
Illex illecebrosus	P
Illex spp	D
Istiophoridae	P
Istiophorus albicans	P
Isurus oxyrinchus	P
Isurus paucus	P
Isurus spp	P
Jujubinus exasperatus	B
Katsuwonus pelamis	P
Kyphosidae	R
Labridae	D
Labrus bergylta	D
Labrus bimaculatus	R
Labrus mixtus	D
Labrus spp	D
Labrus viridis	D
Lamna nasus	P
Lamnidae	P
Lampanyctus crocodilus	P
Lampris guttatus	BaP
Lepas spp	B
Lepidocybium flavobrunneum	BP
Lepidopus caudatus	BP
Lepidorhombus boscii	D
Lepidorhombus spp	D
Lepidorhombus whiffiagonis	D

Lepidotrigla cavillone	D
Lesueurigobius friesii	D
Leucoraja circularis	D
Leucoraja fullonica	D
Leucoraja naevus	D
Lichia amia	P
Limanda limanda	D
Liocarcinus corrugatus	B
Liocarcinus depurator	B
Lithodes maja	B
Lithodes spp	B
Lithognathus mormyrus	D
Littorina littorea	B
Liza aurata	P
Liza ramada	P
Loliginidae	D
Loliginidae, Ommastrephidae	D
Loligo forbesi	D
Loligo forbesii	D
Loligo spp	D
Loligo vulgaris	BP
Lophiidae	D
Lophius budegassa	D
Lophius piscatorius	D
Lophius spp	D
Luciobarbus bocagei	BP
Lutraria spp	B
Macropipus tuberculatus	B
Macroramphosus scolopax	D
Macrourus berglax	BP
Mactridae	B
Maja spp	B
Maja squinado	B
Makaira nigricans	P
Malacocephalus laevis	D
Mallotus villosus	P
Maurolicus muelleri	P
Melanogrammus aeglefinus	D

Melanostomias tentaculatus	BaP
Melicertus kerathurus	D
Merlangius merlangus	BP
Merluccius merluccius	D
Merluccius senegalensis	D
Merluccius spp	D
Microchirus spp	D
Microchirus variegatus	D
Micromesistius poutassou	D
Microstomus kitt	D
Mola mola	P
Molva dypterygia	D
Molva macrophthalma	D
Molva molva	D
Molva spp	D
Mora moro	BaP
Morone saxatilis	D
Mugil cephalus	BP
Mugil spp	BP
Mugilidae	BP
Mullidae	D
Mullus barbatus	D
Mullus surmuletus	D
Mullus spp	D
Munida spp	B
Muraena helena	R
Muraenidae	R
Murex spp	B
Mustelus asterias	D
Mustelus mustelus	D
Mustelus spp	D
Myliobatidae	BP
Myliobatis aquila	BP
Mytilidae	B
Nassarius spp	B
Necora puber	B
Nephrops norvegicus	B
Oblada melanura	BP
Octopodidae	R
Octopus spp	R

Octopus vulgaris	R
Ommastrephes bartrami	BP
Ommastrephes spp	P
Ommastrephidae	P
Oncorhynchus mykiss	BP
Ophidion barbatum	D
Orcynopsis unicolor	P
Ostrea edulis	B
Oxynotus centrina	BaD
Pagellus acarne	BP
Pagellus bogaraveo	BP
Pagellus erythrinus	BP
Pagellus spp	BP
Pagrus caeruleostictus	BP
Pagrus pagrus	BP
Pagrus spp	BP
Palaemon elegans	B
Palaemon serratus	B
Palaemon spp	B
Palaemonidae	B
Palinurus elephas	B
Palinurus spp	B
Pandalidae	D
Pandalus borealis	D
Paphia aurea	B
Paphia rhomboides	B
Paracentrotus lividus	B
Parapenaeus longirostris	D
Patella spp	B
Patella vulgata	B
Patellidae	B
Pecten maximus	B
Pectinidae	B
Pegusa lascaris	D
Penaeidae	D
Penaeus spp	D
Perinereis diversicolor	B
Petromyzon marinus	D
Petromyzontidae	D
Pharidae	B
Phrynorhombus norvegicus	BP

Phycis blennoides	BP
Phycis phycis	BP
Phycis spp	BP
Platichthys flesus	D
Plectorhinchus mediterraneus	D
Plesionika heterocarpus	NB
Plesionika spp	B
Plesiopenaeus edwardsianus	D
Pleuronectes platessa	D
Pleuronectidae	D
Pleuronectiformes	D
Pollachius pollachius	BP
Pollachius virens	D
Pollachius spp	D
Pollicipedidae	B
Pollicipes pollicipes	B
Polyprion americanus	D
Pomadasys incisus	D
Pomadasys jubelini	D
Pomadasys spp	D
Pomatomus saltatrix	P
Pomatoschistus lozanoi	D
Pomatoschistus minutus	D
Pontinus kuhlii	BaD
Portunidae	B
Portunus spp	B
Prionace glauca	P
Psetta maxima	D
Psettodes bennettii	D
Raja alba	D
Raja asterias	D
Raja batis	D
Raja brachyura	D
Raja circularis	D
Raja clavata	D
Raja fullonica	BaD
Raja hyperborea	BaD
Raja leopardus	BaD
Raja lintea	BaD
Raja microocellata	D

Raja montagui	D
Raja naevus	D
Raja oxyrinchus	BaD
Raja spp	D
Raja undulata	D
Rajidae	D
Raniceps raninus	D
Ruditapes decussatus	B
Ruvettus pretiosus	BP
Salmo salar	BP
Salmo trutta	P
Salpidae	P
Sarda sarda	P
Sarda spp	P
Sardina pilchardus	P
Sardinella spp	P
Sarpa salpa	BP
Sciaena umbra	D
Sciaenidae	D
Scomber colias	P
Scomber japonicus	P
Scomber scombrus	P
Scomber spp	P
Scomberesocidae	P
Scomberesox saurus	P
Scombridae	P
Scophthalmus maximus	D
Scophthalmus rhombus	D
Scophthalmus spp	D
Scorpaena loppei	D
Scorpaena notata	D
Scorpaena porcus	D
Scorpaena scrofa	D
Scorpaena spp	D
Scorpaenidae	D
Scyllaridae	B
Scyllarus arctus	B
Scyllarus spp	B
Scyliorhinidae	D
Scyliorhinus canicula	D
Scyliorhinus spp	D

Scyliorhinus stellaris	D
Scymnodon ringens	BaP
Sebastes marinus	P
Sebastes mentella	BaP
Sebastes spp	BaP
Sepia elegans	D
Sepia officinalis	D
Sepia orbignyana	D
Sepia spp	D
Sepiidae	D
Sepiidae, Sepiolidae	D
Sepiola rondeleti	D
Sepiola spp	D
Sepiolidae	D
Seriola dumerili	R
Seriola lalandi	BP
Serranidae	D
Serranus cabrilla	D
Serranus scriba	D
Serranus spp	D
Solea lascaris	D
Solea solea	D
Solea spp	D
Soleidae	D
Solen marginatus	B
Solen spp	B
Solenidae	B
Somniosus rostratus	BaD
Sparidae	D
Sparus aurata	D
Sphyraena sphyraena	P
Sphyraena spp	P
Sphyrna mokarran	P
Sphyrna spp	P
Spicara spp	P
Spicara maena	P
Spisula solida	B
Spondyliosoma cantharus	BP
Sprattus sprattus	P
Squalidae, Scyliorhinidae	BP
Squalidae	BP

Squalus acanthias	BP
Squalus blainville	D
Squalus spp	D
Squatina squatina	D
Squilla mantis	B
Stichopus regalis	B
Stomias boa	BaP
Stromateidae	BP
Stromateus fiatola	BP
Strongylocentrotus spp	B
Symphodus melops	R
Symphodus spp	R
Symphurus nigrescens	D
Tapes decussata	B
Tapes philippinarum	B
Tetrapturus albidus	P
Thunnus alalunga	P
Thunnus albacares	P
Thunnus obesus	P
Thunnus spp	P
Thunnus thynnus	P
Thyrsites atun	BP
Todarodes sagittatus	P
Todarodes spp	P
Todaropsis eblanae	P
Torpedo marmorata	D
Torpedo nobiliana	BP
Torpedo spp	D
Trachichthyidae	BaP
Trachinotus ovatus	P
Trachinotus spp	P

Trachinidae	D
Trachinus draco	D
Trachinus spp	D
Trachipterus arcticus	BaP
Trachurus mediterraneus	P
Trachurus picturatus	BP
Trachurus trachurus	P
Trachurus spp	P
Triakidae	D
Trichiuridae	BP
Trichiurus lepturus	BP
Trigla lyra	D
Trigla spp	D
Triglidae	D
Trigloporus lastoviza	D
Trisopterus esmarkii	BP
Trisopterus luscus	BP
Trisopterus minutus	BP
Trisopterus spp	BP
Umbrina canariensis	D
Umbrina cirrosa	D
Urophycis tenuis	D
Urophycis chuss	D
Veneridae	B
Venerupis pullastra	B
Venerupis rhomboides	B
Venus verrucosa	B
Xiphias gladius	P
Zenopsis conchifer	BP
Zeugopterus punctatus	D
Zeus faber	BP

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