WORKSHOP ON AN ECOSYSTEM BASED APPROACH TO FISHERY MANAGEMENT FOR THE IRISH SEA (WKIRISH6; OUTPUTS FROM 2019 MEETING)

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ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

Contents

i Executive summary

The Sixth Workshop on an Ecosystem Based Approach to Fishery Management for the Irish Sea (WKIRISH6), set out to operationalise the WKIrish regional benchmark process. WKIrish aimed to incorporate ecosystem information into the ICES single-species stock assessment process for the Irish Sea. Three independent ecosystems models have been in development for the Irish Sea. Of these, an Ecopath with Ecosim (EwE) model has been reviewed by the ICES Working Group on Multispecies Assessment Methods (WGSAM). WKIrish propose to use relevant ecosystem indicators to inform the F_{MSY} within the established F ranges ($F_{MSYLower}$ to $F_{MSYUpper}$). F_{IND} uses indicators of current ecosystem suitability for individual stocks to refine the F target values within these precautionary ranges. F_{IND} is based on finding ecosystem indicators which are positively related to the stock development over the model tuning range, and where the likely underlying mechanisms for this link are likely to continue acting in the short to medium term. This approach is based on the assumption that because the assessment model is tuned to data over a period of time, the model may not fully capture environmental variation occurring on a shorter time span, and hence provides a method of adjusting target F to account for this variation. In essence, the proposed system suggests that where the value of the indicator is above average for the model tuning period the ecosystem is in a favourable state for that stock and consequently F in the upper range may be advised. Conversely, where the indicator is below the average, indicating that that ecosystem may be in an unfavourable state for that stock, F should be in the lower range. In no case does the proposed F target lie outside the ranges defined as being precautionary as giving good yield, and thus the system proposed here remains according to the ICES principles of precautionarity and delivering good overall yield. This method also ensures that stock assessment, reference point and stock status determination and quota setting remain within the approved stock assessment model, with ecosystem information only being used to refine the target F.

The EwE model was used to provide ecosystem indicator(s) for individual stocks (cod, whiting, haddock, sole, plaice, herring, and *Nephrops*) in the Irish Sea. The selection of the indicator aimed to cover a range of possible ecosystem processes on each stock. Through this approach, WKIrish has identified a route by which ecosystem information can be incorporated into the current single species assessment process. However, the approach can be developed further; a potential framework for a more complete Ecosystem Based Fishery Management is described. This framework would use ecosystem descriptors to inform decision making within assessment benchmarking processes. This may involve, but is not limited to: exploring productivity change across the assessment time-series, examining trends in aspects of population dynamics such as natural mortality and recruitment success, and input into the definition of reference points.

ii Expert group information

Expert group name	Workshop on an Ecosystem Based Approach to Fishery Management for the Irish Sea (WKIrish6)
Expert group cycle	Annual
Year cycle started	First WKIrish was held in 2015
Reporting year in cycle	1/1
Chairs	Mathieu Lundy, UK
	Daniel Howell, Norway
Meeting venues and dates	14–15 September 2015, Dublin, Ireland (27 participants)
	26–29 September 2016, Belfast, Northern Ireland (13 participants)
	30–3 February 2017, Galway, Ireland (11 participants)
	5–9 November 2018, Dublin, Ireland (17 participants)
	25–29 November 2019, Dublin, Ireland (17 participants)

1 Introduction

The Workshop on an Ecosystem Based Approach to Fishery Management for the Irish Sea WKIrish6 met in Dublin, Ireland, 25–29 November 2019. The purpose of the benchmark workshop was to finalise and operationalise the WKIrish regional benchmark process, WKIrish6 aimed to finalise and review the ecosystem modelling work initiated at the Scoping Workshop (WKIrish1), the Stakeholder Input Workshop (WKIrish4) and the EBFM workshop (WKIrish5). For discussion were practical methods to incorporate ecosystem information into the fisheries stock assessment process, and tactical advice for the Irish Sea.

At WKIrish5, a framework was proposed by which the information from the ecosystem models developed for the Irish Sea could be used to select an F_{MSY} target within the ranges set by single-species assessments. Thus, if indicators for a stock were "good", that stock could be fished at a higher level within the existing ranges. If the stock indicators were "poor", then fishing would be at a lower level within the ranges. In this way, ecosystem considerations could be reflected without violating existing single-species "precautionary" reference points and while retaining "good" yield. Furthermore, by using the ecosystem information to refine the target F in this way, the quota setting could still be conducted within the single-species assessment models. The rationale is that if a process of limited scope for doing this in the Irish Sea can gain acceptance and be seen to add value, it may be taken up in other regions and subsequently broadened out.

Three independent ecosystems models have been in development for the Irish Sea, all initiated through the WKIrish Benchmark process. These models are: an Ecopath with Ecosim (EwE) model, a 'Length-based Multispecies analysis by numerical simulation' LeMans, and the Model for the Simulation of Ecological Systems (MoSES). Progress toward their full implantation was presented at WKIrish6 and is summaried below. The EwE model is the most advanced regarding operational completion. At WKIrish5, it was recommended that a key run of EwE should be reviewed at WGSAM, which was successfully achieved.

2 EwE model

A key run for the Irish Sea EwE model covering 1973–2016 was produced following a review by WGSAM 2019. The Irish Sea EwE model was co-created by researchers and stakeholders as part of ICES WKIrish. A full model description can be found in the Irish Sea EwE annex of the 2019 WGSAM report.

The Irish Sea EwE key run comprises 41 functional groups including two detrital groups (detritus, discards), two primary producers (phytoplankton, seaweed), ten invertebrate groups, 22 finfish groups, two seabird groups (low discard diet and high discard diet), and three marine mammal groups (Figure 1). Cod, whiting, haddock, and plaice functional groups were represented with two life stages, adult and juvenile. Multi-stanza representation of life stages enables the model to account for ontogenetic changes in diet preference and fishing mortality. The models initial diet matrix for finfish was built using information held in the Cefas integrated Database and Portal for STOMach records (DAPSTOM). Diets for mammals, seabirds and invertebrates were taken from literature. Fishers' knowledge regarding the diets of commercially important species was shared during a WKIrish workshop (WKIrish4) held in Dun Laoghaire, Ireland, on the 23–27 October 2017. The aim of the workshop was to update the Irish Sea model so that it used both scientific knowledge and fishers' knowledge of predator–prey interactions for the species they commonly encountered in their operations, and where they would have observed stomach contents whilst processing catches. During the workshop, cod, whiting, haddock, plaice, rays (*Raja spp*.), and Norway lobster were identified as the species for which fishers' felt they had substantial knowledge.

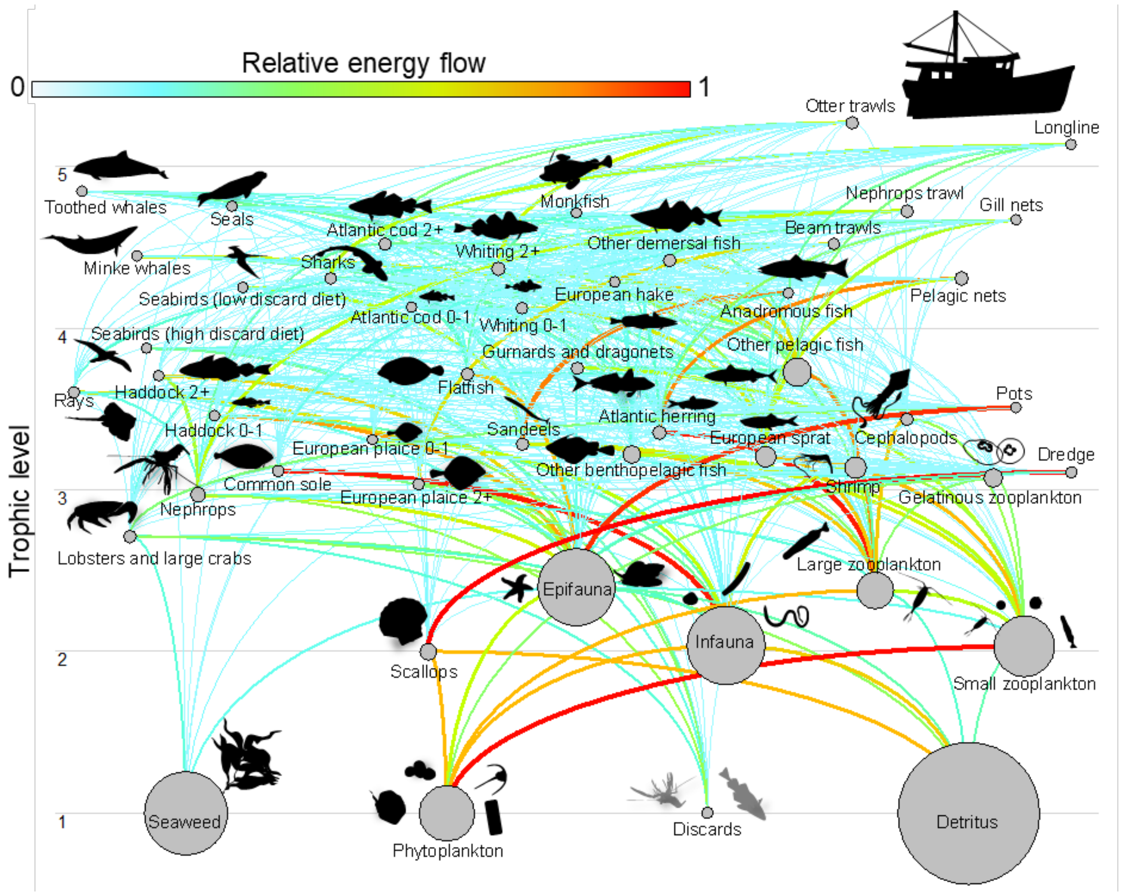


Figure 1. Energy flow and biomass diagram for the Irish Sea Ecopath foodweb model. Functional groups and fleets are represented by nodes, the relative size of functional group nodes denote their biomass whilst the size of fleet nodes denote the size of their catch. Lines represent the flow of energy and the y-axis denotes group trophic level.

The Irish Sea model contains eight fleets, which are based on the aggregation of gear categories used in the STECF (Scientific, Technical and Economic Committee for Fisheries) reports. Catches in the model are assigned using data from ICES landings statistics and STECF records. The temporal Ecosim component of the model runs from 1973–2016. The model is calibrated against 52 biomass and catch time-series and driven by eight fishing effort time-series, environmental forcing on cod and whiting recruitment and zooplankton mortality, and temperature response functions for all functional groups. Model simulations are provided in Figure 2a–d.

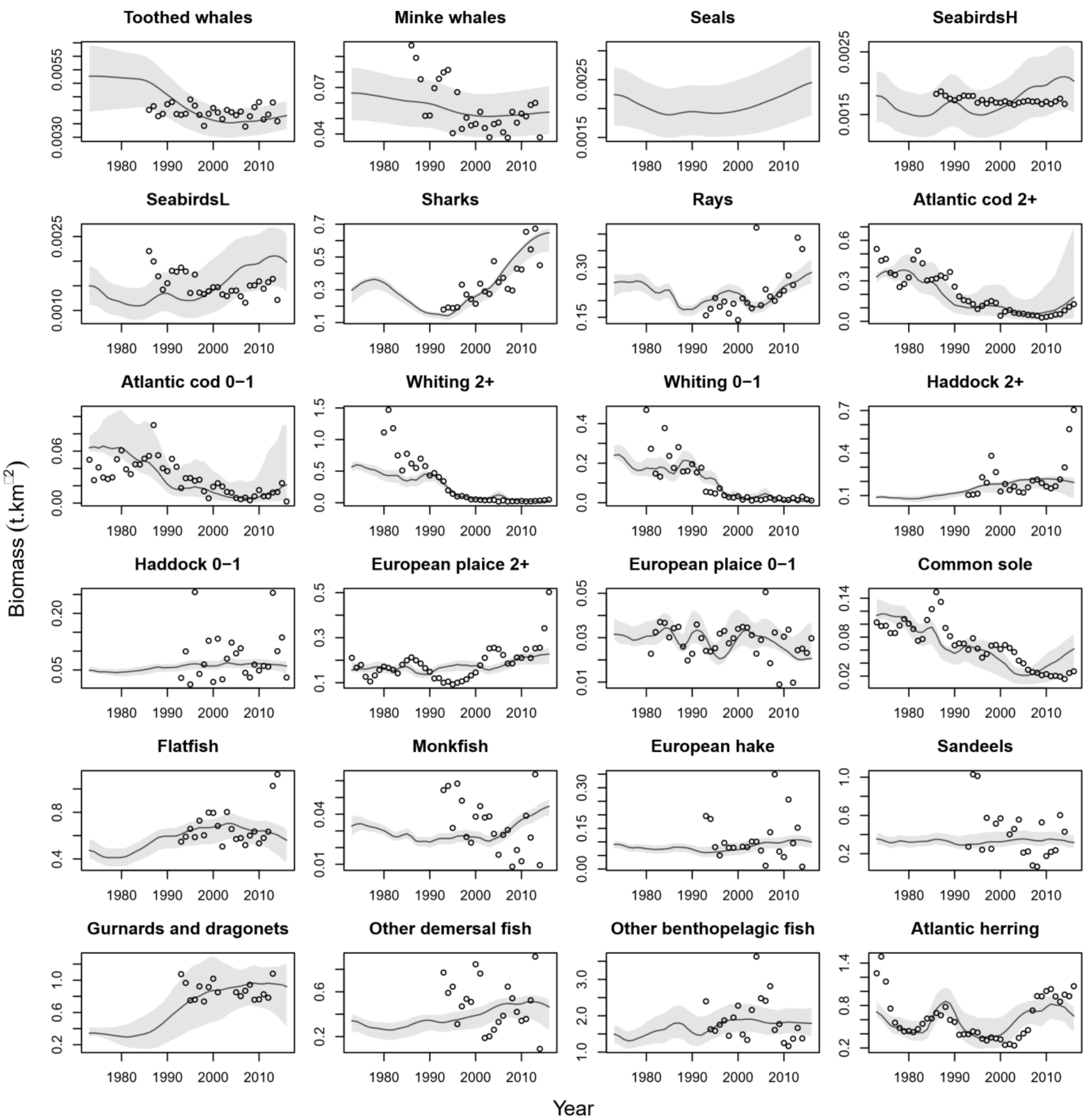


Figure 2a. Ecosim predicted biomass trends (1/2) post WGSAM for functional groups in the Irish Sea Ecopath with Ecosim model. Black lines indicate model simulations against observed data (points). The shaded area indicates 95% confidence intervals based on Monte Carlo simulations varying Ecopath basic input parameters (B, PB, QB, diet).

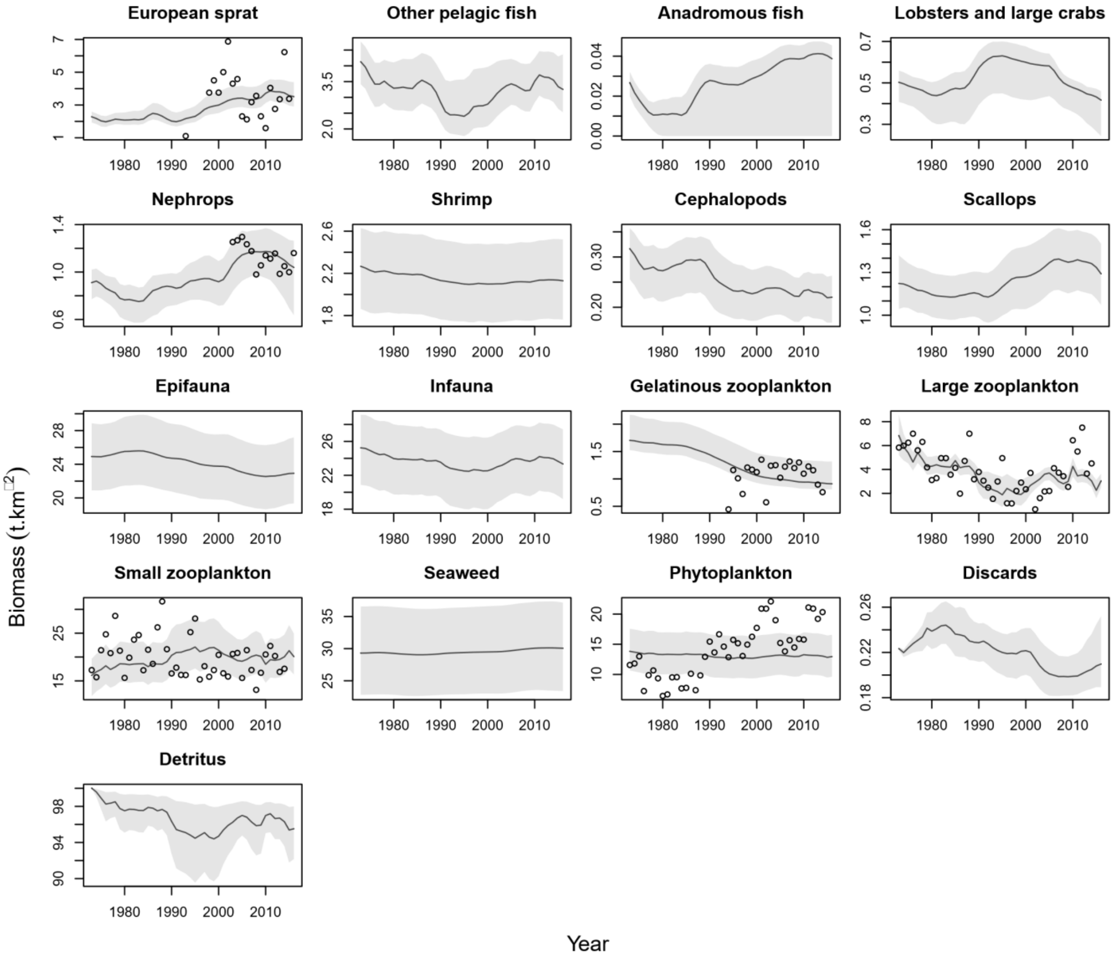


Figure 2b. Ecosim predicted biomass trends (2/2) post WGSAM for functional groups in the Irish Sea Ecopath with Ecosim model. Black lines indicate model simulations against observed data (points). The shaded area indicates 95% confidence intervals based on Monte Carlo simulations varying Ecopath basic input parameters (B, PB, QB, diet).

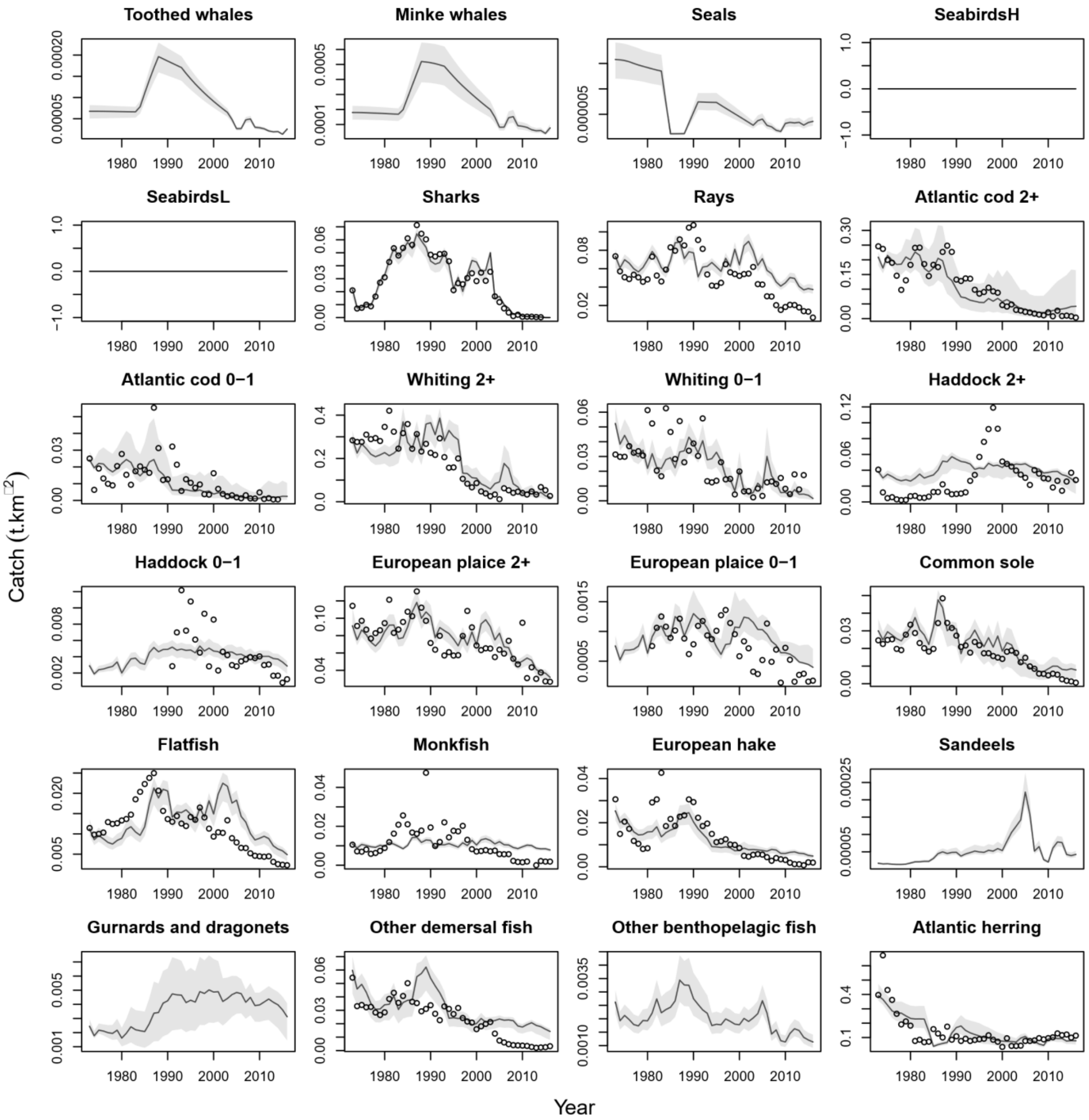


Figure 2c. Ecosim predicted catch trends (1/2) post WGSAM for functional groups in the Irish Sea Ecopath with Ecosim model. Black lines indicate model simulations against observed data (points). The shaded area indicates 95% confidence intervals based on Monte Carlo simulations varying Ecopath basic input parameters (B, PB, QB, diet).

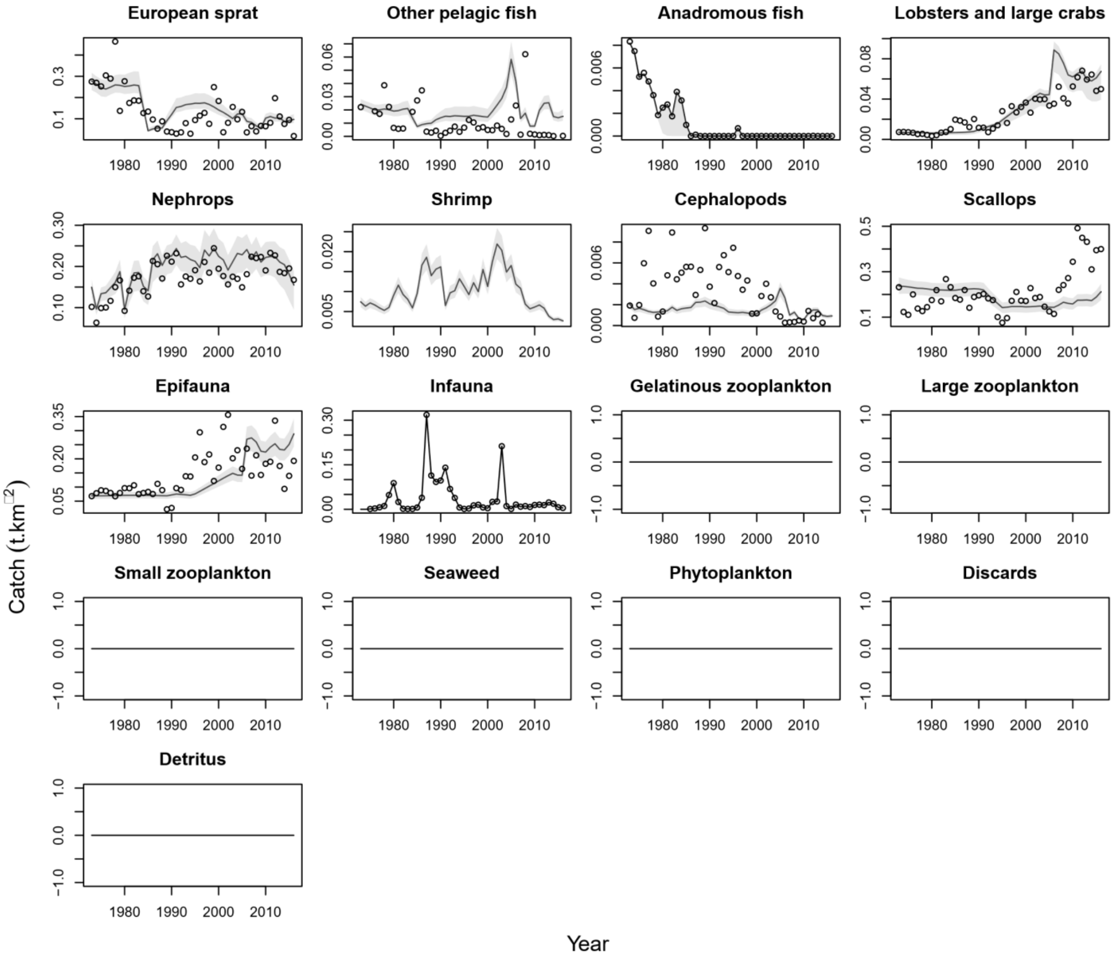


Figure 2d. Ecosim predicted catch trends (2/2) post WGSAM for functional groups in the Irish Sea Ecopath with Ecosim model. Black lines indicate model simulations against observed data (points). The shaded area indicates 95% confidence intervals based on Monte Carlo simulations varying Ecopath basic input parameters (B, PB, QB, diet).

3 LeMans model

Progress toward development of a 'Length-based Multispecies analysis by numerical simulation' LeMans, multispecies mixed fisheries model, for the Irish Sea was presented. The current model incorporates eight key fish stocks (cod, haddock, whiting, plaice, sole, herring North, *Nephrops* West (FU15) and *Nephrops* East (FU14)). The model was developed independently of ICES single-species stock-assessments to conduct a shadow assessment, which can further the understanding of why multiple depleted stocks have not recovered following management measures. The model was fitted directly to landings and survey data, and it was possible to estimate fishing mortality rates that incorporate multispecies interactions. Within this framework, a length-structured fish community is simulated with multiple stocks and fishing fleets explicitly represented. By characterising processes as functions of length (including fishing, natural mortality, and predation), it is possible to reproduce many aspects of the community dynamics (such as the tendency of diet to change with increasing predator size) and incorporate important technical and management measures altering the fishing process (e.g. changes to mesh requirements and restrictions on minimum landing size). The size-based approach also allow for models to be developed with a relatively small number of parameters, and modest data requirements. The modelling approach has been refined by Cefas for the North Sea (Thorpe *et al*., 2015; 2016; 2017; Thorpe and De Oliveira, 2019).

Generally, it was observed that fishing mortality rates from the multispecies model were lower than that of the ICES single-species assessments, but the qualitative patterns were similar. The LeMans model predicted larger spawning–stock biomass (SSB) for whiting and sole, but similar SSB for other stocks.

The model was presented to WKIrish6 and compared to the two other models: Ecopath with Ecosim (EwE) and the MoSES. The group (including stakeholders) acknowledged the added value of a suite of models, in particular the ability of the LeMans model to predict change in unwanted catch of small sized fish and model selectivity patterns of the fishing fleets (which EwE is unable to capture). However, there were some concerns about the natural mortality rates estimated by the model. Future work should focus on addressing the comments of the ICES WKIrish workshop in order to improve confidence in the model fit. This includes i) improving fleet catchability curves for fleets, ii) more formally evaluating predator–prey overlaps and how these have changed over time as an input to predator–prey interactions and iii) incorporating environmental factors in recruitment dynamics.

F_{MSY} values from the multispecies assessment for all but cod are larger than those provided by the current ICES MSY single-stock assessment approach.

4 MoSES

Progress on the development of MoSES (Model for the Simulation of Ecological Systems) was presented. MoSES is a multispecies dynamic metabolic model, currently in development.

The core elements of MoSES are individual species, although for its application to the Irish Sea, some species are aggregated into functional groups, like polychaetes or macro-algae. The formulation of the model follows closely a Rosenzweig-MacArthur predator–prey model, where the state variables are total population biomass for a specified area, so it does not have age or size structure and is not spatially explicit.

MoSES is based on the concept of metabolic allometry, whereby most of the required parameters for each species can be estimated from individual mass which makes it possible to formulate the model with a small set of general parameters and, more importantly, to keep the model very general. Growth and mortality rates for primary produces (as a function of mass) are taken from Marbá *et al*. (2007). For heterotrophs, the central concept is field metabolic rate (i.e. total respiration rate). This is estimated as a function of body mass and temperature, following Giloolly *et al*. (2001), as:

$$R = aM^{b}e^{\frac{-E}{kT}} \qquad \text{[eq. 1]}$$

Where M is mass, T is temperature, k is Boltzmann's constant and a, b, and E are fitted parameters. Equation 1 is fitted to a database of field metabolic rates, body mass and temperature that includes approximately 650 species and 4000 records (Figure 3). This database is not limited to marine systems, but includes data from terrestrial and soil systems as well. Respiration rate, and the energy density of body tissues, determines mass loss rate (i.e. intrinsic mortality rate) for each species. Further, respiration rate ©, together with the efficiencies of assimilation and production and energy density, determines the maximum consumption that a predator requires to offs*et al*l its energy needs. This maximum consumption, in turn, modulates the functional response in the model and, consequently, predation mortality for the prey. Note that in eq. 1 temperature is explicitly included, which provides a mechanistic link between ambient temperature and the dynamics of the foodweb.

Prey preferences are included in MoSES, in the functional response. These define the probability that a predator will actually consume each of its prey. These preferences are estimated based on a linear model fitted to predator–prey mass ratios compiled by Barnes *et al*. (2008), which contains approximately 35 000 records of observed predator–prey interactions in marine ecosystems. This linear model is used to estimate the ideal prey size (preference = 1), and the preference for prey of other sizes based on a normal function (Figure 4).

Fishing mortality is included in MoSES based on the ICES records of landings and discards for each species. During the integration of the system, fishing mortality is calculated at each time step t, as:

$$F(t) = -\log(1 - hr(t)) \qquad \text{[eq. 2]}$$

Where hr(t) is harvest rate at time t, the ratio of species' biomass versus landing plus discards.

4.1 Irish Sea

The list of species included in the current application of MoSES to the Irish Sea was created by taking the groups defined for the EwE model and expanding them to species level. To this, a list of phytoplankton and zooplankton species was added (provided by SAHFOS).

The information to populate the matrix of trophic interactions is taken from DAPSTOM database (Pinnegar, 2014) for fish and some large invertebrates. Only records after 1930 and regions 7.a (Irish Sea) and 7.g (Celtic Sea) were included. If no information about a species was found with those conditions, regions 7.f and/or 7.h were also included. The diet information for other species was taken from the general literature. In total, the current version of the model has 159 species plus detritus: 51 fish, 16 birds, five mammals, 24 phytoplankton, 33 zooplankton and 30 benthic species.

4.2 Calibration

One of the main parameters of the model is the attack rate (α), the slope of the functional response at low prey densities. There is some evidence that attack rates are also correlated with the body mass of both predator and prey (Rall *et al*., 2012). However, the application of these results did not allow to maintain persistent communities. For this reason, the application of MoSES to a specific foodweb requires a process of calibration to find appropriate values of attack rates. This calibration consists of repeated runs of the model (without fishing mortality and with constant temperature) after each of which the attack rates of consumers with low or high biomass are slightly increased or decreased, respectively. The process continues until all (or most) species' biomass are within acceptable limits as defined by the user. For the Irish Sea application, these limits are the biomass estimated for the Ecopath model for 1973, as the lower limit, and three times that as the upper limit.

The calibrated model represents a persistent (or even stable) community in the absence of exploitation. Fishing mortality and variable temperature can then be included to explore their effects on the foodweb. The current focus of the model's development is to explain the strong decline of cod and whiting from the early 1990s. With the current assumptions, MoSES predicts a steady recovery of both species after catches started to decrease from the early 1990s onwards (Figure 5). Other factors are being explored to improve the model's fit to assessment estimates.

4.3 Future development

4.3.1 Possible areas for further development of MoSES

Coupling of the phytoplankton traits with physical variables known to control its growth. Currently, phytoplankton's intrinsic growth rate in MoSES is independent of temperature. There is evidence that temperature has some effect on this trait, although not as strong as on heterotrophs' metabolic rate. Including this effect would allow to simulate more realistically the effects of variable temperature on the community (e.g. effects of climate change).

At present, the model is based on total biomass, with no age or size structure. Introducing size structure (length or mass) would allow a more detailed simulation of several processes, like changing diets with ontogenetic development, changing metabolic rates and size-dependent fishing mortality.

Introducing some level of spatial dynamics, either through a meta-population approach or making the model spatially explicit would be desirable. The distribution of species is not spatially uniform. Different population densities at different areas can change the strength of species interactions at the local scale and, consequently, the dynamics of the community at the regional scale. This is an aspect that is currently not included in MoSES.

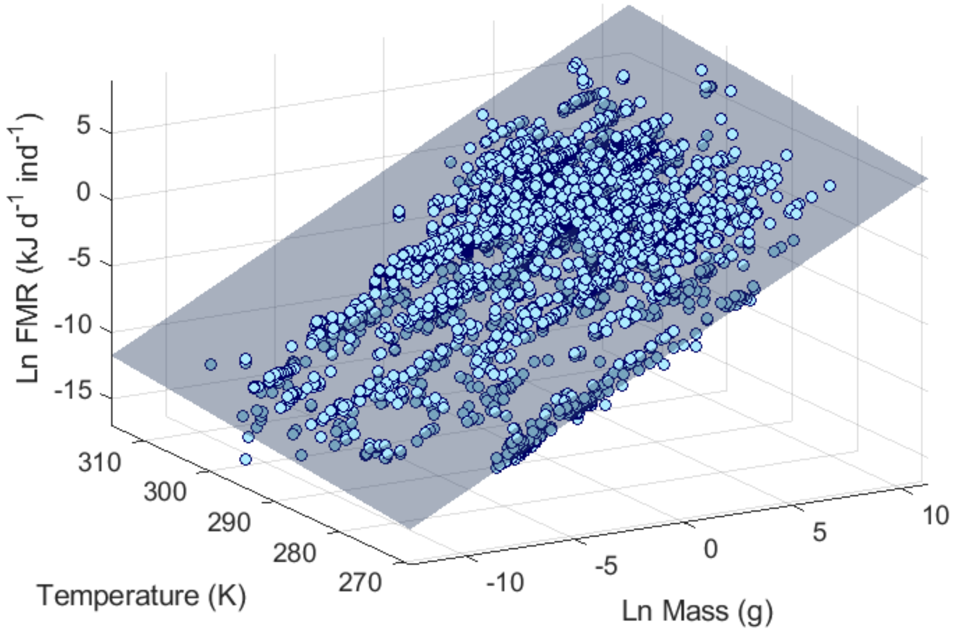


Figure 3. Fit of field metabolic rate (FMR) to body mass and temperature (Eq. 1) in log-log. The figure shows the data for ectotherms. Endotherms are fitted separately.

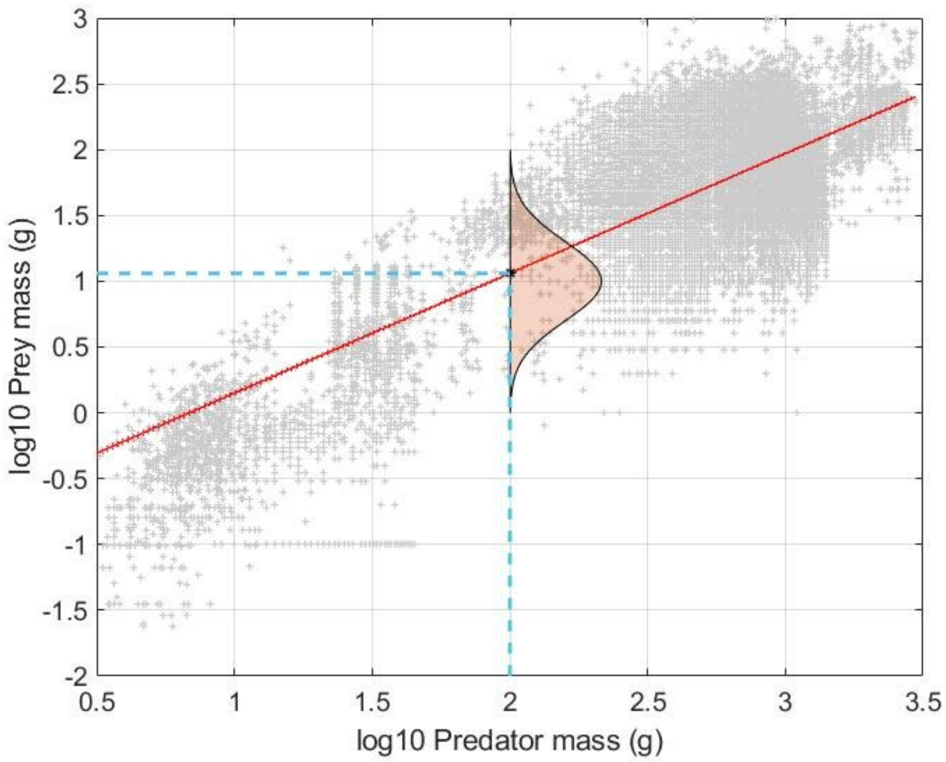


Figure 4. Linear model fitted to predator–prey size data (Barnes *et al.*, 2008). Dotted lines show the predicted ideal size (approximately 10 g) for a predator of 200 g. The shaded area represents the probability (normal function) that a prey of mass above or below the ideal size will be consumed by the predator. This probabilities are taken as prey preferences in MoSES.

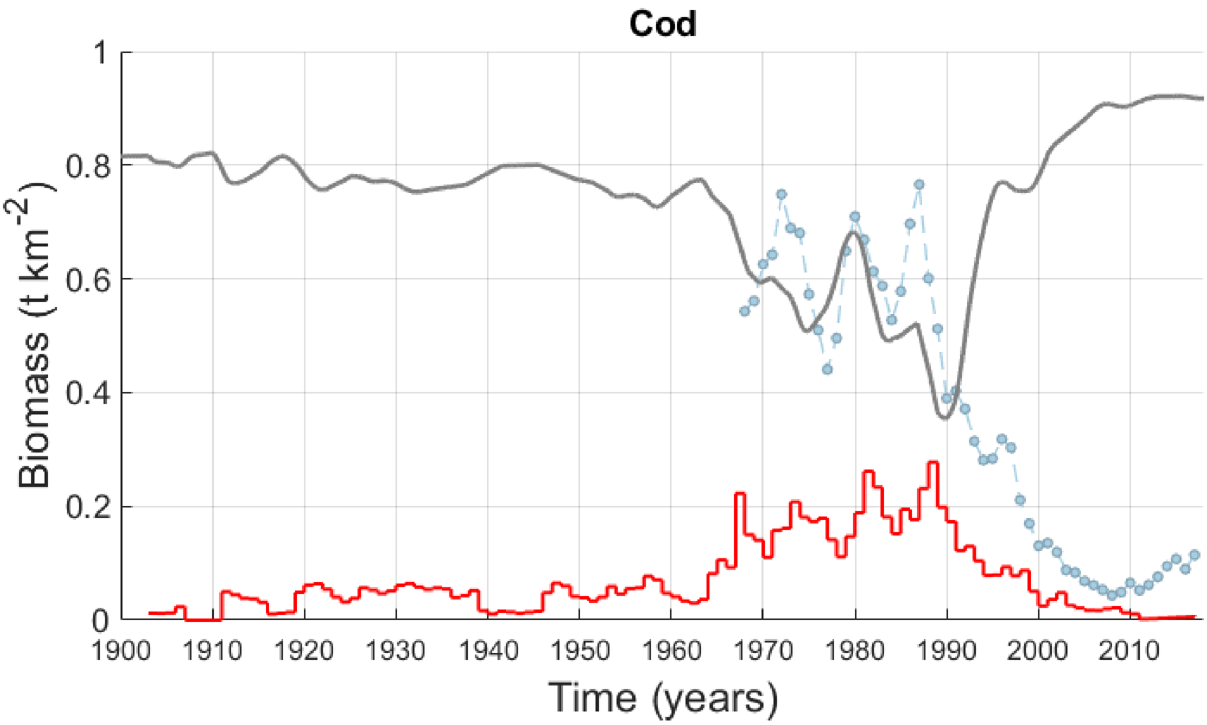


Figure 5. Example of a simulation of cod population with MoSES. The dots and dotted line are the assessment estimation; the grey line is model's prediction; and the red histogram are total catches (landings plus discards). After 1990, when catches started to decline, the model predicts a recovery of the population in approximately a decade.

5 The WKIrish EBFM approach

Through the WKIrish process a EwE model is now in place for the Irish Sea. The model has been reviewed by WGSAM (ICES 2019) commenting:

For the Irish Sea, the ICES WKIRISH requested review of an Irish Sea Ecopath with Ecosim (EwE) model. An aim of the WKIRISH process is to suggest methods by which some of the outputs of the Irish Sea EwE can be used to influence quota setting. The aim of WKIRISH is not to use F values directly from the EwE, but rather to use the EwE output as a synthesized ecosystem indicator to help inform the choice of F_{target} *within the pre-defined* F_{MSY} *ranges. This method would allow for the incorporation of ecosystem information within the quota setting process, while remaining within the existing precautionary fisheries management framework and the current reference point ranges used by ICES.*

WGSAM approves the Irish Sea EwE model as a key run to provide a basis for producing indicator(s) which could be used to inform the selection of fishing mortality targets within a pre-defined range of F values evaluated as precautionary using the single species assessment models. WGSAM does not recommend directly transferring F_{MSY} *values estimated by the EwE model into other models or for direct use in management.*

WKIrish6 continued to develop along this line of work initiated at WKIrish5. Whilst other ecosystem models are in development, the EwE model was the main tool explored at WKIrish6.

The relative trends in modelled predation mortality for the key species in the Irish Sea EwE model are shown in Figure 6. In each case, the mortalities are rescaled to 0–1, so that it is the relative trend that is shown, rather than the absolute magnitudes. While there are key differences between the species, there is a clear overall trend with relatively high predation mortalities in the 1970s and 1980s, followed by a decline in the late 1980s and 1990s as the gadoid stocks in the area are reduced. There is then an upturn in predation mortalities in the 2000s, although with significant variation in magnitude and timing between the stocks. In addition to per species results, the predation mortality on Trophic level 4+ and on all species aggregated by biomass are also shown. It can be seen that the predation mortalities on the trophic level 4+ have increased strongly since ca. 2000, whilst for the biomass the increase is much less and begins in ca. 2010, indicating that the recent increases in predation target the higher trophic level species. This has implications for Ecosystem Based Management, with higher trophic species a much more likely candidate for using predation as a tuning parameter than lower trophic level ones. Cod and sole, in particular, show strong increases in predation mortality over the last two decades and are the only species where predation mortality is modelled as being at, or above, the level in the 1970s. Haddock, *Nephrops* and plaice have all experienced rises in predation mortality in recent years, but this still remains relatively low compared to the 1970s and 1980s.

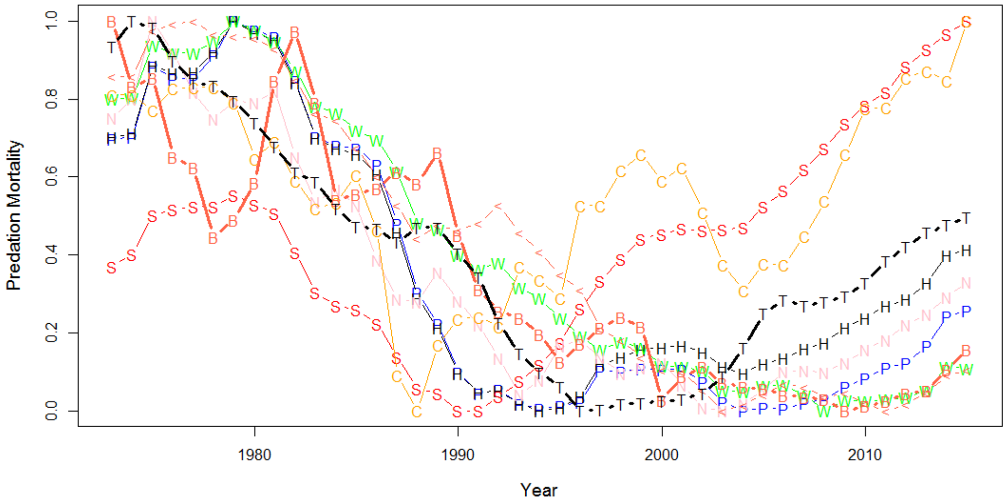


Figure 7. Trends in © Cod; (H) Haddock; (P) Plaice; (W) Whiting; (S) sole; (N) *Nephrops*; (<) Herring; (T) 4+ Trophic leve; (B) system Biomass derived for the Irish Sea EwE model.

6 Towards implementation of the use of ecosystem information into management advice

During WKIrish5, it was proposed to use an ecosystem indicator (or indicators) to inform fishing opportunity for each stock within the range of F_{MSY} values between $F_{MSYLower}$ to $F_{MSYUpper}$. The proposal of WKIrish is to use a relevant ecosystem indicator to inform the target F within that range. The proposed system uses a linear scaling of the indicator relative to its long-term range, and use this to scale the F_{target}. The system thus provides a scaling 0 [F_{lower}]–1 [F_{upper}], by comparing the indicator value in the current period to its long term values and rescaling 0–1. Appling this to select F within the F_{lower}–F_{upper} range provide F_{IND}. The application of the F_{IND} is also demonstrated to fit within the current advice rule, with regard to MSY $B_{Trigger}$ (Figure 8).

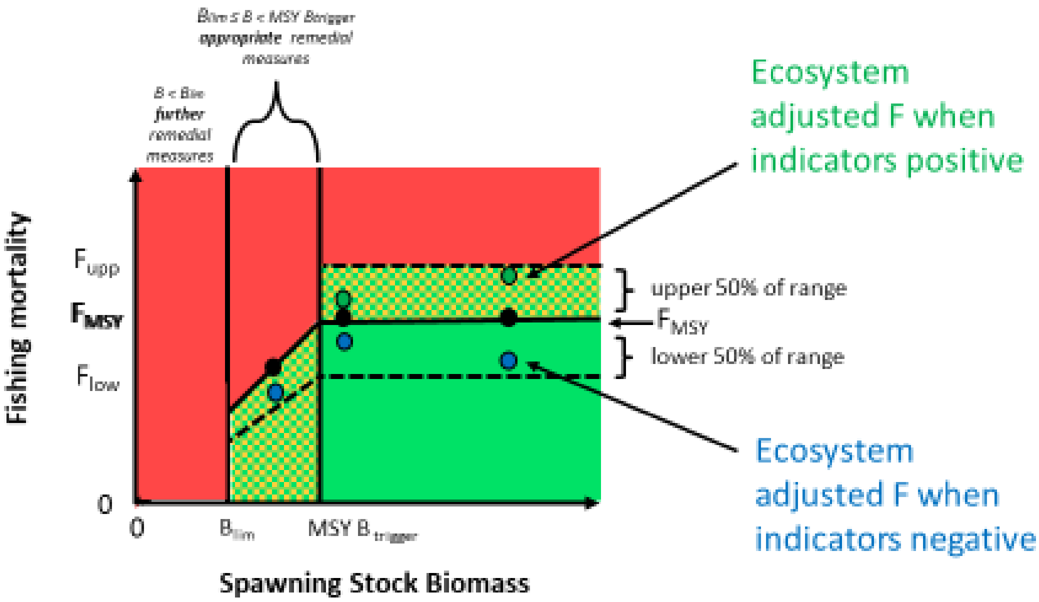


Figure 8. Scenarios of the application of the ICES MSY advice rule when incorporating ecosystem indicators within the F_{MSY} ranges.

Which indicator(s) is/are appropriate will vary by stock. At WKIrish6 candidate indicators were proposed and explored for each of the key Irish Sea stocks (cod, whiting, haddock, sole, plaice, herring, and *Nephrops*). The EwE model was used to explore the relationship between the candidate indicators and the EwE derived trends of stock size. The potential indicators ranged from single parameters such as Sea Surface Temperature or a more complex (EwE) model derived metrics such as the indices of trophic level. Only first order linear relationships were tested in this first round, but it was recommended that further exploration of more complex relationship may yield different candidate indicators. The use of linear relationships also allows for a simple linear scaling of the F_{target}, as described above. WKIrish6 considered that ecosystem indicators could be derived through multispecies or ecosystems models incorporating the key elements of the system within which the stock is contained. The indicator may be an identified environmental driver or an ecosystem derived metric, although in the Irish Sea at present only the EwE model was sufficiently developed for this purpose. These indicators should be based on a biological understanding of the stock that is combining finding a relationship with a biological understanding of the likely mechanism behind the relationship. Where combining multiple indicators is proposed, the evaluation must ensure independence of the indicators and the combination should use weighing the indicators by their relative importance, as quantified in the selected ecosystem model. For the sake of simplicity, there should be strong evidence of the need to include multiple indicators, with a single indicator being the default option in the absence of such evidence. Equally, where multiple possible indicators measure outcomes from a single driver (for examine sea temperature and interdecadal ocean variability) it would be preferable to choose a single indicator to avoid “double counting”.

Candidate indicators were examined for each of the seven currently assessed stocks in the Irish Sea (Table 6 and Figure 9). The selection of the candidate indicators aimed to cover a range of possible ecosystem processes on each stock, including bottom up effects such as primary productivity, top–down effects such as predation, and environmental drivers such as ocean circulation and temperature. Where no convincing relationship could be identified, no indicator is proposed.

Table 6. Candidate ecosystem / environmental variables examined for relationships with stock size as a means to inform F within the F ranges.

<table>
<tr><th>VIIa Stock</th><th>Whole ecosystem indicators</th><th>M</th><th>Stock-specific indicators</th></tr>
<tr><td>Cod</td><td rowspan="7">System production
Primary productivity
Diversity
Average higher trophic level</td><td rowspan="7">Natural mortatlity
Total mortality</td><td>SST
SST (lagged)
East Atlantic Pattern (EAP)</td></tr>
<tr><td>Whiting</td><td>SST
SST (lagged)
East Atlantic Pattern (EAP)</td></tr>
<tr><td>Haddock</td><td>Bottom temperature</td></tr>
<tr><td>Sole</td><td>No stock-specific indicator identified</td></tr>
<tr><td>Plaice</td><td>No stock-specific indicator identified</td></tr>
<tr><td>Herring</td><td>Food availability (zoop.)
NAOw
Bottom Temperature</td></tr>
<tr><td>Nephrops</td><td>No stock-specific indicator identified</td></tr>
</table>

For two stocks (cod and whiting) both Sea Surface Temperature and the East Atlantic Pattern (EAP) were identified as indicators of stock production. It is likely that these effects are occurring due to variations in the favourable spawning habitat. Since these are both temperature related, and both relate to the same mechanism, it is not necessary to use both. The mechanism acting on the favourable habitats is likely to be direct temperature effects, and therefore the use of the EAP would not capture the effects of a long-term trend for increasing temperature. Consequently, SST is the preferred indicator for these species. The relationship with SSB for these stocks was improved by lagging the SST (three years), to align the environmental condition with potential recruitment drivers of stock size. For sole, plaice and haddock no convincing indicators (both strong correlation and mechanism of effect) were identified, and therefore there is no proposal to base advice on these species on ecosystem considerations at this point. Further research is of course encouraged. For herring, the large zooplankton index was observed to be strongly positively correlated with stock biomass and therefore selected as an appropriate indicator of favourable environmental condition for the stock. For *Nephrops* the abundance of higher trophic levels (4.+) was strongly related to the predation pressure on *Nephrops*. In this case, it is considered that foodweb and ecosystem consideration *should be* given to higher trophic levels when setting fishing limits on lower key prey species.

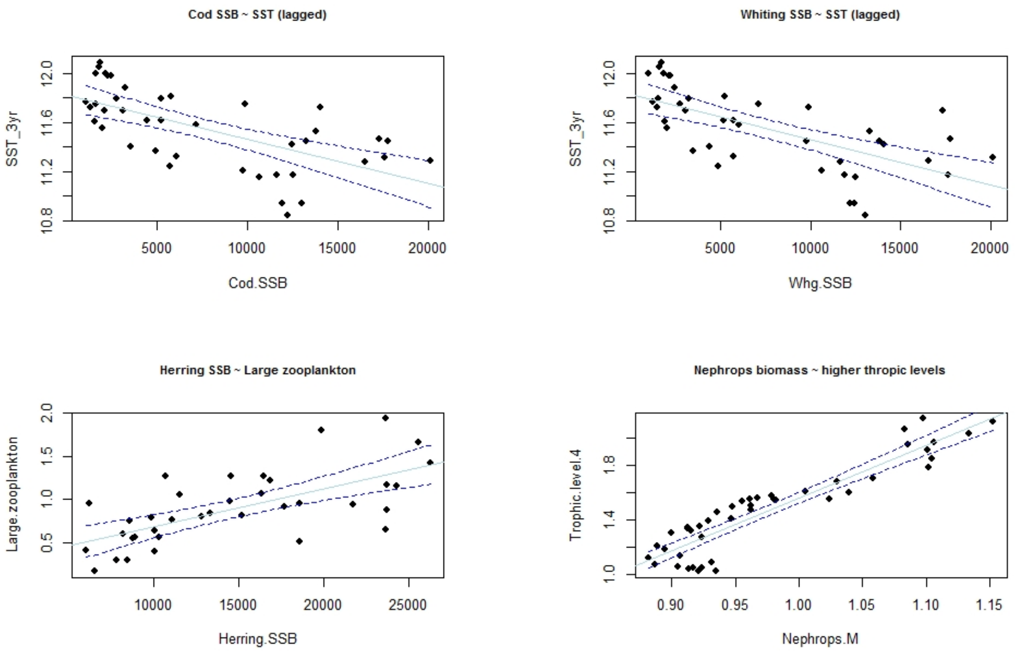


Figure 9. Proposed indicators explored for each of the key Irish Sea stocks cod, whiting, sole, herring and *Nephrops*).

7 Implementation of F_{IND}

The F_{MSY} range [F_{lower}, F_{upper}] principle is intended to deliver no more than a 5% reduction in long-term yield compared with the maximum sustainable yield (MSY). F_{MSY} is set as the F that ◎aniel◎es median long-term yield whilst meeting precautionary criteria. F_{MSY} cannot exceed F_{pa}. These ranges are derived through long-term simulation of observed stock dynamics and include appropriate assumptions of biological variability and assessment process error. Selection of F_{MSY} values and ranges must evaluate the ICES MSY advice rule (AR). The AR applies a linear reduction of F towards zero when SSB is below MSY $B_{trigger}$, with F = 0 when the SSB is below B_{lim}. Comparison of the estimated F_{MSY} and F_{upper} values between simulations including the AR must ensure that the precautionary criterion of having a less than 5% annual probability of SSB $<B_{lim}$ is met. F_{upper} is capped at lower $F_{P.05}$ from simulations that include or exclude the AR. In the case that F_{MSY} exceeds F_{upper}, F_{MSY} is F_{upper}.

WKIrish consider that F_{IND}, the ecosystem advised F, is a precautionary method to advise F within the predefined F_{MSY} ranges. F_{IND} uses indicators of current ecosystem suitability for individual stocks. In essence, F_{IND} supports that when the ecosystem is in a suitable state F in the upper range may be advised for the stock, whilst when the ecosystem is in an unsuitable state F in the lower range should be the target of management. However, within the ecosystem context WKIrish also note that when there is a trend of regime change resulting productivity change within the system the ecosystem approach may inform the appropriateness of the time period over which F ranges are calculated. Only when these aspects are fully considered are the F ranges and in turn the F_{IND} truly precautionary.

For stocks with ranges F_{IND} is selected within the range F_{lower} to F_{upper}. The indicator value is:

$$I = I_{YR} / \max(I_{YR}^{0-n})$$

Where I_{YR} is the final indicator value in the benchmarked ecosystem model and I_{YR}^{0-n} is the time-series of the indicator:

$$F_{IND} = F_{lower} + ((F_{Upper}-F_{Lower})*I)$$

The values of the indicator can be updated annually when derived from environmental time-series or in the case of model derived metrics should be updated at regular benchmark reevaluation of the ecosystem models.

The F_{IND} is considered precautionary given utilization of the existing F_{MSY} range. When SSB is below MSY $B_{trigger}$ F_{IND} is applied to the linear reduced F_{MSY} following the AR:

$$F_{IND} = I*(F_{MSY} \times SSB_{YEAR+1}/MSY\ B_{Trigger})$$

To test the application of the F_{IND} a Management Strategy Evaluation (MSE) was applied using FLR for Irish Sea herring (her.27.nirs). The assessment model(s) does not account for external environmental or ecosystem drivers, outside population and stock dynamics. The MSE is applied to test the robustness of the current assessment and advice framework to the incorporation of F_{IND}. The MSE does not in itself test the role of the identified environmental indicators on the response of the stock and carries forward the current environmental conditions. It would be possible to simulate changing ecosystem or environmental state within the MSE, within WKIrish however, we aimed to demonstrate that F_{IND} met precautionary consideration of the advice framework. The operating model used in the simulations is the assessment model as applied in the annual advice process. The simulations are run with 999 iterations and are used with a 5-year projection window. A 5-year period is used to calculate the averages needed for projections (e.g. mean weights, etc.). The reference points as defined at WKIrish3 are used [F_{lower} = 0.198; F_{upper} 0.345]. The management model uses an a4a statistical catch-at-age model. The first year of the projection window is the intermediate year. The TAC in the final year of data is assumed to be the realised catch for the same year, while the TAC in the intermediate year is set equal to the TAC in the final year of data. The current assessment model is applied in SAM. The MSE as applied at WKIrish6 should be regarded as a simplification of a full MSE that would be required to fully represent stock dynamics and management strategy. However, for its current purpose the MSE as applied at WKIrish gives a guide to the potential appropriateness of the application of F_{IND}. The input data were 'trimmed' to have a terminal year of 2015. This was selected to conform to the current EwE for the Irish Sea and replicate the ICES benchmark schedule. The forward projects were applied for five years, also to reflect the likely ICES benchmark schedule. Two scenarios were applied testing the risk of the stock declining below precautionary biomass reference points using F targets of F_{lower} and F_{upper}. Both F targets of F_{lower} and F_{upper} were deemed to meet the precautionary requirements of management (Figure 10).

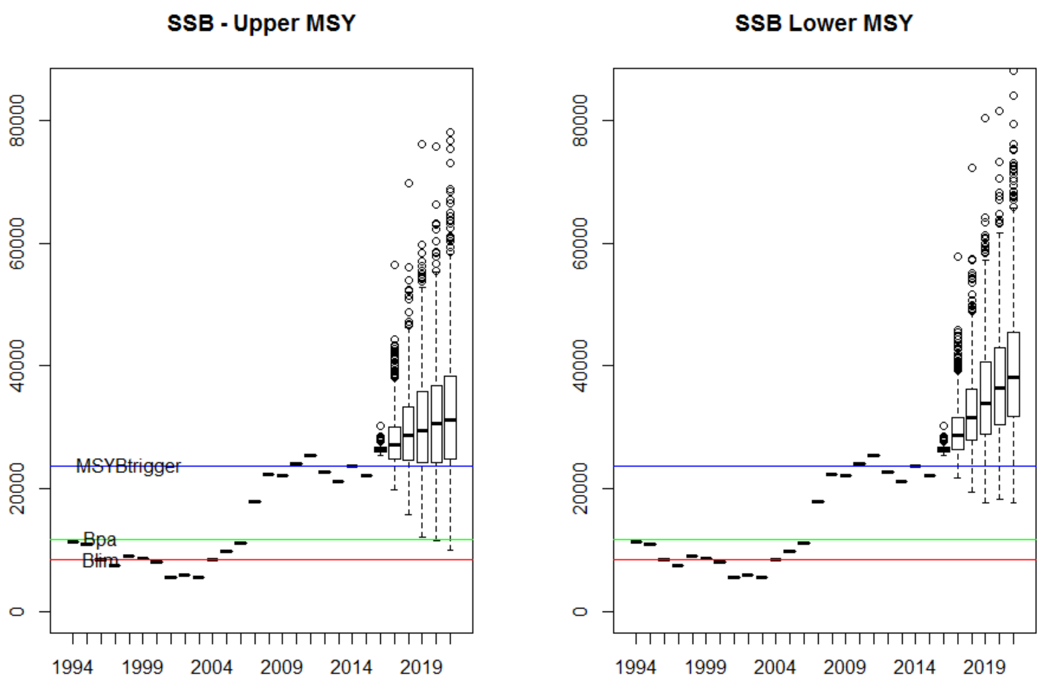


Figure 10. Management Strategy Evaluation base forecast of herring Spawning–Stock Biomass (SSB) when fishing at F_{upper} and F_{lower}.

8 Communication of F_{IND} within advice products

WKIrish6 proposes that the F_{IND} derived from the ecosystem model could be incorporated into the existing advice format (Advice sheets, Figure 11). Possible inclusions are:

a) ICES advice on fishing opportunities : *The ecosystem indicator supports advised catches of 8961 tonnes* ;

b) Basis for the catch scenarios : To include the name of the indicator, the indicator value and the formula for indicator calculation ;

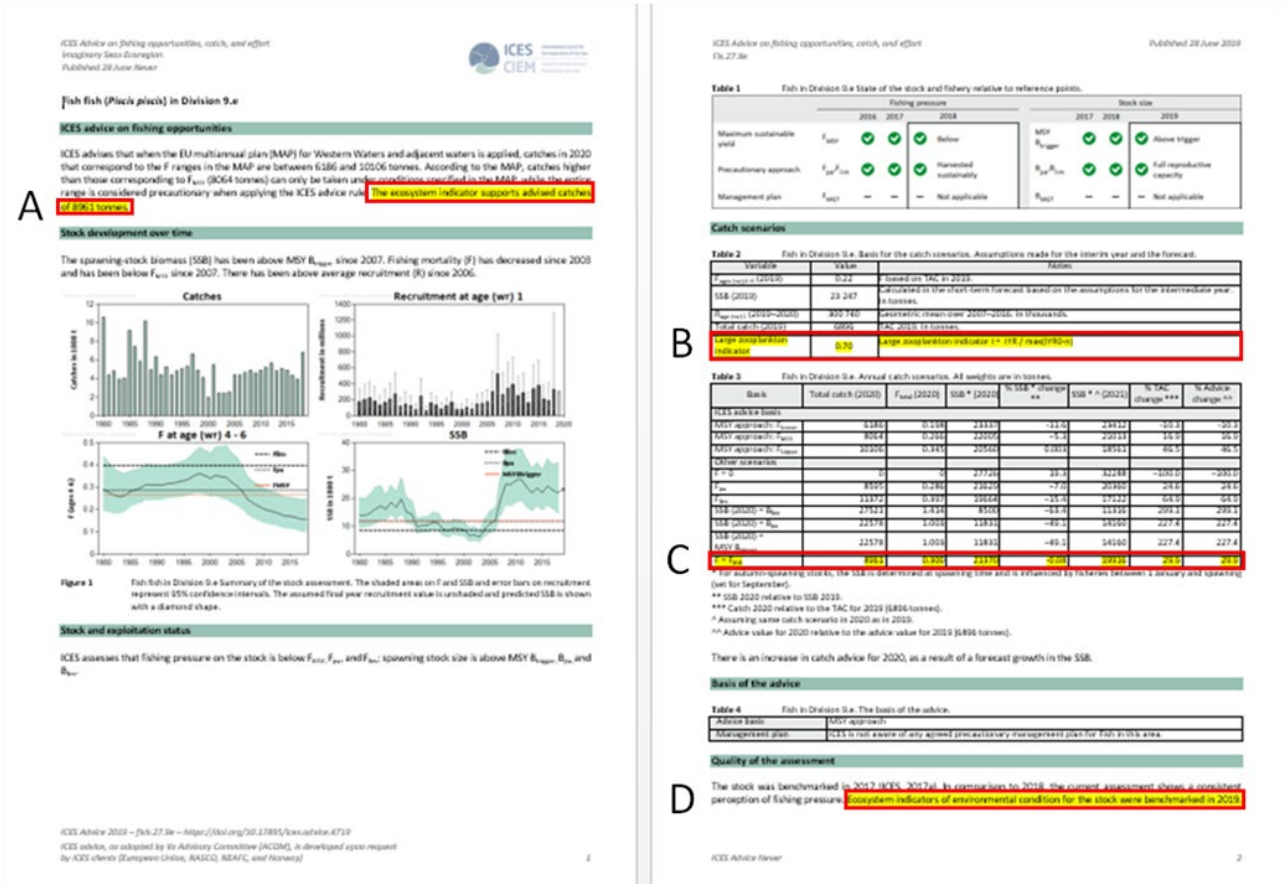
c) Annual catch scenarios ;

d) Quality of the assessment : *Ecosystem indicators of environmental condition for the stock were benchmarked in YYYY. A single ecosystem driver (indicator name) was identified to impact the productivity of the stock. The indicator is updated annually to advice year -2* ;

e) Issues relevant for the advice : The current ecosystem is considered to be in the upper quartile of favourability / middle quartile / lower quartile ;

f) Reference points, values, and their technical basis : Ecosystem Indicator (I) ; F_{ind} ; 0.300 ; $F_{IND} = F_{lower} + ((F_{Upper}-F_{Lower})*I)$ (ICES (2019)) ;

g) Basis of the assessment and advice : Ecosystem Indicator ; derived value of the indicator for the advice year.


A
B
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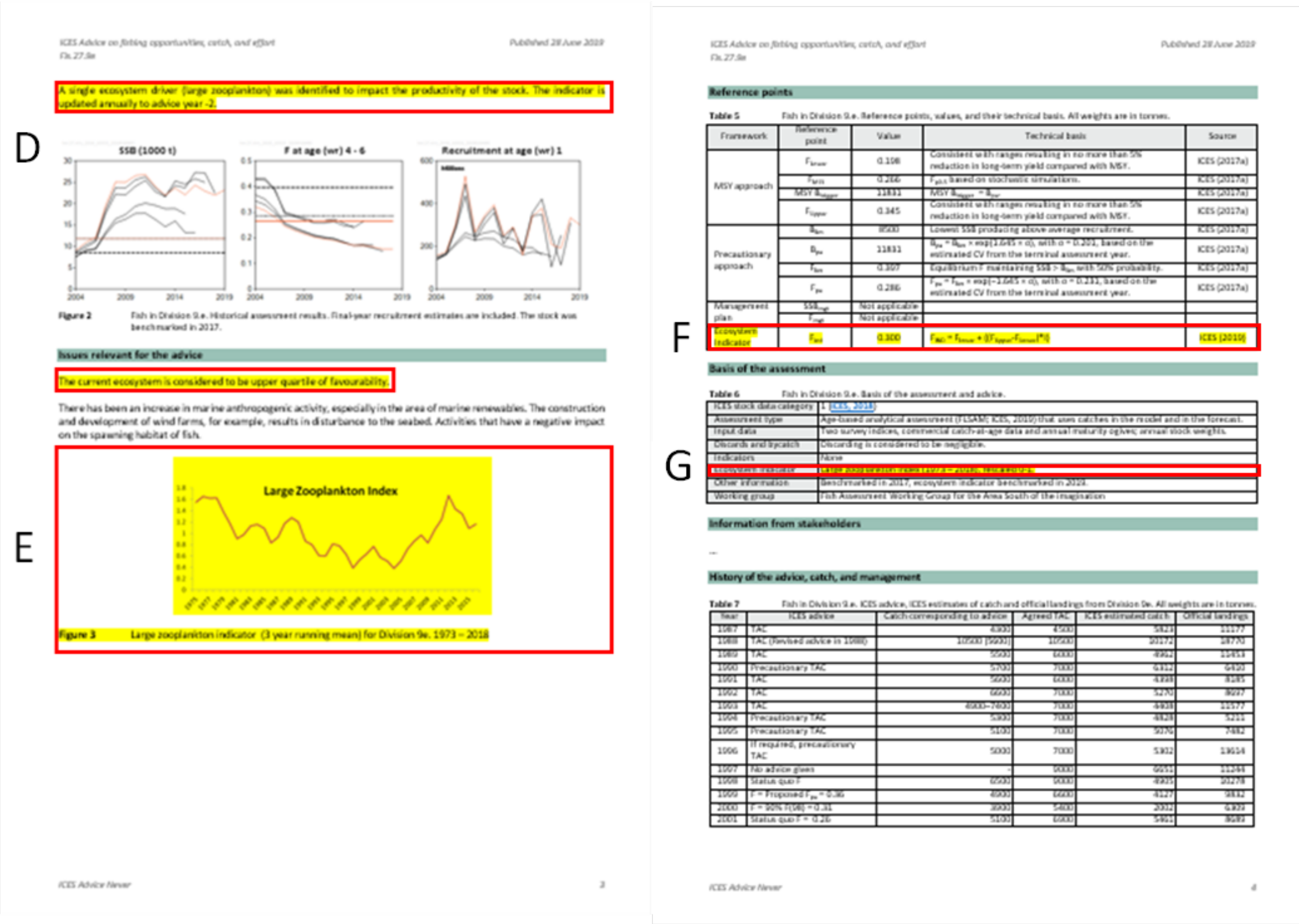

Figure 11. Integration of F_{IND} and the ecosystem indicator with the ICES advice product.

9 Further development of the WKIrish EBFM approach

WKIrish has identified a route by which ecosystem information can be incorporated into the current single-species stock assessment process, without the need to revise any existing ICES protocols. However the approach can clearly be developed further and one possible framework for how a more complete Ecosystem Based Fishery Management could be achieved is outlined below (Figure 12). Beyond the current proposal to utilise ecosystem information to inform an F target within the F ranges, WKIrish6 also considered that the ecosystem model developed can both indirectly and quantitatively inform the decision making within stock assessment benchmarking. These links may include:

- Exploring productivity change across the assessment time-series, to allow appropriate model time-series selection or phases;
- Exploring potential trends in aspects of population dynamics such as natural mortality and recruitment success;
- Defining the reference points. The outputs from the ecosystem models could inform the time-series of stock dynamics that should be used when estimating reference points and their ranges. Additionally it may be possible to use the output of the ecosystem model to identify periods of system productivity similar to present conditions.

The WKIrish approach has facilitated these developments through regional coordination of the benchmark process. This process has brought together industry stakeholders, environmental NGOs, biologists, fishery scientists, foodweb and ecosystem models, social scientists and stock assessment experts. The work of WKIrish has relied on existing core methods and utilising existing data whilst building research outputs.

Future regional coordination of environmental data collection may also allow more efficient development of the underlying ecosystem models. WKIrish has defined a mechanism by which ecosystem information can contribute to current single species advice process. There remains a body of work, which is relevant to a wide range of other assessment groups in ICES such as those developing Integrated Trend Analysis and Ecosystem Overviews. In order to achieve this, WKIrish considers that the ecosystem models, update and development, should be an integral part of the ICES benchmark process, and in particular the definition of reference points. It would be beneficial to continue to develop this work area. Future workshops develop should:

- Seek to examine the combined outputs of the ecosystem models being developed for the Irish Sea. In particular the development of the LeMans and MoSES model.
- The evidence and support for selected indicators.

More generally WKIrish considers that future work should explore:

- How multiple indicators can be combined to inform F within the F-ranges
- The use of ecosystem information to inform reference point selection.

Given the recommendation of WKIrish that the ecosystem models should ‘sit alongside’ the single-species benchmark process this encourages continued develop and maintained links between groups such as WGEAWESS and the other assessment groups. Wkirish6 felt that this would foster a holistic self-perpetuating development of the work area. For this to be success, a fully multidisciplinary approach to the current single-species assessment approach is needed.

WKIrish envisages that this can be a parallel and complimentary process within which the threads of ecosystems modelling and stock assessment are interwoven. The work to integrate the outputs and products of the WKIrish process with groups such as WGEAWESS is ongoing. At WKIrish6 it was discussed that outputs from the ecosystem foodweb models could be used within ecosystem overviews as qualitative or quantitate indictors of ecosystem state.

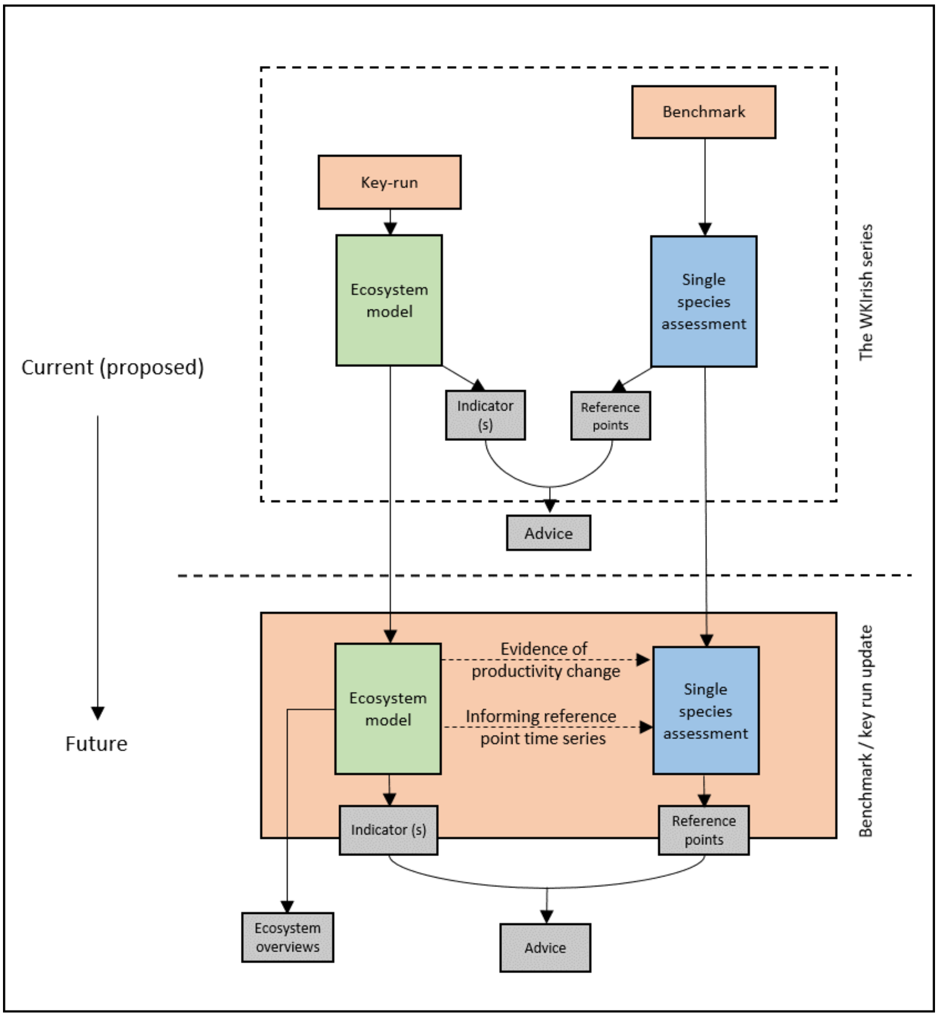

Figure 12. Framework for the interlinkage and interdependency of the WKIrish proposed approach to Ecosystem Based Fishery Management. The framework outlines the current proposal to use ecosystem indicators to define the F target (F_{IND}) within the F ranges and the future development of a holistic EBFM approach within single-species stock assessment benchmarking exercises.

10 Ecosystem based fishery management to address stakeholder needs

Summary overviews of the Ecopath with Ecosim (EwE), MoSES, and the LeMans model were presented to the fishery stakeholders. The group acknowledged the added value of a suite of models, in particular the ability of the LeMans model to predict change in unwanted catch of small-sized fish and model selectivity patterns of the fishing fleets (which EwE is unable to capture). WKIrish5 identified three priority areas within which it was felt that Ecosystem models of the type developed here could be benefit to stakeholders: Stakeholder driven discussion within WKIrish5 led to the identification of priority areas for the fishing industry. These broadly fell within three areas:

- Understanding the role of ecosystem components not currently under management.
- Impact of area closures on commercial stocks and ecosystem effects.
- Management of fishing activities to maximise sustainability of fisheries and socio-economic benefits.

Discussion at Wirish6 focused on the evidence that management measures and environmental state should be considered holistically. The evidence from ongoing ecosystem model development in Irish Sea demonstrates the complex interactions that should be considered with fishery management decisions. It was noted that in particular the LeMans model was suited to addressing tactical fishery management decisions allowing consideration of mixed fisheries, fleet dynamics and fleet selectivity patterns. Additionally it was demonstrated how the LeMans model may provide alternative estimation of F_{MSY} using forecast simulation to 2050.

In order to calibrate the model to simulate future scenarios we defined catch patterns and selectivity profiles that reflect the six main fishing fleet types, capturing the mixed fisheries dynamics in the Irish Sea. However, due to the instability of the model further development is required.

Once the model is operational, it will be possible to evaluate a range of alternative management approaches for Irish Sea stocks. The model will provide a powerful tool capable of assessing:

- Alternative F_{MSY} strategies, including both single-stock and multispecies approaches and use of F_{MSY} ranges and their effect on yield and stock sizes;
- Changes in fleet structure that might lead to improved selectivity and reduce bycatch of non-target species in the long term;
- Trade-offs among yields for different stocks and the impacts on different fisheries.

Within the LeMans model fleets were tailored to the diversity of fisheries in the Irish Sea based on catch profiles using data from STECF (STECF, 2017, data on catches in 2016) and expert knowledge. This resulted in 6 fleet categories with different target and bycatch stocks (Table 7).

Table 7. Fleets in the LeMans model and their target and main bycatch species.

No	Fleet code	Description	Target species	Main bycatch
1	TBB	Beam trawlers	Sole	Plaice
2	OTB_DEF	Bottom otter trawlers (demersal fish)	Haddock	Plaice
3	OTM_DEF	Midwater otter trawlers (demersal fish)	Haddock	Cod, whiting
4	OTB_CRU	Bottom otter trawlers (Crustacean)	*Nephrops*	Cod, haddock, whiting, Plaice
5	FPO	Pots (Creels)	*Nephrops*	-
6	PTM_SPF	Pelagic otter trawlers	Herring	-

The relative contribution of each gear to the total catch of each species demonstrates the main source of fishing mortality for each stock (Figure 13). Each of these fisheries has a different catch composition indicating where mixed-fisheries issues may arise (Figure 14). The majority of the whiting catch is taken in the *Nephrops* fishery as bycatch, while beam trawlers catch most of the sole and plaice, with a bycatch of cod and haddock. Beam trawlers and otter trawlers (targeting demersal fish) catch most of the plaice, which is also caught in the *Nephrops* trawl fishery. *Nephrops* is almost exclusively taken by a directed *Nephrops* trawl fishery, and the same for herring in a targeted herring fishery. While there is a relatively single-stock fishery for *Nephrops* using pots/creels (with only a small bycatch of cod) the landings from this fishery are currently very low. Most of the haddock is caught by a targeted midwater trawl fishery, which also has a small bycatch of cod and whiting (Figure 14).

The different selectivity of the fleets was calibrated using data from the Northern Irish observer programme, where available, else a more general selection pattern was used (e.g. for Beam trawl vessels). The selection patterns for the different fleets reflect the fact that smaller roundfish and flatfish are generally caught in the *Nephrops* fishery compared to the demersal trawl fisheries, which use mesh sizes more appropriate for the minimum landing sizes for these species.

These fleets can be used for simulation of alternative management approaches for the stocks, including evaluating how different fleet efforts affect size-selection and bycatch of non-target stocks in mixed fisheries.

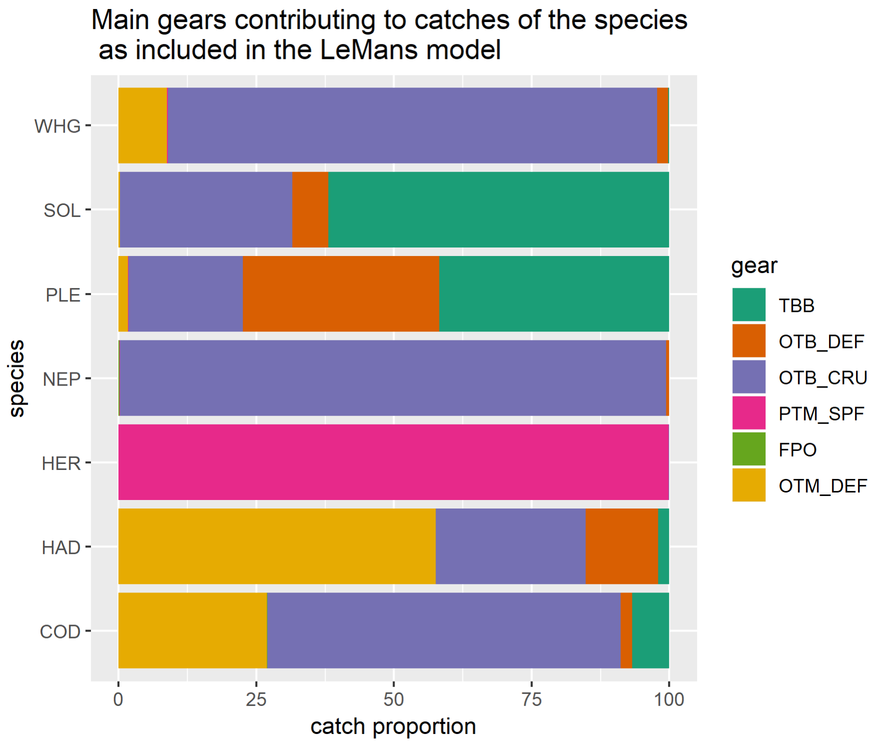

Figure 13. Contribution to the total catch of each species by the gears included in the LeMans model.

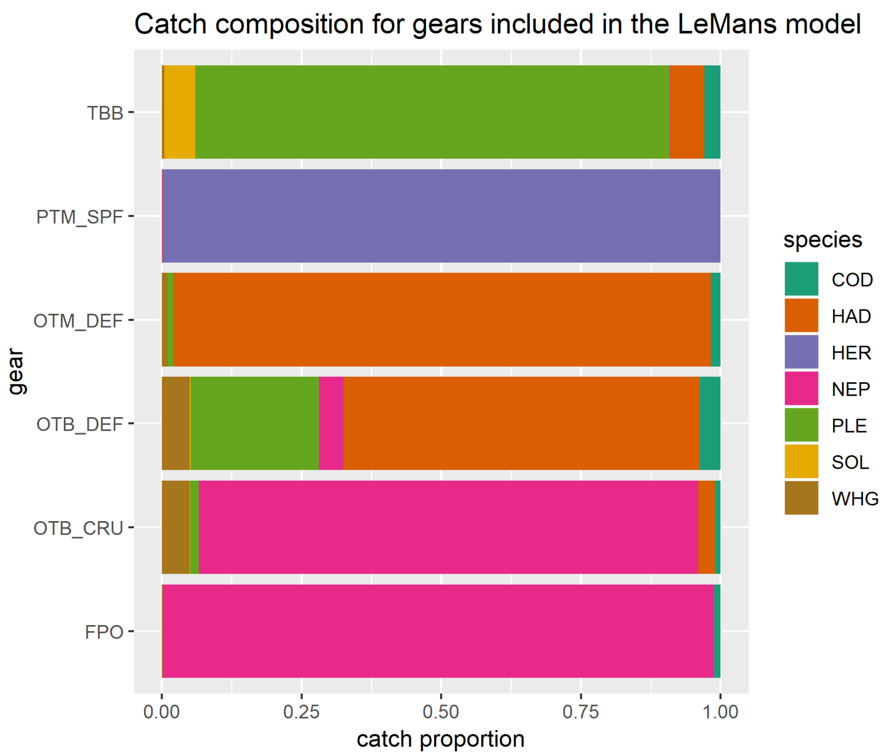

Figure 14. Catch composition (proportion of species in the catch) of the fleets used in the LeMans model

In WKIrish4 stakeholder knowledge was used to inform an ODEMM (Options for Delivering Ecosystem based Marine Management: https://odemm.com/) assessment which examines the impact chains (linkage pathways) between sectors, pressures and ecological components. The Irish Sea assessment was informed by using a Celtic Seas assessment (Pedreschi *et al*., 2018), and tailoring it to the ecological characteristics and relevant sectors for the Irish Sea, and the sector 'Fishing' was further separated into; potting, dredging, beam trawling, bottom trawling, and pelagic fishing (see WKIrish4 report for details). The results from this exercise were presented back to the WKIrish participants, illustrating the main differences which included a clustering of fishing sectors indicating that including them in one sector may be appropriate as differences in ecological impacts between sectors is not as large as previously hypothesised. Fishing related pressures such as 'Bycatch', 'Abrasion' and 'Discards' changed their Total Risk resulting a decrease in their ranking.

WkIrish6 participants, primarily the fishing industry stakeholders, were asked to contribute to a conceptual mapping exercise based on the top risks and sectors identified in the ODEMM assessment (Figure 15). The focus was to identify the relevant social and economic aspects and drivers from the perspective of the fishing industry stakeholders, with comments/questions from the scientific community to elucidate discussion. The discussion identified a range of aspects of relevance to the industry that were input into Mental Modeller (http://www.mentalmodeler.org/) and connections specified as positively or negatively correlated based on the conversations during the mapping exercise. Some additional 'missing links' were identified and included. Some individual connections, The strength of the connections (influence) was not addressed at this point due to time limitation, however, the exercise provides an excellent starting point for these discussions in future, and for identifying aspects of key relevance to these stakeholders to be taken into account in the context of IEA work, and the work of groups like WGECON and WGSOCIAL. This work will be followed up and advanced by WGEAWESS in collaboration with WGSOCIAL and WGECON for future reviews of the ICES Ecosystem Overview of the Celtic Seas.


TAC's
Management
Wages
Fish Prices
Fuel Prices + Weather = time at sea.
MARINE IDENTITY
COMMUNITY
Fishing practice
Shipping
land based Industry
Waste Water
Safety at Sea
time at Sea
Family
Litter
Intro of non-Synth Compounds
Abrasion
Intro of Synthetic Compounds
Litter Removal
Food Provision
Jobs
Maritime Culture and Skills
Job Diversification
Competition (decreasing)

a)

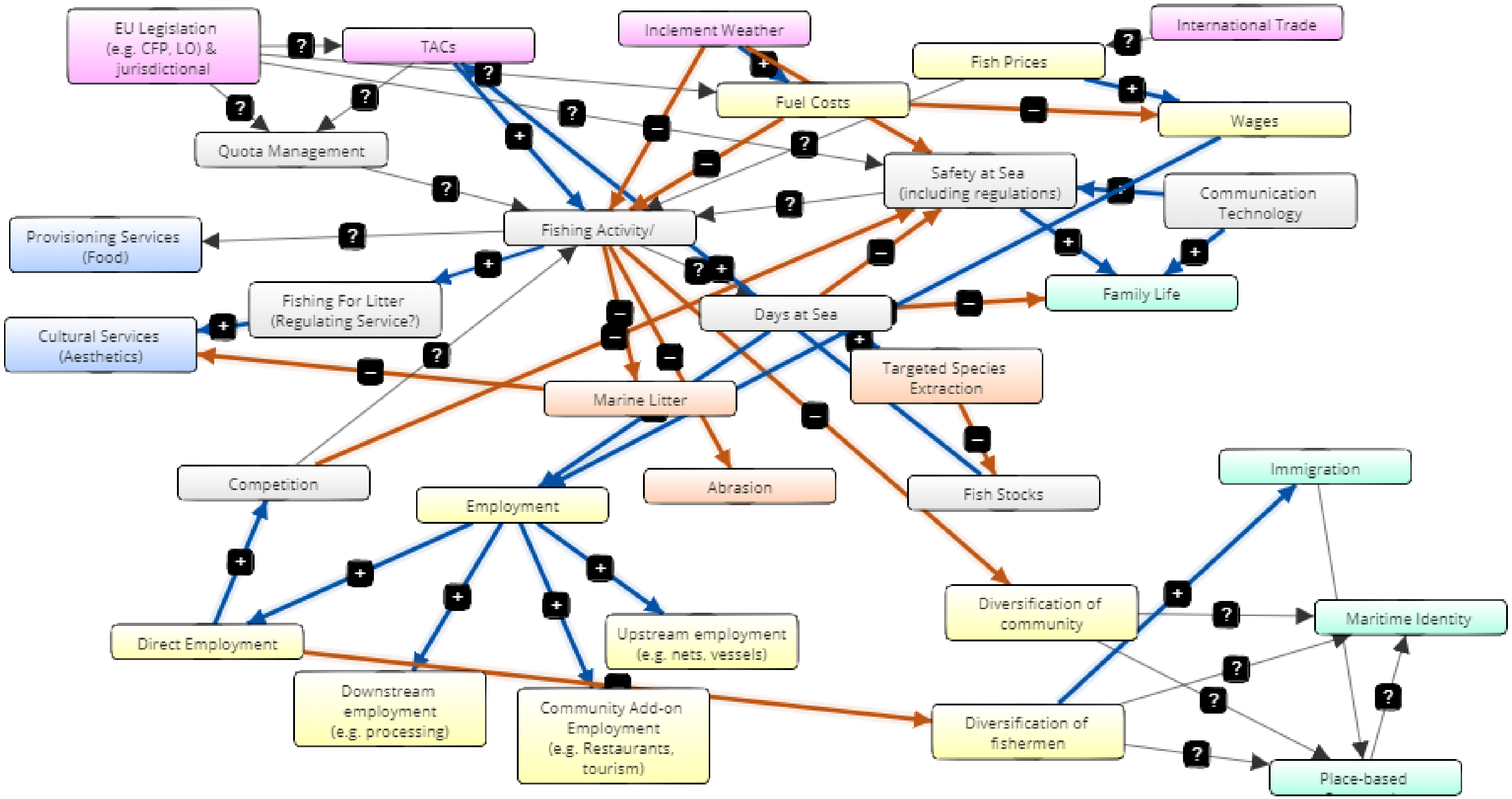

Figure 15. Conceptual map as produced during WKIrish (top) and as input in Mental Modeller (bottom).

Annex 1: List of participants

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Annex 3: WKIrish 6 Reviews

WK-Irish6 Review Report: Alida Bundy

General comments

- This was a very interesting (and exciting) workshop, a mixture of review of completed and on-going work with a definite hands-on component with respect to implementing the use of ecosystem information into management advice.
- The workshop made considerable progress in developing the methodology to incorporate ecosystem information into single-species stock advice, which is exciting.
- There is still work to be done to develop proof of concept. And the question left hanging was how this will be progressed in the future.
- At this stage, the WKIrish EBFM approach is proof concept. In order to operationalize this, the exploration of relationship between indicators of ecosystem pressures (F_{IND}) and stock indicators, needs to be much more rigorous, involve the stock assessment leads as well as oceanographers and ideally be peer reviewed.
- I agree with Daniel Howell; I think F_{ECO} is a better term than F_{IND}. An indicator could be anything, whereas "ECO" is more descriptive.
- There is a lot of scope for the further development of the WKIrish EBFM approach beyond input to single-species assessments (although this is a great place to start). A scoping workshop to explore some of the ideas noted during the workshop and in this report, and to bring in additional ideas from other regional seas groups and jurisdictions would be very worthwhile.

Ecosystem models

- Of the three modelling approaches presented at the workshop, the EwE is by far the most advanced. As recommended by WKIrish5, it has been reviewed by WGSAM and a key run produced, therefore the EwE model is not reviewed here. It should be noted though that the results from this workshop depend heavily on EwE.
- It's unfortunate that the other two modelling approaches (LeMAns and MoSES) are not as advanced, since this would enable a multimodel approach to the use of ecosystem information into management advice, which would add rigour to the approach.
- LeMans: this is still work in progress. In contrast to the EwE model it is length-based and represents eight commercial species. This approach has the potential to compliment the EwE model and I particularly want to address questions concerning bycatch of small fish, size limits and fishing strategies (selectivity). The model is tuned to the empirical data, but does not fit the data well. It would be interesting, when the model fits better, to hindcast and limit the number of years fitted, and then use the remaining years to project to validate the model. Diet is also an emergent property to so this could be validated against empirical diet data.
- MoSES, in contrast to both LeMans and EwE represents 159 species and is based on allometric relationships. It does not include size structure, but has the potential to do so in the future. It is unclear when this model would be sufficiently developed to contribute to the work of WKIrish.

The WKIrish EBFM approach

- What is causing the high predation mortality since the early 2000s? If predation mortality is to be used "as a tuning parameter" in implementing an EBFM, then it is important to know that is causing this mortality. Is it something that can be managed or that needs to be managed for?

Towards implementation of the use of ecosystem information into management advice

- This is where the more "hands-on", workshopping component of the workshop began.
- I think that Figure 8 was an outcome of the workshop, so should be identified as such. Variants of this were also discussed, such as the trajectory of F when MSY_B<$MSYB_{Trigger}$.
- The workshop and report only considered "first order linear relationships were tested in this first round, but it was recommended that further exploration of more complex relationship may yield different candidate indicators". Absolutely!
- I disagree with the suggestion that only one indicator should be used in this analysis. Ecosystem models represent a multidimensional space and reducing this complexity to one indicator while tractable, will run the risk of missing other important drivers. Future work should also explore the interaction of pressure indicators with responses. There may be more than one pressure effecting the stock (eg. predation and SST), and these may interact synergistically, antagonistically, etc.
- Relationships between environmental variables and stock productivity are not permanent. Consideration needs to be given to regular checks to ensure that the relationship between pressure and stock is still valid.
- Selection of Indicators (Table 1) - the workshop would have benefited from the expertise of a physical and biological oceanographer as It was unclear whether there are additional environmental data that would be useful.
- Stock Productivity and indicators: it was unclear to what extent the relationships between the physical/biological environmental indicators (i.e. indicators not derived from EwE) and specific stocks had been explored in earlier WKIrish workshop and/or Irish Sea stock assessments. This would be an opportunity to link this EBFM approach directly with stock assessment.
- Other than *Nephrops*, the indicators that were related to cod, whiting and herring were all non-model derived. Why do we need an ecosystem model? I think that we do, but it begs the question and I think that the case still needs to be made.
- WKIrish may want to consider developing conceptual models of the species of key interest in the Irish Sea, their linkages within the ecosystem, potential drivers of their productivity (mortality, growth, and recruitment) and confidence in our state of knowledge. Conceptual mapping was done during the workshop to map top risks and sectors identified in the ODEMM assessment (Figure 14), to great effect. A similar approach focused on ecological/environmental interaction would inform the WKIrish EBFM Approach and could be expanded to the social, economic and governance aspects over time (e.g. see work of ICES WGNARS, DePiper *et al.*, 2017; Harvey *et al.*, 2016).

Communication of F_{IND} within advice products

- E. Issues relevant for the advice: The current ecosystem is considered to be upper quartile of favourability / middle quartile / lower quartile**.**
    - I think that this referring to the ecosystem indicator rather than the "current ecosystem" (in the example given, large zooplankton index). I suggest that this needs to be rephrased something along the lines of: "E. Issues relevant for the advice: The **ecosystem indicator** is currently considered to be upper quartile of favourability / middle quartile / lower quartile**.**
- Figure 10 is illegible. Needs to be better quality.

Further development of the WKIrish EBFM approach

- "Defining the reference points. The outputs from the ecosystem models could inform the time-series of stock dynamics that should be used when estimating reference points and their ranges." How so? This is a useful point to expand on.
- What about ecosystem level reference points such as total ecosystem catch (Provision of advice on limits for total catches for the ecosystem unit)?
- Figure 11. This figure could be more ambitious, see point above, Patrick and Link (2015) and Koen-Alonso *et al*., 2019.

Ecosystem-based fishery management to address stakeholder needs

- It was not clear what plans are in place to explore the questions of concern to the stakeholders, although there was engaged discussion about these during the workshop.
- Figure 12 check: are *Nephrops* caught in OTB_DEF?

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WKIrish6 Review: Christopher Lynam

General comments

- The development of a stakeholder led approach to implementing the EAFM was interesting and an exciting model for ICES to continue and expand on.
- WKIrish suggested ways in which ecosystem information and foodweb models can feed into single-species stock advice. While this is a useful way to progress, the WKIrish proposal to include F.ind in F-range considerations is particularly limited with the potential to be overshadowed by mixed-fisheries issues.
- A limited range of indicators were considered, additional work should look further at those proposed by Regional Sea Conventions and through the national MSFD submissions. Quantitative indicators, developed elsewhere in ICES, on the wider effects of fishing on the ecosystem were not fully explored e.g. abrasion and degradation of benthic habitats and a further work stream involving ICES WGFBIT, WGSFD, WGECO and others should be considered.
- Finally, a warning for those not involved in the process: the WKIrish suggestions should not be considered a full implementation of EAFM, but only a first step on the way (as acknowledged by all participants).

Ecosystem models

- Three models were presented at the workshop EwE, LeMans and MoSES.
- All were temporal only and no spatial analysis was undertaken.
- All models were too optimistic in terms of the expected recovery of stocks; in particular the rapid recovery of cod expected under low fishing pressure, but not observed in reality. This suggests that fundamental biological knowledge should be improved on the recoverability of stocks.
- EwE has been advanced furthest and a key run produced within WGSAM. Less resource was available to further the other models (LeMAns and MoSES) but they have the potential to add great insights to the effects of fishing on the ecosystem.
- LeMans is a statistically robust approach with freely available source code in the R package LeMaRns. The current implementation presented to WKIrish included eight commercial stocks only and, as yet, the model has not been finalised. The more mature published models for the North Sea demonstrate that this approach has great potential and could be extended to include many more stocks and fleets. Therefore, in future, the model can provide further insights not only on stock interactions but also mixed-fisheries. As LeMans is size-based, the model can estimate the potential bycatch of undersize commercial fish and inform on the benefit of changing commercial gears to alter selectivity.
- MoSES, is a true ecosystem model capturing 159 species at all levels of the foodweb. As such it has great potential. As this is a bespoke and novel model, it is not clear what we can expect of it in future. However, the approach is particularly exciting and of great value scientifically.

The WKIrish EBFM approach

- The advice rule (Figure 8) was discussed during the workshop and provides a clear demonstration of how the indicators can be used to advise on where is most appropriate to fish in the F-range. It was acknowledged that as stock SSB falls below MSY $B_{trigger}$, there is possible a jump down between the level of F suggested if indicators are positive since the upper range of F is no longer appropriate. It was discussed whether or not this figure should be altered so that a smooth transition would be imposed but this was not adopted.

- Although a range of indicators were considered, the best indicators for cod and whiting were suggested to be sea-surface temperature. Other pressures beyond fishing and food-web interactions were not considered in detail, so the current proposals are likely not comprehensive.

Implementation of FIND

I did not see the MSE presented so cannot comment on it in depth. It does present interesting outputs showing the two extreme outcomes when there is a consistently poor of good status indicator, but the actual effect of a change in the ecosystem on herring does not appear to have been modelled (or does SAM do this?). So while fishing at lower F values does indeed appear to lead to greater rebuilding on the stock this may not be the case in reality if the ecosystem is negatively affecting the stock through a lack of zooplankton prey. So this section does not appear useful in the report.

Communication of FIND within advice products

This is a useful demonstration of how the advice rule may be used in practice. Further discussion by the chairs with ACOM and the stock assessors would be welcome.

Further development of the WKIrish EBFM approach

WKIrish have outlined further development of the approach, and this is clearly important for ICES to build on. Figure 11 could be altered to demonstrate the multiple Ecosystem Models should be used in this process. The approach should also be extended to incorporate information from other assessments including non-ICES approaches e.g. HELCOM, OSPAR, EEA and rFMOs where appropriate.

Ecosystem-based fishery management to address stakeholder needs

The stakeholders are clearly looking for additional information to support management that was beyond the remit of WKIrsh, but should be followed up by ICES and in particular WGSOCIAL and WGECON.