WORKING GROUP ON ECOSYSTEM ASSESSMENT OF WESTERN EUROPEAN SHELF SEAS (WGEAWESS)

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WORKING GROUP ON ECOSYSTEM ASSESSMENT OF WESTERN EUROPEAN SHELF SEAS (WGEAWESS)

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Contents

i Executive summary

The ICES Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS) recently completed its third three-year term from 2017 to 2019. This report describes the group's progress on the following objectives: (1) to continue metadata compilation for all ecosystem components in order to carry out integrated ecosystem assessment (IEA) and report ecosystem trends relevant to stock management, (2) to update the ecosystem overviews of the group's two ecoregions, and (3) to explore the potential of models in relation to the previous objectives.

WGEAWESS is responsible for producing IEA reports for two ecoregions: (1) the Celtic Seas and (2) the Bay of Biscay and the Iberian Coast. The group has been successful in identifying databases across these ecoregions, including retrieving some components (e.g., zooplankton) not commonly readily available at the member institutions. Complete datasets have been compiled for Irish Sea, Bay of Biscay (French side), West Iberian (Portuguese) waters and the Gulf of Cadiz. Integrated trend analysis (ITA) have been carried out for those subregions. The West of Scotland and Ireland and the Cantabrian Sea are data rich regions and efforts are being directed to collect data and develop ITAs there to ensure complete coverage of our two ecoregions. The group also explored alternative ITA techniques to those traditionally used by IEA groups, in particular Min-Max Auto-correlation Function Analysis (MAFA) in the Bay of Biscay. This work has fed into the Workshop on Integrated Trend Analyses in Support to Integrated Ecosystem Assessment (WKINTRA).

Additionally, WGEAWESS developed stock cards that showed ecosystem trend information relevant to particular stocks; these cards were then presented at the ICES stock assessment meetings.

WGEAWESS also modified the Options for Delivering Ecosystem-Based Marine Management (ODEMM) methodology to provide guidance for updating the ICES ecosystem overviews (EO) activity-pressure-state diagrams. To do this, we started with the scores assigned by the original ODEMM project for the entire North East Atlantic and modified from there where expert knowledge was available.

WGEAWESS decided to explore the possibilities of models in ecosystem based management, partly driven by the positive experience of Workshop on an Ecosystem-based Approach to Fishery Management for the Irish Sea (WKIrish). Since most of the group expertise was with Ecopath with Ecosym (EwE), WGEAWESS co-organized a workshop, WKEWIEA, to explore the practicality of integrating information from these models and exploring their utility towards informing IEA in the western shelf region.

In the coming years, WGEAWESS will work towards incorporating the social and economic dimensions as well as climate variability in cooperation with other ICES expert groups in order to better align its work with both ICES agenda and EU policy.

ii Expert group information

Expert group name	Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS)
Expert group cycle	Multi-annual Fixed Term
Year cycle started	2017
Reporting year in cycle	3/3
Chair(s)	Eider Andonegi, Spain
	Marcos Llope, Spain
	Debbi Pedreschi, Ireland
Meeting venue(s) and dates	24-28 April 2017, Lisbon, Portugal, (8 participants)
	6-9 March 2018, Nantes, France, (20 participatns)
	8-12 April 2019, Cadiz, Spain, (16 participants)

1 Terms of Reference and Workplan 2017-2019

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
a	Continue metadata compilation for all ecosystem components available for IEA development	Process initiated and completed for specific subregions in previous ToR. Other subregions in draft.	1.9, 6.1, 6.6	3 years, progress updated annually	**Database linked to ICES for Regional Sea Programmes**
b	Continue evaluation of data and trends for a regional Integrated Ecosystem Assessment. Identify ecosystem trends relevant to stock assessment and management	Linked to WKECOVER, WKRISCO, WKDECOVER, and the commitment to provide advice in the context of EBAFM	1.9, 2.1, 6.1	3 years	**Report IEAs and provide advice to fisheries groups as appropriate**
c	Review and update the regional Ecosystem overviews	Linked to ACOM-SCICOM advice	6.5, 6.6, 2.1	3 years	**Ecosystem overviews**
d	Develop and apply ecosystem models to fill identified gaps in empirical data for use in IEAs	This would be linked to activities conducted under previous ToRs	2.2, 5.2, 6.1 or 6.6	3 years	**Regional modelling prodcuts**
e	Development of Interreg Atlantic Area proposal	Funding is being sought to increase the resources and participation of the group	1.9, 6.1, 2.1	1 year	**Successful fund capture**

Summary of the Work Plan

Year 1	The main task will be the development of a proposal for Interreg funding. The group will also be involved with providing advice to WKIrish. We will continue to identify and catalogue datasets available that would be potentially valuable in an IEA and EBAFM. Ongoing analysis of important trends in ecosystem indicators. Improve communication with relevant advice groups (fisheries stock assessment).
Year 2	Continue with Year 1 activities while liaising with relevant ICES WG membership. Development of ecosystem models to fill identified gaps in empirical data for use in IEAs. Scope of IEA and model development will be dependent on successful Interreg funding.
Year 3	Continue with Year 2 activities while liaising with relevant ICES WG membership. Development of ecosystem models to fill identified gaps in empirical data for use in IEAs. Scope of IEA and model development will be dependent on successful Interreg funding.

2 Final report on ToRs and workplan

2.1 ToR a) Continue metadata compilation for all ecosystem components available for IEA development

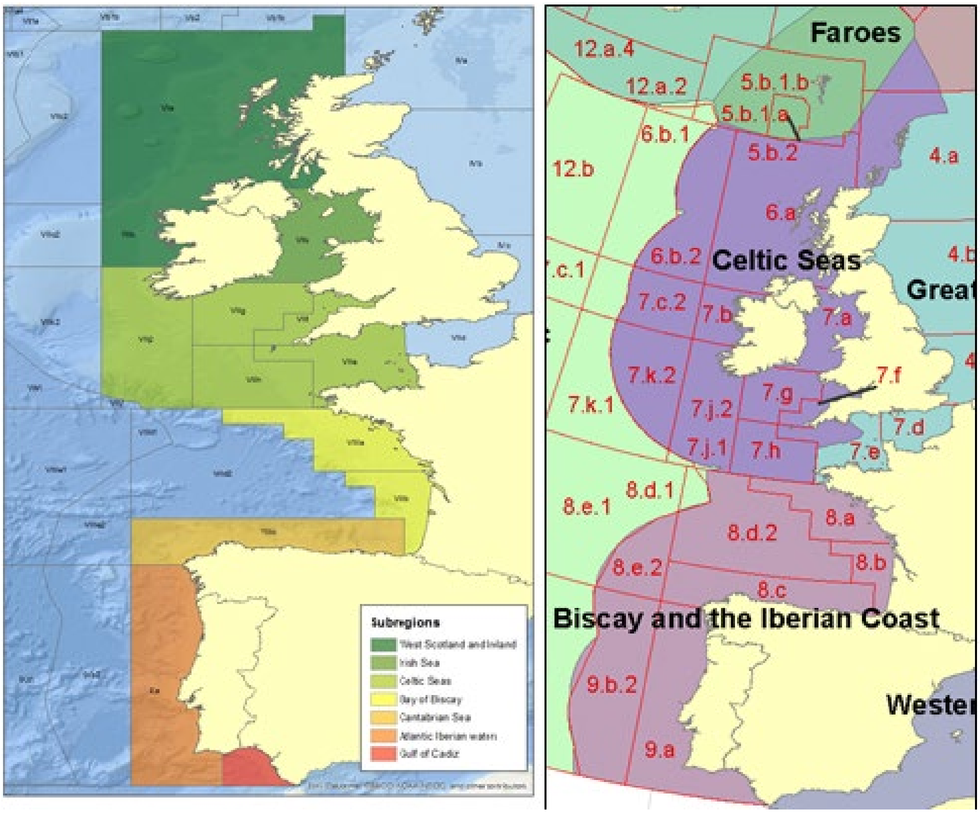


Figure 2.1.1 WGEAWESS geographical coverage and subregions (a) and ecoregions (b).The two maps differ in ICES area 7e and in the northern part in areas 4a and 2a – according to the ICES definitions these areas are only partially in the Celtic Seas ecoregion, however it is hard to separate them out, particularly in relation to fisher-ies, which use ICES areas as management units (e.g. cod 7e-k).

Compilation of existing data

Time-serieswere identified and sourced for the development of integrated trend analysis (ITAs) in all geographic subregions relevant to ecoregions covered by WGEAWESS (Figure 2.1.1). An initial wish list of key common biotic and abiotic variables required for an initial ITA of each subregion was generated based on the criteria for variable selection listed in Diekmann *et al*. (2012).

Following these lines, the ITAs for the Irish Sea and Gulf of Cadiz sub regions were updated. Time-series were identified and updated for the Celtic Sea, Bay of Biscay, and Atlantic Iberian waters, and on a finer scale the Guadalquivir estuary (Ge) system (in the Gulf of Cadiz) based on the available group expertise.Remaining subregions including the West Scotland and Ireland and Cantabrian Sea (8c) are data rich, with many data products identified that may be of use in IEA development.

Modelled products were identified as useful in filling gaps in current physical and biological metadata that would provide harmonized products across the subregions. Modelled products as a source of key environmental variables (SST, salinity, Chl *a*) were identified as a common data sources that could be applied across the entire ecoregions, including those not currently represented by WGEAWESS membership. While the use of modelled products in lieu of real observations is not encouraged, the increasing use of these products in peer reviewed research and ecosystem management products suggest that outputs are trusted to represent true trends in hydrography and biotic variables such as SST and chlorophyll *a*. These being available for the whole geographical region provide a useful source of key physical and biological data where currently the group have not been able to identify other sources. A number of products were identified with good spatial and temporal coverage. The outputs from the identified modelled products were compared with existing point and modelled sources in the Irish Sea. The comparison here suggested that the general trends in SST were comparable. Discussions were instigated with the Working Group on Operational Oceanographic Products for Fisheries and the Environment (WGOOFE), and a presentation received from Dr. Mark Payne of WGS2D (Working Group on Seasonal-to-Decadal Prediction of Marine Ecosystems) to explore and assess the quality of the current outputs available and the feasibility of acquiring outputs on a regional and subregional basis for IEA work.

Due to the importance of primary and secondary production for higher trophic levels, specifically fisheries, products to represent these were identified in the form of CPR (continuous plankton recorder) data. Plankton data remains patchy, however the data available from SAHFOS (currently 'the CPR survey' at the Marine Biological Association) across the ecoregions was requested and received.

Time-series of environmental variables were derived from satellite telemetry (e.g. SST, chlorophyll, particulate carbon) or recovered from in-situ measurements (freshwater discharges from rivers, precipitation). Higher trophic levels and key pressures (fishing activity indicators) were identified for many of the subregions from national surveys and landing statistics, ICES stock assessment group outputs and annual advice sheets. Issues in relation to differences in scale between stock assessment areas and ecoregions or subregional (e.g. ITA/model) scales and how to resolve between them were repeatedly raised and remain an issue. National data may be preferred to avoid/reduce these scaling issues, and to rely on data rather than model outputs.

The focus/expertise of the group is primarily related to fisheries (Ecosystem Based Fisheries Management - EBFM), therefore a gap in societal and economic metadata, along with data related to sectors other than fishing and benthic habitats and species is evident. For a more complete IEA increased interaction with these areas of expertise is needed.

With the volume of metadata and data products increasing in the group, it was suggested that a more structured approach, potentially involving the ICES Data Centre could substantially improve the workflow, including enhanced transparency and repeatability of data used in ITA and future IEA development. This would include the structure, reporting and hosting of metadata, the extraction of time-series and data and the evaluation of data for further use in ITA and IEA.

For an overview of the current metadata available per region see the WGEAWESS 2016 report (Annexe 4) here and the WGEAWESS 2018 report here.

Generation of new data

Unfortunately, the Gulf of Cadiz (GoC) is not covered by the CPR survey. Despite the increasing number of scientific studies carried out over the last decades in this subregion, the zooplankton component has so far received little attention. This is particularly true when compared with other neighbouring areas like the Cantabrian Sea, where time-series were established already back in the 90s.

In an effort to describe this little-known component of the GoC foodweb, samples of zooplankton that were archived in different labs (see sampling sites in Figure 2.1.2) were recovered, processed and analysed. This 'archaeological' effort allowed us to build the longest time-series of zooplankton for this ecosystem to date (2001-2015) and describe its community structure in terms of species richness, diversity and abundance with also some spatial resolution (de Carvalho-Souza *et al.* in review).

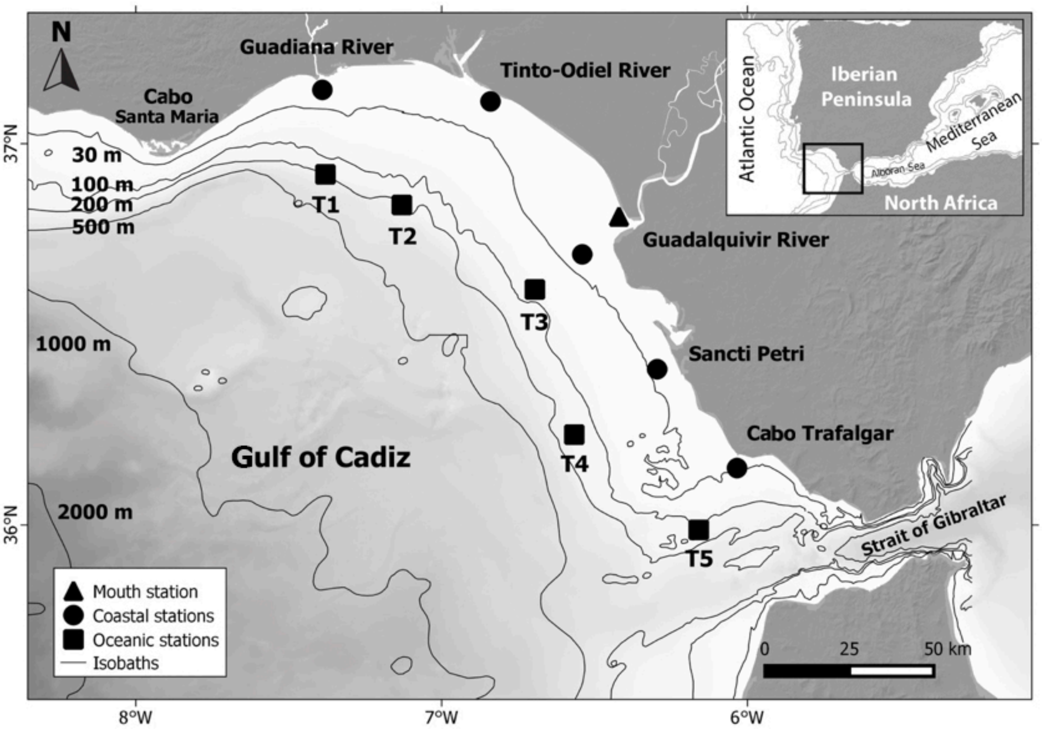


Figure 2.1.2Zooplankton sampling area in the Gulf of Cadiz, between the Guadiana River and Cape Trafalgar. Stations are represented by triangle (mouth), circles (coastal) and squares (oceanic) on the transects of Guadiana (T1); Tinto-Odiel (T2), Guadalquivir (T3); Sancti Petri (T4) and Trafalgar (T5).

Zooplankton in the GoC is dominated by copepods (mainly *Paracalanus*, *Oithona* and *Oncaea*), except in warm periods, when the cladoceran *Penilia avirostris* and some meroplanktonic forms (e.g. Cirripedia, Teleostei larvae) outnumber copepods, accounting for more than 75% of total abundance (Figure 2). From a spatial perspective, copepods are relatively more abundant offshore while cladocerans become more important as we move closer to the coast and to the mouth of the Guadalquivir River (Figure 2.1.3).

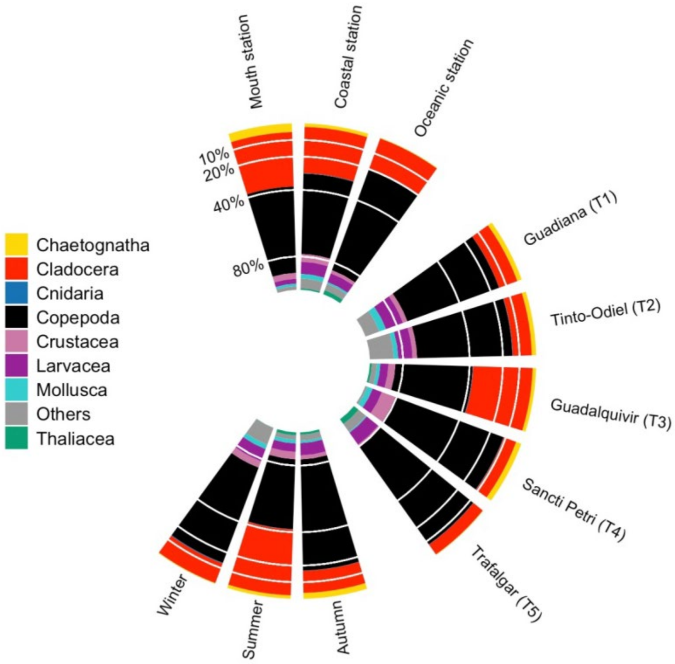


Figure 2.1.3 Zooplankton community. Relative abundance of taxa by station (mouth, coastal and oceanic), transect (T1-T5) and season (winter, summer, autumn), This diagram has been modified from de Carvalho-Souza *et al.* (in review).

2.2 ToR b) Continue evaluation of data and trends for a regional Integrated Ecosystem Assessment. Identify ecosystem trends relevant to stock assessment and management

Trend Evaluation

As outlined in Section 2.1 the ITAs for the Irish Sea and Gulf of Cadiz subregions were updated. The identified time-series outlined above were used to produce ITAs for the Bay of Biscay and Atlantic Iberian waters, and on a finer scale the Guadalquivir estuary (Ge) system (in the Gulf of Cadiz) based on the available group expertise.This work demonstrates the importance for finer scale investigations where important areas are identified such as the Guadalquivir estuary, an important nursey ground for several marine species. Remaining subregions including the West Scotland and Ireland and Cantabrian Sea aredata rich, with many data products identified that may be of use in IEA development.

Irish Sea

The ITA for the Irish Sea continues to be used to inform the WKIRISH initiative. Updated data did not affect the observed trends. For discussion of Figure 2.2.1 see here.

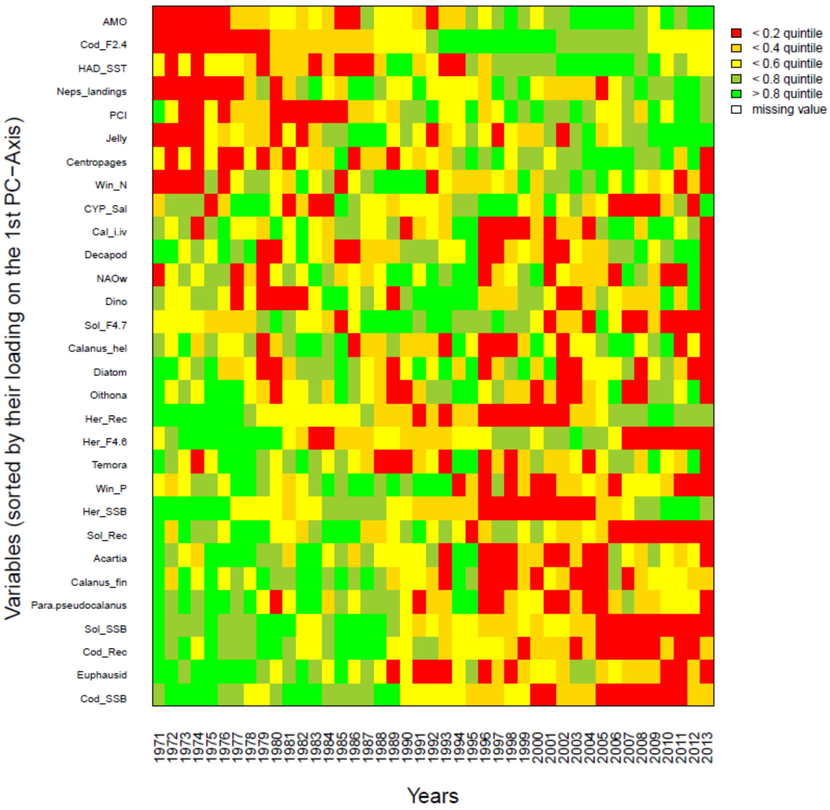


Figure 2.2.1 Traffic light plot of the temporal development of the Irish Sea ecosystem time-series. Variables are transformed to quantiles, colour coded (red- high values, green- low values) and sorted in numerically descending order according to their loadings of the first principle component.

Bay of Biscay

A preliminary ITA was realized for the Bay of Biscay (ICES areas 8a and 8b) following published methodology (Diekmann *et al.*, 2010; Möllmann *et al.*, 2014). Physical data included SST and salinity values, with large climatic drivers represented by the AMO and NAO. The French IBTS EVHOE survey provides a number of biotic variables mostly of fish populations. Finally, ICES landings of key stocks were also included to take into account the main human activity in this area (i.e. fishing). Time-series of available data goes from 1987 to 2016 for this analysis. Data were transformed prior to PCA analysis to ensure normality of data, and PCA scores were used to rank variables in the traffic light plot (Figure 2.2.2). From this preliminary study, key signals over nearly 30 years in the Bay of Biscay appear to be the increasesof gurnard biomass and abundance, the increase of lesser spotted dogfish biomass, and the increase of sea bass biomass and abundance. This was concomitant with a decrease of SST, a decrease of sprat biomass, a decrease of plaice and nephrops landings, and a decrease of the overall biomass of the demersal fish community sampled through bottom-trawl survey.

Following Planque and Arneberg (2018) and WKINTRA conclusions, an alternative methodology has been used to develop further the ITA for the Bay of Biscay. This second ITA involves MAFA (min-max autocorrelation factor analysis) as the method to select the most continous variables, which is coherent with the ITA ojectives of identifying the main changes that occurred in the ecosystem. For this second analysis, data variables have been completed, and two time-series have been identified: i) the longer time-series 1987–2016 includes demersal fish, large climatic indices, river run-offs, abiotic environnement variables, and fishing activities; ii) the shorter time-series 2000–2016 includes the previous variables as well as plankton information and small pelagic fish data.

Due to the amount of available variables, a 2-steps approach is used. First, MAF is performed within each of the following ecosystem compartments: global external drivers, abiotic environment, primary production, small pelagic fish, demersal fish community, human pressure (only data relative to fishing was available at this temporal scale). This step allows identifying the most continuous variable in each of the ecosystem components. Fig 2.2.3 shows the MAFA results for the small pelagic fish compartment, for the smaller time-series. Anchovy biomass is the most continuous variable, followed by sardine mean weight, mackerel biomass and anchovy mean weigth. Mean weights of sardine and anchovy decrease over the period, while mackerel biomass decreases until 2011 and increases after 2011. Anchovy biomass has decreased until 2005, and increased after.

Based on the results of these analyses, a set of highly continuous variables is determined for each ecosystem compartment. The selected variables are then used together in a final MAFA, in order to identify the covariation and main signals of the Bay of Biscay ecosystem. A manuscript detailing the method and results is under preparation.

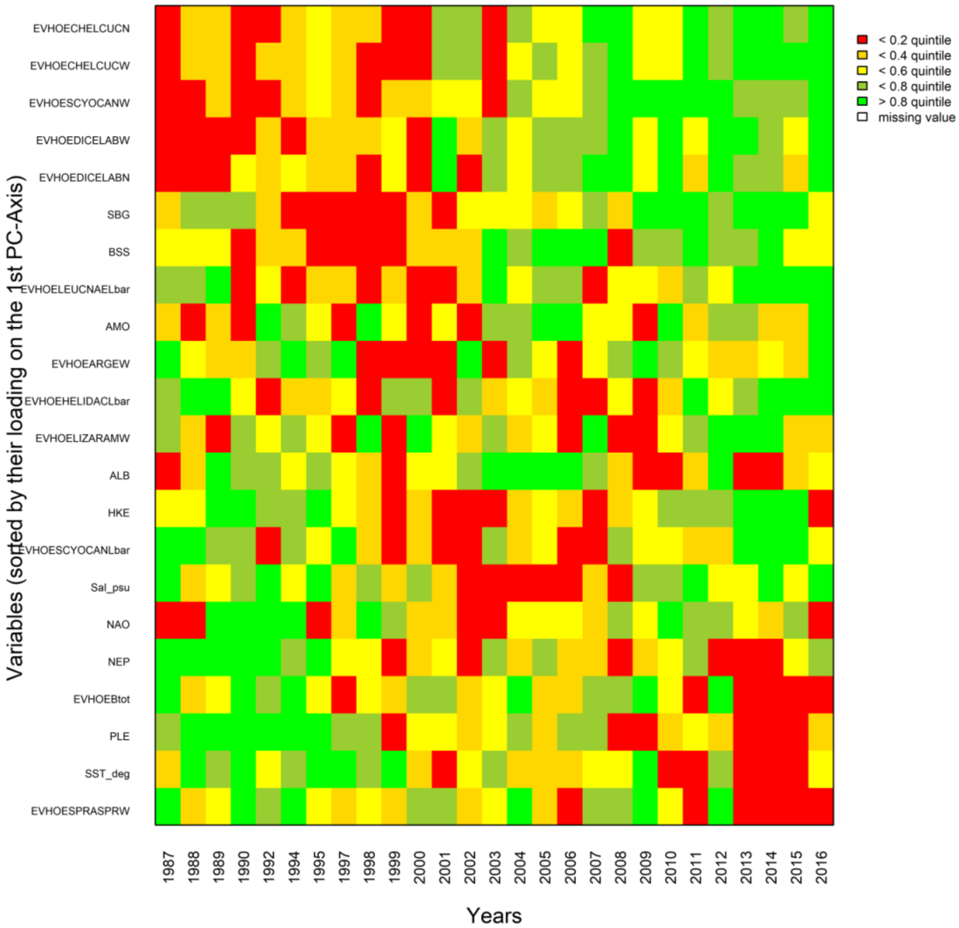


Figure 2.2.2: Traffic light plot of the temporal development of the Bay of Biscay ecosystem time-series. Variables are transformed to quantiles, colour coded (red- high values, green- low values) and sorted in numerically descending order according to their loadings of the first principle component.

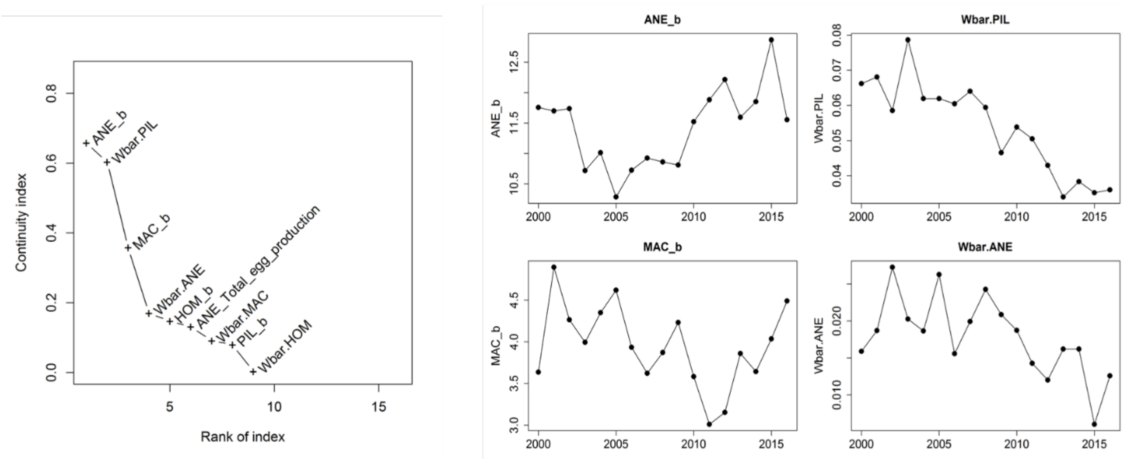


Figure 2.2.3: Results of the MAFA realized on the small pelagic fish compartment. Left: ranking of available variable according to their continuity index. Right: time-series of the most continuous variables. ANE_b is anchovy biomass, Wbar_PIL is mean weight of sardine, MAC_b is mackerel biomass, Wbar_ANE is mean weigth of anchovy.

Portuguese waters

For ITA analysis presented this year for the Portuguese ecosystem, the study area is the same covered by the research vessel sampling described in the DATRAS protocol.

Time-series data from the period 1986–2016 were chosen based on their ecological importance and completeness. In total, 40 biological, 13 fisheries-related and 10 abiotic variables describing environmental and climatic conditions were included in the analysis (Figure 2.2.4).

Survey data from 40 fish species from 1986 to 2016 was used to estimate biomass indices by species, extracted from IPMA/PNAB and ICES/ DATRAS databases. 13 Stock assessment output variables: Sardine, Hake, Megrim and Anglerfish recruitment, spawning biomass and fishing mortality were obtained from ICES stock assessments reports (ICES,1987-2017)

Sea surface temperature anomaly (SST) for the North Atlantic was downloaded from Metoffice website (https://www.metoffice.gov.ukhadobshadsst3data), the North Atlantic Oscillation index (NAO), winter and annual mean (http://www.cpc.ncep.noaa.gov/data/teledoc/ea.shtml), the Atlantic Multi-decadal Oscillation index (AMO) (http://www.esrl.noaa.gov/psd/data/timeseries/AMO) and eastern pattern index (EA) (http://www.cpc.ncep.noaa.gov/data/teledoc/ea.shtml) were downloaded from the NOAA website and the upwelling index was provided by the Instituto Español de Oceanografía (IEO) (http://www.ieo.esinteractivo.html).

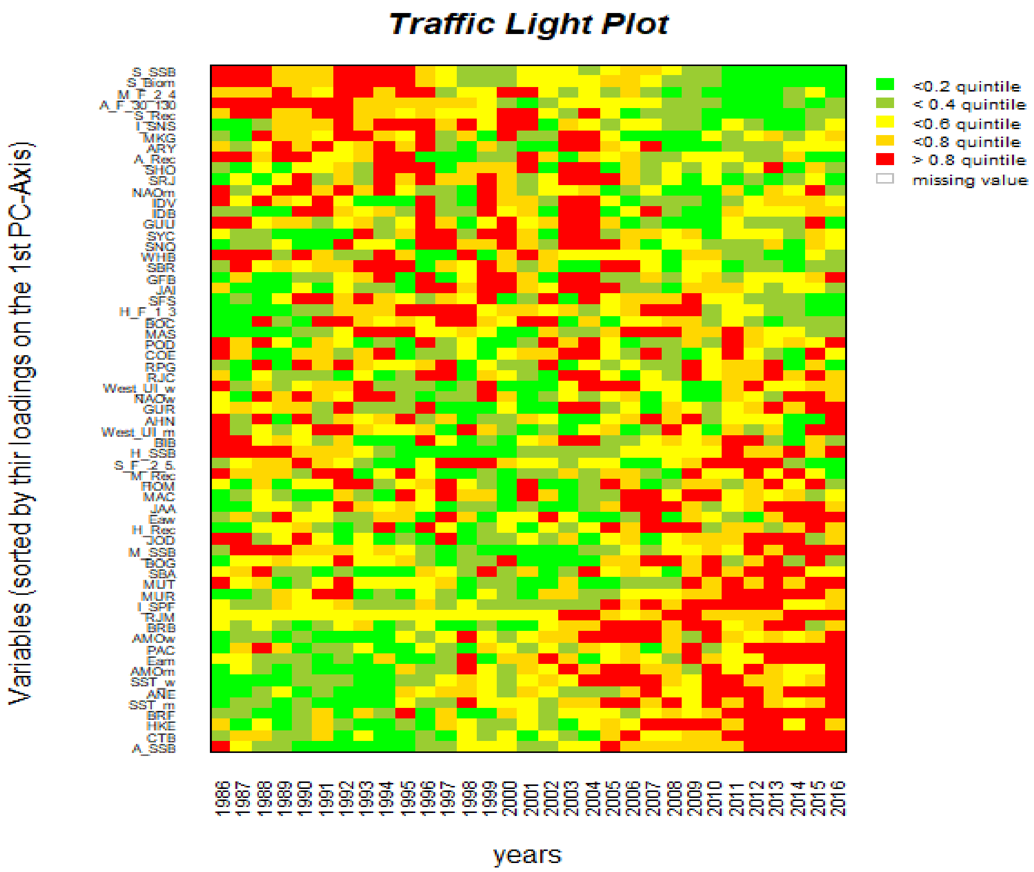


Figure 2.2.4 Traffic light plot of the temporal development of the Portuguese ecosystem time-series. Variables are transformed to quantiles, colour coded (red- high values, green- low values) and sorted in numerically descending order according to their loadings of the first principle component.

The temporal development of PC1 scores was characterized by an initial increase from 1986 to 1996 followed by a decrease from 1995 to 2016, with peaks observed in 1996 and 2003-2004 (Figure 2.5). The PC2 displayed a gradual increase from 1986 to 2003 with two peaks observed in 1996 and 2003. Then, from 2003 to 2016 trend stabilized (Figure 2.2.5).

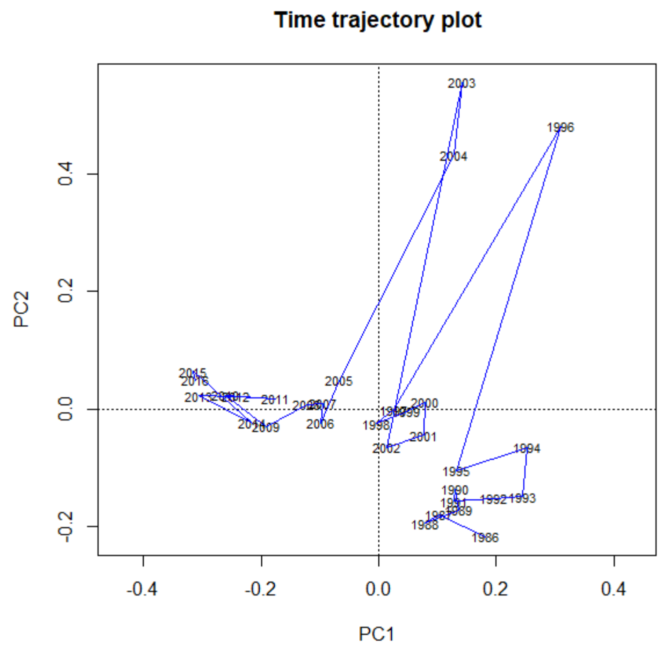


Figure 2.2.5. Results of PCA applied to all variables assembled for the Portuguese ecosystem showing time trajectory of the year scores in the PC1 and PC2 plane. PC1 = 21 %, PC2 = 17 % explained variance.

Our results suggest two transitions in the ecosystem: the first in 1996 and the second in 2003-2004. In our analysis this is associated with the increase in winter upwelling and SST. The analysis therefore indicates that the Portuguese ecosystem is currently in a new state induced by atmospheric and oceanographic conditions that started in 1995-1996 and were intensified in 2003-2004.

Gulf of Cadiz

All the information identified in section 2.1 that was available for the Gulf of Cadiz was compiled. Figure 2.2.6 summarizes the different data sources and spatial coverage of this information. Apart from the newly-generated zooplanktondata (described in section 2.1), these dataset included environmental variables derived from: satellite telemetry (e.g. SST, chlorophyll, particulate carbon) or in-situ measurements (e.g. freshwater discharges from the Guadalquivir), anthropogenic pressures (fishing effort, harvest rate, marine litter) and 30 functional groups of marine organisms as well as separate target species of fish and crustaceans derived from acoustics, demersal and pelagic surveys. Functional groups were chosen based on ecological similarities from an Ecopath model developed with (part of) the same database (Torres *et al.*, 2013). A review and update of the species assigned to each group was performed for the current analysis.

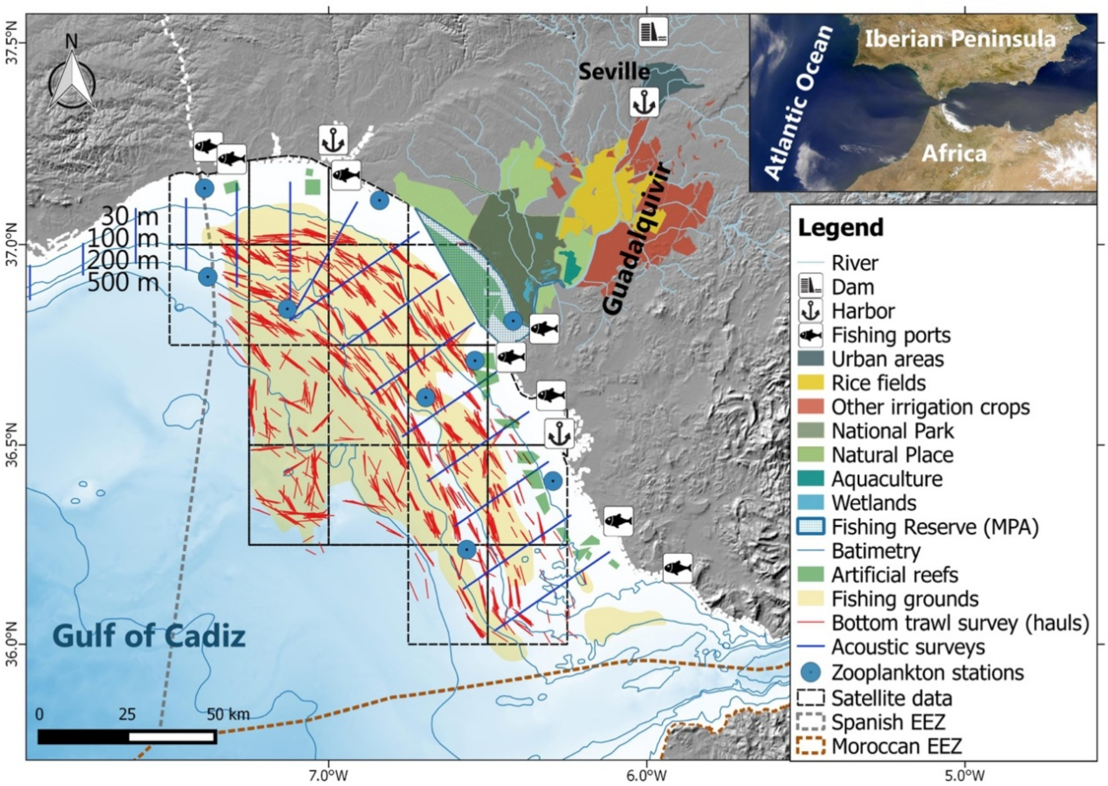


Figure 2.2.6. Map of the Gulf of Cadiz showing the location of the various data sources: satellite squares, zooplankton stations, bottom trawl hauls, fishing ports, Guadalquivir River dam as well as some other important features of the ecosystem, like the Guadalquivir mouth fishing reserve. See legend for details.

Using this information, a traffic-light plot (Diekmann *et al.*, 2012) was built in order to identify trends and also temporal information gaps (Figure 2.2.7). Comparing this updated version with the one that appeared in the 2015 report (Figure 6.5.1, see here) it is apparent the increase in time span and variables since then. Variables were then sorted by the 10-year standardized average and plotted against years. The use of the first Principal Component loadings to sort variables on the y-axis was intentionally avoided in order to make the arising patterns totally independent of Principal Component Analysis (Planque and Arneberg 2018).

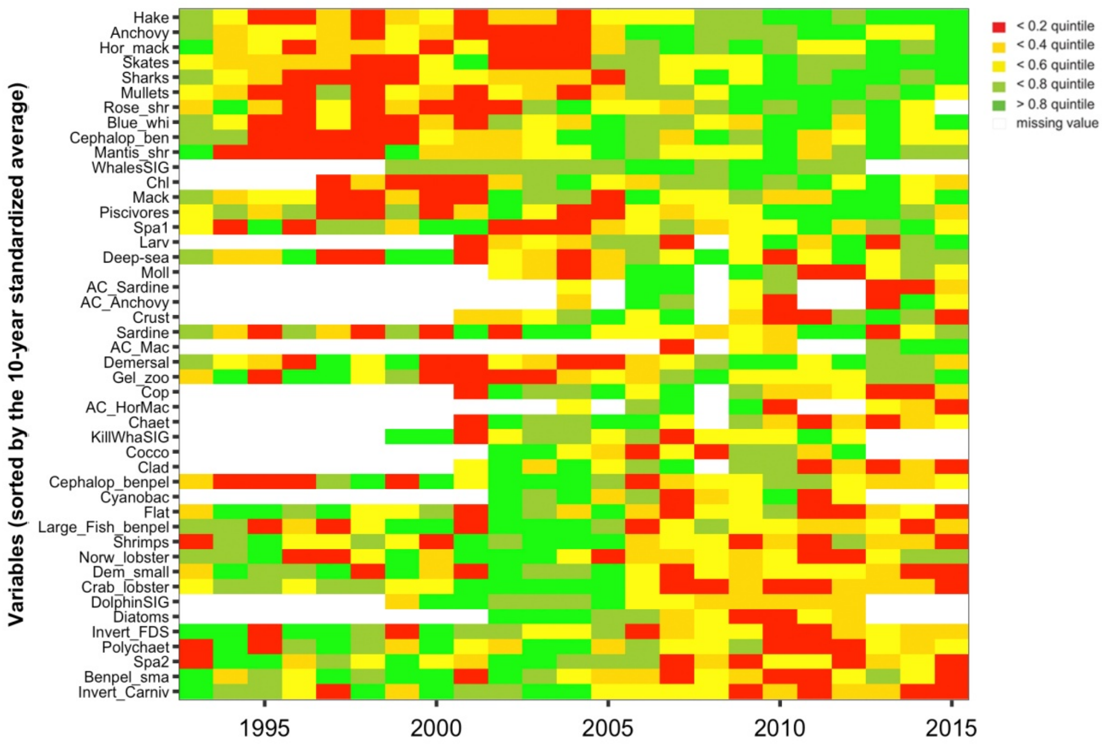


Figure 2.2.7. Traffic light plot representing the development of the Gulf of Cadiz ecosystem over the period 1993-2015. Time-series were transformed to quintiles, colour-coded and sorted in numerically according to the average of their first 10 years. Red represent low values while green represent high values of the corresponding variable. de Carvalho-Souza *et al*. (in prep.).

From top to bottom variables are: hake, anchovy, horse mackerel (Hor_mack), skates, sharks, mullets, rose shrimp (Rose_shr), blue whiting (Blue_whi), benthic cephalopods (Cephalop_ben), mantis shrimp (Mantis_shr), whales sightings (WhalesSIG), chlorophyll (Chl), mackerel (Mack), piscivorous fish (Piscivores), first group of sparids (spa1), Larvacea plankton (Larv), deep sea fish (Deep-sea), Mollusca plankton (Moll), sardine biomass derived from acoustic methods (AC_sardine), anchovy biomass derived from acoustics (AC_anchovy), Crustacea meroplankton (Crust), mackerel biomass from acoustics (AC_Mac), demersal fish (Demersal), gelatinous zooplankton from bottom trawl surveys (Gel_zoo), copepods (Cop), horse mackerel biomass from acoustics (AC_HorMac), chaetognats (Chaet), killer whale sightings (KillWhaSIG), coccolithophorids (Cocco), cladocerans (Clad), bentho-pelagic cephalopods (Cerphalop_benpel), cyanobacterias (Cyanobac), flatfish (Flat), large bentho-pelagic fish (Large_Fish_benpel), shrimps, Norway lobster (Norw_lobster), smalldemersal fish (Dem_small), crabs and lobsters (Crab_lobster), dolphin sigtings (DolphinSIG), diatoms, filter-, detritus- and suspension-feeder invertebrates (Invert_FDS), polychaetes (Polychaet), second group of sparids (Spa2), small bentho-pelagic fish (Benpel_sma), carnivorous invertebrates (Invert_Carniv).

This database is currently being analysed with a panoply of multivariate and plotting techniques, traditionally utilized for IEA. These include: Principal Component Analysis (PCA), Sequential t-test analyses of regime shifts (STARS), Min/max autocorrelation factors analysis (MAFA) and Chronological Clustering (CC). Results are currently being prepared for publication (de Carvalho-Souza *et al*.,in prep.).

Methodological Concerns/Criticisms

Due to recent criticism of the use of PCAs for ITA development (Planque and Arneberg 2018), the group examined alternative/complimentary methods for use. In general, it was felt that with appropriate data screening and cautious interpretation of the PCA outputs ITA approaches are useful in detecting long-term trends and patterns in the time-series available.

Methods developed within the EU project Fisboat to identify changes in series of indicators were reviewed (see the following special issue for further details: https://www.alr-journal.org/articles/alr/abs/2009/02/contents/contents.html). These were: Decision CUSUM, Min/max autocorrelation factors analysis (MAFA) and Multiple factors analysis (MFA). R scripts are available as supplementary material to the publications for implementing the methods.

Decision CUSUM (Mesnil and Petitgas, 2009) is useful for rapidly identifying statistically significant deviations from a reference mean. The method requires defining a reference period, where mean, variance and distribution of the index series are characterized. The CUSUM is then tuned with two parameters and serves to monitor whether the mean deviates with time from the reference mean. One parameter influences the time to detection (mean run length) of the change in the mean after it has happened. The other parameter relates to the deviation in the mean that can be detected with a given time to detection. Applying the method on many indices results in building a "traffic light" table, where changes are monitored with such statistical framework (Petitgas *et al.*, 2009). The method can also be used to monitor changes in spatial patterns, when applied to amplitude series of EOFs (Woillez *et al.*, 2010).

The MAFA of time-series (Woillez *et al.*, 2009) was developed to rank series of indices among a large list, based on the continuity in time-series. For instance, the approach allows to select those series showing the most continuity in time. The rationale for such selection is to identify those series, which can be interpretable more easily because they are continuous (i.e. trend, oscillation). In contrast, indices showing erratic variability (i.e. white noise) will be ranked last. Although interesting, they cannot be used to assess any change in the ecosystem. MAFA is a double PCA, where the second PCA is performed on the increments (at a given lag D) of the PCs of the first PCA, allowing to rank those series with smaller variogram value at lag D. The method was applied to more than 100 indices derived from the integrated pelagic survey PelGas in the Bay of Biscay (Doray *et al.*, 2017). Trends were identified for particular series, including the reduction of length-at-age 1 in anchovy and sardine since 2000. The discussion pointed out different approaches to select indices for assessing ecosystems. Even if trends in particular indices show changes, the fact that other indices are erratic is also informative. From the discussion, it was suggested to compare the results of MAFA with that of PCA on an example case study.

Multiple factors analysis (MFA) may serve to characterize the consistency in time of the correlation structure among many indices (Petitgas and Poulard, 2009). The method requires to organize the data in a three-dimensional structure, where for each time-step the elementary data matrix is composed of the same indices (columns) sampled at the same (spatial) sample stations. The method amounts to performing a PCA on the combined elementary matrices, which have been previously standardized by their first Eigen value and appended by column. The factorial space constructed allows to separate the variability of space from that in time. Each (spatial) sample station is represented geometrically by an average point in time and also by as many points as there are time-steps. The method was applied to a list of indices in the major ecosystem compartments of the Bay of Biscay derived from the integrated pelagic survey PelGas (Petitgas *et al.*, 2017). A hierarchical classification of the time average station positions in the factorial space resulted in identifying and mapping ecosystem subregions. The variability of time was quantified by the inertia in the factorial space around the time average station positions and was mapped, showing areas with greater variability than others. The deviation in time from the average spatial structure could be monitored, for instance by using CUSUM. The discussion raised the issue of identifying ecosystem limits. It was suggested that a similar analysis could be performed at the scale of the WGEAWESS region to identify subsystems and characterize their temporal variability.

The recent criticisms related to the use of PCAs in ITAs (Planque and Arneberg 2018), coupled with recommendations from WKIDEA and work and discussions outlined here, led to a plan to perform a sensitivity analysis of current ITA methods used by IEA groups. This developed into the 2018 WKINTRA workshop, which recognized some of the limitations in the ITAs methods currently used and recommended to approach the evaluation problem through simulation studies, in a way similar to that used earlier in ICES for stock assessment models. Two more INTRA workshops are planned. WKINTRA2 will develop and compare numerical simulation protocols and algorithms; with the aim of simulating few contrasted ecosystem datasets.

ODEMM – Options for Delivering Ecosystem-Based Marine Management

WGEAWESS continues to support the development and use of ODEMM (https://odemm.com/) as an operational tool for EBMM (ecosystem based marine management). ODEMM assessments for the Celtic Seas and Irish Sea were presented to the group highlighting the adjustments made to tailor them for specific purposes. Both assessments present a 'current status' precautionary assessment, rather than a risk forecasting assessment. The Irish Sea assessment splits *Fisheries* into its constituent parts – Beam trawl, Bottom trawl, Pelagic fishing, Dredging, and Potting. These categories were reviewed and scored by stakeholders at the WKIRISH4 workshop. *Bycatch* is treated as a separate pressure to *selective extraction of species* in both the Celtic Seas and Irish Sea assessments, and *Discards* is further separated out in the Irish Sea Assessment. The Celtic Seas assessment has further been linked through to the Marine Strategy Framework Directive (MSFD) descriptors Pedreschi *et al.* (2019) and criteria.

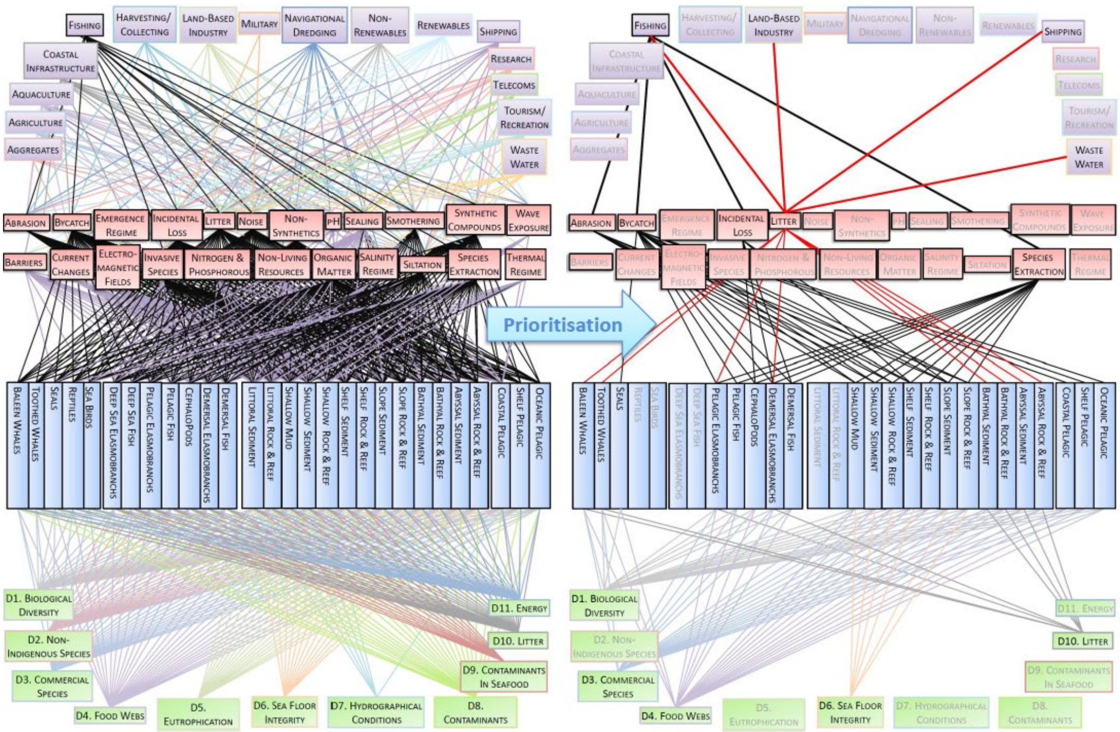


Figure 2.2.8. Horrendograms of the Celtic Seas illustrating the Irish sectors that operate, the environmental pressures they create, the ecological characteristics affected by them, and the Marine Strategy Framework Directive descriptors at risk of not meeting good ecological status (GES). Through the examination of risk scores using the ODEMM approach, the top risks/threats can be identified, focusing attention on areas of priority for action and resource allocation.

Questions arose in relation to the applicability/transferability of the results to other areas, and the aggregation of the scores across linkages (e.g. summing vs. averages) and how these affect rank orders. While many of the linkages may be transferable to wider areas than the study area, it would need to be comprehensively reviewed to ensure agreement with the assessment, and to adjust (at a *minimum*) that overlap and frequency scores of the sectors for different areas. Expert panels from different areas are likely to have different opinions on scores and importance of different impacts – but it may be easier (and perhaps more efficient) to adapt a current assessment than start a new one – stakeholders may be more willing to change scores that seem wrong, than to propose values *de novo*. It is important to note however that it would depend on the requirements of a given area/region – for instance, the focus on fisheries in the Irish Sea arose from the fact that *fisheries* rose to the top of the Celtic Seas analysis, and the group's (both WGEAWESS and WKIrish) particular interest is in fisheries and EBFM.

For updating the Bay of Biscay and Iberian Coast (BoB-IC) ecoregion ecosystem overview (See Section 2.3), the approach was taken to start with the scores assigned by the original ODEMM project for the entire North East Atlantic and modify from there where expert (or empirical) knowledge was available.

It was also noted that climate change is not included in the assessment as an explicit pressure. It is difficult to include, as it is not easily incorporated as a pressure due to difficulty in specific management action to reduce/mitigate it, at least on a national level. Including it as a sector would also not adequately reflect its interactive effects with other pressures, a noted shortcoming of the ODEMM approach, which considers direct effects only. Climate change will certainly have effects on the pressures and ecological characteristics that are assessed, but no current method has been developed for incorporating this into the approach.

Further work has been conducted to develop the ODEMM linkage framework visualization using online tools. The Linkage Framework can help with decision support and visualization of the system and provides the structure within which management options can be explored.

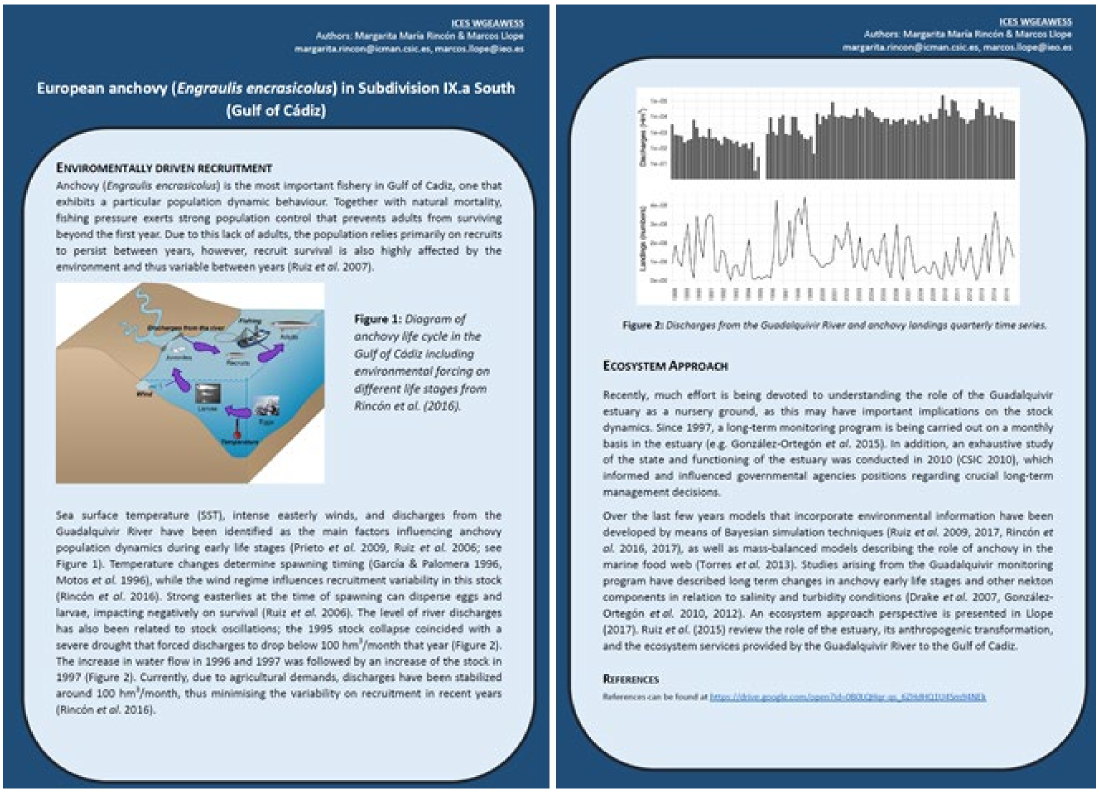
<u>Working with stock assessment groups to include ecosystem information in the advisory process.</u>

The number of stocks managed or reported on within the geographical range of the group is extensive. As such'key fisheries' in each subregion were identified and time-series available to describe changes in abundance and key stock parameters (recruitment, weight at age, maturity) compiled as outlined above.

Potentially relevant ecosystem trends were identified by collating and reviewing documented links between stock trends (recruitment, SSB, mortality) and possible biotic and abiotic drivers (SST, windstress, productivity). Initially 'report cards' were proposed and developed as an easily-digestible format for providing ecosystem trend information of relevance to assessment groups (Figure 2.2.8).The format/ information included varied depending on the relevant information for a given stock. The European anchovy card was presented to WGHANSA in 2018, and various individual stock assessors were approached with the Irish Sea Cod card. All expressed an interest, suggesting the cards would be of value to them in their work. However, it was not currently clear how such information could be incorporated into the stock assessment process. As there is currently no demand coming from the stock assessment groups for this product, WGEAWESS will not continue to speculatively produce these cards. It is unlikely that given the wide number of stocks within the WGEAWESS ecoregions that we would be able to produce cards forall relevant stocks within the limited resources.

Discussions with Daniel Howell and Dave Reid following from the WKIrish process identified the stock assessment benchmark process as a more appropriate avenue for WGEAWESS to productively interact with stock assessment groups. These milestones were identified as the best moment to effectively incorporate ecosystem information, most likely within the Management Strategy Evaluation (operating model).

a)



b)

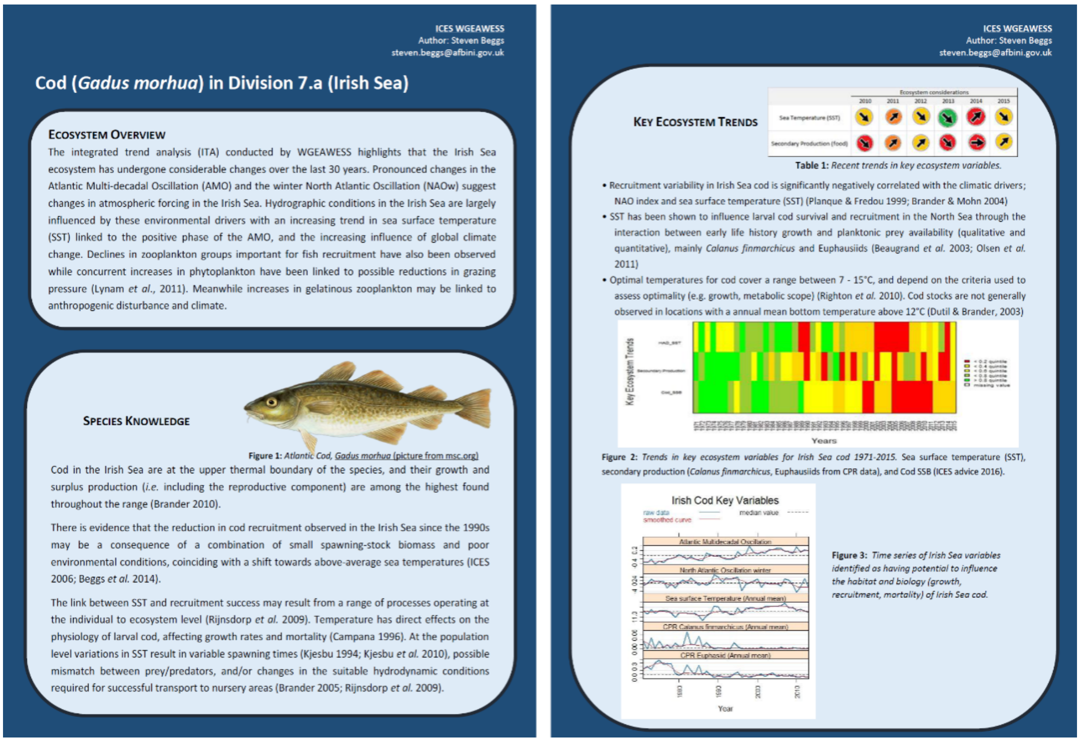


Figure 2.2.9.Example stock cards produced by WGEAWESS. Card a) European anchovy was presented to WGHANSA for review. Card b) attempted to include familiar ICES reporting structures, such as the coloured arrow trajectories.

WGEAWESS is closely linked with WKIrish (Workshop on an Ecosystem-based Approach to Fishery Management for the Irish Sea) series of workshops. WKIrish is a multiyear process focusing on improving single-species stock assessments by incorporating a mixed fisheries model and developing the integration of ecosystem aspects and working towards an integrated assessment and advice, in line with the ICES strategic plan to progress towards integrated ecosystem assessments. WGEAWESS involvement has been in providing much of the ecosystem advice, support and analysis, particularly related to biotic and abiotic trends in the Irish Sea and key drivers of local commercial fish dynamics, specifically recruitment, and in facilitating/supporting industry collaboration. This process has helped to identify this type of meaningful interaction during a multispecies benchmark process as perhaps the ideal avenue for providing relevant contextual ecosystem advice into the advisory process by working together with stock assessment groups and using ecosystem trends as warning flags and/or directional indicators as to where F should be set in the MSY ranges produced by the stock assessment. This is an avenue we will continue to pursue where opportunities arise. See Annexe 4 for details on presentation provided by Dr. Daniel Howell of Institute of Marine Research, Norway.

2.3 ToR c) Review and update the regional Ecosystem overviews

A request was received from ICES to include information on climate change for theecosystem overviews (EO) of our two ecoregions. The template provided was populated using experts both within and beyond the WGEAWESS group. Both EOs were reviewed at corresponding Advice Drafting Group (ADG) in November 2018. However, the only one that was able to be finalized and published was the BoB/IC EO due to the fact there were experts on this ecoregion in the ADG able to interpret and complement the information provided in the template. The ADG suggested modifications to be incorporated in future climate change templates in order to facilitate the process. These recommendations were communicated to ACOM.

Monitoring and high-level review of the ecosystem overviews was carried out at the annual meetings. WKEO3 (Workshop on the design and scope of the 3rd generation of ICES Ecosystem Overviews), along with individual groups have called for a more standardized, open and transparent process for producing and compiling the ecosystem overviews, starting with the risk horrendograms which are present in each of the ecosystem overviews. WGEAWESS developed a new methodology at the 2019 meeting, which used the existing North East Atlantic assessment produced by the ODEMM (https://odemm.com/) project c.2011, and adapted it to reflect the ICES methodology in an attempt to make the process more comprehensive, independent, and less reliant on specific ranking judgement calls. Due to the limited time resources, broad rules were adhered to for the scoring, and where the group did not feel it had the expertise to adjust the previous assessment, existing scores were retained. The full details of the approach are provided in Annexe 5.

The results produced a matrix that sensibly reflected the expert judgement, which they felt comfortable presenting as the basis or updating the diagram for the ecoregion (Figure 2.3.1). Furthermore, this semi-quantitative process facilitates further analysis to be carried out and can become more quantitative as empirical data becomes available.

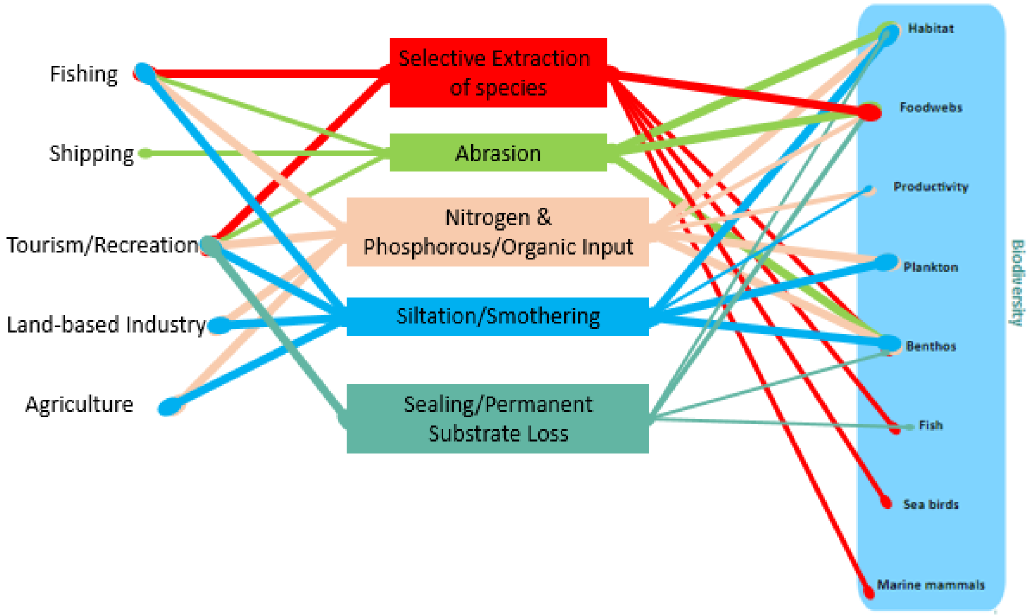


Figure 2.3.1 Draft of the EO diagram for the BoB/IC Ecosystem Overview. This has been created using the top sectors and pressures and together represents 51% of the risk in the ecoregion. Links to 'Foodwebs' and 'Productivity' have been added based on expert knowledge.

Future Development

In 2019, WGEAWESS invited new members and guest speakers to join the group in an effort to investigate avenues for including/ collaborating on developing additional relevant information and indicatorsinto the ecosystem overviews, and for informing the development of the groups new ToRs. Informed by the ecosystem overview work outlined above and that of WKEO3, specific areas highlighted as needing improved knowledge include: foodwebs and ecosystem structure, fishing impact on benthic habitas, climate change projections/predictions, social impacts/priorities, and better linkages to management objectives such as the MSFD. Summaries of the presentations given are provided in Annexe 4.

2.4 ToR d) Develop and apply ecosystem models to fill identified gaps in empirical data for use in IEAs

The use of ecosystem models to provide useful products for ecosystem based management is well advanced. While many models of varying complexity and sophistication exist from single species models to end-to end ecosystem models the main experience of the group lies with the commonly used Ecopath with Ecosim (EwE) model, but is growing to include other modelling capabilities. The accessibility, relative ease of use and therefore availability of Ecopath models for the geographical range of the group was considered to be sufficient for further investigation. The group initially compiled a list of 29 documented Ecopath models within the geographical area of the group. The models however were built for different purposes, encompassed different periods (or none at all if not Ecosim), and had differing functional group descriptions. However, the different models are all attempts to capture the basic dynamics of the foodwebs in these areas and periods. Direct comparison remains difficult, but meta-analysis based on these remain a valuable possibility (Kolding *et al.*, 2015). The group discussed the possibility of a workshop to explore the practicalities of integrating information from these existing Ecopath models and exploring their utility towards informing IEA in the western shelf region. This initiative gave rise to the WKEWIEA workshop.

Synthesis of results for the ICES workshop on operational EwE models to inform IEAs (WKEWIEA)

Presented by Marian Torres (IEO-Spain)

The first Workshop on operational EwE models to inform IEAs (WKEWIEA), originated within the scope of the WGEAWESS, met from the 26th to the 30th of November 2018 in Barcelona, chaired by Maciej Tomczak (Sweden), Marian Torres (Spain) and Eider Andonegi (Spain). The main goal of WKEWIEA was to identify, analyse and provide light on the potential use of ecosystem models to inform the scientific advice currently provided by ICES. The workshop focused on Ecopath with Ecosim (EwE) models as accepted by ICES, since EwE is the most widely used ecosystem modelling tool across ICES IEA regional groups. Different works were shown during the workshop, some providing a general overview of the way EwE models have and/or are being used for solving management and policy related issues, some others showing practical examples on how existing models could be used to inform currently existing Ecosystem Overviews (EOs), etc. Additionally, interesting discussions arose about the need for a well-accepted and known protocol that establishes the basic requirements of these ecosystem models in order for them to be used to inform advice relating to fishing opportunities. The main recommendations provided by the WKEWIEA group to the ICES community are:

i. to develop a key-run and model quality protocol for using EwE models to inform IEAs and ICES advice (together with WGSAM);
ii. to adopt EwE and equivalent models in the ToRs of the ICES IEA regional groups;
iii. to engage relevant EG's to provide advice about indicators from EwE models to be use in IEAs to indicate the state of different ecosystem components;
iv. to seek EG's and Secretariat toprovide some guidelines about the visualization of trade-offs.

Additionally, WKEWIEA strongly recommended setting up a series of workshops to continue working on how to make EwE (and other ecosystem models) operational for ICES advice, starting for a next workshop in 2019 to deal with the intercomparability of EwE models to inform IEAs. Intersessional meeting will also be planned to organize our work and strengthen the links with other ICES WGs identified as key by the group for making our goal a reality in ICES.

Models in the WGEAWESS ecoregions

Different model approaches have been used for various purposes, developed under differing frameworks and therefore have different (usually project-based) objectives. However, they all can contribute to informing IEAs in the WGEAWESS ecoregions. Some of the modelling approaches developed by group members are outlined below.

<u>Celtic Seas</u>

Impact of ocean warming on sustainable fisheries management informs the Ecosystem Approach to Fisheries.

An integrated ecosystem model including fishing and the impact of rising temperatures, relative to species' thermal ranges, was used to assess the cumulative effect of future climate change and sustainable levels of fishing pressure on selected target species. Historically, important stocks of cod and whiting showed declining trends caused by high fisheries exploitation and strong top–

down control by their main predators (grey seals and saithe). In a no-change climate scenario these stocks recovered under sustainable management scenarios due to the cumulative effect of reduced fishing and predation mortalities cascading through the foodweb. However, rising temperature jeopardized boreal stenothermal species: causing severe declines in grey seals, cod, herring, and haddock, while eurythermal species were not affected. The positive effect of a higher optimum temperature for whiting, in parallel with declines of its predators such as seals and cod, resulted in a strong increase for this stock under rising temperature scenarios, indicating a possible change in the contribution of stocks to the overall catch by the end of the century. These results highlight the importance of including environmental change in the ecosystem approach to achieve sustainable fisheries management.

A Stepwise Fitting Procedure for automated fitting of Ecopath with Ecosim models.

The Stepwise Fitting Procedure automates testing of alternative hypotheses used for fitting Ecopath with Ecosim (EwE) models to observation reference data (Mackinson *et al.*, 2009). The calibration of EwE model predictions to observed data are important to evaluate any model that will be used for ecosystem based management. Thus far, the model fitting procedure in EwE has been carried out manually: a repetitive task involving setting >1000 specific individual searches to find the statistically 'best fit' model. The novel fitting procedure automates the manual procedure therefore producing accurate results and lets the modeller concentrate on investigating the 'best fit' model for ecological accuracy.

"Ecology for all": combining ecosystem modelling and serious gaming to aid transnational management of marine space.

The Maritime Spatial Planning (MSP) Platform Edition is a multiplayer serious game, built to provide stakeholders and maritime planners with insights into the diverse challenges and trade-offs of sustainable planning of human activities in marine and coastal areas. To improve its capabilities in representing the impacts of planning decisions on marine ecology, Ecospace, the spatial-temporal module of the Ecopath with Ecosim (EwE) foodweb modelling approach, was integrated into the MSP game environment. We here present this integration, and discuss how two existing EwE models were adapted to drive the ecology in the MSP games of the North Sea and the Firth of Clyde. Results show that integrating EwE models captures the interplay between fisheries, other marine uses, and ecosystem dynamics, with ecological realism, allowing MSP Platform Edition players to experience realistic management trade-offs between conservation and exploitation of marine resources. We discuss the lessons we learned during the development of these two first cases, and provide guidelines for future EwE integration efforts into MSP games. Finally, we discuss how scientifically informed serious games can translate into important training tools for managers and stakeholders, advancing their understanding on integrated ecosystem management, and ultimately, promoting a better-informed management of marine resources, especially across borders and in transboundary situations.

Irish Sea

In line with the ICES Strategic Plan to progress towards integrated ecosystem assessments and the ongoing process of the Benchmark Workshop on the ecosystem-based management of the main Irish Sea fish stocks (WKIrish), a need to develop multispecies modelling capabilities in the Irish Sea was identified. The combined use of Ecopath with Ecosim (Christensen *et al.*, 2008) and multispecies fish community modelling (Thorpe *et al.*, 2015) was advocated as suitable for this purpose. Much of the data needed to populate these models are readily available in the literature, however, as with most complex ecosystem models, data collected for non-commercial species is not always as extensive as data collected for commercial species. The aim of the EwE model was to investigate the drivers surrounding the dynamics of commercially important species in the

Irish Sea. Cod, haddock, plaice, whiting, sole, herring, and *Nephrops* have been included as individual functional groups.

The model is hoped to inform future management, by helping to understand why cod, and other stocks, have acted as observed. Further questions that may be explored:

- Are stocks slow to recover due to trophic dynamics?
- Are they still being overexploited by anthropogenic means despite efforts?
- Has the increasing temperature of the Irish Sea, or any other environmental driver, influenced the behaviour of the Irish Sea foodweb?
- Modelling the foodweb in the Irish Sea in the context of a depleted commercial fish community

The Irish Sea Ecopath with Ecosim foodweb model

Presented by:
Jacob Bentley, *Scottish Association for Marine Science*
Co-authors:
Sheila J.J. Heymans, *European Marine Board*
David Reid, *Marine Institute*
Clive Fox, *Scottish Association for Marine Science*
Natalia Serpetti, *Scottish Association for Marine Science*
David Hines, *University of North Carolina Wilmington*
Stuart Borrett, *University of North Carolina Wilmington*

Under WKIrish (ICES 2015), Ecopath with Ecosim (EwE) was used to construct a foodweb model of the Irish Sea Ecosystem representative of 1973, aiming to underpin the drivers of ecosystem change to inform integrated ecosystem assessment. The modelled foodweb includes 41 functional groups, ranging from detritus and plankton to seabirds and mammals, with a well-defined fish component. (**Figure 2.4.1**). The model's diet matrix was constructed using information held in DAPSTOM (integrated DAtabase and Portal for fish STOMach records) (Pinnegar, 2014) for fish functional groups, and from scientific literature for the mammal, seabird and invertebrate groups. Diet information was also added based on knowledge provided during WKIrish4, where stakeholders designed individual foodwebs for cod, haddock, plaice, *Nephrops*, rays and whiting. We followed recommended best practice methods (Heymans *et al.*, 2016) and ecological rules of thumb (Link, 2010) for ensuring that ecological realism was maintained in the models structure and function. The Irish Sea model includes eight fishing fleets (beam trawl, otter trawl, *Nephrops* trawl, pelagic nets, gillnets, pots, dredge, and longlines) which reflect those deemed most important by fishers during the WKIrish4 workshop. Landings and discards for 1973 were allocated to fleets using data from ICES and the Scientific, Technical and Economic Committee for Fisheries (STECF). For an in-depth description of the methods and parameters used to build the Irish Sea Ecopath model, see the published technical report (Bentley *et al.*, 2018a).

Ecological indicators

The Ecopath model of the Irish Sea has been used to develop state indicators which reflect the structure and function of the foodweb (Bentley *et al.*, 2019a). During this process we designed a new approach which incorporates diet uncertainty into the estimation of indicators, enabling stronger ecological inferences which are crucial to management (**Figure 2.4.2**).

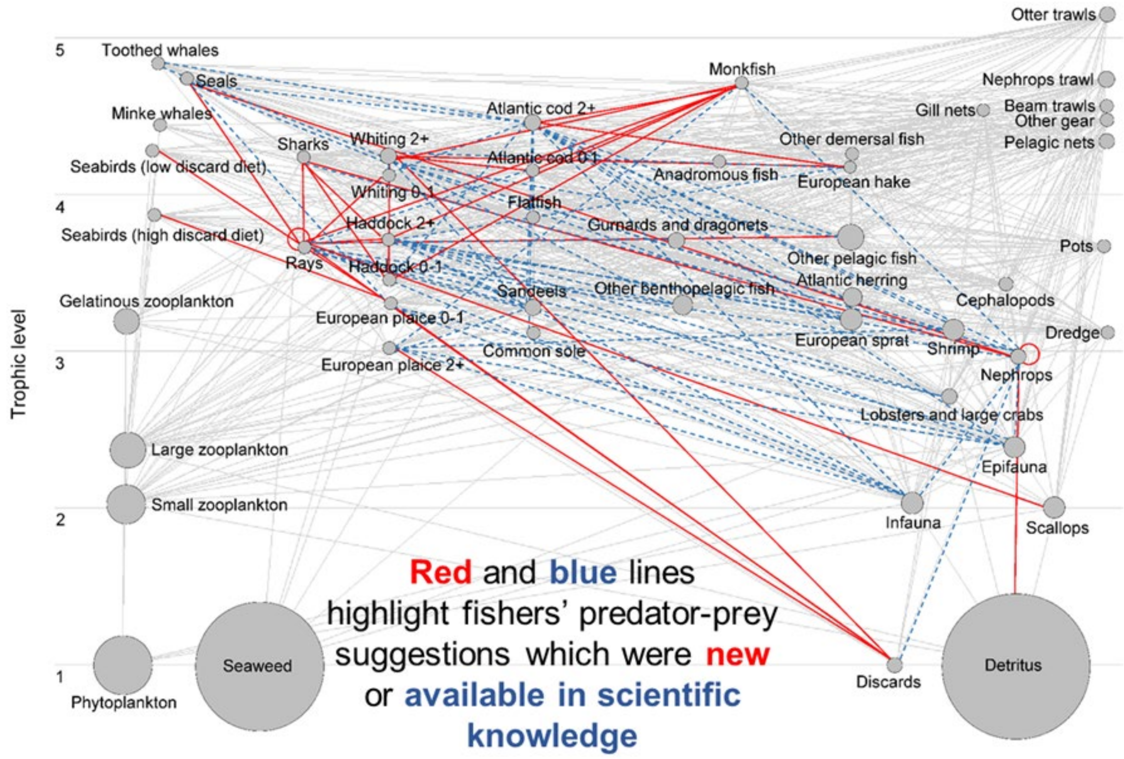


Figure 2.4.1. Energy flow and biomass diagram for the Irish Sea Ecopath foodweb model. Functional groups and fleets are represented by nodes, the relative size of which denotes their estimated biomass in the ecosystem in 1973. Lines represent the flow of energy and the y-axis denotes the trophic level.

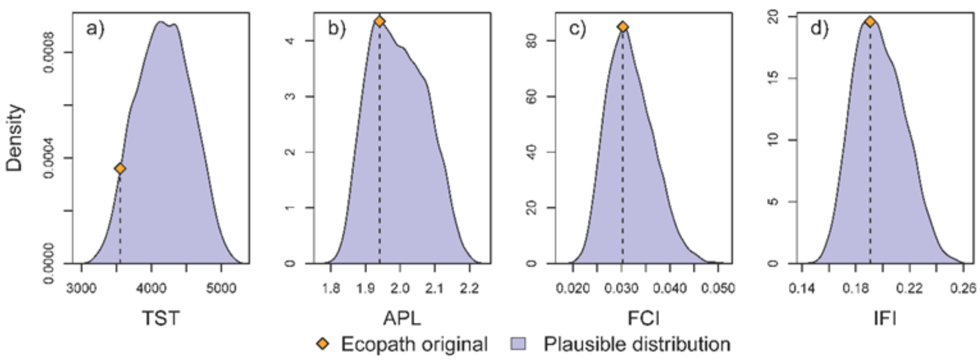


Figure 2.4.2. Probability density plots showing original estimates and distributions of foodweb indicators for the Irish Sea using data guided uncertainty: (a) Total system throughput (TST), (b) Average path length (APL), (c) Finns Cycling Index (FCI) and (d) Indirect Flow Intensity (IFI). ***Figure taken from Bentley et al., (2018b)*****.**

Ecosim

The Ecosim model of the Irish Sea runs from 1973 to 2016. To affect a change in the biomass and catch trends of functional groups over time, the model requires time-series of drivers, such as fishing effort, fishing mortality or environmental change. Ideally, each fishing fleet will have its own effort time-series but available series covering the full extent of the model were only available for three of the eight fleets: beam trawl, otter trawl, and *Nephrops* trawl. During WKIrish4 stakeholders provided effort trends for beam trawl, otter trawl, *Nephrops* trawl, pelagic net, gill-net, pot, dredge and longline fleets. The fishing effort trends fishers provided showed good agreement with scientific estimates for vessels using beam trawl, otter trawl, *Nephrops* trawl and pelagic gears. Fishers trends were drawn on an arbitrary scale, therefore a Bayesian methodology was developed to optimize the magnitudes of change across the effort time-series whilst retaining their trends (Bentley 2019b). Following this, the model performed best when driven by a combination of trends from data (beam trawl, otter trawl, *Nephrops* trawl) and stakeholder's knowledge (pots, pelagic nets, gillnets, dredge, longline) (**Figure 2.4.3**).

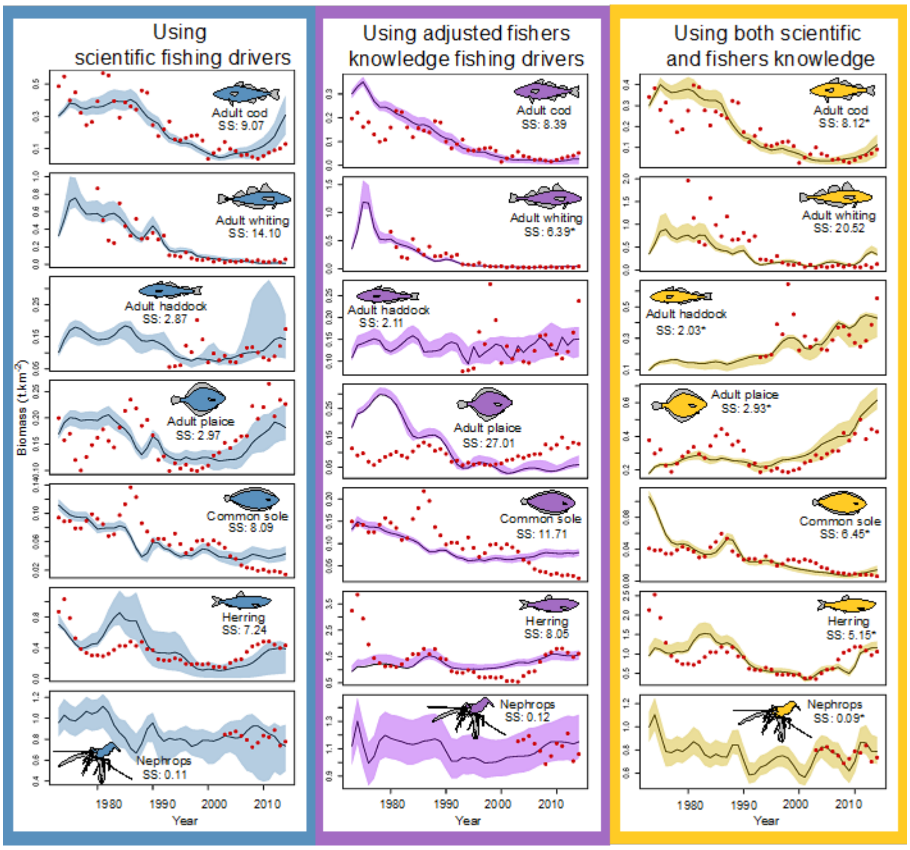


Figure 2.4.3. Biomass trends for the commercially important stocks in the Irish Sea EwE model. Solid lines indicate model predictions and dots represent observed data. Predictions are surrounded by 95% confidence intervals calculated using a Monte Carlo approach, generating 1,000 models within the range of plausible input estimates. Model predictions were generated using four sources of fishing effort data: 1) Scientific knowledge, 2) fishers' knowledge, and 3) hybrid knowledge.

Ongoing work

Through a fitting procedure the model estimated a primary production anomaly for phytoplankton to improve the statistical fit of simulated trends to observed data. The trend estimated for the Irish Sea model negatively correlated with the winter North Atlantic Oscillation Index (NAOw). It was raised at WKIrish5 that the assumption of NAOw having an impact on phytoplankton was unsubstantiated. Therefore, ongoing work is using Pearson's correlation analyses, corrected for autocorrelation, to identify correlations between large-scale climatic drivers (AMO, NAO), temperature, primary and secondary productivity, and fish recruitment in the Irish Sea. Using a hypothesis driven approach, external drivers will be more systematically incorporated into the Irish Sea model to retrospectively identify the direct and indirect impact of environmental change on the dynamics of Irish Sea commercial stocks.

Products available from the Irish Sea model for IEA

Below are a series of data products which are available from the Irish Sea EwE model (and others) which may support IEA. It is preferable that data products are taken from models which have an ICES key-run (WGSAM). The Irish Sea model is scheduled to undergo this process in October 2019.

- Foodweb overviews and quantitative descriptions

- Foodweb indicators (ecosystem function and species dependencies)
- Reconstructed time-series for Integrated Trend Analysis (ITA)
- Retrospective analyses and ecosystem forecasts (climate change)

Ecosystem indicators to inform quota setting ***(stemming from WKIrish5-report and WKEW-IEA discussion)***

Ecosystem models quantify the cumulative impact of fishing and system productivity on stock trends, often concluding that it is a combination of both which drive stock dynamics. It would therefore be valuable to find ways to incorporate indicators of system productivity into the quota setting advice process. As discussed by WKIrish, ecosystem information could be used to suggest where to sit within the F_{MSY}range. For example, if the ecosystem indicator is in positive phase, and the ecosystem information suggests this will not have a negative impact on other stocks, the advice should be to remain in the upper limit of F_{MSY}. Whereas if the ecosystem indicator is in negative phase, the advice should be to remain in the lower limit of F_{MSY} as a precautionary approach (**Figure 2.4.4**).

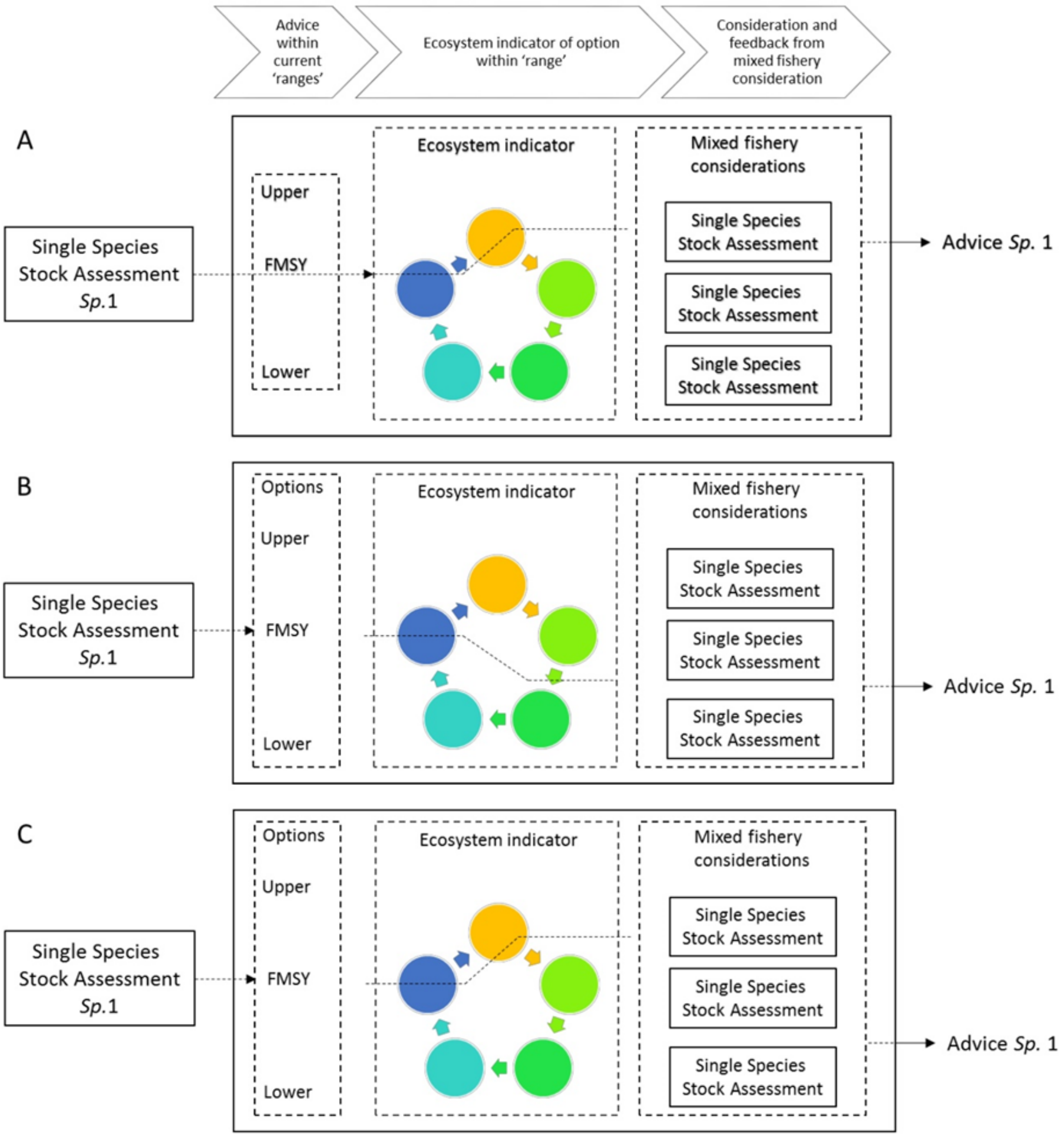


Figure 2.4.4. Ecosystem indicators to inform quota setting *(figure credit: Mathieu Lundy, WKIrish):*

A: Ecosystem indicator suggests upper part of range and mixed fishery consideration supports that thiswith not have a negative impact on other stocks: keep advice in 'upper range'.

B: Ecosystem indicator suggests lower part of range – should be used as a constraint in mixed fisheries assumptions: keep advice in 'lower range'.

C: Ecosystem indicator suggests upper part of range but mixed fishery consideration suggest this would negatively impact other stocks: shift advice to 'lower range'.

Northern Bay of Biscay (French region 8abd)

Integrated ecosystem assessment with a spatial mechanistic model (ISIS-Fish)

Presented byPierre Issac (Ifremer, France).

A framework and modelling tool for ecosystem assessment in the Bay of Biscay area (8ab) is under development, with the aim of providing stakeholders with relevant information for management purposes. As a first step, a network of the relevant ecosystem compartments (abiotic and human pressure effects on biota) will be built based on statistical analyses. Data mining methods (ITA based on MAFA, MFA) will be applied to empirically quantify the strength of the links between ecosystem components and to identify the main drivers of ecosystem dynamics. In a second step, a focus will be done on fisheries and their related ecosystem components. The relationships empirically corroborated will be modelled using ISIS-Fish (www.isis-fish.org) which is a spatially explicit mechanistic model that describes fishing activity (fleets, strategies and métiers) in relation to the dynamics of the target species and management. Two ISIS-Fish model are already existing in Bay of Biscay area 8a and 8b that describe respectively pelagic fleets (targeting anchovy, sardine, sea bass, and albacore tuna) and demersal fleets (targeting hake, Norway lobster, and sole). These models will be used jointly to investigate different management issues regarding interaction between fisheries, and between marine human activities, as well as environmental effects on fish and fisheries. In a third step, we will investigate the impacts of scenarios of change in management, climate conditions, and use of the marine space.

Foodweb-fisheries modelling in the Bay of Biscay

Presented by Verena Trenkel (IFREMER-France)

A statistical foodweb-fisheries model has been developed for the Bay of Biscay (ICES Division 8abd), Northeast Atlantic (Hosack and Trenkel 2019). The main objectives are to evaluate the structure of the foodweb and its changes over last 15 years (2000–2015) as well explore management scenarios for different fishery fleets. The model is a fully Bayesian multivariate Gompertz-style autoregressive state-space model with unknown biological, process uncertainty, catchability, and observation uncertainty parameters. The model was fit to various time-series (total landings, CPUE by broad gear class and survey indices). The model results suggest that the Bay of Biscay ecosystem exhibits very strong top–down density-dependent control, in particular by demersal piscivores, which have increased over the study period while all other functional groups remained more or less stable. However, the long-term stationary distribution is very uncertain. This uncertainty is probably a result of many model parameters and a relatively short time-series. Future work will involve exploring the sensitivity of results to model assumptions and running strategic management scenarios.

Ecosystem evaluation of the Bay of Biscay: Do landings exceed system productivity?

Presented by Verena Trenkel (IFREMER-France)

To assess whether fisheries exploitation in the ICES area met the ecosystem level management objective of maintaining overall productivity, historic landings of small species (<1 kg) by large marine ecosystem were compared with multispecies maximum sustainable yield (MMSY) reference levels (Trenkel, 2018). The MMSY values were estimated by Jennings and Collingridge (2015) using a size-spectrum model and several scenarios for the fishing exploitation pattern but only two scenarios were considered here. The results for the Bay of Biscay showed that landings might have reached the MMSY level in the early 1980s but probably never exceeded it since (Figure 2.4.5). However, it has to born in mind that the MMSY estimates were based on driving system productivity by chlorophyll concentrations and temperature for the years 2010–2012. Hence, the estimated MMSY values are suitable for recent years but might be less appropriate to the earlier period.

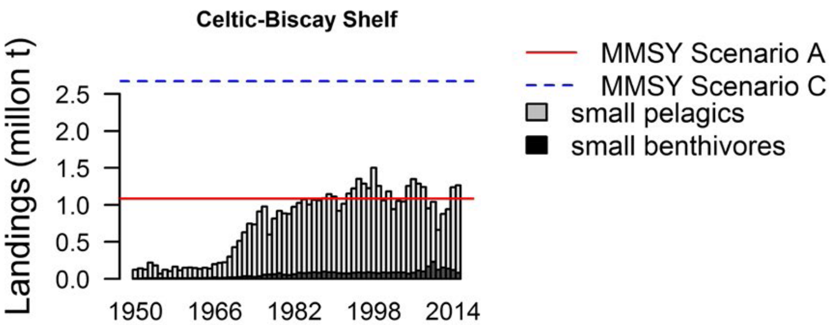


Figure 2.4.5.Comparison between historic landings of small species (< 1kg) in the Celtic Sea Bay of Biscay large marine ecosystem with multispecies maximum sustainable yield (MMSY) reference levels estimated by Jennings and Collingridge (2015) using a size-spectrum model and two scenarios for the fishing exploitation pattern.

MSFD approach for the ecosystem assessment in the Bay of Biscay.

Presented by Anik Brind'Amour (IFREMER-France)

The Marine Strategy Framework Directive (MSFD), adopted in June 2008, recommends Member States to adopt an ecosystem approach to manage the marine environment. By this directive, France aims to achieve a good environmental status (GES) described by 11 descriptors, of its marine waters by 2020. Descriptor 1 stipulates that biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic, and climate conditions (European Commission Decision 2017/848/UE). The ecosystem components of fish and cephalopods must be assessed in the four marine subregions ("English Channel – North Sea", "Celtic seas", "Bay of Biscay" and "Western Mediterranean"). The species groups assessed in this report are the demersal fish of sandy or muddy coastal areas, demersal and pelagic fish of the continental shelf, cephalopods of coastal areas and continental shelf, and fish and cephalopods of deep-sea waters. For the assessment of the species groups mentioned above, except for coastal and pelagic fish, the "Celtic seas" and "Bay of Biscay" marine subregions are united in one Assessment Geographical Unit (AGU) and the "Western Mediterranean" marine subregion is divided into two AGU: Gulf of Lion and Eastern Corsica.

The approach used to assess the GES of each species group in each marine subregion is based on the availability of data from scientific surveys conducted by Ifremer and scientific proven methods for identifying thresholds. This quantitative approach is implemented for criterion D1C2 related to the abundance of populations and to the group of demersal fish of the continental shelf for which sensitivity to fishing pressure is high. It is carried out at the population and community level. However, the beginning of monitoring devices matches with a period of high fishing intensity that does not allow referring to an initial situation without pressure. For the other species groups, criterion D1C2 is indicated by the results of the assessment of Descriptor 3 when stock assessments are available (i.e. D3 report; Foucher and Delaunay, 2018), this is the case of the pelagic fish of the continental shelf, or through a qualitative approach. For the other criteria, a qualitative assessment is proposed. The latter approach describes (albeit non-exhaustively) the state of scientific knowledge of those unassessed species groups. It also suggests future methodological developments, which will likely be used to inform the five criteria of the Descriptor 1 for the next assessments. The assessment of GES of the demersal fish populations of the continental shelf, using the criterion D1C2, indicates that among the 5 AGU, the "English Channel – North Sea", "Celtic Seas and bay of Biscay" and "Gulf of Lion" present populations that don't achieve GES. The number of populations is particularly important in the Gulf of Lion where 28% do not achieve GES. In addition, 30 to 50% of the populations are assessed in GES in all AGU.

The community approach, whose the results are consistent with the previous ones, indicates that the "English Channel – North Sea" AGU shows increasing signals of a return to GES since the 2000s. The populations qualified in GES have doubled since the beginning of the observation series, achieving 40–45% of the populations of sensitive species to the fishing pressure. In the "Celtic Seas and Bay of Biscay" AGU, the environmental status of the populations is stable over the period analysed but it is difficult to interpret that stability as no threshold value of GES formerly exists. Finally, the western Mediterranean with Corsica and the Gulf of Lion have respectively a stable state and a decrease of the number of populations in GES since the end of the nineties. However, in the Gulf of Lion, signals of a return to a GES are observed for the last MSFD cycle.

The qualitative approach highlights the main developments leading to future operational indicators for the next MSFD cycles. This includes work on the coastal demersal fish communities with the data provided by scientific surveys on nursery areas (D1C5), the ICES work on the size and age based on indicators of exploited fish stocks (D1C3), and research development on the geographical distribution of demersal and pelagic populations of the continental shelf (D1C4).

Portuguese waters

Using foodweb modelling to evaluate ecosystem effects of the crustacean trawl fishing in Portugal

Presented by Marian Torres (CCMAR-Portugal).

The first Ecopath model to evaluate ecosystem effects of the crustacean trawl fishing in the South and Southwestern continental coasts of Portugal (SSWPT) was presented by Maria A. Torres. This study is in the framework of the MINOUW Project (http://minouw-project.eu/) WP3 on impact assessment of minimizing unwanted catches and discarding.

The study area (ICES 9a) was modelled to represent the year 2000 covering 4000 km^2 at depths ranging from 200 to 700 m. A total of 34 functional groups were included in the model integrated into four trophic levels (TLs) with anglerfish and hake as top predators. The highest flows to detritus corresponded to the groups positioned at the base of the foodweb moving the energy to the upper TLs groups. The main insights underline strong exploitation by the fisheries on the target species. The keystone species/groups identified corresponded to both groups of cephalopods, rose shrimp and mackerels. The SSWPT network possesses a more web-like structure than chain-like with a large number of connections in the foodweb in line to the opportunistic feeding behaviour of deep-sea species. Those indices related to resilience showed that SSWPT ecosystem had in 2000 relatively low functional redundancy for potential use against natural hazards and environmental disturbances (33%).

The main gaps and limitations arose were discussed with the group associated to biomass underestimation for the demersal and benthic groups, scarce overall information of the benthic and lower TLs groups, local trophic studies and unreported and misreporting landings. Further development of the SSWPT model including temporal dynamic simulations were also introduced in compliance with the EU 'Landing Obligation' (LO). In particular, the main goal will be to evaluate the ecological consequences of using more selective fishing, by means of technical devices to reduce discards, on the SSWPT ecosystem. Similar fishing scenarios will be performed and further compared with the Bay of Biscay model in collaboration with Eider Andonegi to investigate if both ecosystems will respond similarly or differently to the LO implementation by exploring the Network Analysis and ecosystem indicators outputs.

An Ecosystem Approach to pelagic fisheries management in Portuguese continental waters – spatial perspective.

Presented by Dorota Szalaj, IPMA, Portugal.

The study presented an application of spatial method as a tool for an ecosystem approach to pelagic fisheries management in Portuguese continental waters. The objective was to combine geographic information systems (GIS) and Multi-criteria decision method in order to find a set of areas suitable to protect sardine essential habitats and at the same time maintain fisheries socio-economic efficiency.

To perform the analysis, a conceptual suitability model that consisted of 13 criteria was developed (Figure 2.4.6). To minimize negative impact on fishing activities and maintain conservation objectives, the criteria were divided into two parts: suitability (conservation related) and non-suitability (socio-economic related).

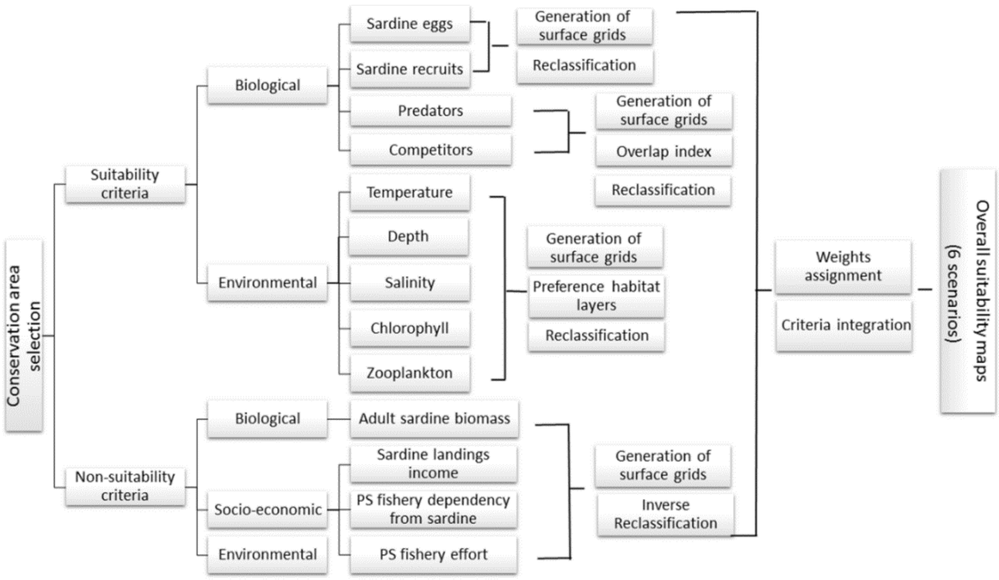


Figure 2.4.6. Methodology applied to combine Geographic Information System (GIS) and Multi-criteria Decision Method (MCDM) as a tool for an ecosystem approach to fisheries management.

Additionally, to represent holistic ecosystem approach, the criteria were grouped into three main dimensions: biological, environmental and socio-economic. The variables that represent criteria were standardized to uniform scale ranged from 1 to 5 where a score of 1 represents no suitability for protection and score 5 indicates high suitability. Weighted combination of all criteria resulted in the production of final suitability maps for 6 scenarios. Scenarios varied with magnitude of weight applied to conservation related criteria and socio-economic related criteria.

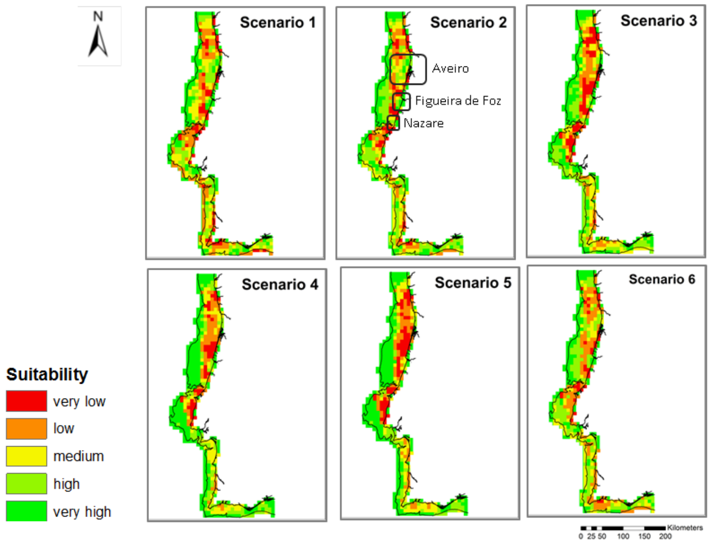


Figure 2.4.7. Final suitability maps produced for 6 scenarios that varied depends on weights applied. The areas selected indicate the areas that have the lowest trade-offs between conservation and fisheries.

Final suitability maps indicated three areas (offshore Aveiro, Figueira de Foz and Nazare) that consistently, across all scenarios, have the lowest trade-offs between conservation and fisheries (Figure 2.4.7). They might be of special interest as potential candidates in the process of conservation area selection. The spatial analysis was performed for the year 2009. In future it will be expanded to cover time range of 5 years (2005-2010).

An Ecopath mass balance model for the Portuguese upwelling ecosystem-

Presented by Maria de Fátima Borges, IPMA, Portugal.

An Ecopath mass-balance model was constructed for the Portuguese ecosystem (Veiga-Malta *et al.*, 2019) using mean biomass, mortality and diet composition data for 33 functional groups for the period 2006-2009. Biomass flows and transfer efficiencies were calculated for each trophic level. Niche overlap was calculated for potential sardine competitors and predators.

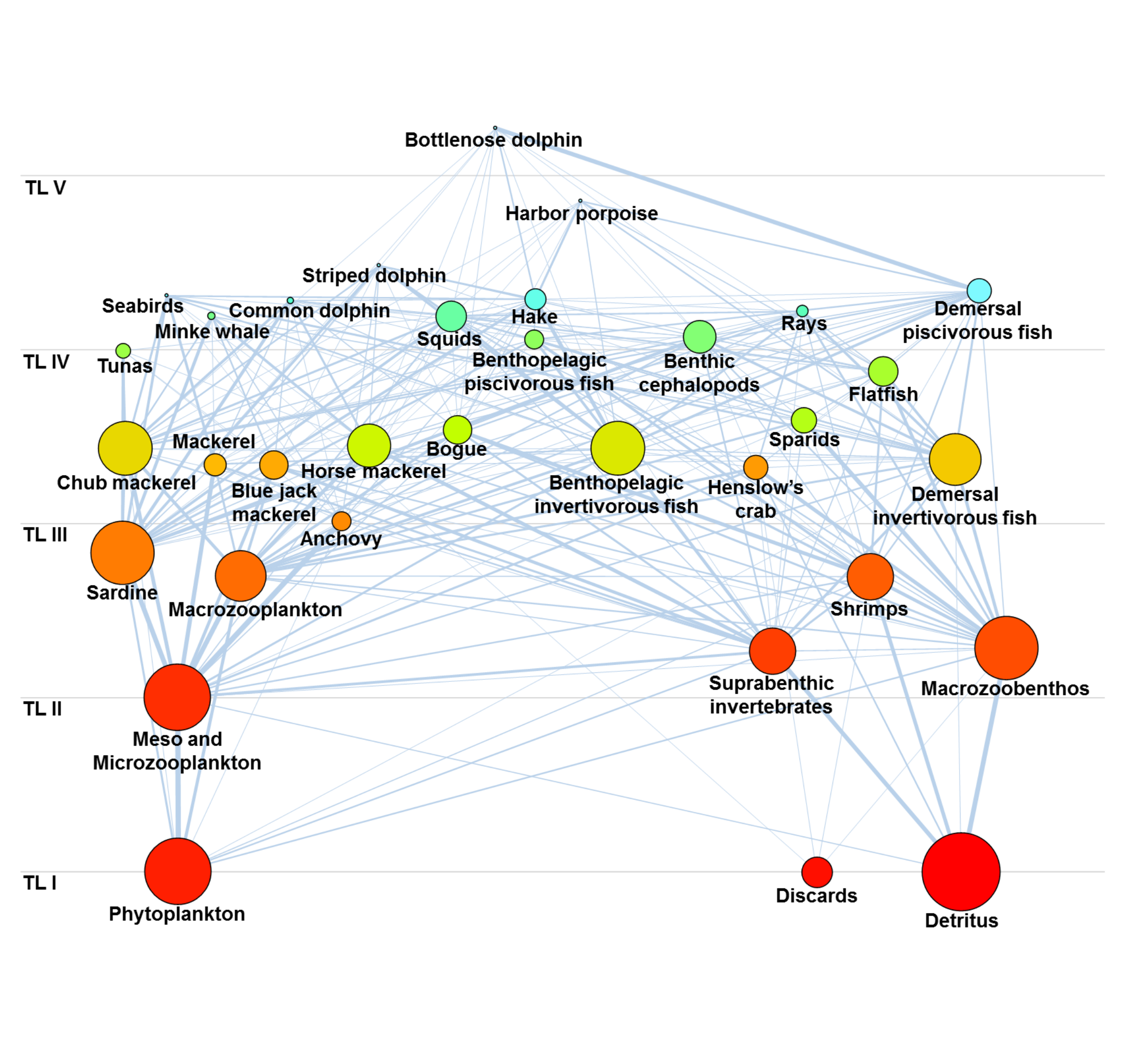


Figure 2.4.8. Trophic structure and energy flows in the western Iberian upwelling ecosystem.

Results indicate that this ecosystem is structured in pelagic demersal and benthic domains connected by small cetaceans, hake and squids. Low trophic levels (TL) groups like sardine, chub mackerel, horse mackerel, dominate over higher TL groups, nearly all flows take place from TL I to TL III which indicates a bottom up or wasp-waisted control of the ecosystem as expected in an upwelling system.

Foodweb dynamics in the Portuguese Continental Shelf ecosystem in 1986-2017: elucidating drivers responsible for sardine decline.

Presented by Dorota Szalaj, IPMA, Portugal.

The foodweb dynamics of Portuguese continental Shelf ecosystem (PCSE) was investigated using a dynamic module of Ecopath with Ecosim software.

In this study, static Ecopath model developed by Veiga-Malta *et al.* (2019) was adapted to 1986 in order to study Portuguese continental shelf ecosystem dynamics between 1986 and 2017.

This model includes 33 functional groups, integrated into 5 trophic levels from phytoplankton to top predators and it focuses mainly on pelagic component of the ecosystem, therefore it attempts to model pelagic groups separately

The main focus of this study was sardine and pelagic component of the ecosystem, motivated by the recent decline in sardine stock observed in the Iberian waters in last decade.

The main objectives of this study were to:

- explore the drivers needed to simulate the observed foodweb dynamics between 1986 and 2017 and
- assess future potential effects of fishing and key trophic interactions on sardine and ecosystem

The model was fitted to available time-series (from 1986 to 2017) and fitting procedure revealed that the main factors that explains the PCSE dynamics between 1986 and 2017 are fishing, trophic interactions and environmental factors (primary productivity anomaly) when considered jointly. They explained about 33% of variability in available time-series (improved model fit by 33% when compared to baseline). When considering sardine functional group separately, the same drivers were identified as the most important in explaining sardine trend between 1986 and 2017 (they explained 78% of sardine variability (improved sardine fit by 78% when compared to baseline)

Ecosim reproduced biomass trends well for several species including sardine, anchovy, horse mackerel, mackerel, sparids, hake, bogue and rays Also, many catch time -series were reproduced well by the model e.g. for mackerel, chub mackerel, rays, bentho-pelagic piscivorous fish, bogue, sparids and flatfish

The key sardine trophic interactions were identified by testing various hypothesis about flow control: top down, bottom up and mixed for sardine direct trophic interactions. (This procedure allows to assess which are the key interactions that help to explain sardine variability (contribute the most to sardine fit improvement that is assessed by the reduction in sardine sum of squared deviations (SS)). Key sardine trophic interaction identified were predators on juvenile sardine (exactly on sardine eggs): chub mackerel, horse mackerel, bogue and predator on adult sardine hake (their top down (in case of chub mackerel, horse mackerel and bogue) and bottom up (in case of hake) control over sardine allows for the highest improvement in sardine fit).

(In the model the predation on juvenile sardine included predation on sardine eggs)

Further in order to investigate the factors influencing decline of sardine stock in PCSE two types of scenarios were performed:

1) concerning different levels of fishing effort on sardine and

2) examine effects of increased biomass of sardine predators (elucidated in the analysis as key predators) on sardine.

Adopting various fishing activity scenarios on sardine, highlighted that fishing at the status quo or even at MSY (decrease 25% decrease of current fishing mortality (F)) would not enable sardine stock to recover. Only decrease of 50% and above of current fishing level is required in order to recover sardine stock.

Adopting various fishing activity scenarios on sardine, highlighted that fishing at the status quo or even at MSY (decrease 25% decrease of current fishing mortality (F)) would not enable sardine stock to recover. Only decrease of 50% and above of current fishing level is required in order to recover sardine stock to the state in 1986.

The important impact of chub mackerel and horse mackerel predation on sardine eggs was further confirmed by future projections scenarios when increase in biomass of these predators caused significant decline in sardine biomass in future.

- Main factors that drives the PCSE dynamics between 1986 and 2017 are fishing, trophic interactions and environmental factors (pp anomaly).
- The same factors are responsible for sardine decline in PCSE

- Key sardine trophic interactions were identified: chub mackerel, horse mackerel, bogue and hake
- The important impact of chub mackerel and horse mackerel predation on sardine was further confirmed by future projections scenarios

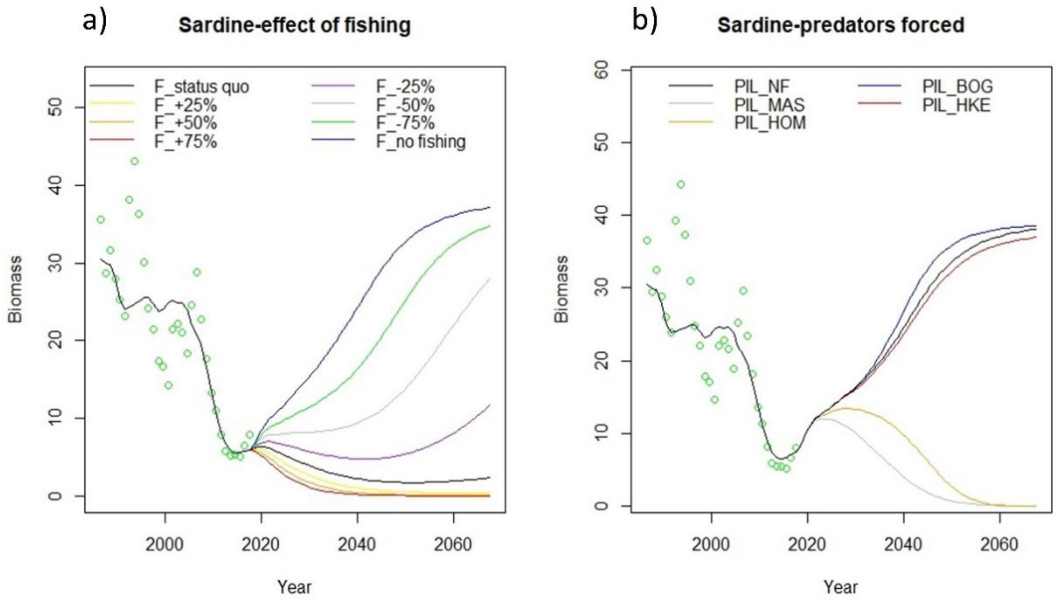


Figure 2.4.9. Results of future projection scenarios that simulate: a) effects of various fishing levels on sardine; b) impacts of key sardine predators forced biomass (increase in predators' biomass) on sardine (where PIL_NF is sardine biomass under no change in predators biomass (no forced); PIL_MAS, PIL_HOM, PIL_BOG, PIL_HKE is sardine biomass under chub mackerel, horse mackerel, bogue, and hake biomass forced respectively.

Gulf of Cadiz

Conceptualization of the Guadalquivir estuary – Gulf of Cadiz socio-ecosystem

A conceptualization of the Guadalquivir estuary – Gulf of Cadiz (GoC-Ge) socio-ecosystem was first carried out as a scoping exercise (Llope, 2017). This study described the GoC-Ge main characteristics, high-level policy goals and the jurisdictional framework, sectors involved, pressures and risks of their activities, as well as reviewed the major events in recent history, current situation and prospects for developing an ecosystem-based style of management.

The socio-ecosystem of the GoC is characterized by a clear focal ecosystem component—the role of the estuary of the Guadalquivir River as a nursery area—that has an influence on the marine ecosystem and at the same time concentrates a number of sectoral human activities (Figure 2.4.10). This nursery role particularly concerns the anchovy fishery, which is the most economically and culturally important fishery in the region. The particularities of the Guadalquivir socio-ecosystem, with an area of influence that extends as far as the city of Seville, requires the consideration of multiple sectors and the corresponding conflicting interests. These include the shipping and tourism sectors, the agriculture, aquaculture, salt and mining industries, and the fisheries and conservation interests.

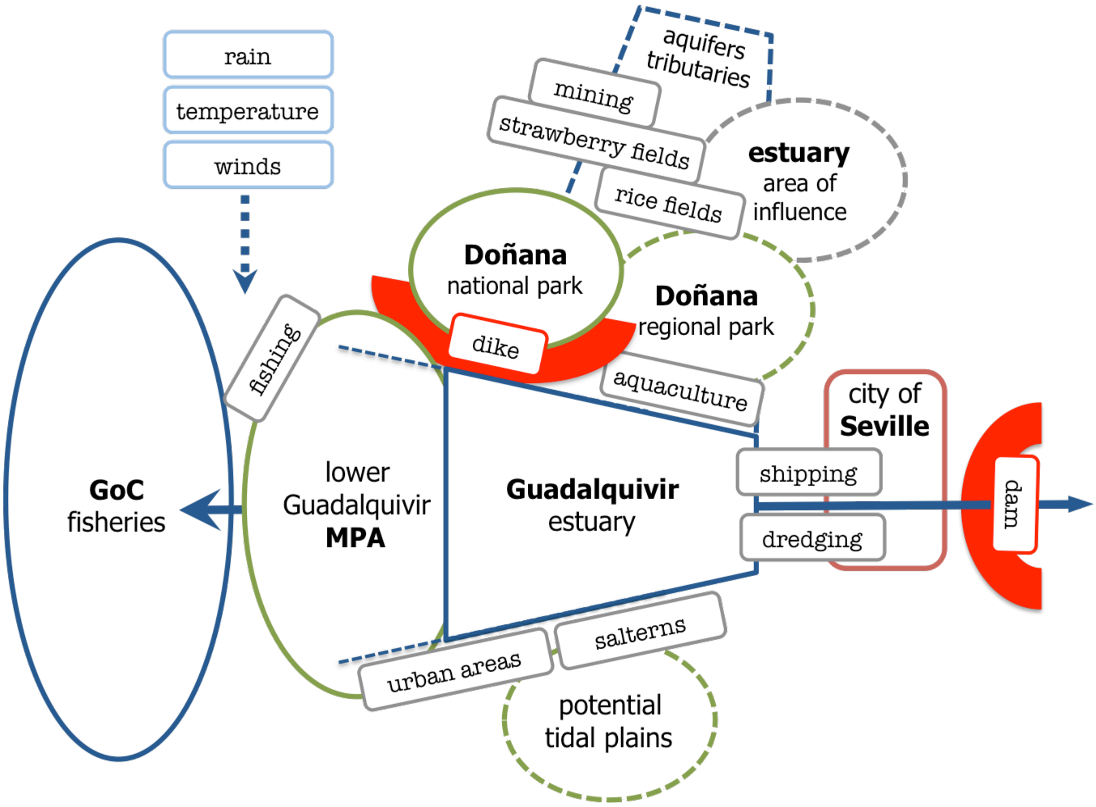


Figure 2.4.10. Conceptualized ecosystem. The horizontal blue arrow represents the estuarine gradient, from the lower Guadalquivir MPA to the upper end beyond the city of Seville. Major infrastructures (dike and dam) are shown in red. Sectors whose activities have consequences through tributaries (mining), aquifers (strawberries) or directly on the freshwater flow (rice) are piled up on the upper side. Activities occupying potential tidal plains (aquaculture, salt production, urban areas) are placed on the estuary. Diffuse infrastructures and risks (dredging, shipping) are shown close to Seville. Non manageable environmental factors (rain, temperature and winds) are shown between the sea and the estuary. This diagram appears in Llope (2017) as Figure 3.

Three main visions of the ecosystem have been identified and their conflicting interests described (Figure 2.4.11): (1) The canal vision conceives the estuary as a navigable waterway to the city of Seville. This vision would favour commercial shipping and tourist cruises. It would be compatible with urban development, mining and hydropower generation but confronted by the alternative visions, legislation and policy statements. (2) The land uses vision perceives the estuary as a productive asset. It challenges the dredging and mining activities and would like to see the frequency and intensity of high turbidity events reduced. It would be in conflict with the healthy ecosystem vision to some extent. (3) Finally, the healthy ecosystem vision conceives the estuary as a degraded and threatened ecosystem that must enhance its functionality and biodiversity. It is in synchrony with the local, national and international legislative frameworks. This vision could be shared to a large extent by both the conservation and fishing sectors. It could, however, collide with some uses and practices developed by the agriculture, aquaculture and salt industries and totally clashes with the canal vision.

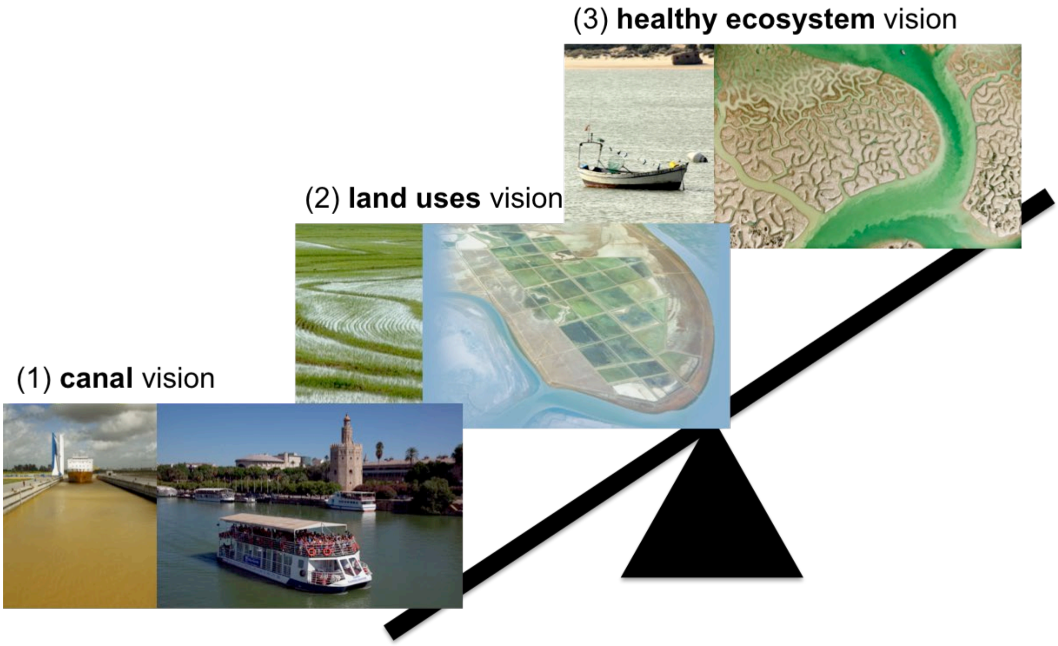


Figure 2.4.11. Balance diagram illustrating the three visions of the system: (1) canal, (2) land uses and (3) healthy ecosystem. This is Figure 4 in Llope (2017).

Despite the complexity of this socio-ecological system much of it converges in two water properties, salinity and turbidity. These two metrics affect anchovy juveniles and larvae (and eventually its fishery) and are of concern to agriculture uses. High turbidity and low salinity have a negative effect on the nursery role while high turbidity and high salinity have detrimental effects for rice production. These two water properties are affected by the timing, frequency, volume and type of discharges and hence, subject to management. Roughly, high discharges reduce salinity posing a trade-off between agriculture and fisheries. There exists enough scientific knowledge based on historical time-series and salinity and turbidity are currently monitored on real time. For these reasons they stand out as candidate indicators. One of the conclusions of the work was that the definition of reference points to these indicators could serve to reconcile multi-sectoral management decisions, basically visions 2 and 3 described earlier (Figure 2.4.10).

Process understanding

Despite their importance of the Guadalquivir estuary (and adjacent waters) for completing the life cycle of some fish stocks, little was known about how early stages of these species responded to changes within the estuarine environment. To increase our understanding of the terrestrial-marine inter-connection in the GoC we investigated the role of the Guadalquivir estuary (Ge) as an essential fish habitat (EFH).

By analysing an 18-year time-series of European anchovy (*Engraulis encrasicolus*) larvae and juveniles and 3 mysid species, we quantified the effects of both natural and anthropogenic factors on the early stages of this small pelagic fish and its prey. Of the factors assessed, freshwater discharges and turbidity —both influenced by human activities— showed a remarkable effect on the abundance of anchovy. Natural environmental variables such as temperature, salinity, winds and prey abundance were also important. The relationship between anchovy and mysids suggests that the Guadalquivir foodweb is predominantly resource-driven and that indirect environmental effects can cascade up through a web of interactions. Based on these databases and analyses we conceptualised the anchovy early stages foodweb at the Guadalquivir EFH (Figure 2.4.12).

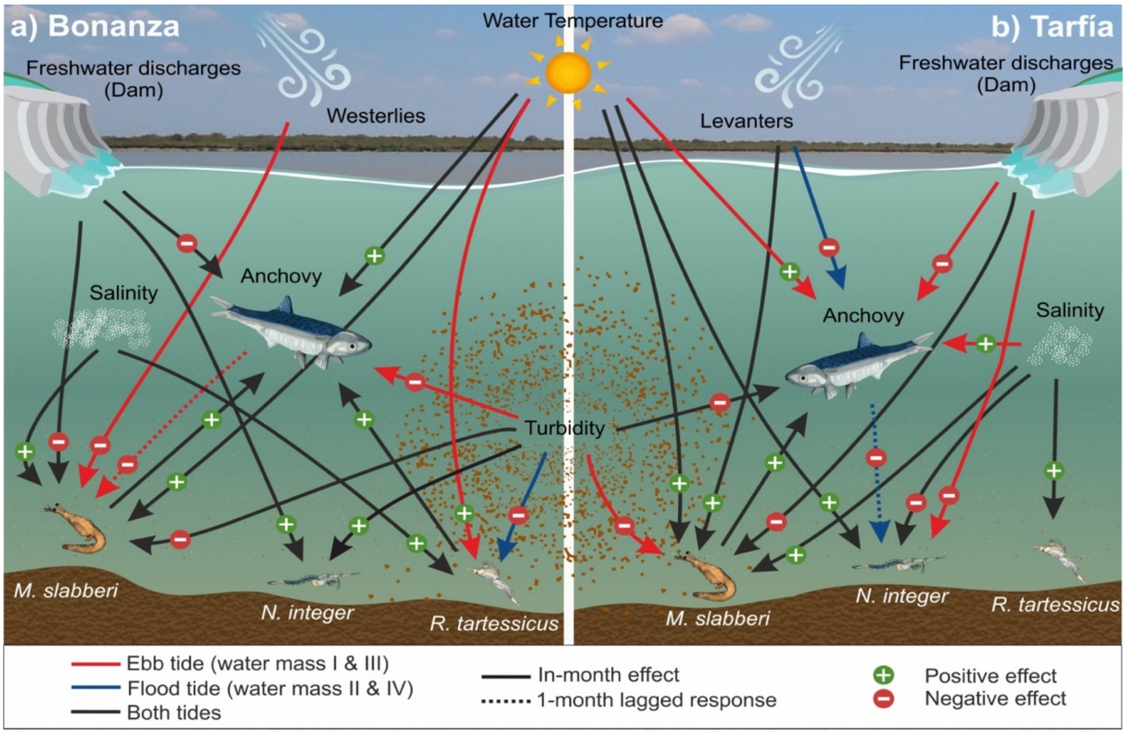


Figure 2.4.12. Significant interactions modelled between anchovy, mysids and environmental drivers along the Guadalquivir estuary in (a) the outer (I and II) and (b) inner water masses (III and IV). Figure 6 in de Carvalho-Souza *et al.* (2019).

In an attempt to assess the nursery role of this EFH we illustrated the development of the estuary over the last 18 years by means of a colour scale, in a similar fashion to a traffic light plot but assigning the colour codes based on the effect of turbidity and discharge on anchovy abundance (Figure 2.4.11)

We can see that on average, turbidity conditions have not improved in recent years and have oscillated between yellow and red (indicating a poor status) since 2008. The 2004–2006 (outer water masses) and 2001–2002 (inner water masses) periods stand out for their good status (green). Two high and persistent turbidity events in 1999–2000 and 2007–2009 are marked as orange/ red, indicating very bad ecological status. Freshwater discharges followed a comparable trend to that of turbidity.

From a seasonal perspective, the most important months are those from May to November, when anchovy (and mysid) densities are at their highest. There seems to be a positive relationship between discharge and turbidity, with the winter months being more turbid and more impacted by discharges (yellow to red) than the spring–summer period (green–yellow, Figure 8). Although this (mean) seasonal pattern does not seem to be too detrimental to the nursery function, there is room for improvement. The slightly negative (yellow) months could possibly improve (to green) if these considerations were taken into account when managing the dam.

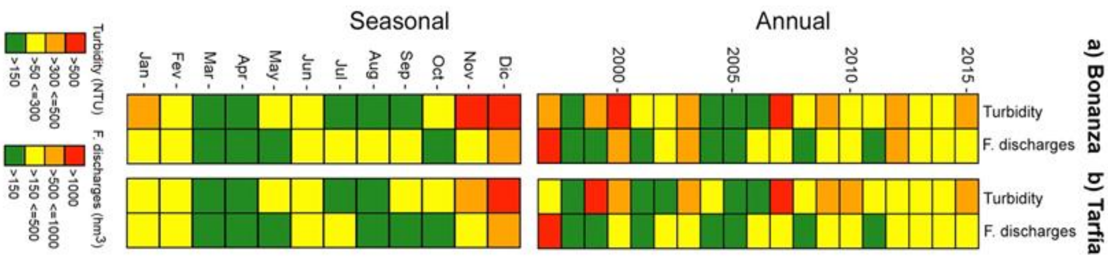


Figure 2.4.13. Annual and seasonal classification of turbidity and freshwater (F.) discharges in (a) the outer (Bonanza station) and (b) inner (Tarfía station) water masses according to the reference points estimated by the models. The scale

is composed of 4 categories: green if the effect is null or positive, yellow: slightly negative, orange: negative, red: extreme values (e.g. high and persistent turbidity events). Figure 7 in de Carvalho-Souza *et al.* (2019).

Since the human-influenced variables are to some extent managed, an ecosystem approach to fisheries management should consider the implications these may have in terms of maintaining a healthy EFH beyond the needs of the rice agriculture sector.

As mentioned above, in an attempt to facilitate dialogue between IEA and stock assessment groups, these results, together with the anchovy species card summarizing the environmental information relevant to the ecology of this species and life cycle, were presented at WGHANSA 2017, which is the ICES stock assessment group responsible for the GoC anchovy stock (ICES 9a).

Future directions

Work in the coming years should focus on assessing socio-economic aspects, which so far have only been scoped. A qualitative or quantitative quantification of trade-offs between human activities feels necessary to support and make headway in EBM. Figure 2.4.14 illustrates an EBFM conceptualisation of the GoC anchovy fishery, which is an expansion of the estuarine foodweb showed in Figure 2.4.12.

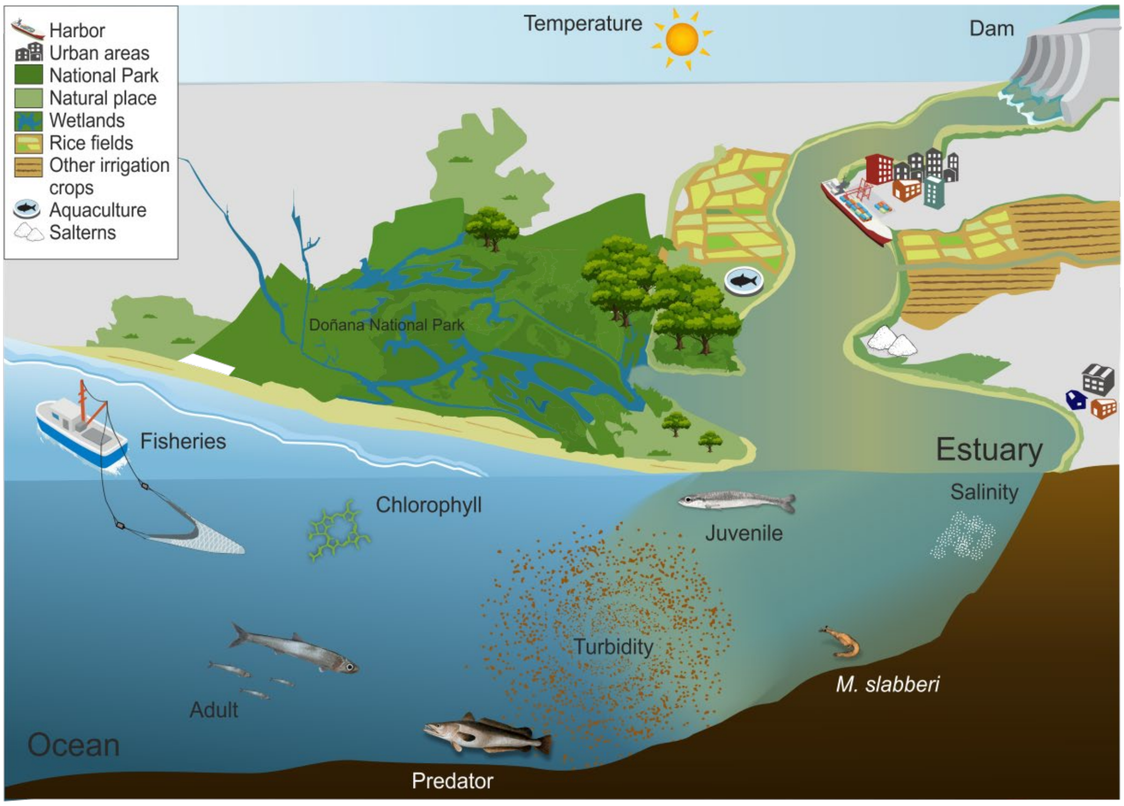


Figure 2.4.13. Main sectors, environmental drivers and processes that should be assessed in order to make progress in EBFM of the anchovy fishery in the GoC.

2.5 ToR e) Development of Interreg Atlantic Area proposal

The WGEAWESS team put together a consortium to apply for Atlantic Area Interreg funding for the AtlantEA project to help to fund the ambitions of the group in relation to advancing and applying EBFM and creating comparable IEAs across the Atlantic ecoregions covered by the group. Much of the work by the members of the group in 2017 was focused on ToR e). The group were successful in reaching stage 2 of the process with our proposal that aimed to make significant progress towards the implementation of an IEA approach within the Western European Shelf Seas. The proposal was structured following the goals of WGEAWESS, so that each of the WPs corresponded to one of the ToRs, with additional WPs included to assure the objectives of the INTERREG call (Figure 2.5.1). The idea was to use develop a common framework using similar techniques/tools as applied in WGEAWESS (ODEMM, ITAs, EwE-Ecospace), but to further develop and link them into an IEA framework, whilst using regional knowledge through stakeholder engagement to ensure regional relevance. The core group of the proposal was composed by WGEAWESS members, who were leading different work packages depending on their expertise in the group, and additional partners were recruited to enhance/complement capabilities, both within the project and the WG.

The proposal was ultimately unsuccessful in 2017, and so in the 2018 group meeting a session was dedicated to reviewing the proposal, in light of the received feedback received, before agreeing to resubmit. Comments received from the proposal reviewers and national contact points were taken as basis of this brainstorming, and the workplan was streamlined. The resubmission process was again time-consuming and despite the hard work of the EG in putting together both proposals, unfortunately we were not successful. Despite requesting feedback for the second submission, it was not forthcoming, neither were scores provided. As such, the consortium decided to close this ToR, with a view to perhaps revisiting should alternative suitable funding opportunities arise in future.

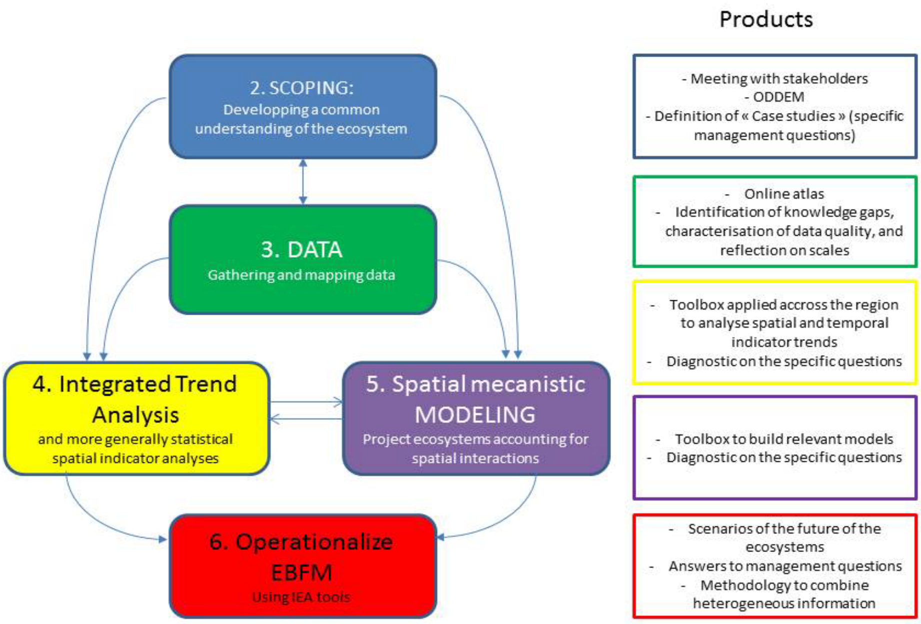


Figure 2.5.1.Conceptual diagram of AtlantEA proposal showing main work packages and operational outputs (products).

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Annex 1: List of participants

Participant	Affiliation	E-mail address	Country	Attendance (dark green= attended, light green = by correspondence)		
				2017	2018	2019
Eider Andonegi	AZTI	eandonegi@azti.es	Spain			
Marcos Llope	IEO-Cadiz	marcos.llope@ieo.es	Spain			
Debbi Pedreschi	MI	Debbi.Pedreschi@Marine.ie	Ireland			
Dave Reid	MI	david.reid@marine.ie	Ireland			
Maria Fatima Borges	IPMA	mfborges@ipma.pt	Portugal			
Steven Beggs	AFBI	Steven.Beggs@afbini.gov.uk	UK			
Marian Torres	IEO-	marian.torres@ieo.es	Spain			
Margarita Maria Rincon Hidalgo	CSIC	margarita.rincon@csic.es	Spain			
Dorota Szalaj	IPMA	dszalaj@fc.ul.pt	Portugal			
Natalia Serpetti	SAMS	Natalia.Serpetti@sams.ac.uk	UK			
Jacob Bentley	SAMS	Jacob.Bentley@sams.ac.uk	UK			
Clive Fox	SAMS	Clive.Fox@sams.ac.uk	UK			
Morgane Travers	IFREMER	Morgane.Travers@ifremer.fr	France			
Pascal Laffargue	IFREMER	Pascal.Laffargue@ifremer.fr	France			
Mathieu Doray	IFREMER	mathieu.doray@ifremer.fr	France			
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Izaskun Preciado	IEO-Santan.	izaskun.preciado@ieo.es	Spain			
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Daniel Howell	IMR	daniel.howell@hi.no	Norway			

Annex 2: New Resolutions 2020-2022 – Draft

Working group meeting draft resolution for fixed-term working groups (Category 2)

The **Working Group on Ecosystem Assessment of Western European Shelf Seas** (WGEAWESS) chaired by Marcos Llope, Spain and Debbi Pedreschi, Ireland and Eider Andonegi, Spain (outgoing), will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2020	16-20 march TBC	Palermo, Italy with WGCOMEDA	Interim report by Date Month May to SSGXXX	
Year 2021		Galway, Ireland	Interim report by Date Month May to SSGXXX	
Year 2022		Canaries?	Final report by Date Month May to SSGXXX	

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
a	Review and update the Bay of Biscay/Iberian Waters (BoB-IW) and Celtic Seas (CS) ecoregion Ecosystem Overviews (EO).	Linked to ICES advice and WKEO3.	6.1, 6.5, 6.6	Ongoing	Ecosystem overviews (EO).
b	Compare and contrast among sub-ecoregion level ITAs to identify and report on commonalities and divergences among areas, with a focus on climate variability.	Responding to requests for standardization of ecosystem advice products and inclusion of climate change information in Ecosystem Overviews. Linked to WKINTRA, WGS2D, WGOOFE and the commitment to provide advice in the context of EAFM.	1.4, 1.9, 6.5	3 years	Inform IEAs/E O. Results in the final report or/and as a collaborative paper.
c	Investigate and report on the sub-regional spatio-temporal entities constituting the Bay of Biscay/Iberian Waters and Celtic Seas ecoregion, and the multiple pressures relevant at these scales	Linked to WKEWIEA, WKIRISH, ToR B and previous group ToRs. Investigation of scaling issues related to summarizing information from locally relevant scales/models.	1.3, 2.4, 6.5	3 years	Inform IEAs/EO. Results in the final report or/and as a collaborative paper.

	in support of ecosystem-based management.				
d	Explore and describe the potential for incorporating additional products (e.g. MSFD indicators, model outputs, social indicators) from ICES EGs and other processes (e.g. OSPAR, EEA, STECF) into the Ecosystem Overviews	Strongly linked to ToR A, WGCERP, WGSOCIAL, WKEO3 and MSFD. Maximizing efficiency across relevant groups for EO development, eliminating redundancy.	4.1, 6.5, 6.6	3 years	**Ecosystem overviews. Collaborative network with improved workflow.**
e	High resolution Ecospace models for selected case studies within WGEAWESS ecoregions to identify opportunities to support marine spatial planning.	Working together with ToR C to explicitly incorporate spatial aspects into regional modelling work, investigating opportunities for trade-off analyses and inclusion of socio-economic considerations	6.1., 6.3., 6.6	3 years	**Regional modelling prodcuts**

Summary of the Work Plan

Year 1	The main tasks will be related to drafting the outline for the papers/process for ToRs B&C, and identifying which group members can apply the agreed upon methodology (within their limited resources). Start the process for reviewing the BoB-IW Ecosystem Overviews. The group will continue to identify data and outputs that may be potentially valuable to IEAs, EAFM, and particularly the Ecosystem overviews (Tors A, D& E). The group will work to improve communication with other relevant groups (e.g. WGS2D, WGOOFE, WGSOCIAL, WGCOMEDA, WGIAB, WGMARS, WGBIE, WGIPEM).
Year 2	Continue with Year 1 activities while liaising with relevant ICES WG and external groups (e.g. OSPAR) as relevant. Progress agreed upon methodologies for ToRs B&C, write papers. Advance ToR E, developing regional models (scope of model development/ number of case studies will be dependent funding).
Year 3	Continue with Year 2 activities while liaising with relevant ICES WG membership. Finalize papers.

Annex 3: List of Outcomes and Achievements (2016-2019)

Publications by group members related to the work of the group:

Baudron, A.R., **Serpetti, N.,** Fallon, N.G., Heymans, J.J. and Fernandes, P.G., 2019. Can the common fisheries policy achieve good environmental status in exploited ecosystems: The west of Scotland demersal fisheries example. *Fisheries Research*, 211, 217–230. https://doi.org/10.1016/j.fishres.2018.10.024

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Bentley, J.W., Hines, D., Borrett, S., **Serpetti, N., Fox, C., Reid, D.G.,**& Heymans, J.J. (2018) Diet uncertainty analysis strengthens Ecopath-derived indicators of food web structure and function. *Ecological Indicators* 98: 239-250.

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Bundy A, Chuenpagdee R, Boldt JL, **Borges MF**, Camara ML, Coll M, Diallo I, **Fox C,** Fulton EA, Gazihan A, Jarre A, Jouffre D, Kleisner KM, Knight B, Link J, Matiku PP, Masski H, Moutopoulos DK, Piroddi C, Raid T, Sobrino I, Tam J, Thiao D, **Torres MA**, Tsagarakis K, Van der Meeren GI, Shin Y-J. (2017). Strong fisheries management and governance positively impact ecosystem status. *Fish and Fisheries* 18 (3), 412-439.

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Declerck, A., Delpey, M. T., Rubio, A., Ferrer, L., Basurko, O. C., Mader, J., Louzao, M. In press. Transport of Floating Marine Litter in the coastal area of the south-eastern Bay of Biscay: a Lagrangian approach using modelling and observations. Journal of Operational Oceanography.

Harvey B., 2018. Impacts of shipping noise on cetaceans on the west coast of Scotland. MSc thesis, St Andrews University.

Kadin, M., Blenckner, T., Casini, M., Gårdmark, A., **Torres, M.A**. and Otto, S.A., 2019. Trophic interactions, management trade-offs and climate change: the need for adaptive thresholds to operationalize ecosystem indicators. *Frontiers in Marine Science*, 6, p.249.

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Ruiz, J., **Rincón, M. M**., Castilla, D., Ramos, F., & del Hoyo, J. J. G. (2017). Biological and economic vulnerabilities of fixed TACs in small pelagics: An analysis of the European anchovy (*Engraulis encrasicolus*) in the Gulf of Cadiz. *Marine Policy*, 78, 171–180.

Saavedra, C., Gerrodette, T., Louzao, M., Valeiras, J., García, S., Cerviño, S., Pierce, G.J., Santos, M.B. 2018. Assessing the Environmental Status of the common dolphin (Delphinus delphis) in North-western Spanish waters using abundance trends and safe removal limits. Progress in Oceanography 166:66-75.https://doi.org/10.1016/j.pocean.2017.08.006

Scott, E, **Serpetti N.,** Steenbeek, J., Heymans, J.J. A Stepwise Fitting Procedure for automated fitting of Ecopath with Ecosim models. *SoftwareX* (2016), 5, 25-30. doi:10.1016/j.softx.2016.02.002

Serpetti, N., Baudron, A.R., Burrows, M.T., Payne, B.L., Helaouët, P., Fernandes, P.G., Heymans, J.J., 2017. Impact of ocean warming on sustainable fisheries management informs the Ecosystem Approach to Fisheries. *Scientific Reports*, 7(1), 13438, doi:10.1038/s41598-017-13220-7.

Spence, M.A., Blanchard, J.L., Rossberg, A.G., Heath, M.R., Heymans, J.J., Mackinson, S., **Serpetti, N.,** Speirs, D.C., Thorpe, R.B., Blackwell, P.G., 2018. A general framework for combining ecosystem models. *Fish and Fisheries*, 00: 1–12. https://doi.org/10.1111/faf.12310

Szalaj D, Wise L, Rodriguez-Climent S, Angélico MM, Marques V, Chaves C, Silva A, Cabral H. (2018) A GIS-based framework for addressing conflicting objectives in the context of an ecosystem approach to fisheries management- a case study of the Portuguese sardine fishery.ICES Journal of Marine Science, 75 (6), 2070-2087. doi:10.1093/icesjms/fsy094

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Virgili, A., Authier, M., Boisseau, O., Cañadas, A., Claridge, D., Cole, T., Corkeron, P., Dorémus, G., David, L., Di-Méglio, M., Dunn, C., Dunn, T.E., García Barón, I., Laran, S., Lewis, M., Louzao, M., Ruiz Sancho, L., Mannocci, L., Martínez-Cedeira, J., Palka, D., Panigada, S., Pettex, E., Roberts, J., Santos, M.B., Van

Canneyt, O., Vázquez, J.A., Monestiez, P., Ridoux, V. 2019. Combining datasets into a basin wide approach to model habitats of deep-divers. Global Ecology and Biogeography 28 (3): 300-314. https://doi.org/10.1111/geb.12850

Poster and Oral presentations and sessions organized/convened

Altuna, M. and **Andonegi, E.** (2017) Moving towards the Ecosystem Approach to Fisheries in the Bay of Biscay. Poster to the Advances in Marine Ecosystem Modelling Research (AMEMR) Conference. Plymouth, July 2017.

Andonegi, E. (2017). Integrated Assessments as the main goal for achieving an Ecosystem Approach to Management in the Western European Shelf Seas. Oral at ICES WGHANSA meeting. Bilbao (Spain). Jun 24-29, 2017

Andonegi, E. and Prellezo, R. (2017). Is the Ecosystem Based Fisheries Management a reality in the Bay of Biscay? Analyzing the effects of the implementation of the Landing Obligation at an ecosystem level. Poster to the MareFrame Scientific Conference "Advances in Ecosystem-based Fisheries Management". Brussels, December 2017.

Canseco JA, **Torres MA,** Ramos, F. 2017. Spatial patterns and inter-annual variability of mid-size pelagic fish species off the Gulf of Cadiz. Poster to the ICES Annual Science Meeting (Fort Lauderdale, Florida, USA, 18-21 September 2017).

Carvalho-Souza GF, González-Ortegón E, Baldó F, Drake P, Ramos F, Sobrino I, Vilas C, **Llope M.** Natural and land-based human factors affect the abundance of anchovy in the Gulf of Cadiz (SW Spain). Poster at the 4th International Symposium 'The Effects of Climate Change on the World's Oceans', Washington DC (USA), Jun 4-8, 2018.

Carvalho-Souza GF, González-Ortegón E, Baldó F, Drake P, Ramos F, Sobrino I, Vilas C, **Llope M.** Natural and land-based factors in the Guadalquivir estuary affect the abundance of anchovy in the Gulf of Cadiz (SW Spain). Poster (and poster presentation) at ICES ASC 2017, Fort Lauderdale (Florida, USA), Sep 18-21, 2017.

Carvalho-Souza GF, Llope M, Baldó F, Vilas C, Drake P, Ramos F, González-Ortegón E. Natural and anthropogenic factors in the Guadalquivir estuary affect the abundance of anchovy in the Gulf of Cadiz (SW Spain). Oral presentation at International Symposium: Drivers of dynamics of small pelagic fish resources, Victoria (Canada), Mar 06-11, 2017.

Gamaza MA, **Torres MA,** Acosta JJ, Erzini K, Sobrino I. The future of the Gulf of Cadiz multispecies trawl fishery under the 'zero' discards policy. Oral presentation to the International conference on advances in marine technologies applied to discard mitigation and management. 2-4 May 2018, Vigo (Spain). Accepted

González-Ortegón E, **Llope M,** Baldó F, Sobrino I, Fernández-Delgado C, Drake P, Vilas C. Modelling the effect of environmental and anthropogenic factors on the abundance of early life-history stages of the European sardine in the Guadalquivir estuary. Poster at International Symposium: Drivers of dynamics of small pelagic fish resources, Victoria (Canada), Mar 06-11, 2017.

Kadin M, Casini M, **Torres MA,** Blenckner T, Gårdmark A, Otto S. Coupled foodweb indicator models and scenario simulations identify robust indicators guiding management actions. 2017. Oral presentation to the ICES Annual Science Meeting (Fort Lauderdale, Florida, USA, 18-21 September 2017).

Kraak, S.B.M, **Pedreschi, D.,** Hamon, K.G., Uhlmann, S. & M. Kraan. Roundtable: To nudge or not to nudge; is nudging in fisheries management necessarily libertarian paternalism? WINK the Nudge Conference, Round table organiser and contributor, Utrecht, Netherlands, June 2017.

Llope, M.*et al.*, Estuarine and marine environmental effects on the Gulf of Cadiz anchovy dynamics. Oral presentation at ICES WGHANSA meeting. Bilbao (Spain). Jun 24-29, 2017.

López-López L, **Preciado I**, Arroyo NL, Castro J, Carrera P, Cerviño S, Iglesias M, Morato T, Muñoz I, Nogueira E, Prado E, Punzón A, Saavedra C, Sánchez F, Serrano A, Somavilla R, **Torres MA.** 2017.

Ecological trends in the Cantabrian Sea ecosystem: A modeling approach including trophic controls. Poster to the MareFrame Scientific Conference "Advances in Ecosystem-based Fisheries Management" (Brussels, Belgium, 14th December 2017)

Pedreschi, D. & Reid, D.G. ODEMM in the Celtic Seas: A Qualitative IEA with Decision Support Tools. Poster presentation at MareFrame: Co-creating Ecosystem-based Fisheries Management Solutions, Brussels, Belgium, December 2017.

Pedreschi, D., Andonegi, E.,de Fatima Borges, M., Llope, M., Beggs, S. & Reid, D.G. WGEAWESS: Integrated Ecosystems Assessment of the Western European Shelf Seas. Oral presentation to the ICES Annual Science Conference, Fort Lauderdale, Florida, USA, September 2017.

Pedreschi, D., Bouch, P., Moriarty, M., Nixon, E., Knights, A.M. &**Reid, D.G.** Interactive Visualisation of an Integrated Ecosystem Assessment in the Celtic Sea. Oral presentation to the American Fisheries Society Annual Conference, Atlantic City, New Jersey, USA, August 2018.

Pedreschi, D., Bouch, P. &**Reid, D.G**. Understanding our seabed integrity and managing our ecosystems. Oral presentation to INFOMAR Annual Seminar 2018, Kinsale, Cork, Ireland, November 2018.

Preciado I., Arroyo N.L. González-Irusta J.M., López-López L., Punzón A., Muñoz I., Serrano A. Small-scale spatial variations of fishing impact on food web structure. Oral presentation to the XVI International Symposium on Oceanography of the Biscay Bay (Anglet, France, June 2018).

Preciado I., Arroyo N.L., López-López L. Ecological network analysis reveals the impact of bottom trawling on food web structure. Poster to the XVI International Symposium on Oceanography ot the Bay of Biscay (Anglet, France, June 2018).

Reid, D.G., Pedreschi, D., Bouch, P., **Bentley, J.,** O'Donnell, F., Thorpe, R., **Beggs, S.,** Schuchert, P. & Heymans, S. WKIRISH: Harnessing Fisher Knowledge. An Example of Positive Collaborative Research. American Fisheries Society Annual Conference, Atlantic City, New Jersey, USA, August 2018.

Reid, D.G., Pedreschi, D., & Beggs, S. (2017). Linking Ecosystem Service Assessments and Fisheries Management – tridirectional question. Oral presentation at the MARE Conference 2017, People & the Sea IX: Dealing with Maritime Mobilities. Amsterdam July 2017

Torres MA, Erzini K, Borges T, Campos A, Castro M, Santos J, Costa E, Fernandes AC, Marçalo A, Oliveira N, Vingada J, Fonseca P. 2017. An ecosystem modeling approach for evaluating the EU Landing Obligation impact on the Portuguese bottom trawl crustacean fishery. Poster (and poster presentation) to the ICES Annual Science Meeting (Fort Lauderdale, Florida, USA, 18-21 September 2017).

Torres MA, Erzini K, Borges T, Campos A, Castro M, Santos J, Costa ME, Marçalo A, Oliveira N, Vingada J, Fonseca P. Ecological impacts of adopting the discard ban policy in the deep-water crustacean trawl fishery off Southern Portugal. Oral presentation to the International conference on advances in marine technologies applied to discard mitigation and management. 2-4 May 2018, Vigo (Spain).

Project proposals

- The WGEAWESS team put together a consortium to apply for Atlantic Area Interreg funding for the AtlantEA project to help to fund the ambitions of the group in relation to advancing and applying EBFM and creating comparable IEAs across the Atlantic ecoregions covered by the group. The consortium worked hard and applied twice in two separate round, but unfortunately we were not successful. Despite requesting feedback, it was not forthcoming, neither were scores provided. As such, the consortium decided to close this ToR, with a view to perhaps revisiting should alternative suitable funding opportunities arise.
- TransEBM - 2017- Transdisciplinary, Coastal and Marine Ecosystem-based Management (EBM) of the Gulf of Cadiz-Gualdaquivir estuary (GoC-Ge). Submitted under the Horizon 2020's Marie Skłodowska-Curie actions call H2020-MSCA-IF-2017. Deadline:

14/09/2017. Score 2018 = 91.2% (not funded, threshold 2018 = 92.5%). Score 2017 = 89.4% - Seal of Excellence 2017

Cooperation/Collaboration/Workshops/Outreach

- D. Reid (chair), D. Pedreschi, S. Beggs, J. Bentley have all been involved in the WKIRISH series of workshops, which have a large stakeholder component. Reports can be seen here: https://www.ices.dk/community/groups/Pages/WKIrish.aspx
- Two joint sessions were organized during 2018 to improve synergies between WGEAWESS and other ICES WGs. The first was focused on the support that WGEAWESS could provide to assessment groups (WGHANSA in this case, with a demonstration of the 'stock cards'; E. Andonegi, M. Rincon, M. Llope) and the second, to join efforts with other (ecosystem) modelling WGs (WGIPEM; E. Andonegi, M. Travers). In the latter case, a joint session with WGIPEM, WGINOSE and WGS2D was organized and attended by several members of the group, that included a presentation of the work done by WGEAWESS during the recent period, leading to interesting discussions.
- M. Torres (IEO, Spain) and E. Andonegi (AZTI, Spain) co-chaired (along with M. Tomczak, Stockholm University, Sweden) the ICES Workshop on operational Ecopath with Ecosim (EwE) models to inform Integrated Ecosystem Assessments (IEAs) (WKEWIEA). 26-30 November 2018 (ICM-CSIC, Barcelona, Spain)
- M. Torres (CCMAR, Portugal) and M.F. Borges (IPMA, Portugal) hosted the back-to-Back meetings of the ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB), with the ICES Working Group on Comparative Analyses between European Atlantic and Mediterranean marine ecosystems to move towards an Ecosystem based Approach to Fisheries (WGCOMEDA) and WGEAWESS. 24-28 April 2017 (IPMA, Lisbon, Portugal)
- S. Lehuta and P. Issac (IFREMER, France) participated to the ICES Workshop on integrated trend analyses in support to integrated ecosystem assessment (WKINTRA) in September 2018.
- I. Preciado was involved in the project DG/ENV/MSFD/Action Plan "Addressing gaps in biodiversity indicator development for the OSPAR Region from data to ecosystem assessment: Applying an ecosystem approach to (sub) regional habitat assessments (EcApRHA)" from 2016 to 2017. The consortium comprised nine partners, coordinated by the OSPAR Secretariat. The consortium members were all engaged in common biodiversity indicator development (pelagic habitats, benthic habitats and food webs) within the OSPAR context. One of the main outcomes was to deliver an Action Plan for further implementation of habitat and food web indicators and progressing integrated assessments at the (sub) regional scale, that contributed to the OSPAR 2017 Intermediate Assessment (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/).
- N. Serpetti is a member of the Ecopath consortium that has leveraged funding from EuroMarine to organise a workshop aiming to improve Ecospace capability: '*Modelling for policy advice under a global change context: expert workshop on measuring and improving the fit of spatial-temporal aquatic ecosystem models*'
- D. Pedreschi has took part in 'Soapbox Scientist' in 2017, a public outreach event highlighting the role of women in science, where she discussed issues relating to mixed fisheries.

Annex 4: Presentations at 2019 meeting

Abstracts of presentations given at WGEAWESS that informed discussions and are not specifically covered in the previous text.

Integrating integrated ecosystem assessments into the ICES advice giving process.

Dr. Daniel Howell, Institute of Marine Research, Norway.

Integrated ecosystem assessments and ecosystem modelling are relatively new tools for improving our understanding of ecosystem functioning and how this is influenced by human actions. To date they have functioned more as tools for research and understanding rather than being fully integrated into our management systems. This presentation focused specifically on fisheries management and quota setting in particular. It looked at reasons why the take-up of ecosystem models and assessment has been slow, and highlighted routes by which such knowledge could successful enter current management schemes. Specifically, identifying key processes required for assessment, forecast or simulation models, and by influencing the choice of target F with the Fmsy ranges which have already been identified as providing good yield with low risk. The last suggestion came from WKIRISH 2018 and will be further developed at the follow-up WKIRISH 2019. It was stressed that such integration would only be possible where the work of the ecosystem group was coupled with that of the assessment groups, and that targeted and specific inputs into the management models were required.

Response of marine top-predators to fluctuations of prey availability

Andrea Fariñas Bermejo, IMBR-Sea/ Galway-Mayo Institute of Technology, Ireland.

The Southern part of the Celtic Sea is known to be a foraging hot-spot for cetaceans. Common dolphins, fin, minke and humpback whales are the most abundant marine mammals. Herring and sprat are the main pelagic prey species of baleen whales in this area. The herring stock dropped in 2013 and currently its spawning biomass is below that needed to achieve Maximum Sustainable Yield. The Celtic Sea Herring Trawl Fishery has lost its Marine Stewardship Council's Certificate of Sustainability. An Ecosystem-Based Management is recommended by the main European fisheries management organizations. This integrative approach to stock assessment also considers the relationships with and among other components within the ecosystem. This study aims to analyse the response of the most common predators to fluctuations in the availability of their main pelagic prey and their relationships with environmental variables.

Social vulnerability of Galician (NW Spain) fishing communities

Sebastián Villasante[1], **Pablo Pita[1]**, Amber Himes-Cornell[2], Lisa Colburn[3], Gonzalo Macho[4]& Stephen Kasperski[3]

[1]University Santiago de Compostela, [2]FAO, 3NOAA, [4]University of Vigo

The use of secondary data in the development of quantitative social and fisheries participation indices as a proxy for measuring fishing community vulnerability and well-being has been used throughout coastal areas of USA (Colburn and Jepson 2012, Himes-Cornell and Kasperski 2015, Himes-Cornell and Kasperski 2016, Himes-Cornell et al. 2016). The methodology and indices is available on the NOAA website: http://www.st.nmfs.noaa.gov/humandimensions/social-indicators/index, while a data management protocol and methodology was made available by Jepson and Colburn (2013).

A research team of the University of Santiago de Compostela and of Vigo in Galicia (NW Spain) has been working with the colleagues that developed the methodology and indices of community vulnerability in the first time to obtain community level indices related to engagement in and dependence on marine resource related activities in Galicia. Other research groups are also doing similar work to this end, developing other cases of study in Europe. These indices will then be used to quantitatively rank coastal communities to assess well-being and understand their relative strengths and weaknesses.

Colburn, L. and M. Jepson (2012). Social Indicators of Gentrification Pressure in Fishing Communities: A Context for Social Impact Assessment. *Coastal Management* 40(3):289-300.

Himes-Cornell, A. and S. Kasperski (2015). Assessing climate change vulnerability in Alaska's fishing communities. *Fisheries Research* 162:1-11.

Himes-Cornell, A. and S. Kasperski (2016). Using indicators to aid in the assessment of vulnerability and resiliency in Alaskan fishing communities. *Coastal Management* 44(1):36-70.

Himes-Cornell, A., C. Maguire, S. Kasperski, K. Hoelting and R. Pollnac (2106). Using grounded theory to extract themes of resiliency in fisheries dependent communities in Alaska. *Ocean and Coastal Management* 142:53-65.

Jepson, M. and L. L. Colburn 2013. Development of Social Indicators of Fishing Community Vulnerability and Resilience in the U.S. Southeast and Northeast Regions. U.S. Dept. of Commerce., NOAA Technical Memorandum NMFS-F/SPO-129, 64 p.

WGS2D – Working Group on Seasonal-to-Decadal Prediction of Marine Ecosystems:user-driven forecasts of physics and biology

Mark R Payne, DTU Aqua, Denmark.

Climate information for Ecosystem Overviews

There is a vast array of climate data and knowledge that could be incorporated into ecosystem overviews. As a tool for discussing these issues, we distinguish between 1. climate knowledge (e.g. projected impacts on a given species) and 2. data characterizing the state of the climate in an ecoregion. It is also useful to think about four different time-scales, which closely mirror the activities in the climate and oceanographic communities: historical observations, seasonal predictions, decadal predictions, and climate projections.

Combining these four time-scales has the potential to give a complete overview of the past and future evolution of the state of the ocean climate. A mock-up of how this might look was presented, showing the average sea surface temperature for a hypothetical ecoregion. The figure gives a sense of the interannual variability, multi-annual variability (e.g. differences in average temperatures between 1980s and 2000s), changes in the near term, and future variability under different emissions scenarios. Such data could also be complemented with spatial information e.g. maps of warming trends within an ecoregion.

Such climate data can be provided by the ICES community, but there is more that can be done to improve both the communication, coverage and usefulness of the data. In addition to changes in the physical environment, climate change will also have important consequences for all organisms in the ocean. There is a tremendous amount of knowledge in this regard in the ICES community, however synthesis and collation activities would be required before this information could be used in an ecosystem overview.

It is also vital to consider how this information will be used by decision-makers and the users of the ecosystem-overviews. Clear dialogue between the ICES climate community and the ecosystem-overview target-audience to define and refine the climate information to be included in an ecosystem overview is absolutely critical to ensure a useful product.

Integrating ecology and oceanography toadvance ecosystem-based management: the CHALLENGES project

Maite Louzao Arsuaga, AZTI, Spain.

To characterise, understand and predict the response of the pelagic ecosystems to changing environmental conditions, we need to better understand the linkages and interactions between different trophic levels and how they are affected by the environment. Within this framework, we developed the CHALLENGES project to study the pelagic ecosystem in temperate latitudes of the NE Atlantic by integrating ecology and oceanography to advance ecosystem-based management. The main objective has been the development of a spatially-explicit ecological modelling framework to better understand the impact of climate change and other human-induced pressures on pelagic ecosystems by focusing on its effects on the top predator-pelagic prey linkages. Based on a multidisciplinary framework, we have characterized the oceanographic conditions and 3D distribution of different pelagic species (plankton, fish) (Boyra et al. 2016) to advance our understanding on the distribution and abundance patterns of different megafauna species based on integrated ecosystem surveys of the Bay of Biscay. Different ecosystem components have been integrated (1) to understand the 3D environment of pelagic predators (Louzao et al. 2019) and (2) to identify interspecific associations of the pelagic predator–prey networks that can be applied for management porpuses (Astarloa et al. under review) such as (3) the assessment of marine protected areas networks (García-Barón et al. 2019), (4) the evaluation of the Good Environmental Status within the Marine Strategy Framework Directive (Saavedra et al. 2018) and (5) the study of physical transport of floating marine litter (Declerck et al 2019) to advance ecosystem-based management.

Boyra, G., Peña, M., Cotano, U., Irigoien, X., Rubio, A., and Nogueira, E. 2016. Spatial dynamics of juvenile anchovy in the Bay of Biscay. Fisheries Oceanography, 25: 529–543.

Declerck, A., Delpey, M. T., Rubio, A., Ferrer, L., Basurko, O. C., Mader, J., Louzao, M. 2019. Transport of Floating Marine Litter in the coastal area of the south-eastern Bay of Biscay: a Lagrangian approach using modelling and observations. Journal of Operational Oceanography. In press.

García-Barón, I., Authier, M., Caballero, A., Murcia, J.L., Vázquez, J.A., Santos, M.B., Louzao, M. 2019. Modelling the spatial abundance of a migratory predator: a call for transboundary marine protected areas. Diversity and Distributions 25 (3): 346-360.

Louzao, M., García-Barón, I., Rubio, A., Martínez, U., Vázquez, J.A., Murcia, J.L., Nogueira, E., Boyra, G. 2019. Understanding pelagic seabird 3D environment from multidisciplinary oceanographic cruises to advance ecosystem-based monitoring. Marine Ecology Progress Series. In press.

Saavedra, C., Gerrodette, T., Louzao, M., Valeiras, J., García, S., Cerviño, S., Pierce, G.J., Santos, M.B. 2018. Assessing the Environmental Status of the common dolphin (Delphinus delphis) in North-western Spanish waters using abundance trends and safe removal limits. Progress in Oceanography 166:66-75.

Small-scale spatial variations of trawling impact on food web structure.

Izaskun Preciado, IEO, Spain.

The impact of bottom trawling on the structure of benthic and demersal communities and the spread of this impact through the food web were explored. For this purpose, nine ecological indicators were developed: 4 community indicators i) total biomass, ii) species richness, iii) Shannon diversity in biomass (H'_b), iv) Shannon diversity in number (H'_n) and 5 trophic indicators v) fullness index, vi) trophic richness, vii) trophic diversity in volume (H'_v), viii) trophic diversity in number (H'_n) and ix) mean Trophic Level of the community using a cut-off 2 (mTL_2). We also analysed the impact of bottom trawling on the biomass of 15 functional groups. Two types of data were used: biological data coming from the IBT survey Demersales (southern Bay of Biscay) and pressure data (Vessel Monitoring System).

Nine out of 15 functional groups showed significant changes, most of them with a decreasing trend with increasing fishing effort: benthic cephalopods, benthivorous fish, echinoderms, large demersal fish, rays and squids. Only 2 functional groups (benthic and deposit-feeder decapods) showed increased biomass in high trawled areas which could be attributed to the removal of large biomasses of their predators. The increase in deposit-feeders decapods (such as squat lobster or pagurid crabs) could also respond to an increase in prey availability, in the form of injured prey and carrion supplied by discards and left by otter trawls.

Significant decrease in total biomass and species richness of the community with increasing fishing effort was also detected. Regarding trophic indicators, we also found significant changes although with different responses. Trophic richness, trophic diversity and mTL declined significantly with increasing pressure. However, fullness index showed significant increase. We also computed changes in mTL between fishing and non-fishing scenario with a spatial resolution of 3 km x 3 km (Figure 1). We first produced a no-fishing scenario (where all VMS values where substituted by 0). Then the difference between both scenarios (fishing and non-fishing) was assessed by computing the percentage of change as follows: % Change in mTL= ΔmTL between scenarios/mTL in real scenario. Red areas in Figure 1 show a 21 % mTL lower values than those expected in a non-fishing scenario.

Using this approach we conclude that 1) biomass and richness of bentho-demersal communities decline with increasing fishing effort, 2) fishing impact spreads through the benthic-demersal food web and 3) mean Trophic Level (mTL) of the community response to fishing pressure. We also stress the need of small-scale spatial resolution when investigating fishing impact.

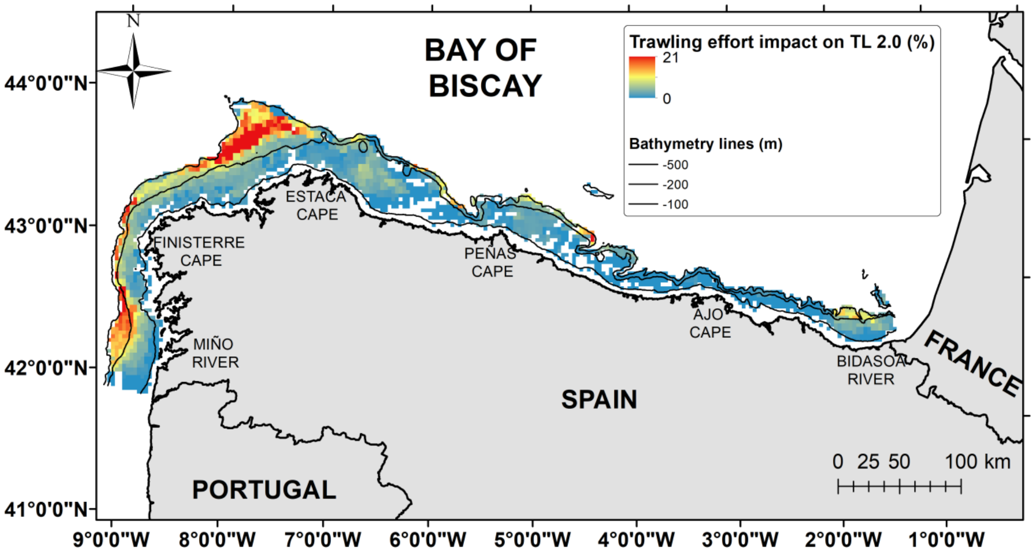

Figure 1. Map showing the decrease in mTL_2 of the community between fishing and non-fishing scenarios according to the predictions made by the Generalised Additive Model.

For full details see Preciado, I., Arroyo, N. L., González-Irusta, J. M., López-López, L., Punzón, A., Muñoz, I., & Serrano, A. (2019). Small-scale spatial variations of trawling impact on food web structure. Ecological Indicators, 98, 442-452.

Modelling the West Coast of Scotland ecosystem

1. *West coast of Scotland fishery (Natalia Serpetti & Mike Heath)*

Since the last 30 years UK landings of all demersal in the West Coast of Scotland decreased due to a reduction of fishing partly designed to protect cod and whiting that showed strong temporal declining trends. Similarly, pelagic fishing effort was alsoreduced to protect herring. However, since 2000s, this low fishing efforts for demersal species allowed other demersal species such as saithe and hake to thrive. Despite reducing fishing mortality rates, herring, cod, whiting and haddock continued to steadily decline. Saithe and hake are strong predators of other gadoids and pelagic species respectively: preliminary results are suggesting that the increasing biomass of these species is causing an increasing predation pressure for cod, whiting and herring preventing their recovery despite the reduction of the fishing effort. These results highlight the importance of considering predation and competition in fishing management policy. Moreover, advised fishing mortalities by both single- and multispecies assessments are not easily achievable in this ecosystem due to also the mixed fishery; cod, whiting, haddock and saithe are in fact mostly caught by the same fleet (otter trawls). This also suggest that species spatial distributions and optimum habitats should be also considered by the fishery management to optimize the suggested policy management measures.

2. *Environmental natural variability and warming waters driven by climate change (Serpetti et al., 2017)*

The best EwE fitted model for the West coast of Scotland highlighted that the fishery activities, water temperature and trophic interactions are the main ecosystem drivers). The model fitting also identify a strong importance of the Atlantic Multidecadal Oscillation (AMO) for this ecosystem suggesting that both environmental natural variability (AMO) and climate change could have a strong impact of future temporal shift of both temperate species (potential niche expansion) and cold water species (niche reduction). For more information please refer to Serpetti et al., 2017.

3. *Developing the Ecospace model for the West coast of Scotland (Natalia Serpetti, Bethany Harvey, James Waggitt, Peter Evans, Yuri Artioli, Sheila Heymans)*

The performances of the spatial predictions of the Ecospace model for the West coast of Scotland were improved by coupling the model with external bottom-up and top-town drivers through the spatial/temporal framework plug-in. Spatial/temporal variations of phytoplankton were driven by coupling this group with NEMO-ERSEM primary productivity, whilst top-predators (cetaceans and seabirds) spatial temporal distributions were used to constrain the model via top-down predation controls. The updated Ecospace model was used to assess the impact of noise on cetaceans species creating species-specific response function to environmental noise*.

*Exploring impacts of noise from shipping andacoustic deterrent devices on cetaceans on the West coast of Scotland using an ecosystemmodelling approach. Bethany Jo Harvey, Master of Science Thesis at University of St Andrews - Ecosystem-Based Management of Marine Systems.

Annex 5: ODEMM/ICES Ecosystem risk assessments/graphs

Points to note:

- This was the first time we had tried to carry out an ODEMM style assessment within the working group, and although all members agreed to contribute, not all members were entirely comfortable with the process due to the wide range of topics to be covered. Experts were worried they would not have the expertise to cover all topics.
- The EG represented expertise on fish, benthos, food webs, marine mammals, seabirds and plankton.
- Interestingly, discussions were more involved, and in some cases more difficult, when touching upon expertise most relevant to the group. This was usually due to the high-level overview summarizing that is necessary with such an approach, which does not account for nuances and complexity inherent in biological systems.
- New members to the group were the most uncomfortable with carrying out the exercise, as they were also the least familiar with the ODEMM process.
- Due to the short time window we had to do the exercise, pragmatic decisions had to be made. Details of the decisions are outlined below and may help to form the basis for future 'pseudo-ODEMM' assessments to inform the Ecosystem Overview network diagrams.

Background:

- The ODEMM project (https://odemm.com/) provides an assessment methodology tracing sector – pressure – ecological characteristic pressure pathways (also known as 'linkage chains'; Figure 1). In the ODEMM project, assessments were carried out for each of Europe's regional seas, including the 'North-East Atlantic' (NEA) during the original ODEMM project which we used as a starting point for this exercise. Similar assessments exist for the Baltic Sea, Black Sea and Mediterranean Sea. Although I could not find the file on the current ODEMM website (many of the links appear to be broken), I have a copy of the file from my previous work. There is a statement on the website advising that the database of outputs can be obtained directly through the ODEMM team, specifically Leonie Robinson (leonie.robinson@liverpool.ac.uk) or Antony Knights (antony.knights@plymouth.ac.uk)

Figure 1. Illustration of a 'linkage chain' or 'pressure pathway'. Each one consists of a sector that creates a pressure that affects a specific ecological characteristic.

- The assessments carried out by the ODEMM project assess threats as present in the period **2010-2012**, and as such require updating. Similarly, the spatial area does not relate to our scale of investigation (north-east Atlantic vs. Bay of Biscay/Iberian Waters (BoB/IC) ecoregion). Furthermore, the categories of sector, pressure and ecological characteristic/state do not match between the ODEMM and ICES assessments.

RECOMMENDATIONS

1. Aligning terminology and definition between the two processes would **greatly** facilitate the uptake of this process.
2. In line with the above, ICES currently has two different elements in the 'state' category – there are ecological components, and there are integrative processes (e.g. 'productivity' and 'foodwebs'). It is exceedingly difficult to assess **direct** impact of a given sector and pressure on such processes. We have made some suggestions below on how to address these categories but consider that more thought needs to be given to the structure. Furthermore, we suggest reconsidering labelling them as 'states' and suggest something like the ODEMM 'ecological characteristics' or the term 'ecological component' is more reflective of their content.
3. For this exercise to be completed successfully, definitions of the various elements should be provided in the EO guidelines. We note that there are definitions on the online interactive diagrams, however, in the context of this exercise, they are often not complete/comprehensive enough to be fully informative. For example the definition of seabirds is very broad, whereas separating habitat from benthos is often quite difficult. In other categories the EG knowledge could be applied to provide a more informative assessment. For example 'Fish' could be split into demersal and pelagic (similar to ODEMM) or/and into commercial and non-commercial (useful for MSFD) which helps to highlight issues of interest such as bycatch and collateral damage. Furthermore, there are no definitions of the sectors and these differ in terminology between ecosystem overviews (e.g. Celtic Seas has 'Urban and Industry run-off', BoB/IC has 'Coastal discharges' – it is unclear what these encompass and whether different sectors such as agriculture, land-based industry and wastewater should be subsumed into one of these categories). For this reason, the sectors have not been changed from the ODEMM sectors presented but can be adjusted if guidance is received.
4. It would be useful to better define/clarify the area of interest. If including the entire ecoregion, most spatial scales will be very small and undifferentiated as the ecoregions contains extensive offshore areas where few activities beyond shipping take place. For this reason, and to focus on the areas of highest risk and conflict, our analyses focused on the shelf habitats and waters, with the acknowledgement that some sectors (e.g. Fishing and Shipping) occur widespread throughout both shelf and offshore waters. Some consideration of how best to represent this is warranted.

Methodology:

The first step in updating the ODEMM NEA assessment to a BoB/IC EO assessment was to map the 'linkage framework'. This is a relatively simple interactive exercise where the group together mapped what pressures affected which states (from the provided ICES list). The exercise was carried out informally, with all members of the group from the ecoregion contributing to the discussion as to what was linked and providing examples/justification from their expert knowledge. Note that ODEMM requires that only **current status** and **direct effects** are considered. Within the overviews there is space to discuss potential future risks, but this assessment focus on the **current situation**

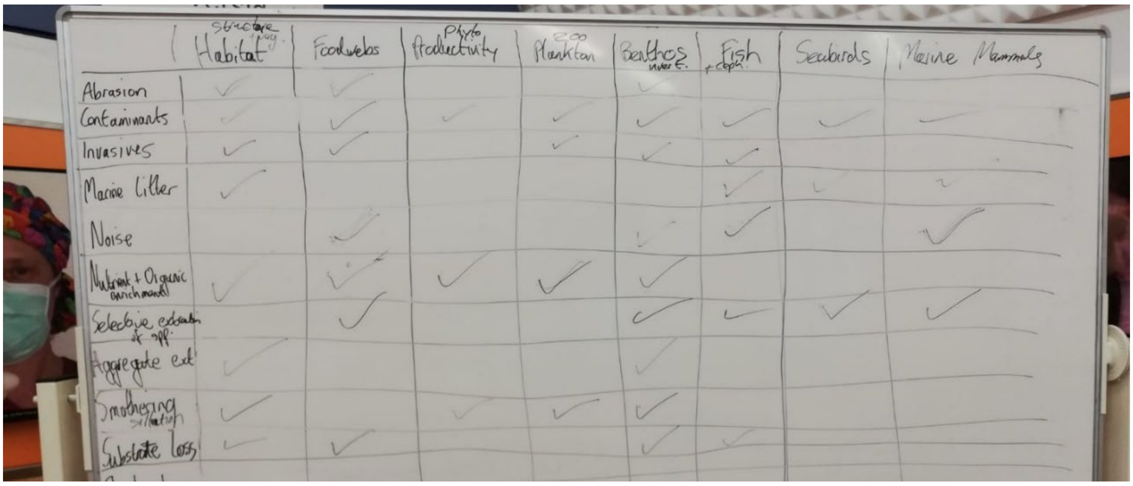

Figure 2: The Pressure-State linkage framework produced for the BoB/IC during WGEAWESS.

- This linkage framework was then used to inform tailoring of the ODEMM NEA assessment to fit the BoB/IC area. As a first step, the categories needed to be made comparable. The categories of Seabirds and Marine mammals were directly comparable, and the category of 'Pelagic Water Column (inc. plankton)' from ODEMM was assigned as the ICES category 'Plankton'. All other categories required either a merge, or a merge-then-split process (outlined in Table 1). For merging of categories, scores for multiple categories were compared and consolidated into one score, using the precautionary principle as guidance (i.e. applying the highest score that occurred across the sub-categories to the new category).

  In one case after being merged, categories needed to be split again. This occurred because in ODEMM, the various benthic habitat categories ***included*** the benthos that live on/in and/or create them, whereas ICES framework requires they be split. For this the scores assigned to 'benthic' were simply copied to both the ICES 'benthos' and 'habitat' categories (i.e. duplicating them). This means at this stage, benthos and habitat are identical, however they were later differentiated.

Table 1: Outlining the process of conversion from ODEMM categories to ICES categories. Conversion was necessary between both ecological components (black text) and pressures (grey text). Categories that needed to be split were more complicated, thus being highlighted in red.

<table>
<tr><th>ODEMM</th><th>Merged</th><th>Split</th></tr>
<tr><td>Deep Sea Fish</td><td rowspan="3">Fish</td><td rowspan="3"></td></tr>
<tr><td>Demersal Fish</td></tr>
<tr><td>Pelagic Fish</td></tr>
<tr><td>Deep Sea Habitat</td><td rowspan="6">Benthic</td><td rowspan="2">Benthos</td></tr>
<tr><td>Littoral Rock</td></tr>
<tr><td>Littoral Sediment</td><td rowspan="4">Habitat</td></tr>
<tr><td>Sublittoral Sediment</td></tr>
<tr><td>Sublittoral Rock</td></tr>
<tr><td>Smothering</td><td rowspan="2">combined</td><td rowspan="2"></td></tr>
<tr><td>Siltation</td></tr>
</table>

Nitrogen and phosphorus enrichment	Nutrient and organic enrichment	
Input of Organic Matter		
Introduction of non-synthetic compounds	Contaminants	
Introduction of synthetic compounds		
Radionuclides		

Note: for the fish categories, there were rarely differences in the scores assigned between categories and thus merging was simple. Similarly NP and Organic matter frequently scored the same as each other.

Note: as highlighted in the recommendations, separating habitat and benthos is difficult. Where do kelp forests or coral reefs fall for instance? Both provide habitats but are also part of the 'flora and fauna found on the bottom, or in the bottom sediment of the sea' (taken from the interactive overview diagrams). We initially tried to keep 'habitat' as just the physical structure (sand, gravel, mud, etc.) but results in the exclusion of vitally important habitats and as such things like seaweed were included.

- Foodwebs and Productivity are processes rather than components of the ecosystem. As such, they were not considered further for this part of the assessment, but were revisited later.
- ODEMM assessments consist of five scores that are assigned for each of the individual sector-pressure-ecological characteristic linkage chains (outlined in Figure 3). For this assessment, it was agreed that the top risks are what should be outlined in the ICES ecosystem overview diagrams, and therefore, analysis continued considering the first 3 scores only; spatial extent (or 'overlap'), frequency of occurrence, and the Degree of Impact (a.k.a. severity/magnitude) which are combined to produce the 'Impact Risk' score. These scores reflect the scoring in the EO guidelines which contain scores for magnitude and probability of occurrence (a product of the spatio-temporal overlap of pressures and ecological characteristics). Scores for 'Persistence' and 'Resilience' which together give an estimate of the time to recovery 'Recovery Lag' were omitted.

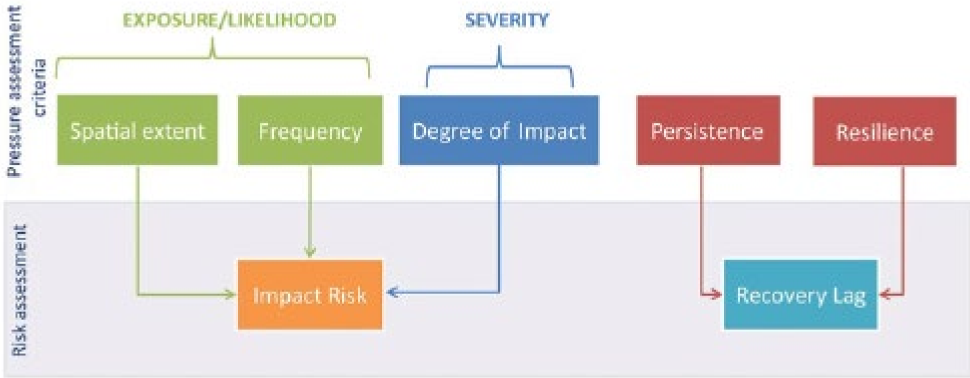

Figure 3: Pressure assessment criteria, illustrating how they are grouped to calculate the I*mpact Risk* and *Recovery Lag* scores for the risk assessment (taken from Robinson *et al.* 2014. Fig 5.2).

- The next step in the process was to use the linkage framework produced by the EG (Figure 2) to inform what parts of the NEA assessment should be included or added. Using the linkage framework, any links identified by both the EG group and the ODEMM assessment remained in the framework. Any that had not been identified by the EG were removed. Those that were highlighted by the EG but that did not occur in the NEA assessment were highlighted for further action during the review.

NOTE: a number of pressures identified by the ODEMM assessment were not included for review as they were not listed in the ICES list of pressures, and were not deemed to be essential pressures by the review panel (Table 2). Furthermore, Climate Change, which is listed in the ICES guidance document as a pressure is considered a driver in this context. Climate change interacts with too many pressures in diverse and indirect ways for it to be considered in a framework such as this. Instead, climate change is discussed in the Climate Change section of the EO. Note there is a high degree of overlap with expected Climate Change impacts and many of the pressures removed from the assessment (Table 2).

Table 2: Outlining the pressures (black) and sectors (grey) that were removed/ not examined. Harvesting/collecting was considered a part of 'Fishing' and or 'Tourism/Recreation'.

REMOVED	
Electromagnetic changes	Emergence
Barriers to species movement	Salinity change
Death or injury by collision	Thermal change
Introduction of microbial pathogens	Research
Water flow rate changes	Desalination
pH changes	Harvesting/collecting
Changes in wave exposure	

- The resultant spreadsheet contains the sector-pressure-ecological characteristic linkage chains informed by the pressure-state matrix produced by the EG. From this spreadsheet, a matrix can be produced which highlights the sector-pressure linkage framework (Table 3). This matrix was reviewed by the panel as a first step to identify any elements that seemed strange and/or that could be removed or should be added.
- Finally, the panel were asked to review the scores assigned for each of the 300+ linkages. Due to the time involved, we had to be pragmatic on how to do this. First we reviewed

all the Degree of Impact/Magnitude scores. In keeping with ICES methodology, we scored these from 1 (low) to 3 (high). With such broad 'state/ecosystem component' categories as used in ICES, it was unclear how to assign these scores, so we interpreted them using the ODEMM guidelines.

- **1** (low) was assigned to a pressure not considered to (currently) produce population level/functional effects
- **2** (medium) was assigned to pressures which may have a population level/functional effects if it has a high enough spatial and or temporal occurrence
- **3** (high) was assigned where acute (immediate) impacts are expected/known to occur.

In keeping with ODEMM methodology, each score is assigned ***independently*** of the other scores. For instance, degree of impact of a specific pressure on an ecosystem component is not expected to change depending on the sector causing the pressure; i.e. 'Abrasion' affecting 'Habitats' will have the same affect on them whether it is caused by 'Fishing' or by 'Navigational Dredging'. This feature means that once the score is agreed for the effect of abrasion on habitats, it can be applied for all sectors causing this pressure to affect the habitat. This speeds up the review process.

- Secondly, the panel were asked to review the 'Extent' (spatial overlap) between the sector (or pressure if known) and the ecosystem components. This requires broad scale knowledge of the activities taking place in an ecoregion. Categories are relatively broad, and were defined as follows:
  - **Site**(>0-5% overlap)
  - **Local** (5-50%)
  - **Widespread**(>50%)

  Similarly, due to time restrictions, these scores were assigned at the sector level and (cautiously) applied to all of its pressures (unless there was a specific reason to change this). For instance, 'Aggregate extraction' is known to be a very site-specific activity, therefore the spatial extent will never be higher than 'Site'. For other activities, such as 'Aquaculture', impacts such as siltation/smothering and abrasion were considered to be 'Site' whereas more diffuse impacts such as those from 'Contaminants' were considered to be 'Local'.
- Next the panel reviewed the 'Frequency of Occurrence' of the pressure from a specific sector. These based on the frequency of the impacting activity (in an average year) and informed by the nature of the pressure in a similar fashion to the 'extent' scores. Categories for Frequency are:
  - **Rare** (e.g. occurs in one month per year)
  - **Occasional** (e.g. occurs in 4 months per year)
  - **Common** (e.g. occurs in 8 months per year)
  - **Persistent** (e.g. occurs in every month of the year)

  For example, Fishing and Shipping are known to occur throughout the year in the ecoregion, however the introduction of 'Non-native invasive species' (and establishment) is considered to happen only rarely.

Note: ideally, all individual linkage chains would be reviewed, assessed and scored independently.

Table 3: Linkage framework of Sectors and the Pressures they cause produced and reviewed by the EG.

	ABRASION	CONTAMINANTS	MARINE LITTER	NON-NATIVE IN-VASIVE SPECIES	NOISE	NON-LIVING RESOURCES	NUTRIENT & ORGANIC EN-RICHMENT	SUBSTRATE LOSS	SMOTHERING/ SILTATION	SELECTIVE EXTRAC-TION
AGGREGATES	X	X			X	X			X	
AGRICULTURE		X					X		X	
AQUACULTURE	X	X	X	X	X		X	X	X	X
COASTAL INFRASTRUCTURE	X	X	X		X	X		X	X	
FISHING	X	X	X	X	X		X		X	X
LAND-BASED INDUSTRY		X	X				X		X	
MILITARY	X	X	X	X	X					
NAVIGATIONAL DREDGING	X	X			X	X		X	X	
NUCLEAR POWER		X								
NON-RENEWABLES	X	X	X		X	X		X	X	
RENEWABLES ENERGY	X	X			X			X	X	
SHIPPING	X	X	X	X	X					
TELECOMMUNICATIONS	X		X		X			X	X	
TOURISM/RECREATION	X	X	X	X	X	X	X	X	X	X
WASTEWATER		X					X			

Table 4: Example of a section of the pressure assessment spreadsheet that was reviewed by the panel.

Region	Sector	Pressure	Eco-component	Extent	Freque	DoI
BoB/IW	Aggregates	Abrasion	BENTHOS	S	R	3
BoB/IW	Aggregates	Siltation/Smothering	PLANKTON	S	R	2
BoB/IW	Aggregates	Contaminants	BIRDS	S	R	1
BoB/IW	Aggregates	Contaminants	FISH	S	R	1
BoB/IW	Aggregates	Contaminants	BENTHOS	S	R	1
BoB/IW	Aggregates	Contaminants	Mammals	S	R	1
BoB/IW	Aggregates	Contaminants	PLANKTON	S	R	1
BoB/IW	Aggregates	Non-living resources	BENTHOS	S	R	3
BoB/IW	Aggregates	Siltation/Sm	BENTHOS	S	R	2
BoB/IW	Aggregates	Noise	FISH	S	R	1
BoB/IW	Aggregates	Noise	Mammals	S	R	1
BoB/IW	Agriculture	Siltation/Sm	BENTHOS	L	C	2

Analysis:

- There are a number of options for how to analyse and present the resulting data. The analysis was carried out following the guidelines provided in the ODEMM guidance documents and published papers (for full methodological details see: Knights et al., 2015, 2013; Robinson et al., 2014, 2013; White et al., 2013) 'Proportional Connectance', and 'Impact Risk' (product of the 'overlap', 'frequency' and 'degree of impact' scores) boxplots and estimates were produced in R as per Pedreschi *et al.* (2019). The Impact Risk scores were log transformed to allow better visual comparison between the scores and their ranks. The code used to produce these estimates is publically available for use at (http://github.com/PaulBouch/ODEMM_Celtic_Sea). The modified/updated script for this analysis is on the WGEAWESS sharepoint. The results are shown in Figure 4.
- The 'top' risks can be calculated in a number of ways
  - The sum of impact risk scores of all linkage changes belonging to a category
  - The mean of impact risk scores of all linkage changes belonging to a category
  - The top scoring individual linkage chains

Both the sum and the mean are influenced by the number of impact chains present although 'summation' is less sensitive to such fluctuations. For this reason, both are illustrated in Figure 3, alongside proportional connectance values, which indicate centrality in the network (e.g. for sectors it indicates how many connections they have to the pressures and ecological characteristics in the network, but with no indication as to the magnitude of the risks/impact). Presenting these metrics together helps to avoid the bias possible using one method alone.

Bias was further mitigated by selecting the highest impacting individual linkage chains as recommended to identify foci for action to decision-makers. These highest risk chains were identified by ranking the Impact Risk scores and selecting those that contribute more than 1% to the overall Impact Risk score as outlined in Piet et al. (2015). Using this process, 22 linkage chains were found to be responsible for 44% of the overall risk in the system. The components contributing to these chains are highlighted in Table 5.

- All of the above options were presented to the EG. It was felt that the final option of selecting the highest individually scoring linkage chains responsible for the bulk of the risk in the system presented both the most immediate relevant threats for inclusion in the ecosystem overviews, but also best represented the systems as reflected by the knowledge in the group. As a result, Table 5 was taken as the basis for the Ecosystem Overview Graph.
- As the filtration exercise resulted in only 3 sectors, the next highest risk contributing sectors were also added to Table 5 to provide the top 5 Sectors and Pressures. With their addition, Table 5 now represents the top 34 linkage chains that account for 51% of the risk in the system.

Table 5. The components contributing to the highest impacting linkage chains, and the percentage of impact risk in *the whole system* associated with them (in brackets). Sectors in grey do not appear in the 'top risks' filtering exercise but are included to include the top 5 sectors for the Eos.

Sector	Pressure	Ecological Characteristic
Fishing (43%)	Species Extraction (15%)	Benthos (29%)
Shipping (19%)	Abrasion (14%)	Habitat (23%)
Tourism/Recreation (18%)	NP/Organic input (13%)	Fish (14%)
Land-based Industry (8%)	Siltation/Smothering (11%)	Plankton (12%)
Agriculture (6%)	Sealing/Substrate Loss (4%)	Mammals (12%)
		Seabirds (10%)

Figure 4. Proportional Connectance, Impact Risk, and Impact Rank Boxplots. Each component assessed is listed in order of its average Total Risk Rank. The thick black vertical lines on the boxplots indicate the median values, with the box lengths representing the 25% quartiles and the whiskers representing 1.5 times the interquartile range. Outliers are shown as black dots. The small Impact Risk scores have been log-transformed ('Impact Rank') to allow visual comparison

between the assessed components. Components are ordered on the y-axis in order of the sum of their Impact Risk (top=high, bottom=low) to aidinterpretation. For instance, Fishing has the highest risk scores regardless of the metric used (sum or mean), and has a high proportional connectance, but not as high as that from Aquaculture. In contrast, looking at the pressures we can see that if using Sum as the metric for ranking, Contaminants come out on top, whereas using the mean Species Extraction comes out as the highest risk – this is due to the differences in their connectance values (contaminants has many low scoring linkage chains (low mean) but that when summed add to a high value (high sum)).

- For informing the thickness of the connections in the ICES diagrams, we examined the number of connections between each of the elements listed in Table 5 (see Appendix 2). The number of connections between them ranged from 1-4. As there are three thicknesses used in the ICES diagrams, we took anything from >=3 as the highest level.
  This results in connections that reflect the number of connections between the components, but not their severity – we could score them based on the severity instead if preferred, however the presence of the various components in the diagram, plus their order gives an indication of magnitude (Figure 5). This can be relatively easily adjusted if required.

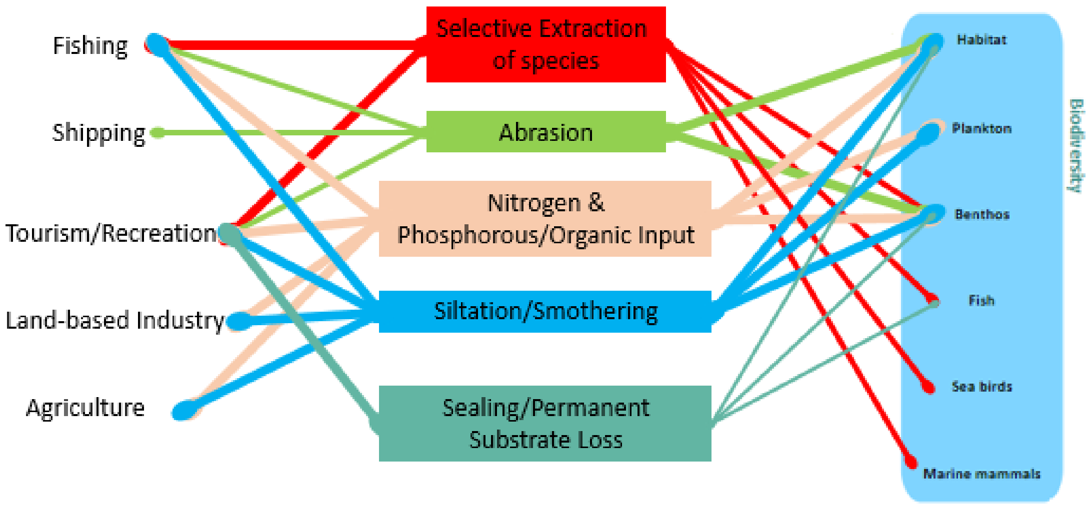

Figure 5. Draft of the EO diagram for the BoB/IC Ecosystem Overview. This has been created using the top sectors and pressures and together represents 51% of the risk in the ecoregion.

Foodwebs

As mentioned earlier, 'Foodwebs' and 'Productivity' are difficult to incorporate into an assessment such as ODEMM as they are not (relatively) simple components of the ecosystem upon which direct effects can be measured and/or estimated, but instead they are processes and/or interact across many levels of the ecosystem. As such, it was not possible (at least not within the time available) to assess these components in the same comprehensive manner as the above.

Instead, we took a simplified approach in which we simply used the matrix we had produced earlier to score the various pressures and the effects they would be expected to have (Table 6). This allows us to draw the lines on the EO network diagram, but does not allow us to include them further into the other analysis at this time (Figure 6).

DP has developed a methodology for linking the ODEMM framework through to MSFD descriptors, and this may be a way to link (and analyse) Foodwebs via D4.

Table 6. Matrix produced by the EG assigning scores to the pressures affecting Productivity and Foodwebs

	Productivity	Foodwebs
Abrasion		3
Aggregate extraction		
Contaminants	1	2
Marine Litter		
Invasives		3
Noise		1
Nutrient & Organic Enrichment	2	2
Substrate Loss		2
Smothering (& Siltation)	1	
Selective extraction		3

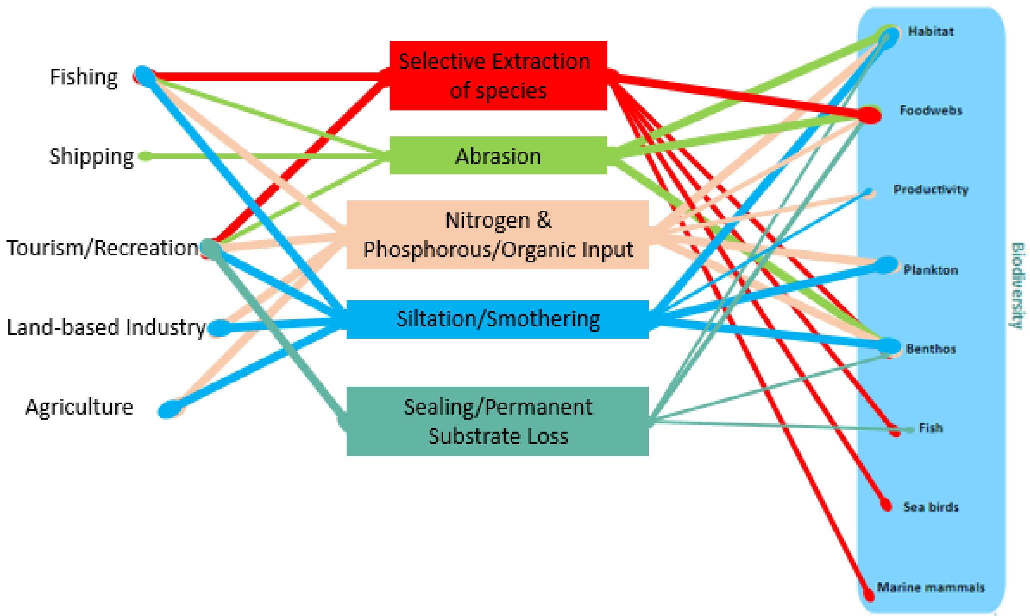

Figure 6. Draft of the EO diagram for the BoB/IC Ecosystem Overview. This has been created using the top sectors and pressures and together represents 51% of the risk in the ecoregion. Links to 'Foodwebs' and 'Productivity' have been added based on expert knowledge.

Simple methodology

The approach outlined above for the 'foodwebs' and 'productivity' categories, where groups simply fill in the boxes of a matrix with an 'interaction score' according to expert knowledge is probably the simplest way of creating a common methodology for use across all IEA groups. However, this method facilitates no further analyses and as such is less informative for an IEA. Furthermore, it is more openly accessible to influence and/or bias. The rigour of the ODEMM-style approach (even as adapted here) acts to mitigate such bias.

Reasons to use ODEMM

- As outlined above, ODEMM through its more rigorous approach helps to avoid extreme bias as each element is assessed in isolation before producing the final product.
- As demonstrated, the semi-quantitative analyses made possible by the ODEMM approach are much more informative than more simple options.
- ODEMM assessments are meant to be 'living tools' that are updated as new knowledge is produced. A relatively simple exercise such as the one outlined here can be made more detailed as required, and data to support elements of the assessment can be directly incorporated to move more towards quantitative assessment where data allows. For example, quantitative estimates of spatial overlap of a given sector and or pressure could be directly incorporated where they exist to replace broad scale expert knowledge categorical assessment. There is potential for directly linking such an assessment to the data and metadatabases held/managed by ICES.
- Furthermore, areas of concern highlighted by current knowledge but with insufficient data to quantitatively incorporate them are not overlooked and are also included in this assessment. This process ensures both that no aspects are overlooked, thus delivering a truly integrated assessment, and serving as a gaps analysis for future work.
- An initial methodology for linking ODEMM assessments to MSFD GES descriptors has been developed by DP and maybe of use within the context of the EOs, IEA in general, and specifically for helping to inform some of the 'foodweb' aspects (via D4).
- Work is ongoing to link the framework through to Ecosystem Services, another area of interest and priority for the EOs highlighted at the recent EO review workshop.

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Appendix 1

List of ODEMM categories as outlined in: Robinson, L.A., White, L., Culhane, F.E. and Knights, A.M. 2013. ODEMM Pressure Assessment Userguide (Version 2). ODEMM Guidance Document Series No.4. EC FP7 project (244273) 'Options for Delivering Ecosystem-based Marine Management'. University of Liverpool. Free to download at: http://odemm.com/content/pressure-assessment

Pressures used and definitions

01. Smothering – Cover habitat surface with materials falling to the seafloor from activities in the water column (e.g. waste substances from aquaculture cages), on land (e.g. in run-off or effluent), or around activities (e.g. around trawling gear), or from disposal of materials onto the seafloor (e.g. disposal of materials from dredging). Smothering may lead to reduced functioning (e.g. feeding) or mortality of benthic animals living on or in the seafloor.

02. Sealing – Physical loss of habitat from sealing by permanent construction (e.g. Coastal defences, wind turbines)

03. Changes in Siltation – Change in the concentration and/or distribution of suspended sediments in the water column from run-off, dredging etc.

04. Abrasion – Physical interaction of human activities with the seafloor and with seabed fauna/flora causing physical damage and/or mortality (e.g. from trawling or anchoring).

05. Selective extraction of non-living resources – Includes sand and gravel (aggregates) extraction, removal of surface substrates for exploration of seabed and subsoil, or removal of seawater for e.g. cooling industrial plants or for desalination

06. Underwater noise (e.g. from shipping, acoustic surveys)

07. Marine Litter – Litter originating from numerous sources but entering the marine environment and consisting of different materials including: plastics, metal, glass, rubber, wood and cloth

08. Thermal change – Change in temperature of the water (average, range or variability) e.g. due to outfalls from industrial plants.

09. Salinity change – Change in salinity (average, range or variability), e.g. due to outfalls from industrial plants or alterations in coastal structures affecting mixing.

10. Introduction of Synthetic compounds – Introduction of manmade compounds such as pesticides, antifoulants and pharmaceuticals into marine waters.

11. Introduction of Non-synthetic compounds – Introduction of heavy metals and hydrocarbons into marine waters.

12. Introduction of Radionuclides – Introduction of radionuclides into the marine environment.

13. Nitrogen and phosphorus enrichment - Input of fertilisers, and other Nitrogen and Phosphorous rich substances, including any subsequent associated deoxygenation

14. Input of organic matter – Organic enrichment and any subsequent deoxygenation e.g. from industrial and sewage effluent into rivers and coastal areas, or from the waste from aquaculture or from fishing discards.

15. Introduction of microbial pathogens – Introduction of microbial pathogens into marine waters.
16. Introduction of non-indigenous species and translocations – Introduction of non-indigenous species and translocations by the activities of a particular sector (e.g. through exchange of ballast waters by shipping or from release of individuals from aquaculture).
17. Selective extraction of species – Extraction (and subsequent mortality) of any marine fauna (vertebrate or invertebrate) from their natural habitat, including incidental non-target catch (e.g. by commercial fishing, recreational angling and collecting/harvesting).
18. Death or injury by collision – Death or injury of marine fauna due to impact with moving parts of a human activity, e.g. Marine mammals with ships/jet skis, seabirds with wind turbines etc.
19. Barrier to species movement - Preventing the natural movement of motile marine fauna along a key route of travel (e.g. a migration route) due to barrages, causeways, wind turbines, and other man-made structures.
20. Emergence regime change – Changes to natural sea level regime (average, range or variability) due to barrages or other manmade structures such as coastal defences.
21. Water flow rate changes – Changes in currents (speed, direction or variability) due to barrages or other manmade structures such as coastal defences.
22. pH changes – Changes in pH (average, range or variability) e.g. due to run off from land-based industry.
23. Electromagnetic changes – Change in the amount and/or distribution and/or periodicity of electromagnetic energy emitted in a marine area (e.g. from electrical sources such as underwater cables)
24. Changes in wave exposure – Change in the size, number, distribution, and/or periodicity of waves along a coast due to installation of coastal structures

Ecological Components used:

01. Seabirds
02. Marine Mammals & Reptiles
03. Fish Deep Sea
04. Fish
05. Fish Demersal
06. Pelagic Water Column (inc. plankton)
07. Deep Sea Habitat (inc. benthos)
08. Littoral Rock (inc. benthos)
09. Littoral Sediment (inc. benthos)
10. Sublittoral Sediment (inc. benthos)
11. Sublittoral Rock (inc. benthos)

Sectors:

01. Aggregates
02. Agriculture
03. Aquaculture
04. Coastal Infrastructure
05. Desalination
06. Fishing
07. Harvesting/ Collecting
08. Land-based Industry
09. Military
10. Navigational Dredging
11. Nuclear
12. Oil & Gas
13. Renewable Energy
14. Research

15. Shipping
16. Telecommunications
17. Tourism/ Recreation
18. Wastewater Treatment

Appendix 2

Sector	Number of Connections	Pressure	Pressure	Number of Connections	Ecological Component
Fishing	2	Abrasion	Abrasion	3	Benthos
	3	Siltation/Smothering		3	Habitat
	3	NP/Organics			Fish
	4	Spp_extract			Plankton
		Sealing/Substrate Loss			Mammals
Tourism/Recreation	2	Abrasion			Seabirds
	3	Siltation/Smothering	Siltation/Smothering	4	Benthos
	3	NP/Organics		4	Habitat
	3	Spp_extract			Fish
	3	Sealing/Substrate Loss		4	Plankton
Shipping	2	Abrasion			Mammals
		Siltation/Smothering			Seabirds
		NP/Organics	NP/Organics	4	Benthos
		Spp_extract		4	Habitat
		Sealing/Substrate Loss			Fish
Land-based Industry		Abrasion		4	Plankton
	3	Siltation/Smothering			Mammals
	3	NP/Organics			Seabirds

		Spp_extract	Spp_extract	2	Benthos
		Sealing/Substrate Loss			Habitat
Agriculture		Abrasion		2	Fish
	3	Siltation/Smothering			Plankton
	3	NP/Organics		1	Mammals
		Spp_extract		2	Seabirds
		Sealing/Substrate Loss	Sealing/Substrate Loss	1	Benthos
				1	Habitat
				1	Fish
					Plankton
					Mammals
					Seabirds

Appendix 3

Please find below some of the clarifications/definitions of how we applied the process.

- In coastal infrastructure we included managed beaches (linking coastal infrastructure to aggregates pressure)
- Radionuclides were included under contaminants rather than as a separate pressure to fit better with ICES EOs (see table 1)

Annex 6: WGEAWESS network

WGEAWESS participants completed a table indicating their individual group memberships to indicate the breadth of their participation both within ICES and beyond. This provides us with a first stop to identify individual champions to help facilitate collaboration between ICES groups, and to eliminate redundancy in effort among groups. This table will be actively maintained and used to spark collaboration, including identifying suitable partners for back-to-back meetings, organising joint workshops, symposia and training, and cross-pollination of ideas and expertise. The network diagrams below illustrate the WGEAWESS network.

It is worth noting that between 14 members membership of 32 groups (21% of the ICES network) is represented.

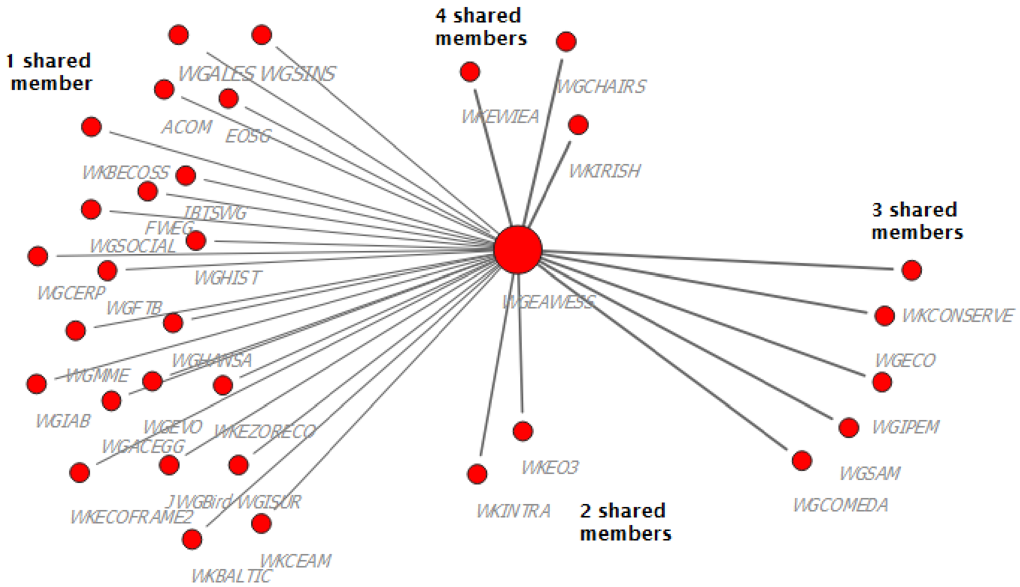

Figure A6.1. Diagram illustration the groups that WGEAWESS members interact with, clustered by number of shared members.

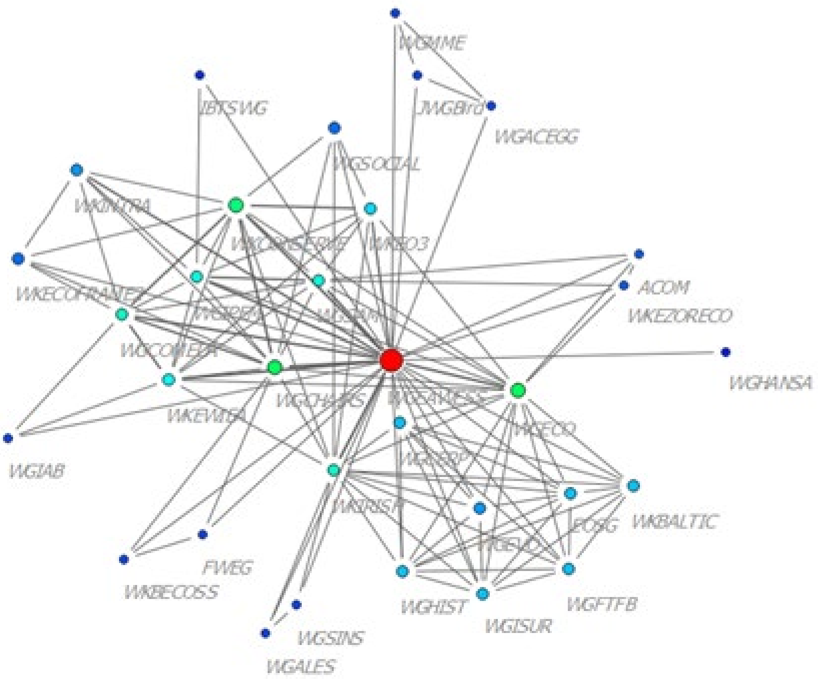

Figure A6.2: Network diagram illustration the WGEAWESS ICES group network.