ICES WGSAM REPORT 2014

Interim Report of the Working Group on Multispecies Assessment Methods (WGSAM)

20–24 October 2014

London, UK

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Contents

Executive summary

In this eight report of the pan-regional Working Group on Multispecies Assessment Methods (WGSAM), work focused on five (A, B, C, H) of the multi-annual ToRs.

Based on their knowledge, participants provided an updated inventory of progress of multispecies models in ICES Ecoregions (ToR A), noting those regions where no information was available. While none of the participants at this year's WGSAM was able to provide a verbal update, written contributions highlight that progress is being made with the development of ATLANTIS ecosystem models in ICES several ecoregions: notably the North Sea, Baltic Sea, Eastern Channel and Barents and Norwegian Seas.

Work from multispecies modelling was presented suggesting that improvements in yields and predictability could be expected from multispecies management plans that set targets for stock sizes rather than fishing mortalities (Section 2.1.1).

A Key Run of the North Sea Stochastic Multispecies Model (SMS) (ToR B), was presented and discussed. The key run includes several developments to the model structure, extending its capability beyond the previous key run (Annex 5). Difficulties in obtaining data set necessary to update the key run were discussed. The pragmatic solution was to use what was available now, rather to wait without certainty that the information would be forthcoming.

Comparison with the 2011 Key run show that estimated stock sizes and fishing mortalities in the 2014 key run are pretty similar to the single species trajectories for most of the species (Figure 4.1.14). The changes introduced since the last key run (lower historical cod catches, higher biomass of medium-large grey gurnards and large starry rays, inclusion of hake, revision of mackerel assessment, revision of the haddock stock definition and the division of sandeel into two stocks) resulted in lower cod biomass and hence predation by cod, higher predation by grey gurnards and starry ray, increasing predation by hake and some questionable results in the last part of the period for the two sandeel stocks and sprat.

Regarding ToR C, the proposed mechanism for accepting new multispecies models into the ICES advice giving process developed during the previous meeting (WGSAM 2013) has been submitted to ICES for consideration, but no formal response has been received. The newly formed Benchmark Steering Group is scheduled to discuss the WGSAM proposal and give a recommendation.

WGSAM and WGMIXFISH held a joint workshop in London on 23rd October 2014 to address ToR H - Work towards providing ecosystem advice consistent with species and technical interaction in mixed fisheries (Annex 6). Objectives of the workshop were:

1) Identify the linkages between multi-species and mixed fisheries issues and describe what strategic (i.e. goal setting) or tactical advice is required from multi-species and mixed fishery model applications.

2) Identify where outputs of the multi-species or mixed fishery models could inform one another, or where benefits can be gained from coupling models or developing more holistic models dealing with both issues simultaneously.

There were two principal outcomes of the discussions:

1) WGMIXFISH to undertake a principle component analysis (PCA) on the méti-er data used by the group, to see how many aggregated fleets resulted and to show how the variance in catch composition changes with different levels of fleet aggregation.

2) WGSAM and WGMIXFISH participants agreed there was value in continued effort to integrate thinking in order to be able to provide consistent advice in the future. Each group extended an open invitation to one another for future meetings, and it was felt that a further joint session would be helpful, alt-hough this is unlikely to occur in 2015 due to the groups' prior commitments.

In addition to anticipated Key Runs of the North Sea EwE model and Baltic Sea SMS, work in 2015, (Woods Hole, 19–23 October 2015) will focus on ToR F and H.

1   Opening of the meeting

The **Working Group on Multispecies Assessment Methods** [WGSAM] met in London, UK, 20–24 October 2014. The list of participants and contact details are given in Annex 1. The Terms of Reference for the meeting (see section 2) were discussed, and a plan of action was adopted with individuals providing presentations on particular issues and allocated separate tasks to begin work on all ToRs.

1.1   Acknowledgements

WGSAM would like to thank Steven Mackinson for logistics during the meeting and Maria Lifentseva of the ICES Secretariat for her continued support with the WGSAM SharePoint site.

1.2   Terms of reference

The **Working Group on Multispecies Assessment Methods** (WGSAM) chaired by Daniel Howell, Norway and Steven Mackinson, UK, met in London, UK, 20–24 October 2014 to work on all ToRs with focus on B, C, H, A (in bold) and ToR B restricted to North Sea SMS.

ToR A. Review **further progress** and report on key updates in multispecies and eco-system modelling throughout the ICES region;

ToR B. Report on the development of key-runs (standardized model runs updated with recent data, producing agreed output and agreed upon by WGSAM participants) of multispecies and eco-system models for different ICES regions (~~including the Baltic EwE 2013, Barents Sea 2014, North Sea EwE 2014,~~ North Sea SMS 2014, ~~Baltic Sea SMS 2015~~ and others as appropriate);

ToR C. Where possible, develop standards for 'Key Runs' of other modelling approaches (e.g. Size spectra, TGAMs);

ToR D. Develop and compare food web and ecosystem indicators (e.g. from the MSFD) and advice produced by multispecies key runs (preferably together with WGFE and WGECO);

ToR E. Report on progress on including new stomach samples in the ICES area in multispecies models;

ToR F Explore the consequence of multispecies interactions and environmental factors in practical multispecies advice for fisheries management (MSY related and other biological reference;

ToR G. Compare methods used to include spatial structure (predator prey overlap) in multispecies prediction models (preferably together with WGIPEM);

ToR H. Work towards providing ecosystem advice consistent with species and technical interactions in mixed fisheries (in connection with WGMIXFISH).

2 ToR A: Review further progress in multispecies and ecosystem modelling throughout the ICES region

The review of progress of multispecies models in ICES Ecoregions given below is not intended to be comprehensive and exhaustive. It reflects the knowledge available to the participants at the meeting and input from WGSAM who were not able to attend in person.

There was no participation from the US or Canada at this year's meeting, and consequently no update on modelling from across the Atlantic. However the 2015 meeting will be held in the US, and we anticipate having a summary of the progress in US modelling in next year's report.

In addition to this overview, we refer the readers to a recent overview of modelling tools and applications prepared by the partners of the European Framework 7 project DEVOTES under Deliverable 4.1 http://www.devotes-project.eu/deliverables/

2.1 Generic

2.1.1 The impacts of the structural instability of ecological communities on effectiveness of management for MSY

The ICES Working Group on Methods of Fish Stock Assessments recently observed that (ICES WGMG, 2013)

> In all cases [considered by WGSAM] ecosystem models are hard to calibrate and there are uncertainties regarding parameters and outcomes related to external pressure such as fishing mortalities.

WGMG describe the phenomenon of *structural instability*, which has long been known among food-web ecologists: small changes in model parameters or external pressures can lead to large changes in system states (Yodzis, 1988, Yodzis 1998, Novak, 2011), so that coexistence among model species is difficult to achieve. Yodzis (1988), for example, writes that

> When the sizes of direct interactions [in an ecosystem] are determined to within an order of magnitude, the long-term outcomes of press perturbations are highly indeterminate, in terms both of whether species density increases or decreases, and of which interactions have the largest effects.

Structural instability is known to become more pronounced when the number of species interacting in a model increases (Novak *et al.*, 2011, Rossberg 2013). It is not an artefact of unfortunate model architecture. Natural ecological communities are structurally unstable (Rossberg 2013). Good community models simply reproduce this phenomenon. While it is typically possible to predict qualitatively the effect that changes of a prey population have on its predator populations and vice versa, any indirect effects in food webs are hard to predict, even when these are, in aggregate, strong (Berlow *et al.* 2009).

The most important "external pressures" or "press perturbations" in the context of fisheries management are fishing pressures. Structural instability implies that the long-term consequences of a given set of exploitation rates of stocks are hard to predict. This calls into question our ability to achieve maximum sustainable yield from a community of interacting fish species by exposing the community to a prescribed set of fishing pressures (i.e. fishing mortalities F): the community state resulting from

these pressures is hard to predict, and so are the resulting yields. A demonstration of this phenomenon using multispecies age and stage-structured fisheries models can be found in part iii of Section 2.7.8 below.

In a recent study, Farcas and Rossberg (2014) asked how choices of management objective, management strategy, and method to compute reference points affect the impacts of structural instability on management outcomes. They addressed this question using a management strategy evaluation where the operating model was the PDMM food-web model (Rossberg *et al.* 2008, Fung *et al.* 20013), which naturally exhibits structural instability (Rossberg 2013), and the management model a multispecies Schaefer model of the fish community. Figure 2.1.1 is a simplified representation of their main results.

Yield (% of theoretical maximum sustainable total yield)				
Strategy	Conservatism	Objective		
		open	Nash	Total Yield
Pressure ('*F*') Target Control	none		50.6	33.9
	standard		56.7	55.9
State ('*B*') Target Control	none		70.6	57.0
	standard		73.3	84.8
Singe Species Control		51.7		
Ease-of-negotiation Score				
Pressure ('*F*') Target Control			75.0	25.0
State ('*B*') Target Control			100.0	50.0
Singe Species Control		50.0		

Figures 2.1.1. Simplified summary of the management strategy evaluation by Farcas & Rossberg (2014). The objective Nash means to effectively "maximize the yield from each stock independently", i.e., to choose exploitation rates so that changes in the exploitation rate of any stock cannot increase the yield from that stock. Objective Total Yield means to maximize the total yield (in tons) from the mixed fishery. Pressure Target Control means to fix fishing mortality rates at the values F_{MSY} predicted by the management model. State Target Control means a strategy to adjust fishing mortality rates so as to drive stock sizes towards the values B_{MSY} predicted by the management model. Single Species Control models ICES' current approach of computing pressure targets from independent management models for each stock. Ease-of-negotiation-score is based on expert judgment. Conservatism denotes the degree to which targets similar to the current situation are preferred over more different, but theoretically higher-yielding, targets. Intensity of colouring increases with score attained.

In particular, Farcas and Rossberg (2014) found:

1) Single Species Control, where pressure targets are derived from uncoupled single-species management models, as currently envisaged for multi-annual plans, is among the least-yielding options considered.

2) Management strategies based on harvest control rules that target specific community states, i.e. B_{MSY}, lead to higher yield than those targeting specific pressures, i.e. F_{MSY}. This can be understood as resulting from structural instability of ecological communities.

3) Management strategies with pressure (F_{MSY}) targets computed using a multispecies management model do not lead to much higher yields than corresponding strategies using single-species models.

4) Management with the objective of "maximizing the yield from each stock separately", i.e., of attaining a Nash Equilibrium, can, surprisingly, lead to higher

total yields than management strategies perusing the objective of maximizing total yield. This, too, can be understood as a result of structural instability.

5) Conservatism in stetting management targets, i.e. a preference for small changes over larger ones that might give higher yields, can improve management outcome.

The observed differences in yields speak in favour of adopting state rather than the currently preferred pressure targets in long-term-management plans.

Cross-validation using ensembles of multispecies models can be used to determine good degrees of conservatism.

2.2   Ecoregion A: Greenland and Iceland Seas

There is no progress to report on multispecies modelling in Ecoregion C this year.

2.3   Ecoregion B: Barents Sea

2.3.1   Symbioses

The "Symbioses" project has now been completed. This projected has constructed an end2end model to examine potential oil impacts on eggs and larvae in the spawning grounds on the Lofotens, linking oceanography, ecotoxicology, plankton, larval models with a Gadget multispecies fish model. This tool has now been built, and is in a follow-up project to present and evaluate the results and identify aspects which need further development.

2.3.2   STOCOBAR

An evaluation of the long-term impact of management restrictions in annual changes of TAC on North-East Arctic cod stock dynamics has been conducted using the STO-COBAR model. The results demonstrate that limits of ±30% in annual change do not influence cod stock dynamics. Limits of ±10–15% resulted in increases in both annual cod stock biomass and TAC. The explanation of this relates to multispecies and ecosystem relationships. Firstly it should be noted that the stock is well above the level at which recruitment overfish would occur, and the stability criteria would be suspended if the stock falls below Bpa. Therefore the changes in SSB are not impacting on recruitment to the population. The TAC restrictions result in decreasing fishing pressure on cod population when cod stock is increasing (favorable ecosystem conditions, high capelin stock, low cannibalism). In this case, restriction of TAC helps to allow rapid growth of the cod stock. On the other hand, TAC restrictions result in increased fishing pressure when the cod stock declines (unfavorable ecosystem conditions, low capelin stock, high cannibalism). This further reduces the stock of larger cannibalistic fish. In this case, fishing mortality acts to decrease in cannibalism and improves conditions for cod stock growth when ecosystem conditions improve. STOCOBAR may be applied as a tool for study of this mechanism.

2.3.3 Atlantis

Work is continuing on the Atlantis model for the Barents and Norwegian Seas. The model is now stable and is at the stage where it can form the basis for investigations and project proposals, although further development work is ongoing.

2.4 Ecoregion C: Faroes

There is no progress to report on multispecies modelling in Ecoregion C this year.

2.5 Ecoregion D: Norwegian Sea

There is no progress to report on multispecies modelling in Ecoregion C this year.

2.6 Ecoregion E: Celtic Seas

2.6.1 Ecopath in the Celtic Sea

Work on modelling the Celtic Sea continues under the MERP programme in a collaboration with Cefas and Dr Lauria (Plymouth University). Time series fitting of the model is being updated to 2013 and extensive work has been undertaken to develop a spatial model (Figure 2.6.1), for evaluation of spatial management strategies. It is intended that the updated calibrated model will be presented to ICES WGSAM as a Key Run, with the spatial fitting process used to help define Key Run standards for Ecospace applications.

Figure 2.6.1. Habitat definition for Ecospace model of the Celtic Sea being developed by Cefas. Habitats are defined by a combination of simplified sea bed sediments derived from the BGS 250k data set and biozones from UKSeaMap 2010, expressed as majority habitat at the resolution of the ICES quarter-rectangle.

2.6.2 Ecopath in the Irish Sea

The Scottish Association of Marine Science is taking the lead in continuing development of the Irish Sea ecopath model, where students are working on applications for tracing pollutants and ecosystem impact studies. Links are also being made with the Marine Institute in Ireland where work has gone on to improve parameterization of marine mammal groups. In collaboration with AFBI, Northern Ireland, funding is being sought for continued development.

2.7 Ecoregion F: North Sea

2.7.1 Moment-based delay difference model in the North Sea

A presentation "Moment based delay difference models for considering population dynamics of fish: How far can we extend this approach? Might it be useful for a simple area based model?" was made by John Pope. This briefly explained the moment based approach to assessment proposed in Pope 2003. The 0th to 4th uncentred moments $\sum_{all L} N(L) * L^i \ldots . i = 0 : 4$ (where N(L) is the number at length L) of a populations size distribution, provides both a parsimonious description (using only 5 numbers per population) and a means of modelling it. Not only do the moments provide the basis for the statistical measures of mean, standard deviation, skew and kurtosis of the population's size distributions but also the 1st moment also provides the biologically relevant measure of the population abundance and the 3rd moment, with the addition of a condition factor, provides overall biomass (assuming isometric growth). Moreover, at least in simple cases (i.e. those with constant natural mortality rate at age) linear difference equations can be written showing how the state vector of moments changes with time. Equivalent analyses to VPAs, long term yield predictions and forward simulations can thus be simply made. Including non-linear effects such as predation into the difference equations had previously proved difficult. However, the approach of converting moments back into size distributions (see Hallfredsson and Pope 2007) gave a possible solution to estimate moment losses from these non-linear processes, but their back conversion method proved to be very time consuming. The adoption of pseudo-inverses approaches to making the conversion to size distributions now gives a much quicker way of making these conversions.

Using this latter approach the author had successfully emulated the Charmingly Simple Model (CSM) of Pope *et al.* 2006 both as a long term steady state model and as a transient state model. These models have then been used to investigate changes in the slope of the size spectrum seen in the IBTS spring survey between 1977 and the present. A longer description of this work has been filed on the WKSAM server as "Deliverable 4.1 for the North Sea". This showed a decline in size spectrum slope for the North Sea until about the mid-1990s but thereafter this remained fairly constant at the low level. The CSM predicts that spectrum slope in a steady state would have a close relationship to fishing mortality rate. While this prediction could be consistent with the observed increasingly negative slope of the size spectrum seen up until the mid-1980s when overall fishing mortality rate was increasing in the North Sea, it would not explain why size spectrum slope has not subsequently become less negative, since after that date fishing mortality had decreased substantially in the North Sea. To explain the tendency of the slope to remain strongly negative after the mid-1980s requires the transient state model to be used and differential Fs to be applied to the different Loo trait groups included in the CSM formulation. It was noted that the fishing mortality rate on the largest species had the most leverage on the slope of the size spectrum and also that while fishing mortality in the North Sea had declined on smaller species it had not declined much on the larger species such as cod and saithe. It was also noted that there was an appreciable time lag of up to 10 years before the transient model converged from different starting values.

The author then went on to describe how he hoped to create an area explicit size based model of the North Sea that was suitable for helping stakeholders, such as NSAC, formulate management proposals. He thought it should prove practical in the first instance to make a simplistic model by using the results of the SMS key run of

the North Sea together with data from the ITBS surveys and the STECF fleet data base to give the spatial dimension. The species at length by rectangle data from the ITBS and the STECF data sets of fleet catch and effort by species and by rectangle and their data of each fleets overall effort and catch at age might help to provide the building blocks for such a model. Clearly how to have this model handle migration will be a key decision. It was also noted in discussion that including seasonality may be valuable but that the present level of disaggregation of the STECF data might preclude this. It was also noted that fishing effort (e.g. that available from the STECF data sets) might not always be a clear indicator of fishing mortality rate. The author felt that the model might be best formulated using a moment based model since this would help reduced the large number of population descriptors that would inevitable need to be carried in the model. Estimation of the Jacobian of fleet(f) yield of species(s) might perhaps be developed using the approach shown in Pope, 1989, which is available as an annex to the Authors note, "Response Surfaces for cheaply approximating the steady state response of age based multispecies models and suitable fleet definitions", that is available on the WGSAM site. The new work described in this note is being carried out under the MAREFRAME project of the EU's 7th Framework Programme.

2.7.2 SMS (Stochastic Multispecies Model) in the North Sea

See ToR B.

2.7.3 Ecopath with Ecosim in the North Sea

Consistent with ICES strategy for mixed fisheries and multispecies modelling (ACOM 2012), expectations for ecosystem models to become useful advisory tools continue to influence the direction of developments in this area. Three particular areas of development on EwE modelling are:

(i) representation of fleet structure/ segmentation

    - analysis of the linkages of fishing effort (at various fleet segment levels) and fishing mortality has led to a paper in submission (Garcia-Carreras *et al.*); (see Figure 2.7.1)

    - the joint WGMIXFISH and WGSAM (reported under ToRH) provided recommendation on use of ICES and STECF approaches to defining fleet aggregation for use in models.

(ii) validating modelled spatial distribution of fishing

    - a paper examining the quality of the existing spatial representation of the North Sea model has been submitted (Romagnoni *et al.* in press). The paper provides recommendations on improvements and these are being taken up in the development of the spatial model of the Celtic Sea and will be applied to North Sea when the opportunity arises.

(iii) evaluating impacts of uncertainty in model parameters.

A plug-in routine (intended for release within the EwE software in 2015 (Figure 2.7.2) has been developed for assessing the impact of model parameters uncertainty on the performance of alternative fishery management strategies. Documentation and initial tests are completed (Figure 2.7.3), with Beta-testing by users due to start from November 2014. Through definition of harvest control rules and management regulations the routine allows uses to examine consequences of discard policies consistent with an MSY framework. It is also relevant to evaluation of management strategies

consistent with achieving GES (under MSFD) because harvest control rules (HCRs) for commercial species can be contingent upon conservation species. Future work will focus on publishing and application, ensuring robustness of the tool and routines for plotting results that are 'accessible' for managers and users.

Figure 2.7.1. Graphical relationship of the impact of fishing gears on target species (DRAFT – DO NOTE CITE without PRIOR REF TO AUTHOR: Bernardo.garcia-carreras@cefas.co.uk

Figure 2.7.2. Examples screen shots of the tool for evaluation of management strategies taking account of model parameters uncertainty. Currently under development within the Ecopath with Ecosim software, due for release in 2015.

Figure 2.7.3. Illustrative examples of outputs where distribution of biomass for species and catches for principal fleets are shown. NOTE: these are illustrative only. Note, following need for precautionary information, the distribution of minimum biomass over the simulation period is show. End biomass (corresponding to equilibrium) can also be given.

2.7.4 tGAM the North Sea (with reference to Baltic and Black Sea also)

Cefas with collaborators from SAHFOS, University of Oslo, JNCC, University of Hamburg, Instituto Español de Oceanografía (IEO), have developed a statistical model of the North Sea that links planktonic functional groups, fish stocks and drivers of change (temperature, fishing pressure) (Lynam *et al.* in prep) Similar models have been developed for the Black Sea (Llope *et al.* 2011) and Baltic Sea development (Blenckner *et al.* in prep). Using time-series data on temperature (sea surface temperature and Atlantic Multidecadal Oscillation (AMO) variability), plankton abundance, fish biomass and mortality (1964–2010) and seabird breeding success (1989–2010). The model distinguishes between temperature and fisheries effects on ecosystem components and demonstrates key interactions, both predator-prey and competitive, between species. (Figure 2.7.4). The model presents the following:

- Plankton groups are strongly influenced by temperature and the interactions between components.

- Changes in zooplankton abundances alter the biomass of their predators (sprat, herring, sandeel and haddock), with some negative feedback by sprat and sandeel, and cascade up to predatory saithe, whiting and seabirds.

- In contrast, Norway pout are strongly influenced by interactions with herring, suggesting negative effects of competition and/or predation on Norway pout.

- All fish species are negatively impacted by fishing impacts, but for whiting this occurred only through indirect fishing effects on sprat and sandeel prey.

- Sandeel and cod are also influenced by temperature directly in the model and declined to low levels during the 2000s as the sea warmed.

- Scenario testing indicates that if temperatures had not risen since the mid-1980s, sandeel, cod and herring would have benefited to the detriment of Norway pout, sprat, whiting and saithe. Nevertheless the general trajectory of the biomass of fish stocks would have been little changed due to the stabilising effect of fishing.

- The simulated breeding success of seabirds did respond to climate effects via the differing responses of sprat and sandeel, which were modulated by the levels of fishing mortality imposed.

- Fishing mortality can be considered the greatest driver of change in the biomass of commercial fish stocks in the North Sea since the mid-1960s and has likely had a cascading effect on the breeding success of marine birds.

Figure 2.7.4. Diagrammatic representation of the significant interactions modelled between functional groups and drivers (sea surface temperature and stock specific time-series of fishing mortality). Lines point from the *predictor* to the *response* and are

labelled with + if the relationship is positive, - if an inverse relationship modelled and, in one case, a v where the relationship curves up at both extremities of the data range. Thick solid lines are relationships without lag, thin lines with a single year lag and dashed lines if a two year lag was modelled. Coloured lines indicate that thresholds exist in the relationships such that the predictor variable (from which the arrow emerges) has a differing effect on the response variable (pointed at by the arrow): the effect is mediated by the AMO if the line is red, whereas green lines indicate that diatom abundance mediate the effect.

An interactive version (for interactivity download the pdf file) of this figure is available:

http://figshare.com/articles/Significant_interactions_in_the_North_Sea_ecosystem_modelled_using_statistical_tGAMS_Interactive_with_key/967833

The model simulations are being used to evaluate the responsiveness of indicators (e.g. OSPAR pelagic habitat 'lifeform' indicators, trophic level of the fish community, mean maximum length of demersal fish and seabird productivity) to key food-web links, climate change (sea surface temperature) and fishing pressure. Work will be fed directly to ICES WG Integrated Assessments of the North Sea (WGINOSE) and ICES WG Biodviersity Science (WGBIODIV); (ICES 2015).

The following OSPAR indicators can be derived directly from the model simulations of state:

Biodiversity indicators (Descriptor 1)

- Breeding success/failure of marine birds
- Changes in plankton functional types (life form) index ratio
- Plankton biomass and/or abundance
- Population abundance/biomass of a suite of selected species
- Mean Maximum Length (MML) of demersal fish and elasmobranchs

Food web indicators (Descriptor 4)

- Reproductive success of marine birds in relation to food availabilty
- Changes in the average trophic level of marine predators (cf MTI)
- Change in plankton functional types (life form) index ratio
- Biomass and abundance of dietary functional groups
- Changes in the average faunal biomass per trophic level (Biomass Trophic Spectrum) (however this indicator has not been investigated yet)

Additionally the Large Fish Indicator (LFI) can be predicted based on inference only, given the strong response of the LFI to the biomass of cod and saithe. The LFI is considered by OSPAR for use an an indicator of both biodiversity and foodwebs:

- EcoQO for proportion of large fish
- Size composition of fish communities

2.7.5 Ecopath with Ecosim for the southern part of the North Sea

The parameterization of an Ecopath model for the southern part of the North Sea (ICES areas IVb&c), led by the Thünen-Institute of Sea Fisheries in Hamburg partnered by the IHF of Hamburg University, IMARES in IJmuiden and CEFAS in

Lowestoft, has finished and provides a snapshop representation of the 1991 food-web.

A time dynamic Ecosim version of the model is now able to deliver plausible representation of observed biomasses and catches of the 60+ functional groups throughout the period 1991 – 2010. Relating cod productivity to ambient temperature appears to be crucial in explaining past patterns of stocks and food-web. Best ways of representing that in the model are still being explored.

As a first application, the southern North Sea model is being used to explore effort regimes of the three focal fleets in the region, i.e. beam, shrimp, and otter trawlers, that would lead to all key commercial stocks being exploited at a sustained high rate (one possible interpretation of a multispecies MSY) while maintaining a good environmental status (GES) of the ecosystem. (Figures 2.7.5 and 2.7.6)

Figure 2.7.5. Viable volume of effort regimes leading to all key stocks (Plaice, sole, cod and brown shrimp) being extracted at 80% single species MSY or more (*preliminary results*).

Figure 2.7.6. Viable volume of effort regimes leading to good environmental status (GES) of the southern North Sea food-web. GES here refers to biomass or fishing mortality of plaice, sole, cod, spurdog and turbot satisfying ICES recommendations and proportion of large demersal fish (Large Fish Indicator, LFI) being equal or above 2010 effort regime (*preliminary results*).

Focus and detail of the model parameterization deem it promising for potential management strategy evaluations of the currently unregulated *Crangon crangon* (brown shrimp) stocks in the North Sea.

2.7.6 Ecopath with Ecosim in the Eastern Channel

Collaboration between Cefas and the University of Kent has led to a publication on evaluating the ecosystem and fishery effects of the size and location of marine protected areas derived from Marxan analysis (Metcalfe *et al.* in press). To investigate the potential trade-offs associated with adopting different spatially explicit MPA management strategies, Marxan and Ecopath with Ecosim software packages were used to determine: either (i) if strict no-take MPA networks justify the cost of their implementation; or (ii) whether MPA networks comprised of multiple zones with different management restrictions could achieve similar results. Results from an example in the Eastern channel show that:

- Limited-take MPAs, which restrict the use of some fishing gears, could have positive benefits for conservation and fisheries in the eastern English

Channel, even though they generally receive far less attention in research on MPA network design.

- No-take MPAs should form an integral component of proposed MPA networks in the eastern English Channel, as they not only result in substantial increases in ecosystem biomass, fisheries catches and the biomass of commercially valuable target species, but are fundamental to maintaining the sustainability of the fisheries.

- Using these existing software tools in combination provides a powerful policy-screening approach that could help inform marine spatial planning by identifying potential conflicts and designing new regulations that better balance conservation objectives and stakeholder interests. In addition, it highlights that appropriate combinations of different spatial management strategies, such as no-take and limited-take MPAs might be as effective as and less politically contentious than a network of no-take MPAs.

2.7.7 ATLANTIS models in the North Sea and the Eastern Channel

Development of Atlantis models in the North Sea and Eastern Channel (Figure 2.7.7) has taken place under the FP7 project VECTORS (Vectors of Change in Oceans and Seas Marine Life, EU FP7, 266445). After 3 years, some calibration is still ongoing, with some applications in preparation. The first management scenarios tested are being tested with the North Sea model. The Eastern English Channel ATLANTIS has been calibrated on a métier basis and is designed to build in fleet dynamics (coupling with fleet dynamics model is ongoing).

One of the conclusions from the lessons learned during development is that such complex models should be used with great caution because they are (i) Difficult to validate all processes at all resolution levels with existing data, (ii) Sometimes dynamically unstable, (iii) Robustness should be tested through sensitivity analyses. Thus, making these complex holistic models operational for routine advice is a challenge for research scientists in the near future.

	North Sea	Eastern Channel
Spatial structure	26 boxes	35 boxes
Hydrodynamics	HAMSOM model	MARS3D model
Habitats type	Figge + benthos survey + literature	CHARM3 atlas
Functional groups	53	40
Initialisation	- North Sea surveys - EwE, ECOHAM, SMS	- Channel surveys - EwE, ECOMARS3D
Stock-recruitment	Hockey-stick + ICES data	Hockey-stick + fitted
Fisheries	F by fleet and by species for all countries (EwE, STECF, ICES)	- Dynamic effort by fleet & métier for French sole fisheries - F by species for other fleets

Figure 2.7.7. Summary specification of the North Sea and Eastern Channel models (Source: M. Peck, University of Hamburg).

2.7.7.1 ATLANTIS in the North Sea

Within VECTORS, the Atlantis model framework developed by Beth Fulton, has been used to build an ecosystem model for examining how various pressures of change, such as the installation of wind farms, will influence the North Sea Ecosystem. Scientists from the University of Hamburg, the Centre for Environment, Fisheries & Aquaculture Science (CEFAS) and the Thünen Institute of Sea Fisheries (TI) in close cooperation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Institut francais de recherche pour l'exploitation de la mer (IFREMER) are involved in this process.

Key development steps included data assimilation and assignment of parameter values and the definition of the model domaign. Most recently, the balancing of the biological interactions as well as their fitting to time series data.

A total of 25 areas, so called polygons or boxes, has been defined (Figure 2.7.8) consisting of 91 interacting polygon boundaries and a maximum of 7 different depth layers. Depth layers were set to 0, 10, 20, 30, 50, 100, 200 and 1000 m water depth. Polygons were defined based on species compositions, hydrographic features, bathymetry, sediment types and influence of coastal processes such as river runoffs.

0	BS	Boundary SW
1	CH1	Channel N
2	CH2	Channel M
3	CH3	Channel S
4	UKS1	United Kingdom S coast
5	UKS2	Unitek Kingdom S offshore
6	NL2	Netherlands nearshore
7	NL1	Netherlands coast
8	UKN1	United Kingdom N coast
9	UKN2	United Kingdom N offshore
10	DB	Dogger Bank
11	NL3	Netherlands offshore
12	Ger3	Germany/Denmark offshore
13	Ger2	Ger/Denmark nearshore
14	Ger1	Ger/Denmark coast
15	OS	Orkney Shetland N
16	O	Orkney (def. as island)
17	S	Shetland (def. as island)
18	OS	Orkney Shetland N
19	FG	Fladen Ground
20	NCNS	Northern Central
21	NorC	Norway Coast & Trench
22	Sk1	Skagerrak 1
23	Sk2	Skagerrak 2
24	BN1	Boundary N
25	BN2	Boundary NW

Figure 2.7.8. Polygons used to define regions in the NS Atlantis model.

The physical forcing (exchange between polygons, temperature and salinity data) were extracted from the Hamburg Shelf Ocean Model: HAMSOM (Backhaus, 1985, Pohlmann, 1996a,b, 2006), which provides the fluxes between polygons as well as daily temperature and salinity values. An average seasonal cycle for solar radiation and observed daily nutrient contribution from all major rivers were included to serve as basis for the food web.

The Ecosystem contains a total of 53 different biological groups of all trophic levels (Table 2.7.1), based principally on the North Sea EwE model (Mackinson and Daskalov 2007). These groups include three mammal groups, one bird group, three shark and ray groups, 24 fish groups, 11 invertebrate groups, 6 plankton groups and four detritus or carrion groups. Each of the 31 upper trophic level groups is separated into 10 age classes whereas the invertebrate and plankton groups are biomass pools.

Table 2.7.1. Biological groups in the NS Atlantis model.

Index	Code	Name	Long Name
1	BWH	baleen_whales	Baleen whales
2	TWH	toothed_whales	Toothed whales
3	SEL	seals	Seals
4	SEB	seabirds	Seabirds
5	PSH	piscivorous_sharks	Spurdog, large piscivorous and juvenile sharks
6	OSK	other_sharks	Other small sharks
7	RAY	skate_ray	Spotted ray, skate and cuckoo ray
8	COD	cod	Juvenile and adult cod
9	WHG	whiting	Juvenile and adult whiting
10	HAD	haddock	Juvenile and adult haddock
11	POK	saithe	Juvenile and adult saithe
12	HKE	hake	Hake
13	WHB	blue_whiting	Blue whiting
14	NOP	norway_poud	Norway pout
15	OLD	other_large_demersals	Other large gadoids, catfish and large demersal fish
16	OSD	other_small_demersals	Other small gadoids, dragonets and small demersals
17	MON	monkfish	Monkfish
18	GUR	gurnards	Gurnards
19	HER	herring	Juvenile and adult herring
20	SPR	sprat	Sprat
21	MAC	mackerel	Mackerel
22	HOM	horse_mackerel	Horse mackerel
23	SAN	sandeel	Sandeels
24	PLE	plaice	Plaice
25	DAB	dab	Dab and flounder
26	WIT	witch	Witch, long rough dab and lemon sole
27	SOL	sole	Sole
28	TUR	turbot	Turbot, brill, megrim and halibut
29	ESB	bass	Bass
30	MUR	red_mullet	Red mullet
31	SPF	small_pelagic_filterfeeders	miscellaneous filter feeding pelagic fish
32	SQZ	squid	Cephalopod
33	PAD	pandalus	Pandalus borealis
34	CSH	crangon	Crangon crangon
35	NEP	nephrops	Nephrops
36	LCR	large_crabs	Large crabs
37	SEP	small_epifauna	Small mobile epifauna
38	SES	sessile_epifauna	Sessile epifauna
39	MEP	epifaunal_macrobenthos	Epifaunal macrobenthos
40	MIP	infaunal_macrobenthos	Infaunal macrobenthos

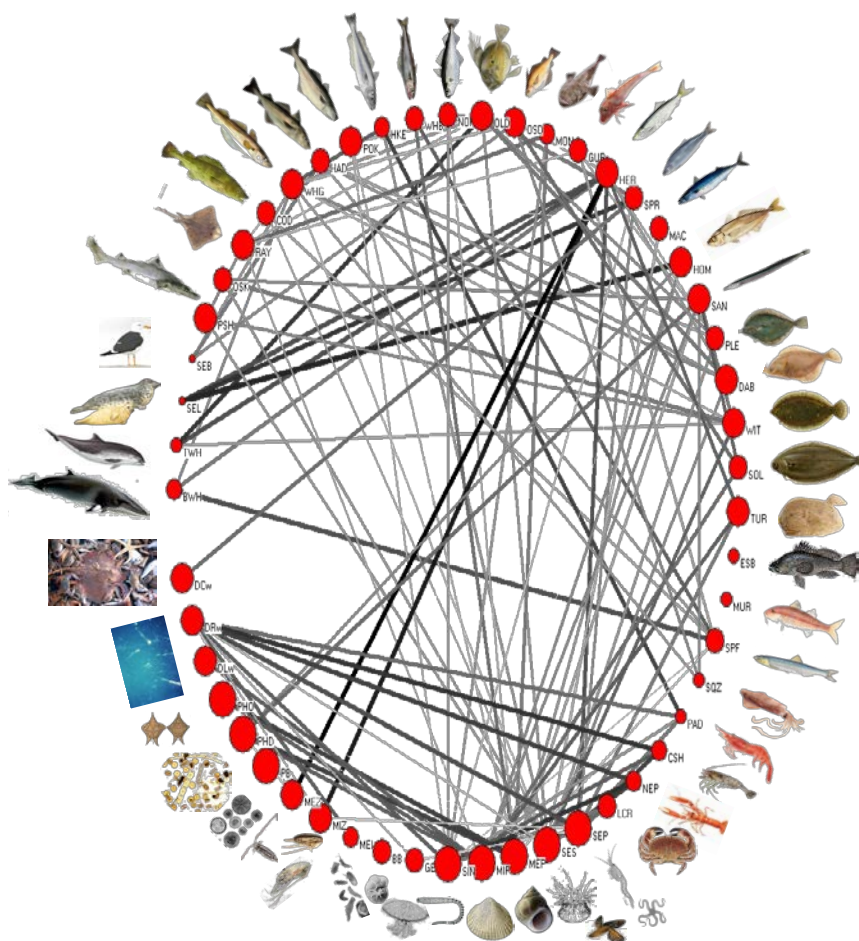| 41	SIN	small_infauna	Small infauna
42	GEL	gelantinous_zoo	Gelatinous zooplankton
43	BMI	benthic_microflora	Benthic microflora
44	MEI	meiofauna	Meiofauna
45	MIZ	micro_zoo	Microzooplankton
46	MEZ	meso_zoo	Mesozooplankton
47	PMI	planktonic_microflora	Bacteria and heterotroph nanoflagellates
48	PHD	diatoms	Phytoplankton (diatoms)
49	PHO	other_phytoplankton	Phytoplankton (non diatoms)
50	SPO	sediment_detritus	Particular organic matter in sediment
51	LDT	labile_detritus	Labile detritus
52	RDT	refractory_detritus	Refractory detritus
53	CAR	carrion	Discards

The top-down control of the ecosystem in the form of fishing pressure was included as F by species and fleet using disaggregated landings and discards data from the STECF effort database for the years 2003 to 2010 and from the EWE North Sea model (Mackinson and Daskalov 2007) for the years before 2003 (Table 2.7.2). In total 10 different fishing fleets based on gear, mesh size and target assemblage were defined.

Table 2.7.2. Fleets specified in the NS Atlantis model.

Fishery	Gear	Cod Plan	Mesh size	Main species	Remarks
Industrial	Otter, Pelagic Trawls, Pelagic Seines	TR3=16-31	<16; 16-31	NOP, SPR, SAN, (HER, WHB)	
Pelagic	Otter, Pelagic Trawls, Pelagic Seines		32-54; 55-69	HER, MAC,JAX, WHB	
MIXED Demersal	Otter, dem Seines	TR1	100-119; >120	POK, HAD, COD, WHG, PLE, ANF	TR2 France
Nephrops	Otter, dem. Seines	TR2	70-79; 80-89; 90-99	NEP, HAD,WHG, COD	SCO, ENG, NIR, DEN
Shrimp	BEAM		<16; 16-31	CSH	
Mussel	Dredge		all	MUS	
Beam Trawl	Beam	BT2; BT1	80-89; 90-99; 100-119; >120	PLE, SOL, COD	
Drift and fixed nets	GILL; Trammel	GN; GT	all	COD,ANF,PLE,SOL,(HKE)	
Longliner	Longline	LL		HKE,MAC, COD, LIN,....	
Pots	Pots			Cancer pagurus	

Species interactions are mainly based on 1991 stomach data transformed to the ATLANTIS availability parameter which indicates the interaction and availability of different prey species to a specific predator. A simplified version is shown below in Figure 2.7.9.

Figure 2.7.9. Overview of the food web interactions in the NS Atlantis model.

For the start year 1991 all initial biomasses, total numbers, the amount of structural and reproductive tissue (Nitrogen) and the age structure of the population of each species group is required. These were derived from single species assessment data, the statistical multispecies model SMS (Vinther and Lewy 2004), the International Bottom Trawl survey, and the North Sea Ecopath and Ecosim Model (Mackinson and Daskalob 2007). IBTS and ICES benthos survey data were used to derive the spatial distribution of each group 1) in the setup year 1991 and 2) in each quarter of the year. The latter is used to determine migration patterns of each group.

The model includes a large number of parameters that require values including growth rates derived from von Bertalanffy growth parameters, clearance rates, mouth gapes, vertical distribution and migration, stock recruitment relations, linear and quadratic mortality rates representing habitat limiting factors, viruses and diseases and habitat types and preferences. Better estimates for some parameters (beyond generic settings) are still needed based on published literature for North Sea species.

The calibration of the model is still ongoing. One of the challenges is the uncertainty in initial biomasses for species of the North Sea that are not assessed or monitored in a sufficient way. Due to a lack of large-scale stomach sampling, species interactions are based on data collected during a single year and migration patterns are, thus far, hard wired based on known differences in quarterly distribution. Despite these short-comings the model is already able to represent biomass trends for several groups as shown in the very preliminary results below (Figure 2.7.10).
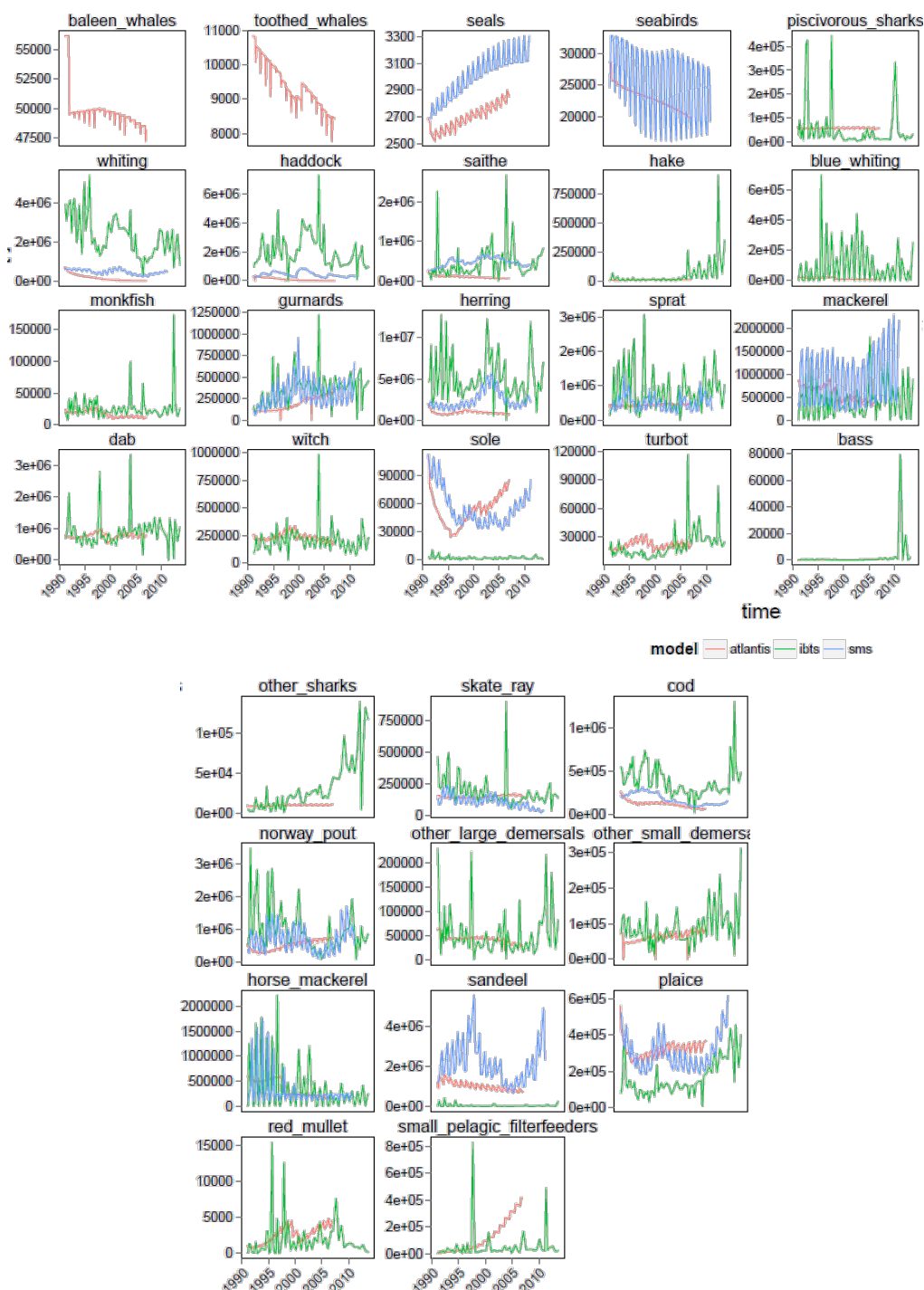
Figure 2.7.10. Preliminary results on modelled biomass trends.

Further work including several consistency and scenario tests is needed to create a model that represents the features of the ecosystem in a robust manner. When ready, this tool can be used to evaluate different ecosystem management strategies in light of projected changes in interacting pressures (fishing, wind farms, conservation and climate) on a variety of time scales. For example within the VECTORS Project Atlantis is being used to test the effects of installing large numbers of wind farms in combination with closing these and NATURA 2000 sites for fishing. Utilizing Atlantis as a management evaluation framework can be done after the economy module is parameterized and calibrated.

2.7.8   LeMANS in the North Sea

2.7.8.1   Further model development

A size-structured North Sea fish community model has been further developed. The core of the model is derived from the Hall *et al.* (2006) model for the Georges Bank, as modified by Rochet *et al.* (2011) for the North Sea. Since the time of the last WGSAM Report (Stockholm, 2013) further improvements have been made:

Incorporation of new data from the 2013 ICES assessment round regarding the status of sprat between 1990 and 2010, bringing the total number of assessed stocks in the model to 10 out of 21.

Incorporation of new life history information from Blanchard *et al.* for 12 stocks; sprat, Norway pout, sandeel, dab, herring, sole, whiting, gurnard, plaice, haddock, cod, and saithe.

Incorporation of data from Denney *et al.* (2003) on the relationship between fecundity and asymptotic length.

A revised value for "other food", to bring the calculated predation mortalities into line with those reported by Sparholt *et al.* This involved reducing the amount of other food by a factor of 60, and resulted in much stronger interactions between model stocks (Figure 2.7.11):
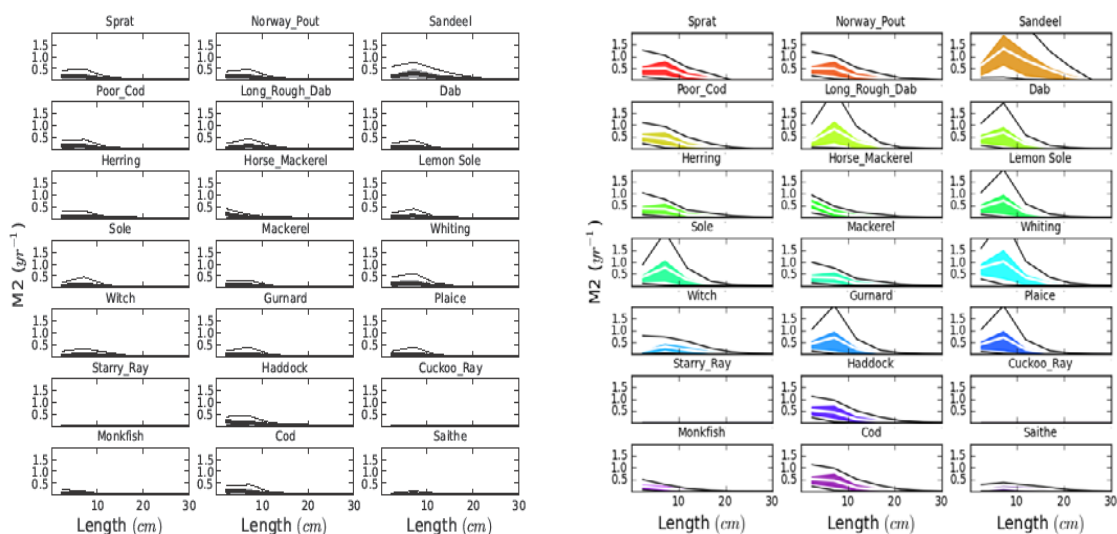

Figure 2.7.11. Ensemble model predation mortality (M2) estimates for a) other food = 10^{11} g (1/6 th of Rochet *et al.* 2011) and b) other food =10^{10} g (1 /60th).

The model has been through the peer review process, and the details will appear shortly in Journal of Methods in Ecology and Evolution (Thorpe *et al.*, in press): http://onlinelibrary.wiley.com/doi/10.1111/2041-210X.12292/abstract

2.7.8.2   Community responses to fishing

The model was initially used to consider the impact of varying fishing mortality across the community in equal instalments of 0.1 x single species FMSY estimates (FSSMSY) from 0 to 4.9 x FSSMSY. Three questions were addressed:

- Is it safe to fish at FSSMSY ? (Yes, see Figure 2.7.12.)
- Does this provide a good yield? (Yes, see Figure 2.7.13.)
- Assuming that fishing at FMSY is good, and at historic levels is bad, can various community indicators (mean length -ML, large fish indicator - LFI, size spectrum slope -SSS, and mean maximum weight -MWB) distinguish between them? (In terms of signal to noise indicator performance is SSS > LFI > MWB > ML , see Figure 2.7.14.)

Figure 2.7.12. Proportion of ensemble members with successively more collapsed stocks as a function of fishing mortality. All stocks are preserved to the left of the left-most line. At F=FMSY all stocks are safe for all ensemble members. There is a 50% chance of at least one stock collapsing at F=1.7 FMSY, and at F=3 x FMSY at least one stock is predicted to collapse in all ensemble members.

Figure 2.7.13. Total fish community yield as a function of fishing mortality. The yield at FMSY is around 90% of the maximum.

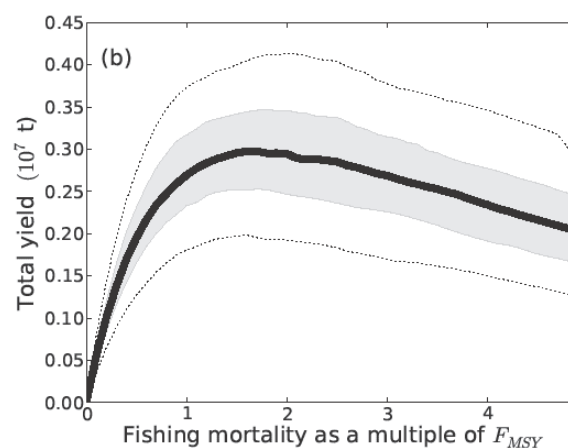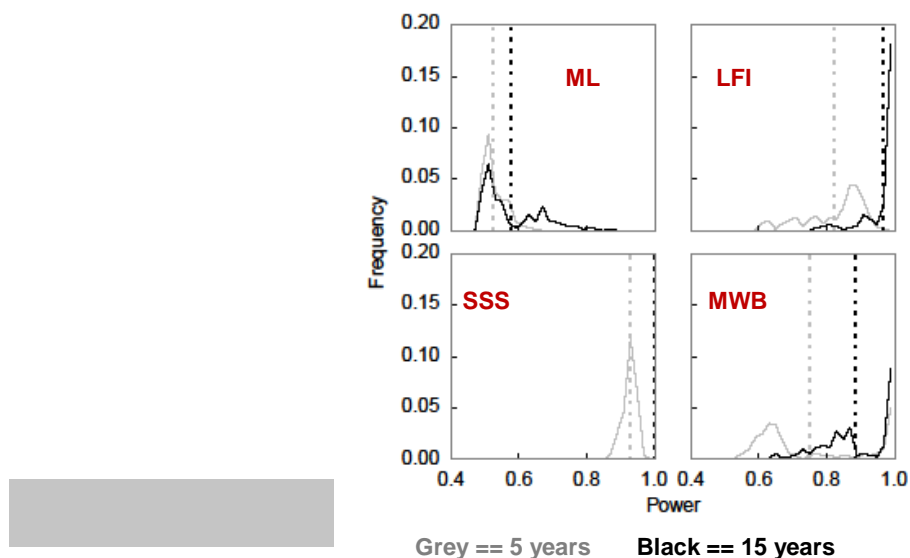# Would a survey detect indicator change?

Grey == 5 years   Black == 15 years

Figure 2.7.14. Power to detect change between fishing at F=FMSY and F=3x FMSY (approximating historic fishing from 1990–2010) for four community indicators, a) mean length (ML), b) large fish indicator (LFI), c) size spectrum slope (SSS), d) mean maximum weight by biomass. Results are presented for a change over 5 years (grey) and 15 years (black). Size spectrum slope is the most discriminating indicator and mean length the least.

2.7.8.3 Multispecies interactions

Subsequently, the model has been used to consider the community response to independently fishing 8 commercial stocks, sprat, Norway pout, sandeel, herring, whiting, haddock, cod, and saithe, using a subset of 18 ensemble members which is representative of the full 188 member filtered ensemble. The 13 other stocks were fished at their single species FMSY estimates. Two main questions were addressed:

i) Does LeMans produce qualitatively similar outputs to SMS (answer no, see Figure 2.7.15)?

ii) Are the outputs similar across the 18 LeMans ensemble members (answer no, see Figure 2.7.16)?
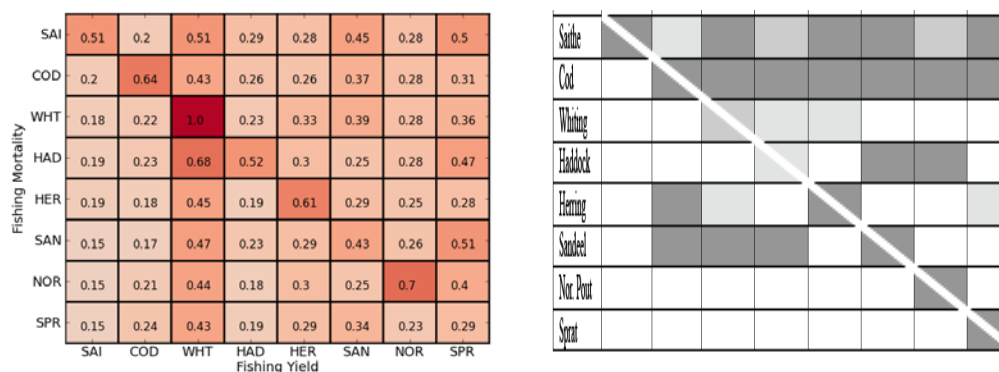
Figure 2.7.15. Interspecies interactions amongst eight key commercial stocks from the ensemble mean for LeMans (left) and SMS (right). Darker colours mean stronger interactions. Multispecies (off-diagonal) interactions are important in both models, but there are significant differences between LeMans and SMS, with more impacts on sprat and whiting in LeMans, and fewer strong interactions involving cod.

Ensemble member 3

Ensemble member 15

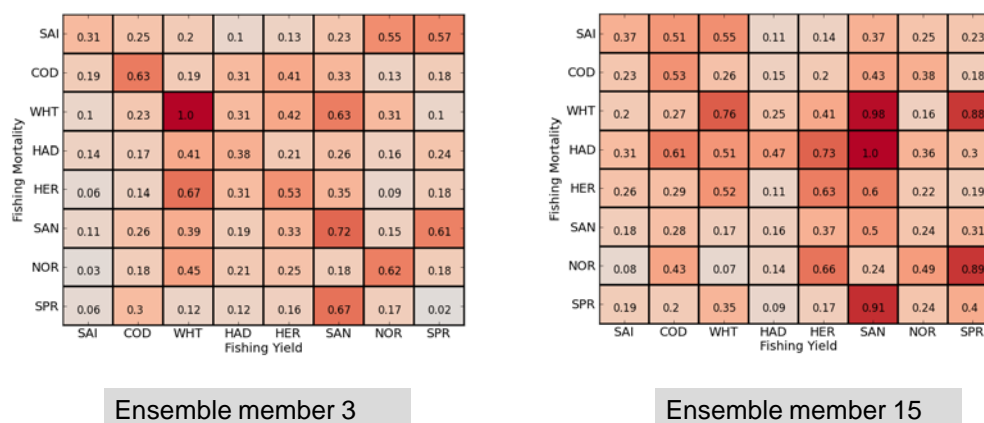**Figure 2.7.16. Interspecies interactions amongst eight key commercial stocks for two different LeMans ensemble members. Darker colours mean stronger interactions. Multispecies (off-diagonal) interactions are important in both ensemble members, but are generally stronger in ensemble member 15 (right). Both ensemble members have the same diet matrix, so this effect is down to the combination of the other parameters being varied.**
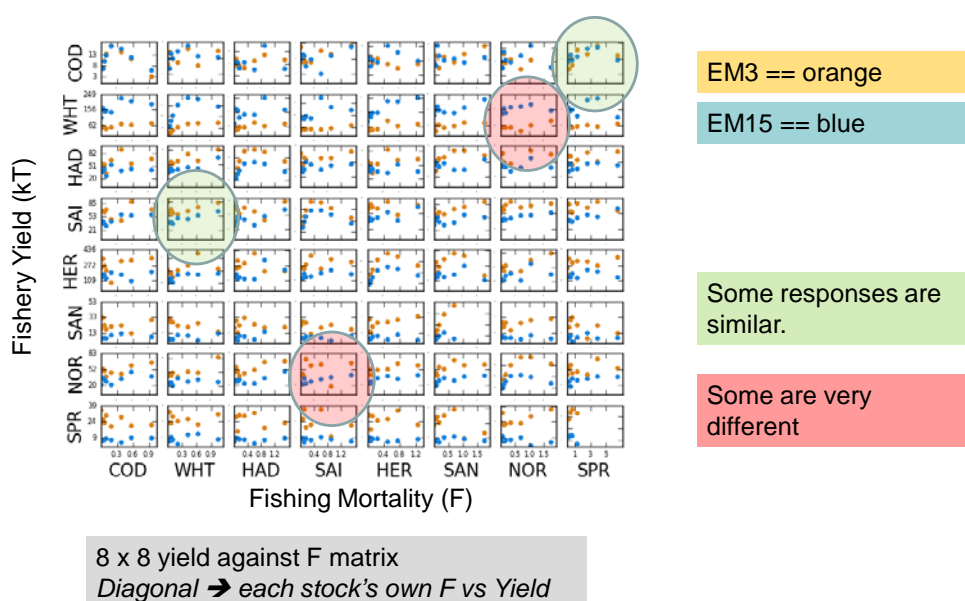
Figure 2.7.18. Plots of fishing mortality against stock x against yield of stock y for 8 key commercial stocks from two LeMans ensemble members (no 3 in orange and no 15 in blue). Some responses are similar and some are different, showing that stock yield responses are sensitive to parameter uncertainty.

Overall we find that responses in the yield of one species to fishing mortality of another species is sensitive both to the choice of models (SMS or LeMans) and the choice of parameters within LeMans, so both structural and parameter uncertainty appear to be important (see also Section 2.1.1 above). This highlights the merits of using a multi-model ensemble which can address both sources of uncertainty to generate multispecies advice. It may also be beneficial to use a wider range of possible M2s to drive the single species stock assessments used in tactical management advice.

2.8 Ecoregion G: South European Atlantic Shelf

Different ecosystem/multispecies modelling exercises continue in this ecoregion in the framework of different EU and regional projects. The ROMS-$N_2P_2Z_2D_2$-OSMOSE model has been updated under the EU DEVOTES project framework. In the same project, an as a result of collaborative research, effort is being done aiming to fit an Ecosim model to fisheries time series data in ICES Divisions VIIIa and VIIIb, as a continuation of the Ecopath model developed by Lassalle *et al.* (2011).

Different Gadget models are also being implemented for different species in the Bay of Biscay and the Iberian Waters. In both cases, single-species models are being implemented for species such as hake (northern and southern stocks, corresponding to each of the regions previously cited), dolphins (Iberian Waters) and low and medium trophic level pelagic species, such as anchovy and mackerel in the case of the Bay of Biscay. The Common dolphin model has been linked to the Southern Hake assessment model, aiming to evaluate how the existing biological interactions affect the dynamics of this demersal species.

New research has just started on implementing an Atlantis model in the Southeastern Bay of Biscay to analyse potential effects of different coastal maritime activities on that ecosystem.

2.9 Ecoregion H: Western Mediterranean Sea

There is no progress to report on multispecies modelling in Ecoregion C this year.

2.10 Ecoregion I: Adriatic–Ionian Seas

There is no progress to report on multispecies modelling in Ecoregion C this year.

2.11 Ecoregion J: Aegean–Levantine

There is no progress to report on multispecies modelling in Ecoregion J this year. There were no participants present at the 2014 meeting from this Ecoregion.

2.12 Ecoregion K: Oceanic northeast Atlantic

There is no progress to report on multispecies modelling in Ecoregion J this year. There were no participants present at the 2014 meeting from this Ecoregion.

2.13 Ecoregion L: Baltic Sea

2.13.1 ATLANTIS model in the Baltic

An Atlantis model of the Batlic Sea has been developed under the FP7 project VEC-TORS (Vectors of Change in Oceans and Seas Marine Life).

The Baltic ATLANTIS model: implementing a holistic framework to evaluate eco-system-wide responses to changes in climate and anthropogenic forcing.

Authors: A. Palacz, J. R. Nielsen, H. Gislason, A. Christensen, F. Bastardie, K. Geitner, M. Maar, M. Hufnagl, M. Lindegren, B. Fulton

One major contribution of VECTORS was to set-up a holistic modelling tool capable of establishing operational links between some of the advanced tools and relevant datasets describing various physical, biological and socio-economic processes and their complex interactions for relevant marine ecosystems. Here we present initial results of implementing such a holistic framework in the Baltic Sea using the state-of-the-art whole-of ecosystem model ATLANTIS. This has been done in cooperation with the Danish Strategic Research Council Project IMAGE. The complex ATLANTIS model consists of a multitude of distinct but coupled modules all together representing a spatially explicit multi-trophic level marine ecosystem and associated fishing and management systems. The Baltic ATLANTIS application resolves processes in three spatial dimensions with 29 polygon-shaped boxes delineated across 9 vertical layers, and with a 12-hour temporal resolution. The model simulates dynamic changes for 33 biological functional groups from the coupled benthic-pelagic realm. The food-web module spanning from bacteria to marine mammals is informed by a comprehensive set of field data and results from other models covering spatio-temporal patterns in abundances and biomasses as well as constraints on many physical, chemical and biological rate parameters. The model is forced with hydrodynamic fields from the coupled physical-biological ERGOM-HBM model, and riverine nutrients loads from the HELCOM database. We present the results from a balanced, near-equilibrium ecosystem calibrated to 2005 initial conditions of climate, eutrophication and fishing exploitation. Moreover, we demonstrate the model's capability to simulate ecosystem-wide responses under scenarios of change in eutrophication pressure, and discuss the model's strengths and weaknesses in light of its current assumptions and limitations.

2.13.2 Ecopath and Ecosim modelling for the Baltic

No progress was reported beyond that described in the 2013report.

2.13.3 Multispecies Integrated Stochastic Operative Model, MSI–SOM in the Baltic Sea

No progress was reported beyond that described in the 2013report.

2.13.4 A Gadget framework for the Baltic Sea

Cod, herring and sprat populations in the Baltic Sea have experienced large variability in abundances and spatial distribution during the last decades, likely induced by a combination of processes, i.e. density-dependence, environmental variability, fishing exploitation.

Recent correlative studies have suggested that cross-sub-basin effects may be relevant on the trophic interactions between these species in the Baltic, and how the structure of the food-web is shaped across the different sub-basins (Casini *et al.* 2012; Lindegren *et al.* 2014). However, the population level and demographic consequences of these spatial dynamics and their effects on trophic interactions have been poorly investigated.

A Gadget modelling framework (Begley and Howell, 2004) is currently under development in the Baltic Sea to bring those initial correlative analyses forward into an age-length based and process oriented context.

The work is leaded by SLU and carried on within the project MareFrame (EU FP7 #613571).

2.14 Ecoregion M: Black Sea

There is no progress to report on multispecies modelling in Ecoregion M this year. There were no participants present at the 2014 meeting from this Ecoregion.

2.15 Ecoregion: Canadian Northwest Atlantic

Flemish Cap is an underwater mountain located out of Canadian waters, in the Northwest Atlantic Fisheries Organization (NAFO), division 3M. Main commercial species in this fishing ground are cod, redfish and shrimp. The isolation of this system, its relative ecological and biological simplicity, the apparent connection in the dynamic of cod, redfish and shrimp and the availability of data from commercial fleet and research surveys, make the Flemish Cap a suitable and interesting system to develop a multispecies model.

Alfonso Pérez Rodríguez presented the project GADCAP, an EU Marie Curie program project which deals with the development of a GADGET (Globally applicable Area Disaggregated General Ecosystem Toolbox) multispecies model for the Flemish Cap cod, redfish and shrimp. This project started on January 2014, with two years duration, and will be develop under the supervision of Daniel Howell, from the IMR in Bergen (Norway). The goals of GADCAP are 1) Single-species models for cod, redfish and shrimp; 2) Connecting these species in a Multispecies model; 3) Management strategy evaluation (depending on the positive evolution of the project). The most important Researchers from different institutions and countries, like Spain (IIM and IEO), Portugal (IPMA) and Canada (DFO), most of them members of the SC of NAFO, are collaborating in this project, both providing survey and commercial fleet information and their long experience with these databases and the stocks being modeled.

2.16 Ecoregion: US Northwest Atlantic

There is no progress reported on multispecies modelling in Ecoregion M this year. There were no participants present at the 2014 meeting from this Ecoregion.

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3   ToR B: Report on the development of key–runs (standardized model runs updated with recent data, and agreed upon by WGSAM participants) of multispecies and eco–system models for different ICES regions (including the Baltic Sea, and others as appropriate)

3.1   North Sea SMS model

A key run for the North Sea SMS model was produced. This included updates to the input data and some modification to the structure of the model. These are described in detail in Annex 5.

3.2   North Sea EwE

EwE Sea key run was not performed at WGSAM meeting 2014, and has been postponed for next year.

4   ToR C: Where possible, develop standards for 'Key Runs' of other modelling approaches (e.g. Size spectra, TGAMs) ToR C. Where possible, develop standards for 'Key Runs' of other modelling approaches (e.g. Size spectra, TGAMs)

4.1   Key runs and model acceptance

A proposed mechanism for accepting new multispecies models into the ICES advice giving process was developed during the previous meeting (WGSAM 2013). This has been submitted to ICES for consideration, but no formal response has been received. The newly formed Benchmark Steering Group is scheduled to discuss the WGSAM proposal and give a recommendation.

5   ToR D: Develop and compare foodweb and ecosystem indicators (e.g. from the MSFD) and advice produced by multispecies key runs (preferably together with WGFE and WGECO)

The term of reference to develop and compare foodweb and ecosystem indicators and advice produced by multispecies key runs together with other groups have followed WGSAM since 2012. In that period, the group has produced an overview of suggested indicators for which multispecies models can provide advice (WGSAM 2012) and a rating according to the guidelines produced by WGBIODIV 2013 and WGECO 2013 of the suggested indicators (WGSAM 2013). WGSAM members have since then participated in the subsequent re-rating of the indicators in WKFoowI (2014), showing high consistency with the original rating and in the following workshop to produce guidelines for the revision of the MSFD (WKGMSFDD4 2014). The workshop recommended that Descriptor 4 (foodwebs) should have just two criteria (4.1 Structure and 4.2 Function of foodwebs). The concept of trophic guilds should be used rather than with species-specific indicators and an indicative list of trophic guilds was provided, where most multispecies model cover mid- and higher trophic levels and some models also cover benthos and lower trophic levels. Criterion 4.1 Structure was subdivided into biomass of guilds over time and size structure within those guilds, both of

which are aspects for which a variety of indicators can be produced in multispecies models. The workshop also considered in line with WGSAM that environmental influence often has a high impact on foodweb structure and function. The workshop therefore recommended that the indicators of D4 could be treated as surveillance indicators (for monitoring change in the foodweb). The causes of movement beyond specific bounds could in some cases be investigated using food web models.

With this summary, WGSAM considers that it has performed the intended work on development of food web indicators. If requested by other groups, the group can provide an overview of the temporal development of a series of indicators as done in the suggested multispecies advice from 2012 in connection with key runs.

6 ToR E: Report on progress on including new stomach samples in the ICES area in multispecies models

6.1 Predicting diets from morphological trait

Diet data are expensive. To make best use of the available data, it can be desirable to use the data to parameterize a model which would then give more consistent estimates of diets for both predator-prey pairs for which diet data is available, and for those where it is not. An early model of this form is the rank proportion algorithm developed by Link (2004). Nagelkerke & Rossberg (2014) recently demonstrated a new, innovative approach building on the concept of a trophic niche space, in which the strength of feeding interactions is estimated as depending on the distance in niche space between abstract vulnerability traits of prey i and the foraging traits of predators j. Foraging and vulnerability traits are parameterized in terms of morphological traits of prey and predators. These, and the resulting trophic interaction strengths, can therefore be computed for species not entering the model fit. A promising avenue for future work is to attempt to fit this model to diet data from marine fish communities. The fitted model could then be used to provide estimates of interaction strengths as inputs to multispecies stock-assessment models.

6.2 Analysing prey preference from single station data

It was noted that the suitability of fish as prey for a particular predator might be thought of as being composed of three components; size ratio of predator to prey, species behavioural characteristics e.g. benthic or pelagic feeding behaviour and their spatial overlap. Relative values of the first two components might be considered by comparing the feeding of different ages and species of predator from individual samples where all predators could be considered to feed differentially from the same range of prey. Thus, consumption(s,l,S,L) of prey species s of length l being eaten by predator species S of length L, might be written as:

Consumption(s,l,S,L)=biomass(s,l)*SSuit(l/L)*SpSuit(s,S)*ration(S,L)/Sum all suitable prey of (S,L)

Where SSuit denotes the size suitability function and SpSuit the species suitability.

Since biomass(s,l) may be regarded as the same for all predators sampled from one station it should be possible to estimate at least relative values of SSuit(l/L) and SpSuit(s,S). The Thesis of Susan Singh (at CEFAS) considered this possibility.

6.3 New stomachs from the Stomach tender project

The study financed by the Commission to sample stomachs in the Baltic and North Sea in 2013 (MARE/2012/02) provided as expected an increase of the Baltic Sea stomach data base by 150% and supplied new data for three predators in the North Sea (mackerel, grey gurnard and hake).

Grey gurnard and hake stomachs were used in the new SMS keyrun for the North Sea and a description of the diet composition found in the stomachs is given in Annex 5. Hake could be implemented as "other predator" in the North Sea SMS for the first time. Mackerel data were available short before the WGSAM meeting but because of time limiting constraints it was not possible to bring the data into the right format for SMS. These data will be included in the next key run at latest. A new keyrun for the Baltic is planned for next year.

The project has provided insight into potential challenges when sampling on existing surveys, most dominantly in areas such as the North Sea where a large range of fish species must be sampled for biological characteristics such as age and maturity. The IBTS surveys in 2013 have both been challenged by periods of inclement weather, limiting the time available to process catches to the absolute minimum. In this situation, it was not always possible to obtain the targeted number of stomach samples as task funded directly under the DCF which take precedence over added tasks such as stomach sampling. On some research vessels, this problem can be addressed partly by increasing the number of staff members, but this is not possible on all vessels and also represents an unnecessary added cost in cases where the weather on the entire survey is fair.

6.4 Update on stomach sampling in the Baltic

The sampling and analyses of new stomachs for multispecies assessments, funded via a data tender by the European Commission, has been split into a larger Baltic Sea study and a smaller North Sea study. The available resources were allocated primarily to stomach analyses of predators in the Baltic Sea, but supplemented with samples of selected predators in the North Sea.

Stomach analyses in the **Baltic Sea** mainly focused on **cod** as the major predator and the only predatory fish included in multispecies models. However, **whiting** may be an important source of mortality in the Western Baltic. Therefore, a small effort dealt with stomach analyses of this predator to reveal the extent to which it will be necessary to include this species in models of the Western Baltic in particular.

In the **North Sea**, the general strategy has been to use the limited share of the funding to obtain the "most benefits for least cost". Large scale stomach sampling exercises have previously covered a wide variety of North Sea species. However, a few species, in spite of their large possible impact on prey fish, have only been subject to very limited sampling. Focus has been put on predators for which the diet is presently poorly known or is expected to have changed significantly since the last sampling efforts in this area. According to these criteria, the three most relevant predator species were judged to be **grey gurnard, mackerel and hake** as they have had the lowest sampling level while still having a large potential effect, and stomach analyses of these species even at a low level will increase knowledge substantially.

Furthermore, substantial **historic stomach data** already existed in the partnering institutes, much of which could be used in the estimation of multispecies interactions with a much lower cost than that incurred by sampling new stomachs. In both the

Baltic and North Sea, a large effort has been made to retrieve such data and make them available to multispecies models in the format used by ICES in their stomach database. This provided a data series stretching back in time and hence lend support to the long term stability of the models.

All existing and new samples and data will be included in a common stomach database in ICES exchange format, which will be made available to the scientific community via ICES. This database can be used to re-estimate multispecies reference points such as F_{MSY} of the three species.

6.5 Update of DAPSTOM database

Major re-building of the DAPSTOM stomach database has now been completed and published (Pinnegar 2014), with North Sea data ready for loading ICES Stomach Database for future use by WGSAM.

The most recent version of the DAPSTOM dataset (Version 4.7, collated in January 2014, see Pinnegar 2014) includes 226,407 records derived from 449 distinct research cruises, spanning the period 1837-2012. The database contains information from 254,202 individual predator stomachs and 188 predator species. As such, this represents one of the largest and most diverse compilations of marine food-web data anywhere in the world.

Substantially re-engineered as part of the EU MARE/2012/02 project the DAPSTOM database has been to enable users to output data in a form that is consistent and compatible with the ICES 'Year of the Stomach' dataset. The re-building work has involved adding new tables and database fields, including correction and standardization of taxonomic information to encompass TSN and WoRMS Aphia species codes.

A major task has involved the estimation of prey weights consumed, using a new look-up table of average prey wet mass. This required gathering literature data on all 1267 prey species cited in the database. The resulting gravimetric estimates of diet composition for predators should prove useful for multispecies modelling and food-web analysis.

A new sub-set of the DAPSTOM data has been generated focusing on 10 predators in the North Sea (cod, haddock, whiting, saithe, hake, grey gurnard, mackerel, horse mackerel, starry ray and harbour porpoise). This data extraction provides information in an ICES compatible format and has been made available to the project co-ordinators and the ICES data centre.

6.6 References

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mortality within MSVPA". Submitted to the School of Life Sciences in the University of Buckingham.

7 ToR F: Explore the consequence of multispecies interactions and environmental factors in practical multispecies advice for fisheries management (MSY related and other biological reference points)

No contributions were made under this ToR in 2014.

8 ToR G: Compare methods used to include spatial structure (predator prey overlap) in multispecies prediction models (preferably together with WGIPEM)

No contributions were made under this ToR in 2014.

9 ToR H. Work towards providing ecosystem advice consistent with species and technical interaction in mixed fisheries (preferably together with WGMIXFISH)

On the 23 October, WGSAM and WGMIXFISH convened a joint meeting to address ways to better integrate research for provision of ICES advice on mixed fisheries and multispecies issues. A separate report is provided in Annex 6.

9.1 "Response Surfaces for cheaply approximating the steady state response of age based multispecies models: suitable fleet definitions" (John Pope)

The author suggested that some simplified, speedier and more user friendly form of multispecies model would be useful. One possibility is Bulk Biomass models fitted to the results of age based models. He noted that in fact (Multispecies Schaefer and Multispecies Fox models have a long history of use in ICES multispecies working groups. Section 8.1 of the 1989 Multispecies working group (Anon. 1989) shows results from such models based upon a method presented as a working document to that body (Pope, 1989a) and a simple spreadsheet model that was devised that would allow for use by non specialists. Subsequent these ideas have been further developed by Collie *et al.* (2003) but in both cases the work was done somewhat before the need for it became apparent. However, its further development would now seem to be timely.

Ideally, to fit such models requires estimation of the steady state at status quo or some other specified effort levels of designated fleets and the enumeration of the yield of each species for each fleet and of the Biomass and SSB of each species. It further requires similar results when each of the fleets' effort is independently increased by a small factor, usually 10%. However, the author considers that if necessary it might be possible to generate the latter results theoretically (Pope. 1989b). However, it would be wise to have at least few worked examples to check the theoretical results against. This requires that some definition of suitable fleets has been prepared. In the first instance the author intended to define a modest set of fleets (perhaps about 10) to describe main features of the North Sea's fishing effort. The author had made a start by defining effort by using STECF, 2013, data of catch and effort by gear types and by

country and then classifying these in terms of which grouping of the main commercial species comprised the major part of their catch. Fleets were defined as those have a maximum landings weight of Flatfish (ple+sol)=FLAT, of Herring (her)=HER, of Industrial fish (nop+sandeel)=IND, of Mackerel=MAC, of Nephrops=NEP, of Roundfish (cod+had+whg)=RF, of Saithe =SAI, of Sprat =SPR or as having a total of all of the above less than 25=DUD It was noted that for each grouping there was a cline from fleets which caught almost only the target species (or group of target species) to some fleets for which this major species grouping was less than 50% of the total and which were thus much more mixed in their targeting. The set the author developed needs further refinement and in particular requires the inclusion of the Norwegian fleets which are not recorded in the STECF data base. More importantly it needs interaction with stakeholders to choose what the most appropriate fleet definitions would be. It was suggested that a Principle Component analysis (or the like) of the fleets might be a useful way of categorising fleets. This work was conducted under the MARE-FRAME project which is funded under the EUs Framework 7 programme.

References

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9.2 An initial uncertainty analysis of management of the North Sea fish community using three simple idealised fleets (Robert Thorpe)

An initial uncertainty analysis of the impact of managing the North Sea fish community using 3 simple idealised fleets was presented. The general approach is outlined in Figure 9.2.1

Figure 9.2.1. Schematic showing the methodology for producing projections of the impact of three idealised fishing fleets (demersal, pelagic, and benthic) on community yield and the risks of stock depletion.

The base model used is LeMans for the North Sea (Thorpe *et al.*, 2014), a length-structured model of the North Sea fish community with 21 fish stocks, including the major commercial ones (cod, saithe, haddock, whiting, herring, sprat, sandeel, Norway pout). The model ensemble is generated in the following manner. 7 key parameters (2x stock recruit, life history, predation size preference, growth efficiency, diet matrix, M1) were allowed to take one of five values based on literature giving 5**7 or 78,125 possibilities. Each of these was tested to see if it could reproduce ICES estimates of spawning stock biomass (SSB) for the period 1990–2010. Those that were more than a factor of 2 out for any stock, or failed to preserve all 21 stocks when unfished were discarded, leaving 188 successful ensemble members. Sample output is shown in Figure 9.2.2 for a) a hindcast of cod biomass under 1990–2010 fishing, and b) a forecast of cod biomass under "MSY" fishing. The improvement in stock condition as fishing mortality declines to F_{MSY} is apparent.

Figure 9.2.2. Ensemble cod stock biomass projections for a) fishing at average 1990–2010 mortality, and b) fishing at F=F$_{MSY}$. The grey histogram shows the unfiltered 78125 member model ensemble, the black histogram the 188 member ensemble consistent with stock data. The shaded blue area denotes the range of ICES stock estimates for the 1990–2010 period.

The fish community has 21 stocks, hence a potential 21-dimensional management space, but here we assume that we have to manage the system via 3 fleets, demersal, pelagic, and benthic. Two cases were considered, an idealised case where the stocks and fleets align so each stock is caught by one fleet only, and "historic" fleets based on average recorded catches and assuming constant effort across demersal, pelagic, and benthic stocks. Ten different fishing levels were considered for each fleet independently, ranging from zero to 3x F$_{MSY}$, giving a total of 1,000 independent simulations for each of 24 ensemble members.

We considered the overall yield, and the risk of stock collapse, defined as any ensemble member projecting a stock biomass below 10% of the unfished value. Some risk surfaces for the three fleets are shown in Figure 9.2.3.

Results suggest that the benthic fleet can operate safely even when its mortality is high, provided that there is low mortality from the other fleets. On the other hand, several stocks are at risk if demersal mortality is high, regardless of the mortality from the other fleets. The pelagic fleet provides similar yields to the demersal one, but with much lower levels of risk.

Risk Profiles

| Demersal F=3.0 | Pelagic F=3.0 | Benthic F=3.0 |

demersal fleet puts >5 stocks at risk at high F

pelagic fleet puts >1 stocks at risk at high F

benthic fleet can operate safely at high F, if the other fleets have low Fs.

White =all stocks safe, dark pink = 10 stocks at risk

Figure 9.2.3. Numbers of stocks at risk for different levels of fleet mortality with a) high demersal mortality, b) high pelagic mortality, and c) high benthic mortality.

The effect of fishing at $F=F_{MSY}$ across the fleets was considered, and it was shown that this led to good overall yield whilst keeping all stocks safe. In this modelling study, fishing the system at single species estimates provided a reasonable solution, suggesting that this may be an adequate way to manage the system, and that problems in the North Sea fishery are more to do with not sticking to the given advice rather than the single species methods per se.

References

Thorpe, R.B., LeQuesne, W.J.F., Luxford, F., Collie, J.S., and Jennings, S.: Evaluation and management implications of uncertainty in a multi-species size-structured model of population and community responses to fishing, Journal of Methods in Ecology and Evolution, doi: 10.1111/2041-210X.12292

10   Response to Requests to WGSAM

10.1 Requests

ID	Request	WGSAM Action/ Response
Inigo Martinez 29 Aug 2014	Produce four short paragraphs for the ICES Ecosystem Overviews on the structure and function of the foodweb, one paragraph for each of the following ICES ecoregions: Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast and Baltic Sea. *Supporting information* Each paragraph should be maximum 150 words in length and can be support by one figure. Paragraphs for each ecoregion should be similar in style and address the overall state and comment on the pressures accounting for changes in state. These will go in section four of the ecosystem overviews and not supposed to be long descriptions, but a short synopsis of important points for managers and policy developers. (Template and Guidelines for Ecosystem Overviews)	Paragraphs produced for Greater North Sea, Celtic Seas, Bay of Biscay & the Iberian coast and Baltic Sea.
Cristina Morgado 5 Sept 14	Provide support to Baltic Sea cod assessment by providing relevant information (datasets or methodologies) on environmental and ecosystem conditions that may influence the assessment of the cod stocks and the fisheries. Contact the WKSIBCA chairs, Marie Storr-Paulsen (msp@aqua.dtu.dk) and Maciej Tomczak (maciej.tomczak@su.se), to coordinate and integrate the work.	Stefan Neunfelt provided a presentation and led a discussion that led to specific recommendations on how to proceed regarding understanding the issue of starving cod in the Baltic. (See, 10.2.1)
Carmen Fernandez	"Consider ways to integrate sensitive species bycatch (e.g. for marine mammals or sharks) into the fish stocks advice. Consider a range of possible options, which can be model-based or of a more qualitative type."	Chairs of WGSAM, MIXFISH, WGECO and WGNSSK met to consider response. A document describing way forward was produced (see 10.2.2)

10.2 Responses

10.2.1 Special request from WKSIBCA on Eastern Baltic cod

There was a special request from WKSIBCA for WGSAM to discuss the poor condi-
tion and growth in the Eastern Baltic Cod. To address this, there was a presentation
of the problem, a discussion of the issue, and several suggestions for analyses which
might help in understanding the causes of the problem.

Presentation of the issue

Cod in ICES Sub-division 25 have shown a considerable decrease in weight at length since 2007. We used newly available data from an EU financed stomach sampling scheme to investigate, if cod between 30 cm and 40 cm total length consuming less food nowadays, and if yes, the difference a possible cause for stunned growth. Using first a stochastic stomach content model, we found that average meal intensity (number of meal per day if searching for food) increased, but that average daily food consumption decreased by about 35%. The ratio of fish compared to benthos in the stomachs decreased since 2009, but is on the same level as in the 1980s, when there was no poor condition observed in cod of the investigated size group. Second, we applied a bioenergetic model in order to investigate, if the cod between 30 cm and 40 cm total length consumed enough energy to support somatic growth. The alternative estimate of daily consumption was considerably lower than the one derived by the stochastic mode, implying that the assumption of log-normally distributed meal sizes in the stochastic model has probably been misleading. Daily consumption, estimated based on food intake of benthos and fish with different energy densities, ranged in the new collected stomachs between 10.7 kJ/day in 2012, and 18.6 kJ/d in 2008. These values are in line with literature values, but at the lower end of consumption rates supporting somatic growth. Accounting for the food conversion, and cost of activity, the excess energy was about 20%, i.e. the consumed energy was c. 20% than the estimated standard metabolic rate. This energy excess has to be distributed over somatic growth, and maturation, and is possibly compromised by the increasing degree of infection with parasites.

Discussion

Following the presentation there was a discussion of the issues, and a number of suggestions for exploratory analysis that might help identify the causes of the poor condition of the cod.

It was noted that for stock assessment, understanding the mechanism was not an absolute requirement – simply knowing what the effect of the change was and when it occurred would allow for formulation of a model. However for selecting and evaluating remedial measures, an understanding of the mechanisms would be critical. For example, if locally low levels of sprat are the problem then closing the sprat fishery in the surrounding areas might help, whereas if the issue is in benthic feeding conditions then such a closure would impose economic costs without giving any result.

There was little correlation between total prey biomasses and biomasses in stomachs, indicating that co-occurance or ability to catch prey is likely to be an important factor.

The higher level of parasites in recent years was discussed. It was agreed that poor health due to poor feeding conditions could result in increased parasite load. However it was also pointed out that the causation change could be reversed, with higher parasite load being a possible cause of the poor condition.

Age reading is highly problematic for this stock, with traditional otolith reading not giving reliable age estimate. It was noted in the presentation that as well as tagging a chemical analysis of the otoliths may give an age estimation, though at rather high cost.

Noted that anoxia could impact on god growth, but since the cod only make feeding dives into low oxygen conditions, and can rest in oxygen rich waters, this is unlikely

to be a factor. However oxygen conditions may have indirect impact through changing benthos.

Much of the discussion was around the benthic feeding conditions, and change in the benthos to be more "worm" dominated. The main issue was whether the poor condition was affecting all cod (including those which had previously been piscivourous) or only those which had not yet become piscivourous, and which were then unable to start eating fish. If the starvation were affecting only the early benthic stages, then this would show up as reduced proportions of fish in the total stomach data set due to fewer cod being able to eat fish, rather than due to reduced availability of fish prey.

One suggestion was that possibly the change in diet composition of the biomass may have increased the concentrations of detrimental chemicals (e.g. thiamine which can reduce overall consumption) in the cod.

Hypotheses

We thus have a number of competing hypotheses for the causes of the poor condition and lowered fish contents in the stomachs:

> 1. Fish prey being unavailable for some reason (e.g. spatial mismatch)
>
> 1b. Parasite load on all fish reducing condition
>
> 2a. Benthic feeding conditions being too poor to allow young cod to grow enough to become piscivourous
>
> 2b. Increased parasite load on young cod preventing them from growing to become piscovourous

In terms of exploratory analysis, the key difference between possibilities 1 and 2 is whether previously healthy piscivourous fish have begun to starve, or if the larger fish have continued at reasonable conditions and the impact is via small cod not growing. Given the age reading problems this cannot be addressed by looking at "young" and "old" fish directly. However length data is available, and could be used for this purpose.

Suggested analyses

- **For each year, plot the fraction of "fat" and "thin" cod by length**

  This should directly identify if previously healthy cod become thin, or if the poor condition is only in cohorts that began with poor condition

- **For each year plot the length distributions**

  May help to identify how the growth has changed through time

- **Attempt to estimate the energy density of the changing benthic community**

  Would support or contradict a "food in the benthos" hypothesis

- **Take poor condition cod into a tank and feed them**

  Would help identify if there were underlying issues (e.g. parasites) beyond simple food availability

- **Research project into changing parasite load and impacts**

  This is already underway, and may help separate food limitation from parasite effects

10.2.2 Roadmap to advice on risk to sensitive species, sensitive habitats and key trophic guilds in ICES by WGSAM, WGMIXFISH, WGNSSK and WGECO Chairs (to be sent to WGMAMMAL, WGEF, WGBIODIV and WGBYC chairs)

Daniel Howell, Paul Dolder, Alex Kempf and Anna Rindorf had a short subgroup meeting at the WGSAM/WGMIXFISH meeting in London to discuss how risk based advice could be given on sensitive species (as biodiversity indicators), food webs and habitats. Since the joint experience was limited on habitats, this was only discussed briefly. The following list described the steps necessary before risk based advice for sensitive species, food webs and to some extent habitats can be provided.

1. Definition of:
   a. sensitive species (biodiversity) - WGBYC/WGECO/WGMAMMAL/WGEF/BIODIV
   b. sensitive habitats (tell VMS and WGECO and others?) - WGVMS/WGECO/BEWG/WGOTHER?
   c. key trophic guilds in the food web – WGSAM, intersessional?/WGECO

2. List of:
   a. sensitive species WGBYC/WGECO/WGMAMMAL/WGEF/BIODIV
   b. sensitive habitats - WGVMS/WGECO/BEWG/WGOTHER?
   c. key trophic guilds in the food web– WGSAM, intersessional?/WGECO
   d. métiers and type of information needed – MIXFISH (intersessional)

3. List of metiers catching sensitive species and a qualitative evaluation of catches WGBYC /WGMAMMAL/WGEF

4. List of metiers affecting sensitive habitats and a qualitative evaluation of impact BEWG/WGECO

5. Reference levels for acceptable risk to
   a. sensitive species – WGBYC/WGEF/WGMAMMAL/WGECO
   b. sensitive habitats ??
   c. key trophic guilds in the foodweb WGECO/WGSAM

6. MIXFISH will provide guidance on likely change in effort in metiers with high catches of species at risk given current catch advice for target stocks in the fishery – MIXFISH.

7. MIXFISH cannot provide guidance on likely change in habitat impact given current catch advice for target stocks in the fishery. Actual group to decide will require more consideration – MIXFISH.

8. Individual assessment groups will provide guidance on the risk to members of trophic guilds, the joint index is estimated by ICES and reviewed by an ADG – Individual assessment groups.

Annex 1: List of participants

Name	Address	Phone/Fax	Email
Daniel Howell (co-chair)	Institute of Marine Research P.O. Box 1870 Nordnes Norway		danielh@imr.no
Steve Mackinson (co-chair)	Cefas Pakefield Road Lowestoft UK NR33 0HT		steve.mackinson@cefas.co.uk
Alexander Kempf	Thuenen Institute of Sea Fisheries Palmaille 9 22767 Hamburg Germany	+494038905194	alexander.kempf@ti.bund.de
Anna Rindorf	DTU-Aqua Charlottenlund Casttle 2920 Charlottenlund Denmark	+4535883378	ar@aqua.dtu.dk
Andrea Belgrano	Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of Marine Research, Turistgatan 5, SE-453 30 Lysekil, Sweden and Swedish Institute for the Marine Environment (SIME), Box 260, SE-405 30 Göteborg, Sweden	+46 70 8433 526 (cell)	andrea.belgrano@slu.se
Robert Thorpe	Centre for Environment, Fisheries and Aquaculture Science (CEFAS) Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 Fax +44	robert.thorpe@cefas.co.uk

Eider Andonegi	AZTI-Tecnalia Txatxarramendi Ugartea z/g 48395 Sukarrieta (Bizkaia) Spain	Phone: +34 667174414 Fax: +34 946572555	eandonegi@azti.es
Axel Rossberg	Centre for Environment, Fisheries and Aquaculture Science (CEFAS) Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 Fax +44	axel.rossberg@cefas.co.uk
Stefan Neuenfelt	DTU-Aqua Charlottenlund Casttle 2920 Charlottenlund Denmark	+4535883378	stn@aqua.dtu.dk
Morten Vinther	DTU-Aqua Charlottenlund Casttle 2920 Charlottenlund Denmark	+4535883378	mv@aqua.dtu.dk
Valerio Bartolino	Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of Marine Research, Turistgatan 5, SE-453 30 Lysekil, Sweden and Swedish Institute for the Marine Environment (SIME), Box 260, SE-405 30 Göteborg, Sweden		valerio.bartolino@slu.se
John Pope	NRC (Europe) Ltd		popejg@aol.com
Alfonso Perez Rodriguez	Institute of Marine Research P.O. Box 1870 Nordnes Norway		perezra@imr.no

Annex 2: Agenda

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ICES Working Group on Multispecies Assessment Methods
(WGSAM),

October 20th-24th

Defra, **Room:** LG01

3-8 Whitehall Place

London

SW1A 2AW ([map](#))

</div>

Start time: Monday 20th, 10:30am

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Draft Agenda

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NOTE: ToRs in bold are the focus ToRs for 2014

Date	What and Who
Monday	• Agree Agenda and confirm contributions from participants **ToRC. Where possible, develop standards for 'Key Runs' of other modelling approaches (e.g. Size spectra, TGAMs)** • Uptake of 2013 WGSAM work on model acceptance procedure. Feedback from ICES and feedback from how it feeds in to the Benchmark SG. (Daniel Howell) ToR A. Report on further progress and key updates in multispecies and ecosystem modelling throughout the ICES region. **Presentations** 1. Application of Lemans and presenting output as an 8x8 interaction table comparable to SMS output –discuss!(Robert Thorpe) 2. Towards a working Proto-Moment Based Multispecies Model "Golden Ages or Magic Moments" (John Pope) 3. Structural instability of ecological communities and community models, what it means for integrated, long-term management plans, and how our models will be useful: a management strategy evaluation (Axel Rossberg). 4. Morten – Marine Mammal stomach bias 5. Gadget for the Baltic Sea – plans to work on this (Valerio Bartolino) 6. Southern North Sea EwE and Atlantis progress? (Alexander Kemp) ??? 7. Risk-based ecosystem evaluation of management strategies us-

	ing EwE (Steve Mackinson) [possibly on a different day] 8. Alfonso – Flemish Cap **Later in the day…if there are any offerings**
Tuesday	**AM** **ToR B. Report on the development of key-runs (standardized model runs updated with recent data, producing agreed output and agreed upon by WGSAM participants) of multispecies and eco-system models for different ICES regions (Barents Sea 2014, North Sea EwE 2014, North Sea SMS 2014, ~~Baltic Sea SMS 2015~~ and others as appropriate)** • North Sea SMS – (Morten Vinther) – discuss data etc and pick up later in week • **PM**: Work on ToRs A, B and Requests (see table below) ToR F Explore the consequence of multispecies interactions and environmental factors in practical multispecies advice for fisheries management (MSY related and other biological reference points) `16:45 (08:45) (via Skype) Kirstin Holsman, NOAA (Washington). Presentation on work on using MSM to evaluate climate effects on harvest rates and estimated MS ref points.`
Wednesday	**AM** **Brief considerations of (pending any specific contributions) :** ToR D. Develop and compare food web and ecosystem indicators (e.g. from the MSFD) and advice produced by multispecies key runs (preferably together with WGFE and WGECO) ToR E. Report on progress on including new stomach samples in the ICES area in multispecies models - Presentation from Axel ToR G. Compare methods used to include spatial structure (predator prey overlap) in multispecies prediction models (preferably together

	with WGIPEM)
	PM
	Pick up on North Sea SMS Key run
	Trip to Greenwich
Thursday	**ToR H: Work towards providing ecosystem advice consistent with species and technical interaction in mixed fisheries.**
	'In 2014, WGSAM will invite WGMIXFISH (and possibly WGMG) members to discuss synergies in the use of models to address mixed-fisheries and multispecies issues. In particular, the discussion will focus on the level of fleet aggregation in multispecies models and how outputs on fishing mortality from multispecies models might be useful to feed into mixed-fisheries models.'
	SEE SEPARATE AGENDA "Joint WGSAM_WGMIXFISH agenda.docx"
	PM
	Work on Report
Friday	- Reflect on ToRs and tweak where necessary. - Decide date and location WGSAM 2015 - Work on Report - Aim to finish by 13:30

Annex 3: WGSAM terms of reference for the next meeting

The **Working Group on Multispecies Assessment Methods** (WGSAM) chaired by Daniel Howell, Norway and Steven Mackinson, UK, will meet in Woods Hole, USA, 19–23 October, 2015.

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
A	Report on **further progress** and key updates in multispecies and ecosystem modelling throughout the ICES region	This ToR acts to increase the speed of communication of new results across the ICES area	Use codes	3 years	Reports on further progress and key updates for internal use in WGSAM as well as externally.
B	Report on the development of **key-runs** (standardized model runs updated with recent data, producing agreed output and agreed upon by WGSAM participants) of multispecies and eco-system models for different ICES regions (including the Baltic EwE 2013, Barents Sea 2014, North Sea EwE 2014, North Sea SMS 2014, Baltic Sea SMS 2015 and others as appropriate)	The key runs provide information on natural mortality for inclusion in various single species assessments	Use codes	3 years	Output of multispecies models including stock biomass and numbers and natural mortalities for use by single species assessment groups and external users.
C	Where possible, develop standards for 'Key Runs' of other modelling approaches (e.g. Size spectra, TGAMs)	This work is aimed at expanding the key runs to include methods not currently suited for providing this type of information.	Use codes	3 years	Key run standards for use under ToR b and externally

D	Develop and compare **foodweb and ecosystem indicators** (e.g. from the MSFD) and advice produced by multispecies key runs (preferably together with WGFE and WGECO)	Foodweb and ecosystem indicators are increasingly demanded in management, pariculary through the implementation of the MSFD. To be succesful, the ToR requires a supporting ToR in WGECO and/or WGFE	Use codes	3 years	Foodweb indicators and advice on their development under different fisheries management scenarios (as part of multispecies advice) for WGECO, other ecosystem groups and single species assessment groups
E	Report on progress on including **new stomach samples** in the ICES area in multispecies models	WGSAM actively works for obtaining new stomach sampling programmes and incorporating the data from these programmes in multispecies models.	Use codes	3 years	New stomachs are included in the models to enhance the quality of deliverables under ToR b.
F	Explore the consequence of multispecies interactions and environmental factors in practical multispecies advice for fisheries management (**MSY related and other biological reference points**)	Multispecies reference points such as those related to MSY and the effect of environmental changes on these reference points is a key point in multispecies advice.	Use codes	3 years	Multispecies advice will be provcided wherever possible based on key runs developed under ToR B. Uncertainties in models will be taken in to account.
G	Compare methods used to include **spatial structure** (predator prey overlap) in multispecies prediction models (preferably together with WGIPEM)	Spatial structure is increasingly taken into acount in retrospective multispecies modelling. Methods are currently developed in several groups and a comparison of these methods would facilitate the future development. To be succesful, the ToR requires a supporting ToR in WGIPEM		3 years	Report on joint activities together with WGIPEM for use as basis of future work in WGSAM, WGIPEM and other groups addressing spatial concerns.

| H | Work towards providing ecosystem advice consistent with species and technical interaction in mixed fisheries (preferably together with WGMIXFISH) | Currently, ecosystem advice on mixed fisheries and mutlispeciesissues are parallell and not coordinated. This coordination is of great importance to avoid inconsistencies. To be succesful, the ToR requires a supporting ToR in WGMIXFISH | 3 years | Joint multispecies-mixed fisheries ecosystem advice for use in single species assessment groups. Where models are used as a basis for advice, effects of model uncertainties will be taken into account. |

Summary of the Work Plan

Member contributions to any of the ToRs will be accepted in any year, but where possible, effort will be made to focus WG activities on particular ToRs as proposed below:

Year	Work
Year 1	Work on all ToRs. Tor B restricted to Baltic EwE. Focus on D, E, G
Year 2	Work on all ToRs. Tor B restricted to Barents Sea Gadget, North Sea EwE 2014 and North Sea SMS. Focus on B, C, H
Year 3	**Work on all ToRs. Tor B restricted to Baltic Sea SMS. Focus on F, H**

Plans for 2015

a) In 2015 the group will outline suggestions for selection criteria for multi-model ensembles for use in advice and discuss how output from different models can be usefully combined for ensemble-type provision of advice. This will be built upon in future years.

Supporting information

Priority	The current activities of this Group will lead ICES into issues related to the ecosystem effects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. Depending on the requirements for advice, additional resource might be required to undertake ToR H since the resource needed to shape the research into ICES advice and communicate it is likely to be more substantial than research projects can provide.
Participants	Approx 20. Expertise in ecosystem, modelling and fish stock assessment from across the whole ICES region.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	ACOM, most assessment Expert Groups

Linkages to other committees or groups	WGMIXFISH, WGDIM, WGBIFS, IBTSWG, WGECO, WGFE, WGINOSE, WGIAB, WGNARS, WGIPEM, most assessment Expert Groups, most EGs in the regional Seas Programme. STECF Ecosystem Approach WG.
Linkages to other organizations	

Annex 4: Recommendations

None.

Annex 5: North Sea SMS model Key Run

Overview

A key run for the North Sea SMS model was produced. This included updates to the input data and some modification to the structure of the model. These are described in detail below.

SMS (Lewy and Vinther, 2004) is a stock assessment model including biological interaction estimated from a parameterised size dependent food selection function. The model is formulated and fitted to observations of total catches, survey CPUE and stomach contents for the North Sea. Parameters are estimated by maximum likelihood and the variance/covariance matrix is obtained from the Hessian matrix.

In the present SMS analysis the following predator and prey stocks were available: predators and prey (cod, whiting, haddock), prey only (herring, sprat, northern and southern sandeel, Norway pout), predator only (saithe), no predator prey interactions (sole and plaice) and 'external predators' (8 seabirds, starry ray, grey gurnard, western mackerel, North Sea mackerel, North Sea horse-mackerel, western horse-mackerel, hake, grey seals, harbour porpoise and hake). The population dynamics of all species except 'external predators' were estimated within the model.

To reflect the current sandeel assessment, the sandeel in the North Sea were divided into two stocks, a southern containing assessment areas 1 and 2 and a northern area containing areas 3, 4, 5 and 7. The development in the combined biomass of the two new stocks closely follows that of the previously estimated total biomass. However, the dynamics of the two stocks differ as does the relative importance of different predators, with fewer predators exerting a substantial effect on natural mortality in southern than northern areas. Sprat data were also revised in accordance with the most recent benchmark, but as no reliable information existed on the age composition of catches of small pelagics prior to 1974, the key run update only includes data from 1974 onwards.

Cod data were also revised to mirror the latest benchmark decisions on the most appropriate input data. The revised cod catches were lower than previous catches and as a result, a lower biomass of predatory cod was estimated with an associated lower natural mortality of the major prey of larger cod (particularly herring and 1-year old gadoids). In addition to the cod time series, the time series of grey gurnard and starry ray biomasses were updated with a resulting larger number of piscivorous individuals of both species. Finally, hake was added as a predator and exerted an increasing effect on herring and Norway pout in the last years of the time series.

1. Input data update

Catch at age (including discards), weight in the catch and in the stock were extracted from the 2014 assessment reports of WGNSSK, HAWG and WGWIDE. The assumptions used in official single species assessments were reproduced as much as possible. In general, the survey time series were identical to the ones used in single species assessments. Only for the 0-groups of some species and early years in the time series additional surveys (e.g., ENGFS, SCOGFS) were utilized. The data for sprat catch at age by quarter and mean weight were revised at WKSPRAT and an accepted age based assessment produced since the 2011 key run and the new data were included instead of the preliminary data used in the previous key run.

The working group reports unfortunately no longer provide information on the quarterly distribution of catches with the exception of the catches of sandeel, Norway pout and sprat. To estimate these proportions, the average proportion of the catch taken in each quarter was calculated for the years 1972 to 2003 (using an old key run) where quarterly catch data were available without discard and unallocated landings. However, in many cases data have been revised to include discard and unallocated landings and these revisions have not been accompanied by revised estimates of the proportion of the catch taken in each quarter. Using the average proportions from the years 1972–2003 corresponds to using the same discard percentage in all quarter. While this is probably not correct, the working group was unable to provide better estimates without new information on the quarterly distribution of catches, discards and unallocated landings. WGSAM considers that establishing quarterly catch histories for the remaining species should be a priority area for research and data compilation.

Historically, information on the proportion of the mackerel and horse mackerel stock which was inside the North Sea has been provided by the relevant working groups. However, in later years updated information has not been available and in 2007 it was decided not to continue the acoustic survey of mackerel due to large variation in the measurements. The quarterly proportions of the western stocks in the North Sea were therefore assumed to be constant in the last 24 years. With the assumed proportions and the official assessment results the numbers of mackerel and horse mackerel in the North Sea could be estimated for each quarter and year. However, WGSAM considers that the determination of the actual proportion of the stocks present in the North Sea should be a priority area of study.

For a more precise estimate of the partial M2 from western mackerel, the previously used grouping of ages (two groups: age 1-2, and age 3+) was divided into six groups (age1 to age 5 and age 6+).

The numbers of seabirds, grey seals and harbour porpoises in the North Sea were assumed to have remained constant since the last data update in 2011 (WGSAM 2011). Their predation on southern and northern sandeel was determined assuming sandeel eaten by grey seals to be northern sandeel, seabird consumptions to be 50% of each of southern and northern sandeel and harbour porpoise consumption to be 66% northern sandeel. Distribution of grey seals and harbour porpoise (the latter from the scans surveys) were available from S. Smout, University of St. Andrews, and were used to estimate the proportion of individuals in the northern North Sea. WGSAM considers that more accurate distributions of seabirds should be derived before the next key run.

The time series used for external predators can be seen in Figure 4.1.1.

Three major changes occurred in the input data; sandeel division into two stocks, cod total catch revisions by WGNSSK and revisions of the time series of grey gurnard and starry ray abundance.

2. Division of sandeel into two stocks

In 2010, the sandeel assessment was changed from a single stock assessment covering the entire North Sea to analytical assessments of 3 sub-stocks with an additional 2 stocks remaining unassessed. WGSAM considered that sandeel in the multispecies model should also be divided into subpopulation to facilitate the delivery of relevant natural mortalities for sandeel in the different stocks. However, adding all stocks separately would most likely produce problems with limited data was available for

some of the stocks. Instead, it was decided to join sandeel assessment areas 1 and 2 into a southern assessment and sandeel assessment areas 3, 4, 5 and 7 into a northern assessment. Predation by fish predators were divided between the two stocks according to their distribution across roundfish areas. As the new assessment data commence in 1983, the catch, age composition and mean weight at age from earlier north/south separated assessments were used for the period 1974–1982.

The ICES (single species) sandeel analytical assessments are conducted using a special model which estimates fishing mortality as a function of fishing effort. This is conceptually equivalent to using commercial catch per unit effort per age as a survey series, and therefore the survey time series included were commercial CPUEs and dredge survey time series for sandeel assessment areas 1 and 2 for southern sandeel and areas 3 and 4 for northern sandeel (Figure 4.1.2).

Estimating mean weight in the stock is a special concern for sandeel, as weight of 1-year olds and older fish in the catch in the months from July onwards is likely to be biased towards lower mean weights due to differences in the onset of burying of large and small sandeel (Pedersen *et al.* 1999). Further, weight in the catch of 0-group is highly variable as the 0-group fishery only occurs in part of the time series and the exact timing of it varies. For these reasons, it was decided to use the mean weight of sandeel in the catch in the second quarter as mean weight in the sea of sandeel of ages 1+ in all quarters. The mean weight of 0-groups was estimated as the long term average weight of 0-group in the catch in quarter 3.

3. Cod catch data update

Since the last key run in 2011, WGNSSK revised the scaling factors used to estimate unallocated removals for cod. All values were decreased and the unallocated removals assumed to be absent from 2006 onwards. This decreased the cod removals in later years by around 25% with a similar decrease in estimated SSB (WGNSSK 2010, 2014). WGSAM uses the unallocated removals scaling factors when estimating total catches in each year, and hence catches were substantially reduced compared to the previous key run with a resulting decrease in SSB similar to the effect seen by WGNSSK (2010, 2014).

4. Change of stock area for Haddock

At a benchmark in 2014 it was decided to include area VIa to the stock distribution of haddock, such that it now comprises the North Sea, Skagerrak and area VIa. The inclusion of area VIa increases the estimated historical SSB by around 20% compared to the stock size in the North Sea and Skagerrak. WGSAM decided to use the catch data for the new stock definition in the key-run, ignoring the bias by increasing the stock distribution area. For other stocks, e.g. North Sea cod, the stock areas do also extend outside the key-run area, which is just the North Sea.

5. Updated time series of grey gurnard and starry ray

The time series of grey gurnard and starry rays are estimated from IBTS CPUE by length, scaling the CPUE index to an average biomass over the time series of 205 000 ton and 100 000 ton, for grey gurnard and starry ray, respectively. This time series was extended to 2013, but in doing so, an error in the distribution of biomass into age groups was discovered and corrected. This substantially increased the catch of size 20–30 cm grey gurnards and >30 cm starry rays while decreasing catch of other size groups (Figure 4.1.3 and 4.1.4). The groups considered that though the new data were

estimated in accordance with survey catches, the survey is likely to considerably underestimate the abundance of smaller individuals and hence the average biomass refers to only larger fish. As smaller fish do not eat fish prey, the effect in the model is a possible overestimation of consumption by these two predators if the average biomass estimates should include small individuals. WGSAM recommends that the method used to estimate grey gurnard and starry ray abundance is reviewed prior to the next key run to identify the reference period and sizes to which the average biomass estimates apply.

In addition to the existing stomach data for grey gurnards, new stomach data collected in the DGMARE stomach sampling tender were included (Figure 4.1.5). In the third quarter of 2013 similar prey was found as in 1991 but their contribution to the diet changed. Southern sandeel and Norway pout were eaten to a larger extent in both years. 0-group gadoids like whiting and cod were found also in 2013, but to a lesser extent than in 1991. Especially the relative stomach of 0-group cod decreased to below 0.1 % for larger grey gurnard. This can be explained by a much lower abundance of 0-group gadoids in the sea in 2013 compared to 1991. In addition, a lower number of stomachs was sampled in 2013 decreasing the probability to detect relatively seldom interactions. Northern sandeel was hardly found in the stomachs from 2013 but were eaten to a larger extent in 1991. In the first quarter only Norway pout and "Other Food" was found in 2013 while in 1991 especially whiting contributed to the diet of grey gurnard.

6. Adding hake as a predator

This year for the first time hake was implemented in SMS as "external predator". In recent years considerably more hake has been caught in the IBTS survey and also information from the fishing industry points in the same direction. Therefore, the quantification of predation by hake gives valuable information on the role of hake in the North Sea food web and its impact on the dynamic of commercially important fish stocks. Abundance per size class, diet information and consumption rates are also added to include an "external predator" in SMS.

6.1 Diet information

During 2013 hake stomachs were sampled inside the EU tender project "Study on stomach content of fish to support the assessment of good environmental status of marine food webs and the prediction of MSY after stock restoration" and from a French phD project funded by France Filière Pêche. Overall a reasonable number of stomachs from the northern North Sea could be collected (Figure 4.1.6 and 4.1.7). For some hake length classes only a small number could be sampled, but small hake (<250mm) only feeds on "Other Food" (see below) and the abundance of large hake is low in the first quarter (see under description of abundances).

Average relative stomach contents for the whole population were derived by applying the same calculation steps as used during the year of the stomach and described in ICES CRR 219 from 1997. First an average per hauls was calculated and afterwards an average per ICES rectangle. Finally, an average over the whole North Sea area was derived by estimating a weighted mean with CPUE of the predator as weighting factor. It was found that small hake only feeds on Other Food, while medium sized hake feeds on Norway pout and Other Food (Figure 4.1.8). Large hake (>=600mm) in addition feeds to a larger extent on herring. It has to be noted that Other Food also includes fish prey, i.e. blue whiting.

6.2 Abundance per size class

Based on the diet composition it was decided to have three size classes of hake in the model (<250mm; 250 - <600mm; >=600mm). There is no assessment for hake in the North Sea. There is only an assessment for northern hake. This assessment includes all sea areas from the northern Bay of Biscay up to the Norwegian Sea. Three different surveys (IBTS, SWC-IBTS, EVOHE; all from the second half of the year) were available for the years 1997- 2013 from Datras to calculate the proportion of the total Northern hake abundance and biomass resident in the North Sea in the second half of the year. When using CPUE per rectangle * number of rectangles in the survey area as index, it turned out that only 10- 15% of the hake stock in numbers can be found in the North Sea (Figure 4.1.9) while in biomass it is a much larger fraction of the stock (Figure 4.1.10). The reason is that especially large hake can be found in the North Sea in the second half of the year (Figure 4.1.11). For the years before 1997 it had to be assumed that the proportion of the northern hake stock in the North Sea stays constant at the average from the years 1997-2001, i.e. before CPUEs started to increase in the IBTS.

The overall biomass and abundance present in the North Sea was afterwards splitted into the size categories by using the size distribution observed in Q3 IBTS hake catches. From the biomass and abundances obtained for the second half of the year, the abundances in the first half of the year were calculated by multiplying the abundances in the second half of the year with the ratio of CPUEs per size class observed between the 1st quarter and 3rd quarter IBTS. While small and medium sized hake is present in both quarters, large hake is caught to a much lesser extent in the first quarter (Figure 4.1.12). The diet composition used in SMS is seen in figure 4.1.13.

6.3 Consumption rates

No information on consumption rates was available for hake in the North Sea. It was assumed that the consumption in percent body weight is the same as given for saithe at a similar weight. The values used were compared to consumption rates estimated for hake species in other sea areas (Table 4.1.1). The values used were inside the range of observed values apart from the smallest length class. This length class only feeds on "Other food" and has no impact on model results. However, literature values varied to a large extent. More work is needed to come up with consumption rates specifically for hake in the North Sea. A general revision of consumption rates for all predators is planned for the next keyrun.

Table 4.1.1. Consumption per year divided by body weight observed for hake in different sea areas and values used in the SMS keyrun.

Hake size class	Average Weight	Consumption per year/body weight based on SMS input for saithe	Consumption per year/body weight Bay of Biscay hake: Santiago Cervino (pers. communication)	Celtic sea hake. Du Buit,1996, Fisheries Research 28, pp. 384. Consumption per year/body weight. Consumption rates were calculated based on the equation given in the paper: $C_i = 0.082W^{0.79}$ (r2 = 0.98)	Punt and Leslie (1995), S. Aft: .l. mar. Sci. 16: 37-55. M. capensins age4+; consumption per year/body weight	Livinston (1983), Fishen' Bul/ .. Wash. 81(3): 629-636. Pacific hake of 50cm. Consumption per year/body weight
<= 250mm	0.0373	7.55	29.20	38.35		
250mm - <600mm	0.53	6.97	6.95	21.96		9.1
>= 600 mm	2.2	5.82	3.22	16.29	4.4	

7. Revision of start year of the model

In the previous key run, the model included the period back to 1963, though it was considered by WGSAM that the age composition and total catches of industrial species in the period 1963 to 1974 were highly uncertain. With the division of sandeel into a northern and southern stock, it was not possible to estimate the north and south catches of sandeel in any reliable way, and it was therefore decided only to include data from 1974 onwards, consistent with the health warning concerning the quality of catch data from beginning of the period given by WGSAM (2011).

8. Diet composition of harbour porpoise

A preliminary study of the effect of differences in digestion rate of different sizes of otoliths in harbour porpoise stomach content was presented to the group and demonstrated that the consumption of large fish such as cod and whiting may be considerably overestimated whereas that of small fish is severely underestimated. The group considered that this may potentially have a large impact on the estimated consumption of harbour porpoise and that the estimation of correction rates applicable to North Sea harbour porpoises should be a priority area of study before the next key run is conducted. However, as no quantitative correction factors were available to the group, no correction could be made in the current key run.

9. Model settings

The basic model settings, e.g. the uniform prey size selection for all predator species, were the same as used for the 2011 key run.

With updates and changes of catch data and CPUE time series the settings, e.g. age ranges for constant catchability and variance, were modified to better reflect the new data. The full set of model settings and input data can be found on the WGSAM webpage hosted by ICES.

Key run summary sheet

Area	North Sea
Model name	SMS
Type of model	Age-length structured statistical estimation model
Run year	2014
Predatory species	Assessed species: Cod, haddock, saithe, whiting Species with given input population size: North Sea mackerel, western mackerel, North Sea horse mackerel, western horse mackerel, grey gurnard, starry ray, hake, fulmar, gannet, great black backed gull, guillemot, herring gull, kittiwake, puffin, razorbill, grey seal, harbor porpoise
Prey species	Cod, haddock, herring, Norway pout, southern North Sea sandeel, northern North Sea sandeel, sprat, whiting
Time range	1974–2013. Model output for 1963–1973 is considered less reliable due to poor quality of catch data of mainly the forage fish before 1974.
Time step	Quarterly
Area structure	North Sea

Stomach data	Fish species: 1981, 1985, 1986, 1987, 1991, 2005, 2013 Grey seals: 1985, 2002 Harbour porpoise: Decadal 1985, 1995, 2005
Purpose of key run	Making historic data on natural mortality available and multispecies dynamic
Model changes since last key run	Sandeel split into northern and southern stocks, hake added as a predator, new data on sprat included, cod catch updated, all time series updated
Output available at	Morten Vinther have added all input and output data to the WGSAM web-page (and also to the WGSAM Share-Point site)
Further details in	Report of the Working Group on Multispecies Assessment Methods 2014

10. Results

The population dynamics of all species except 'external predators' were estimated within the model. The key-run converged and the uncertainties of parameters and key output variables were obtained from the inverse Hessian matrix. A summary of results is provided in Figure 4.1.13.

The input and output from the model are available online as ASCII file downloads from WGSAM web-page.

11. Comparison with the 2011 key run

Estimated stock sizes and fishing mortalities in the 2014 key run are pretty similar to the single species trajectories for most of the species (Figure 4.1.14). The changes introduced since the last key run (lower historical cod catches, higher biomass of medium-large grey gurnards and large starry rays, inclusion of hake, revision of mackerel assessment, revision of the haddock stock definition and the division of sandeel into two stocks) resulted in lower cod biomass and hence predation by cod, higher predation by grey gurnards and starry ray, increasing predation by hake and some questionable results in the last part of the period for the two sandeel stocks and sprat.

11.1 Comparison of 2011 and 2014 key run natural mortality at age

Lower cod biomass occurred as a result of the revision of historical catches to a lower level of unallocated mortality and as a result, the main prey of cod were predicted to have a lower natural mortality (Figure 4.1.15). In some species, this effect was counteracted by the increased estimated biomass of grey gurnards, starry ray and, in the later years, hake. However, these predators did not have a substantial effect on the natural mortality of large (3+) herring and 1-group whiting, and hence the estimated natural mortality of these were substantially reduced as a result of the lower cod biomass following the lower historic cod catches. For the two sandeel stocks, the most recent high increase in SSB in 2011 and recruitment in southern sandeel in 2013 is not supported by single species assessments which show substantially lower increases. For sprat, there appears to be a couple of recent years where mackerel did not exert a significant mortality on this species.

WGSAM discussed these feature of the results in detail and concluded that:

- The new time series is seen as more accurate than the previous time series as the change in historic catches by WGNSSK is based on the best available knowledge

- The increased cod biomass in the last two years is uncertain and hence smoothing the values at least in the last years of the period is recommended

- WGSAM does not recommend updating existing data series of natural mortality by simply adding the latest three new years. The time series as a whole shows patterns which are not retained by this procedure. For example, herring shows an increased natural mortality over the past decade, but adding only the latest three years will give the impression that natural mortality has decreased over the last five years.

- The recent high SSB and recruitment of sandeel should be considered highly uncertain.

11.2 Predation mortality by source (M2)

The overall picture of M2 at age (Figure 4.1.17) is highly variable between species. For cod and whiting the steep increase in abundance of the predator grey gurnard has led to increase in M2 of 0-group fish in recent years. Further, mortality of 3-year old cod has increased substantially as a result of the recent increase in grey seal abundance. Haddock natural mortality particularly of age 2 fish has decreased over time with the decreased in the biomass of large cod. The same trend is seen for 2+herring, but here the effect is counteracted in later years as the biomass of large hake has increased. Similarly, the decrease in herring natural mortality induced by cod is counteracted by an increase in grey gurnard predation.

The two sandeel stocks show markedly different patterns in the main predators, with cod, mackerel, whiting, saithe, seabirds and in later years grey seals all exerting a significant impact on northern sandeel whereas grey gurnards, mackerel, whiting and seabirds are the main predators on southern sandeel. Natural mortality of southern sandeel seems to have increased over the period whereas that of northern sandeel and has fluctuated without a clear trend. Natural mortality of Norway pout increased in the late 1990s whereas the mortality of sprat has decreased more or less monotonically since the mid-1980s.

12. Identified areas of priority research

WGSAM considers that the following topics should be priority areas of study prior to the next North Sea key run:

- estimating the proportion of hake, mackerel and horse mackerel stocks present in the North Sea and their distribution in northern and southern areas;

- review and if necessary revise the daily rations of the fish predators in the model;

- estimating distributions of seabirds in southern and northern North Sea;

- reviewing the method used to estimate grey gurnard and starry ray abundance to identify the reference period and sizes to which the average biomass estimates apply;

- estimating correction rates applicable to derive North Sea harbour porpoises diet composition from stomach content composition;

- investigate the most appropriate species and size selection of different predators;

- update the number of grey seals and harbour porpoise with the most recent information;

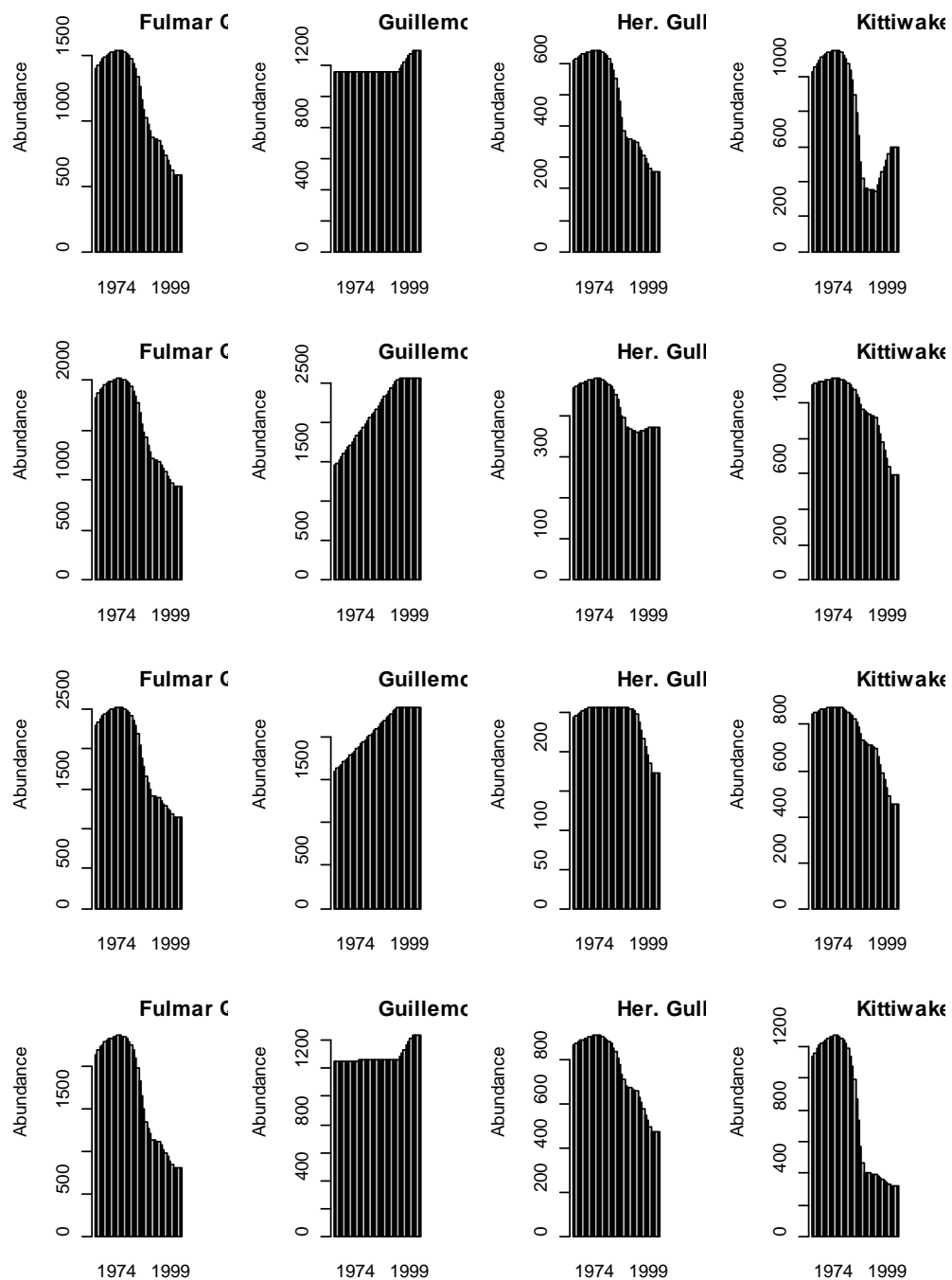- establishing quarterly catch histories for the all species.

Figure 4.1.1. Estimates as used by SMS of the abundance of "external predators" present in the North Sea presented by year and quarter. (Abundance of birds and marine mammals are given as numbers (1000), and as population biomass (1000 t) for fish species.
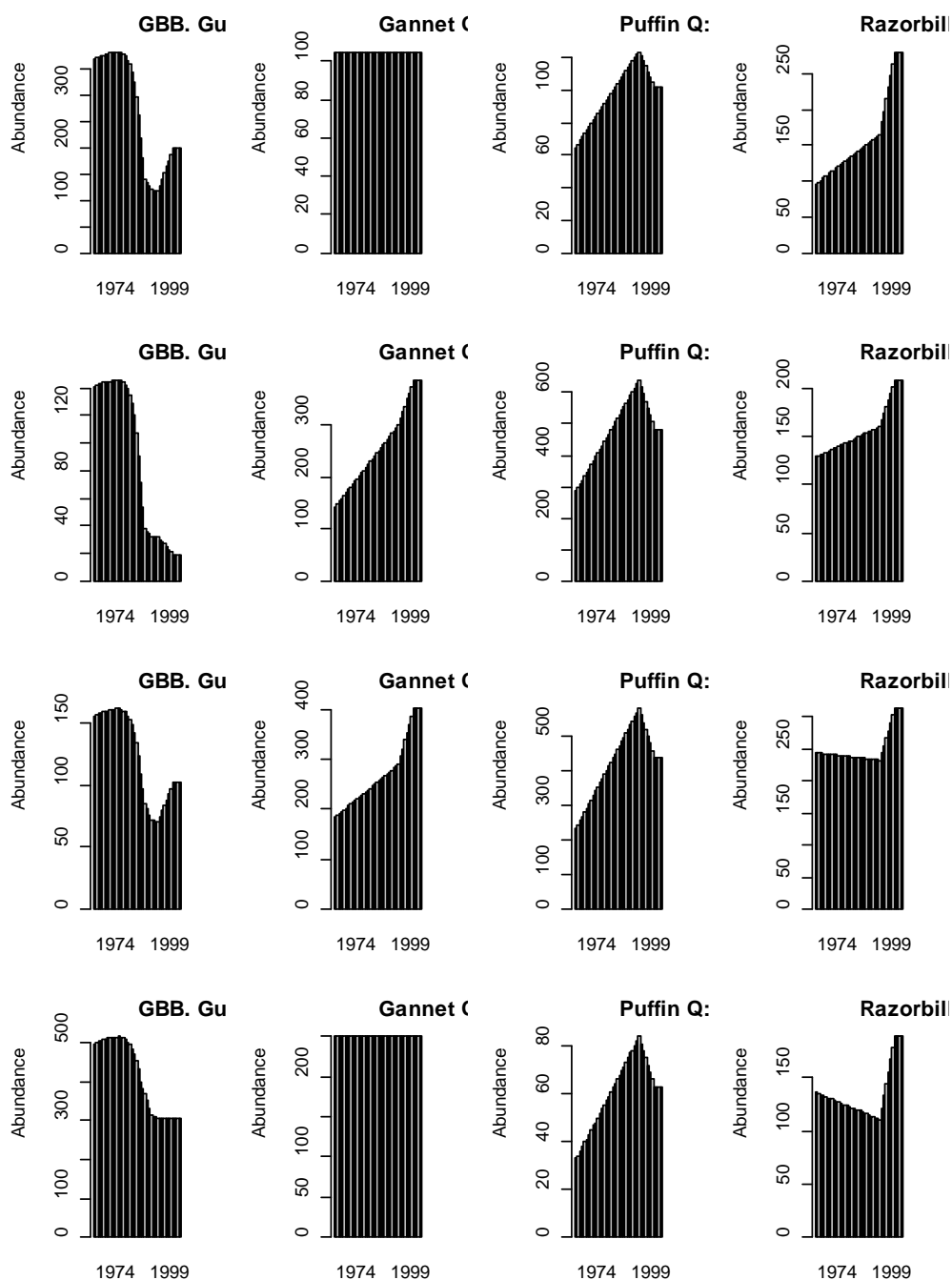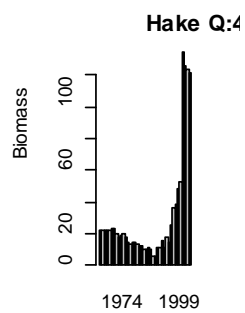
Figure 4.1.1. (Continued) Estimates as used by SMS of the abundance of "external predators" present in the North Sea. (Abundance of birds and marine mammals are given as numbers (1000), and as population biomass (1000 t) for fish species.
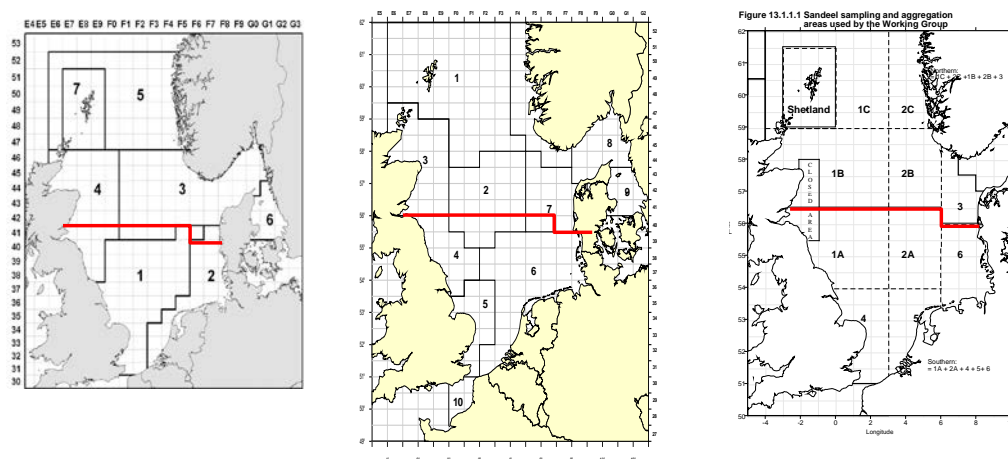
Figure 4.1.1. (Continued) Estimates as used by SMS of the abundance of "external predators" present in the North Sea. (Abundance of birds and marine mammals are given as numbers (1000), and as population biomass (1000 t) for fish species.

Figure 4.1.1. (Continued) Estimates as used by SMS of the abundance of "external predators" present in the North Sea. (Abundance of birds and marine mammals are given as numbers (1000), and as population biomass (1000 t) for fish species.

Figure 4.1.1. (Continued) Estimates as used by SMS of the abundance of "external predators" present in the North Sea. (Abundance of birds and marine mammals are given as numbers (1000), and as population biomass (1000 t) for fish species.

Figure 4.1.2. Northern and southern sandeel areas in relation to current assessment areas (left), roundfish areas (middle) and historical industrial sampling areas (right).

Figure 4.1.3. Old (blue) and new (purple) time series of numbers of grey gurnard by size group. Age 1: <10 cm, Age 2: 10-20 cm, Age 3: 20-30 cm, Age 4: >30 cm.

Figure 4.1.4. Old (blue) and new (purple) time series of numbers of starry ray by size group. Age 1: <20 cm, Age 2: 20-30 cm, Age 3: >30 cm.

Figure 4.1.5. Stomach content composition in new (2013) and existing (1991) grey gurnard stomachs.

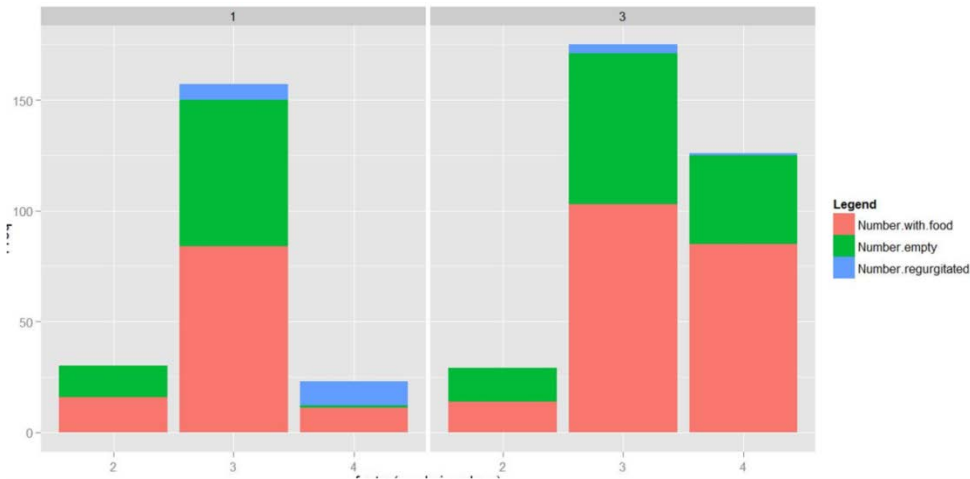**Figure 4.1.6. Samples of full stomachs in the 1st (left) and 3rd (right) quarter.**

Figure 4.1.7. Number of stomachs sampled per hake size class (2= <250mm; 3= 250mm - <600mm; 4= >=600 mm) and quarter.
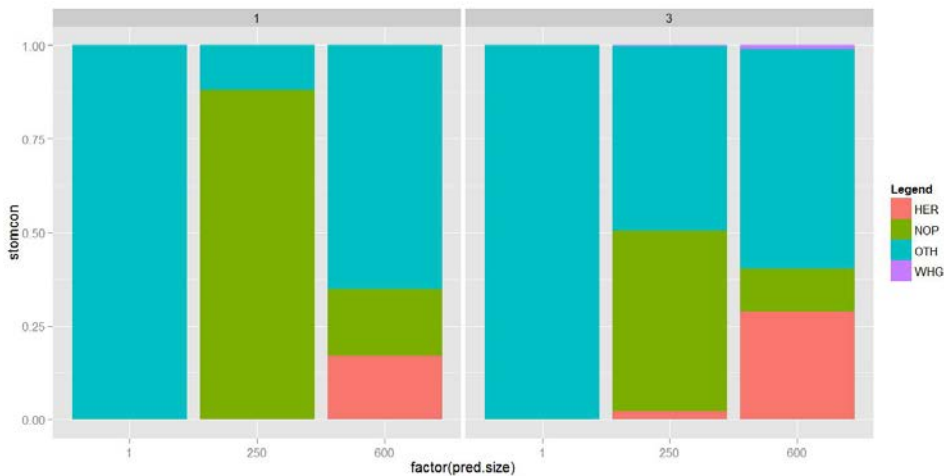

Figure 4.1.8. Relative stomach contents of hake per size class and quarter.
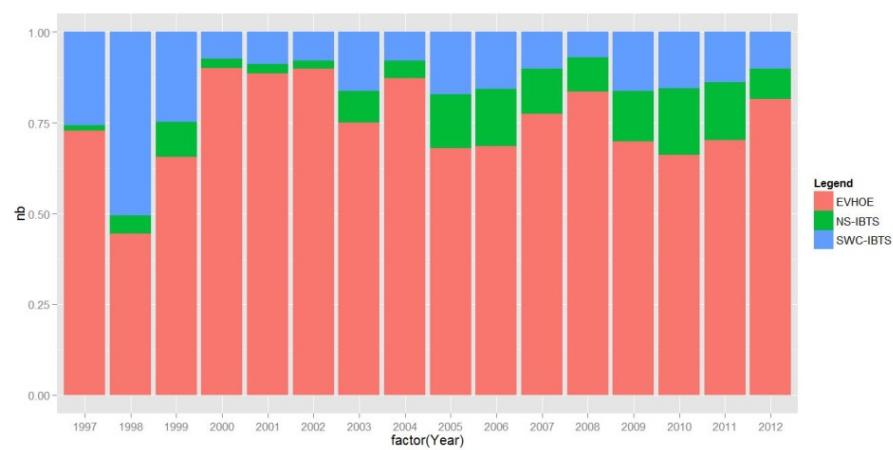
Figure 4.1.9. Proportion of hake caught in each of the three surveys in numbers.
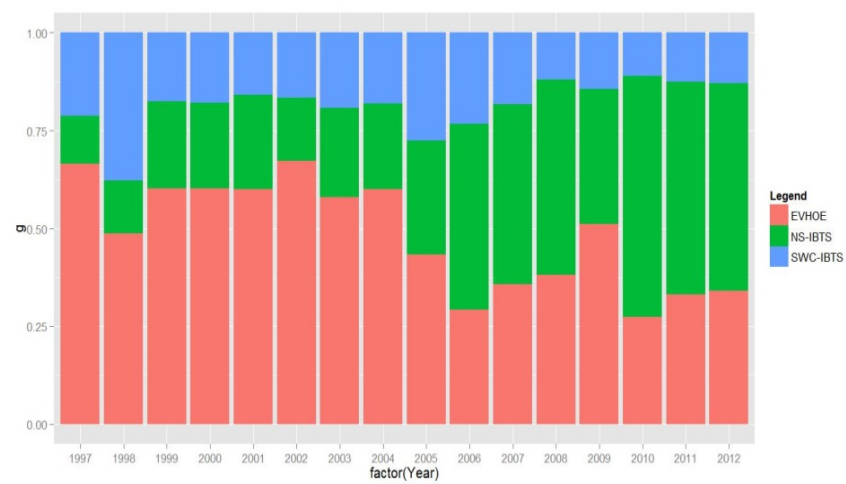

Figure 4.1.10. Proportion of hake caught in each of the three surveys in biomass
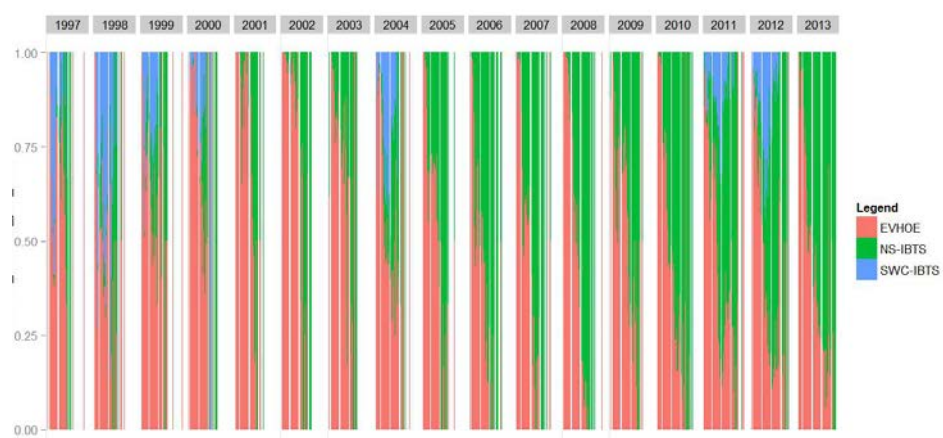

Figure 4.1.11. Proportion of numbers caught in each of the three surveys as function of size.
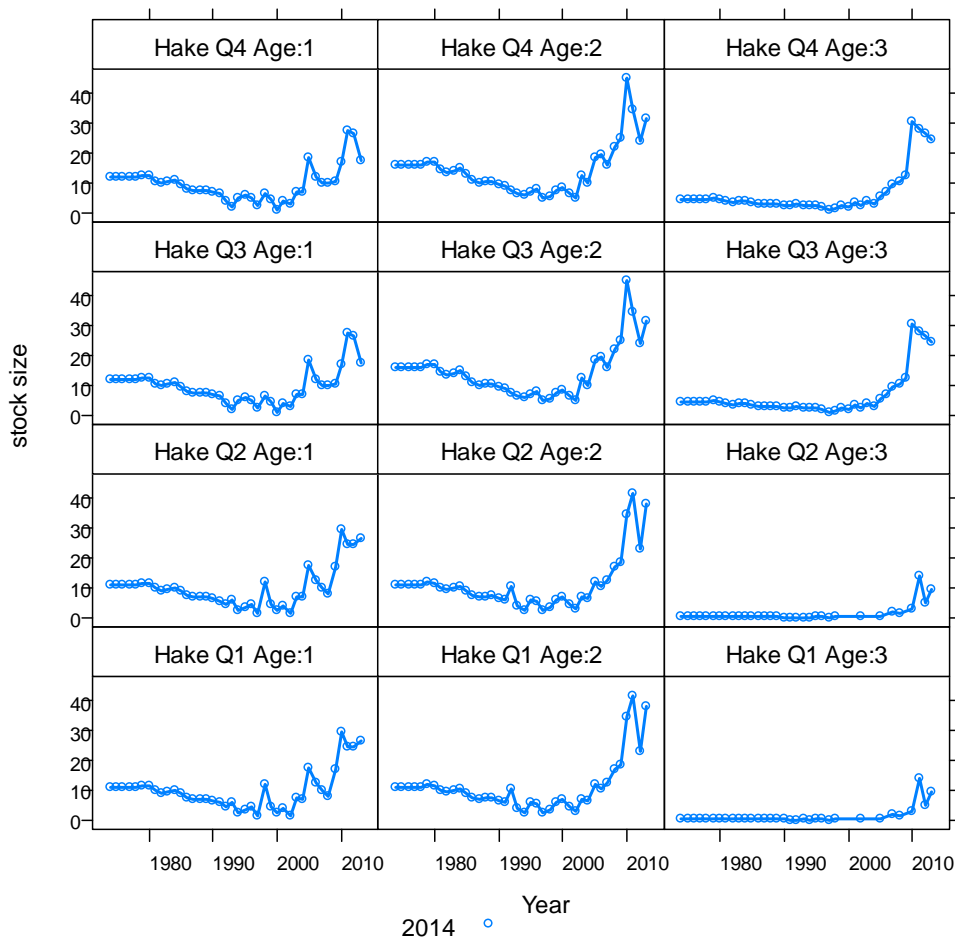
Figure 4.1.12. Time series of numbers of hake by size group. Age 1: <25 cm, Age 2: 25-60 cm, Age 3: >60 cm.
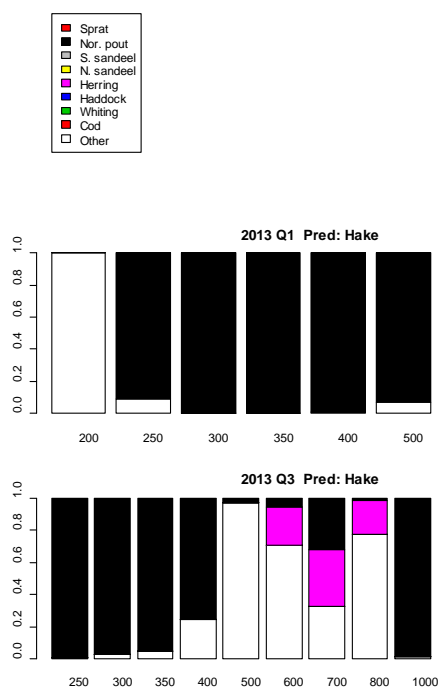

Figure 4.1.13. Stomach content composition in new (2013) hake stomachs.
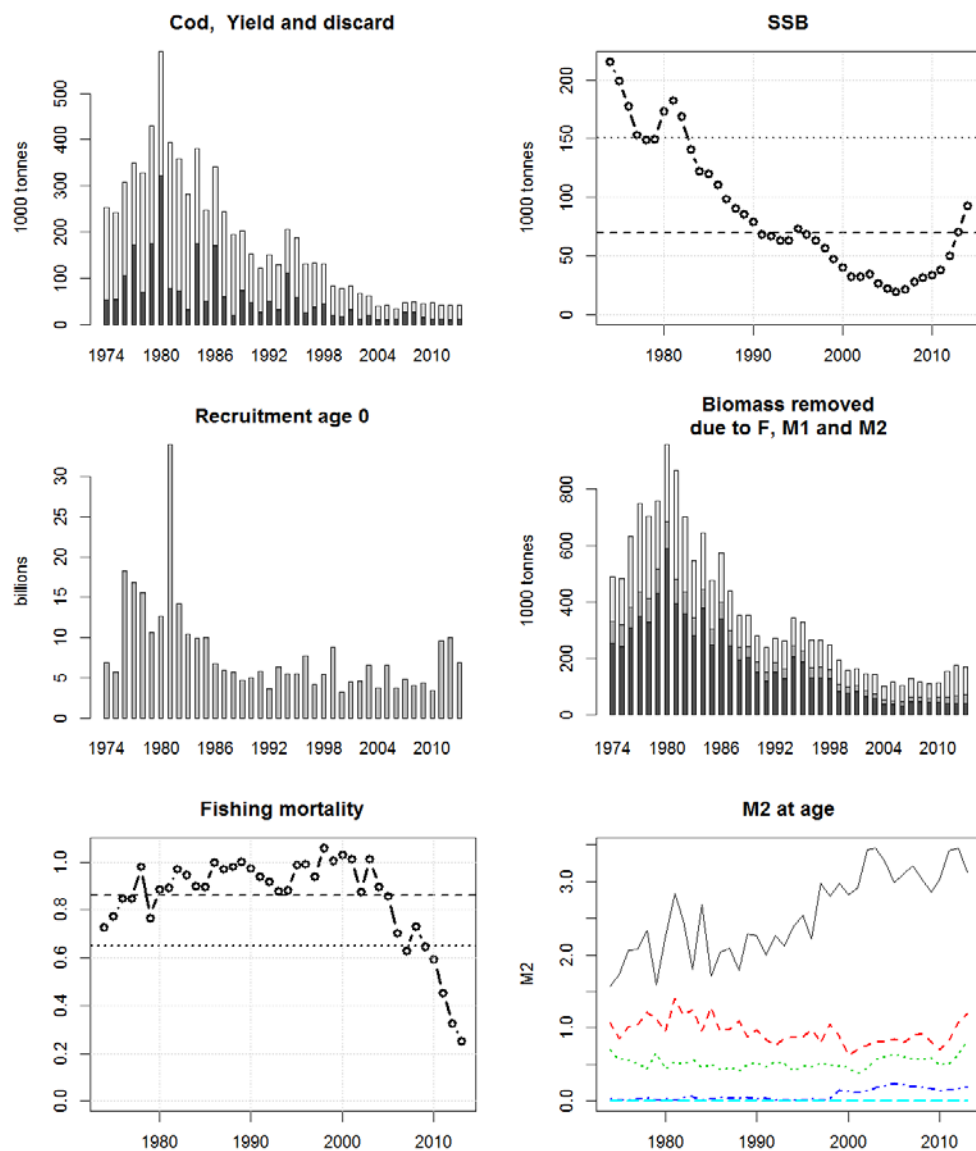
Figure 4.1.14. SMS output for cod. Catch weight divided into yield (landings) and discards, Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.
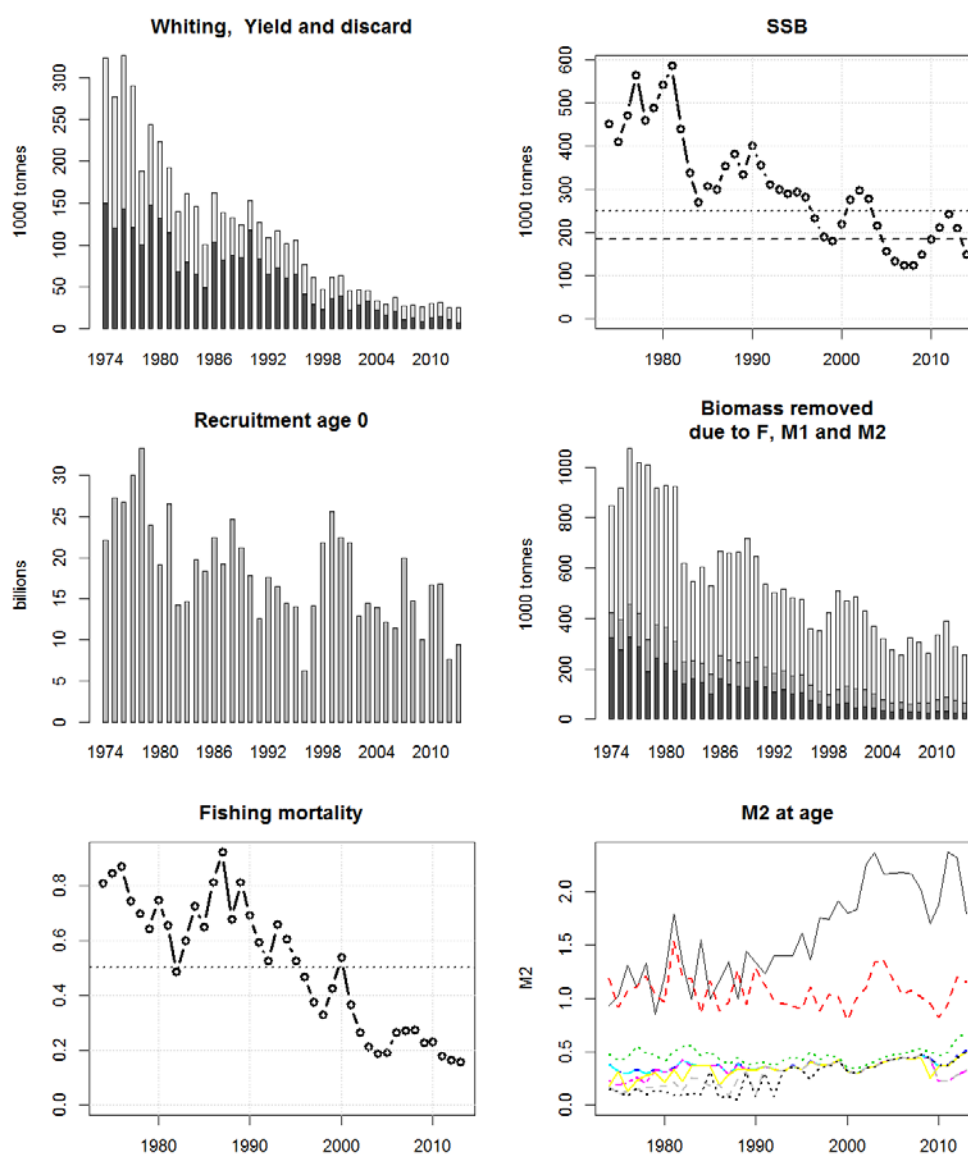
Figure 4.1.14 cont. SMS output for whiting. Catch weight divided into yield (landings) and discards, Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.
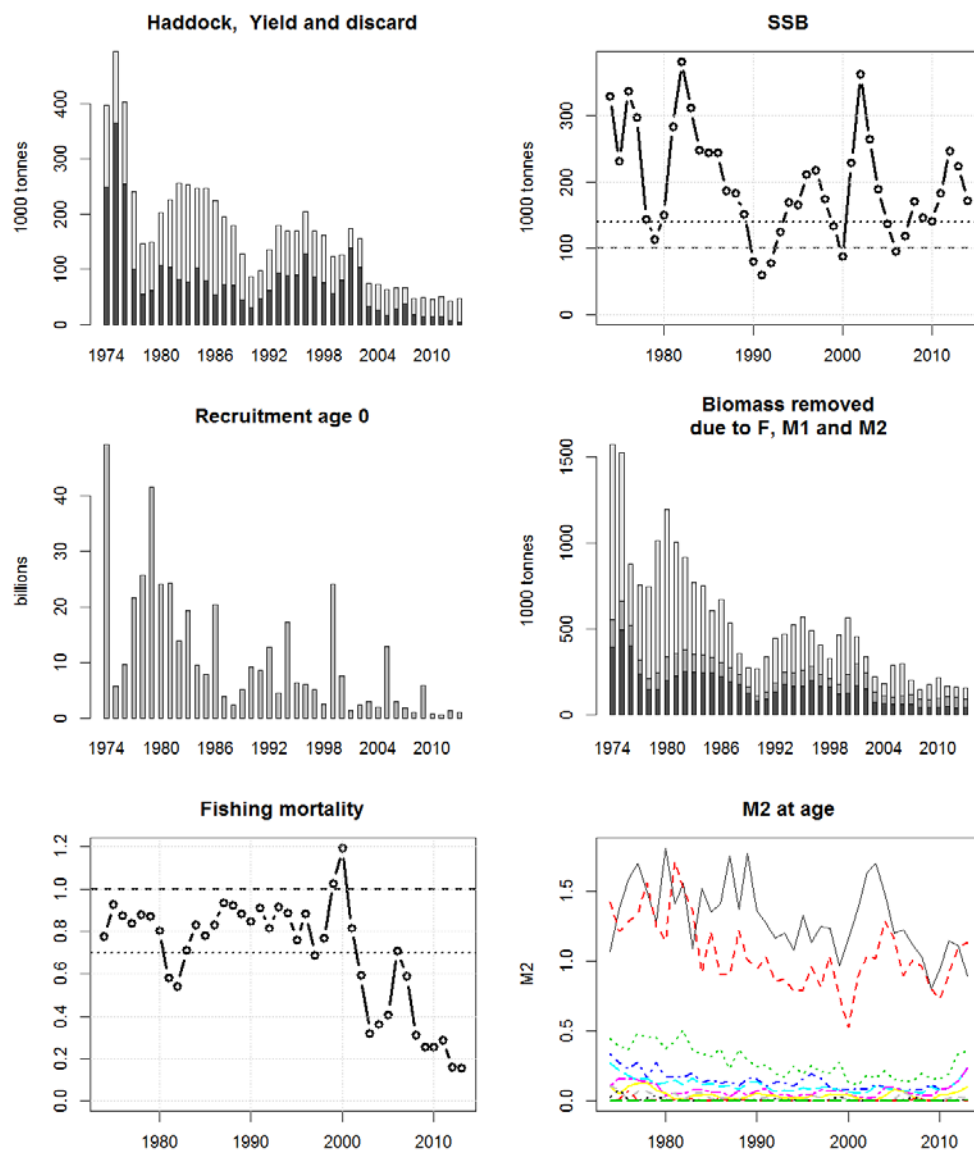
Figure 4.1.14 cont. SMS output for haddock. Catch weight divided into yield (landings) and discards, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.

Figure 4.1.14 cont. Catch weight (landings), Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.

Figure 4.1.14 cont. SMS output for herring. Catch weight (landings), Recruitment, F, SSB, Bio-mass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.

Figure 4.1.14 cont. SMS output for northern sandeel. Catch weight (landings), Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.
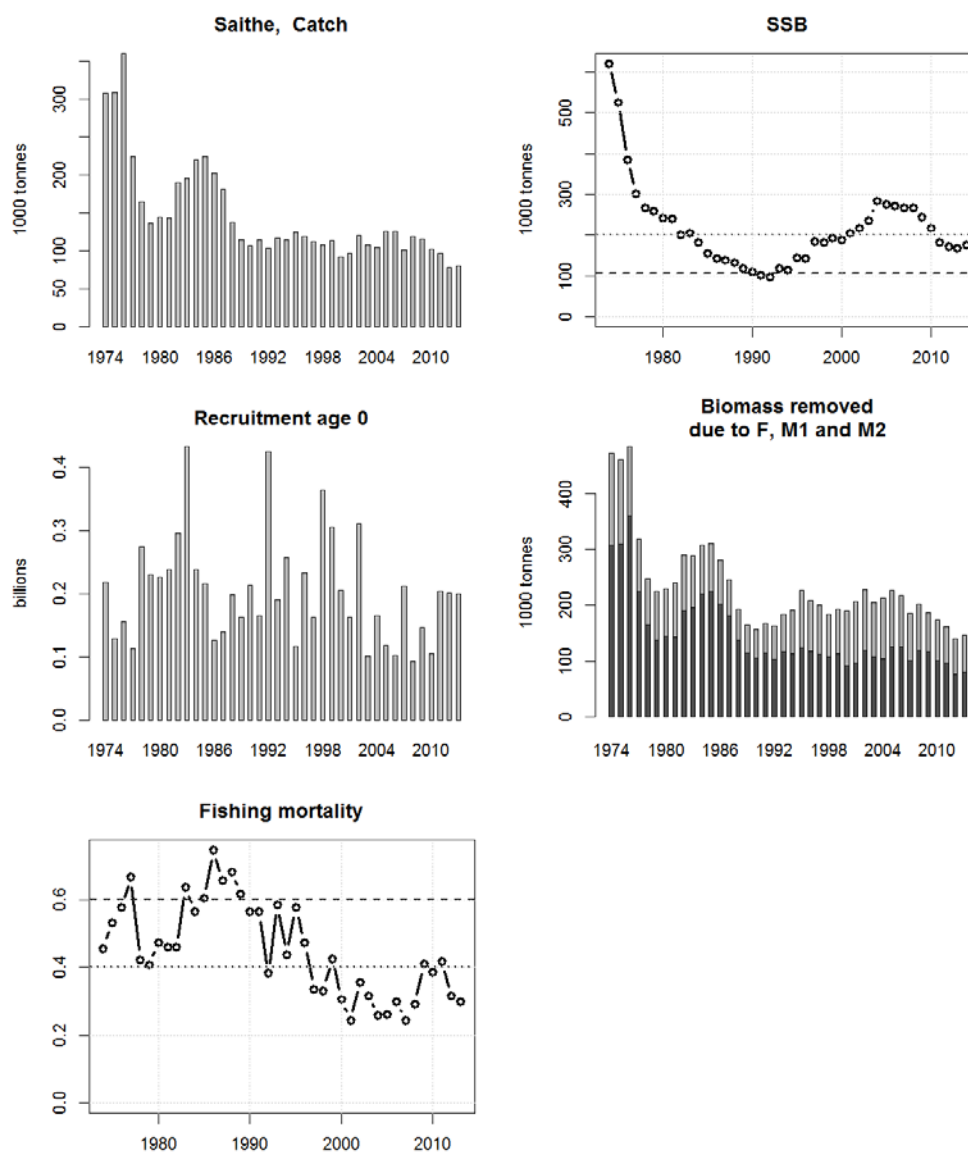
Figure 4.1.14 cont. SMS output for southern sandeel. Catch weight (landings), Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.
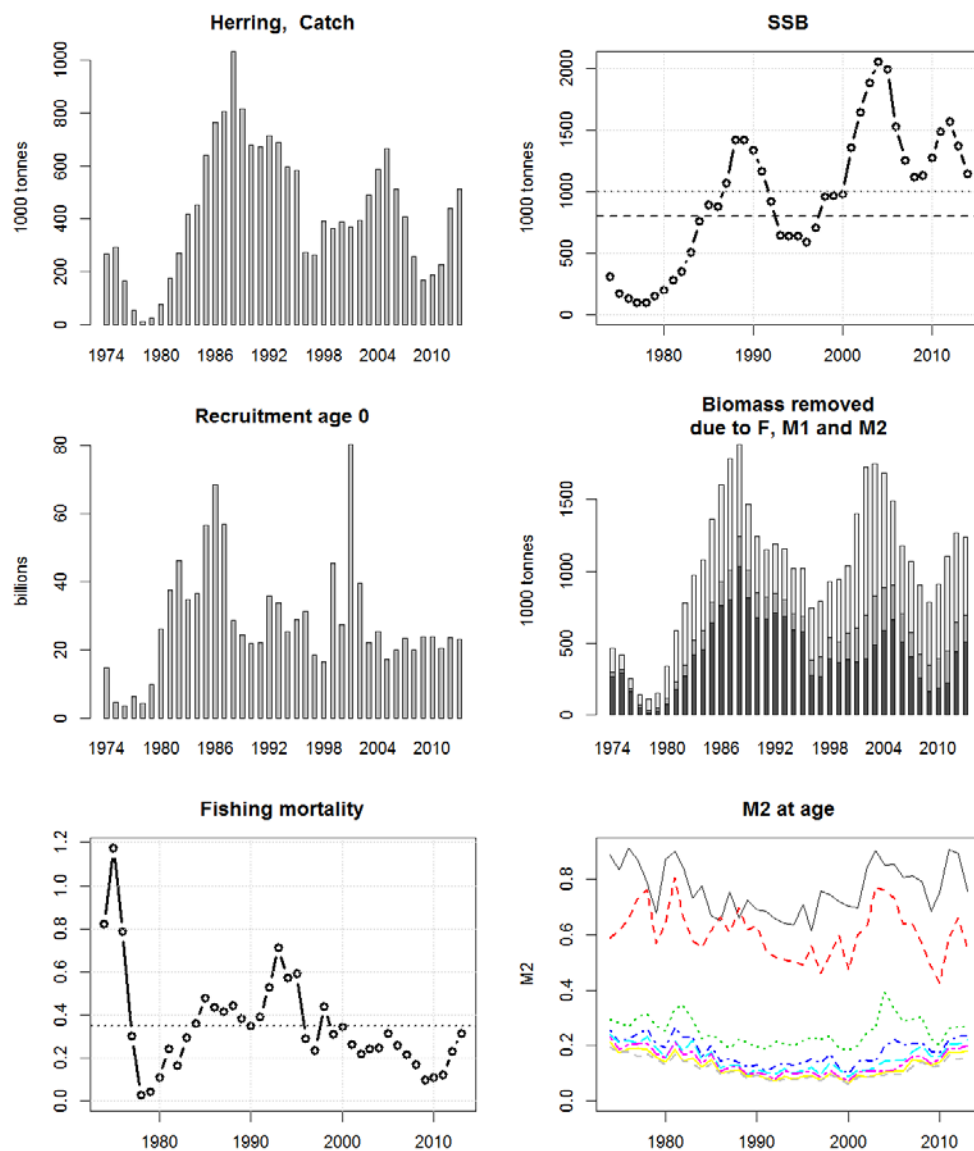
Figure 4.1.14 cont. SMS output for Norway pout. Catch weight yield, Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.
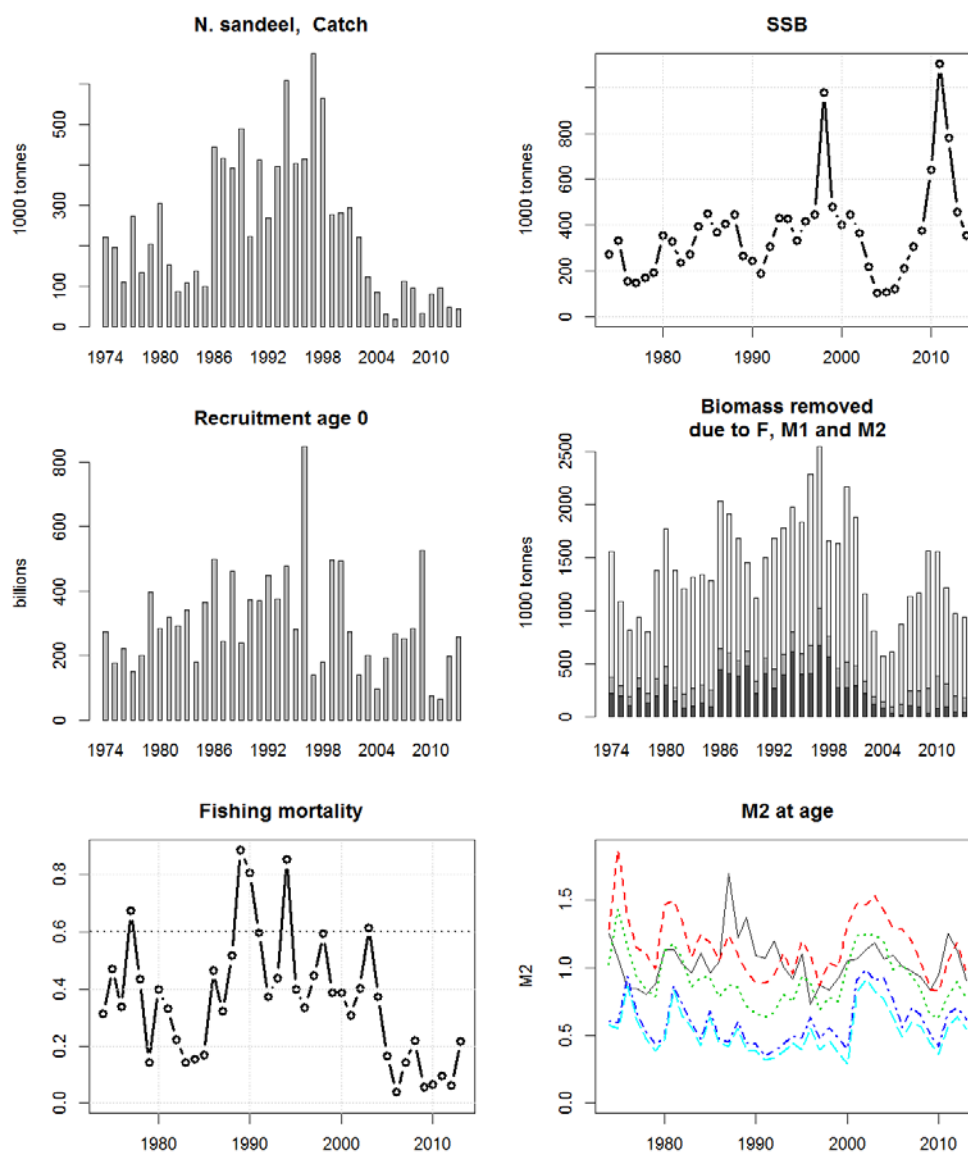
Figure 4.1.14 cont. SMS output for sprat. Catch weight (landings), Recruitment, F, SSB, Biomass removed due to fishery (F), predation by SMS species (M2) and residual natural mortality (M1). The predation mortality (M2) presented by the 0-group (black solid line) is for the second half of the year. The M2 for the rest of the ages are annual values.
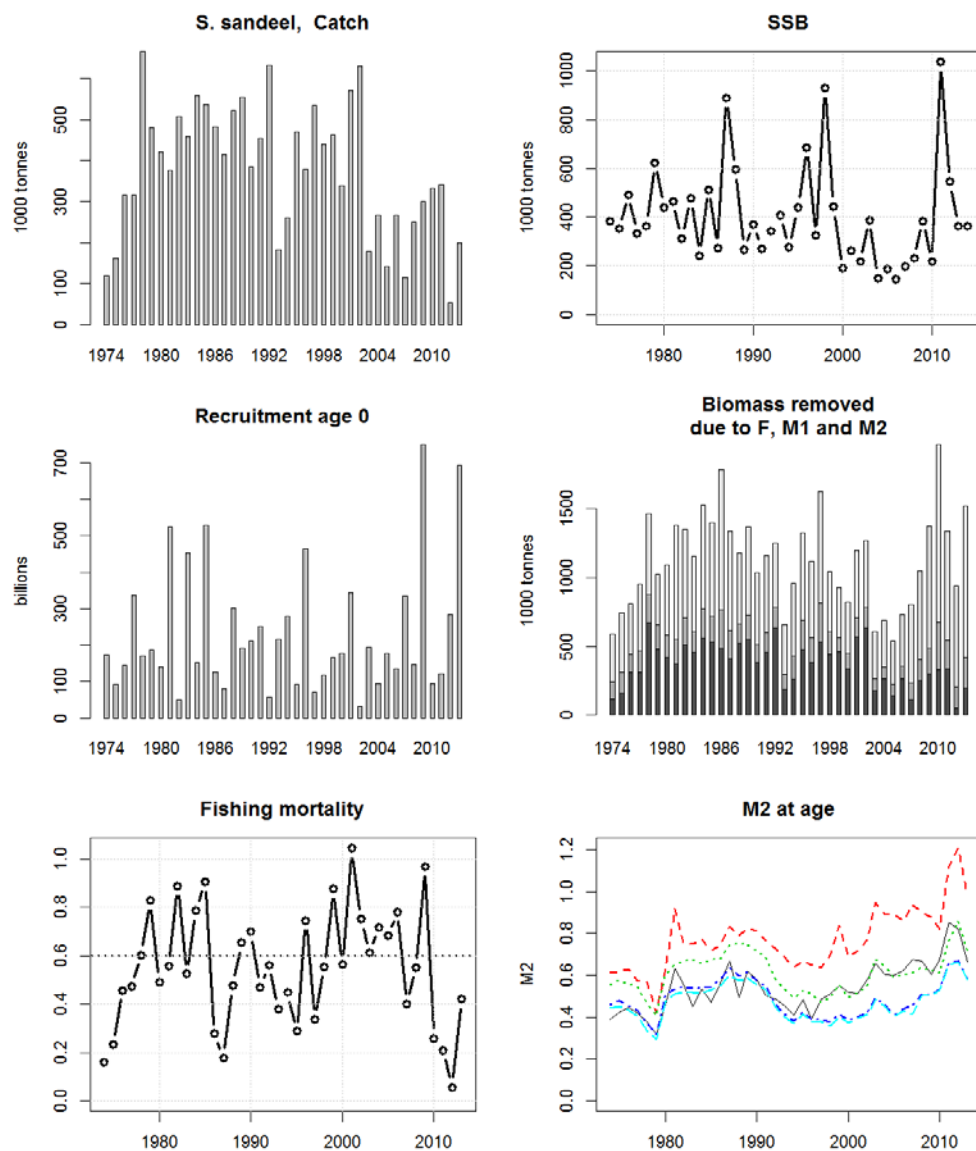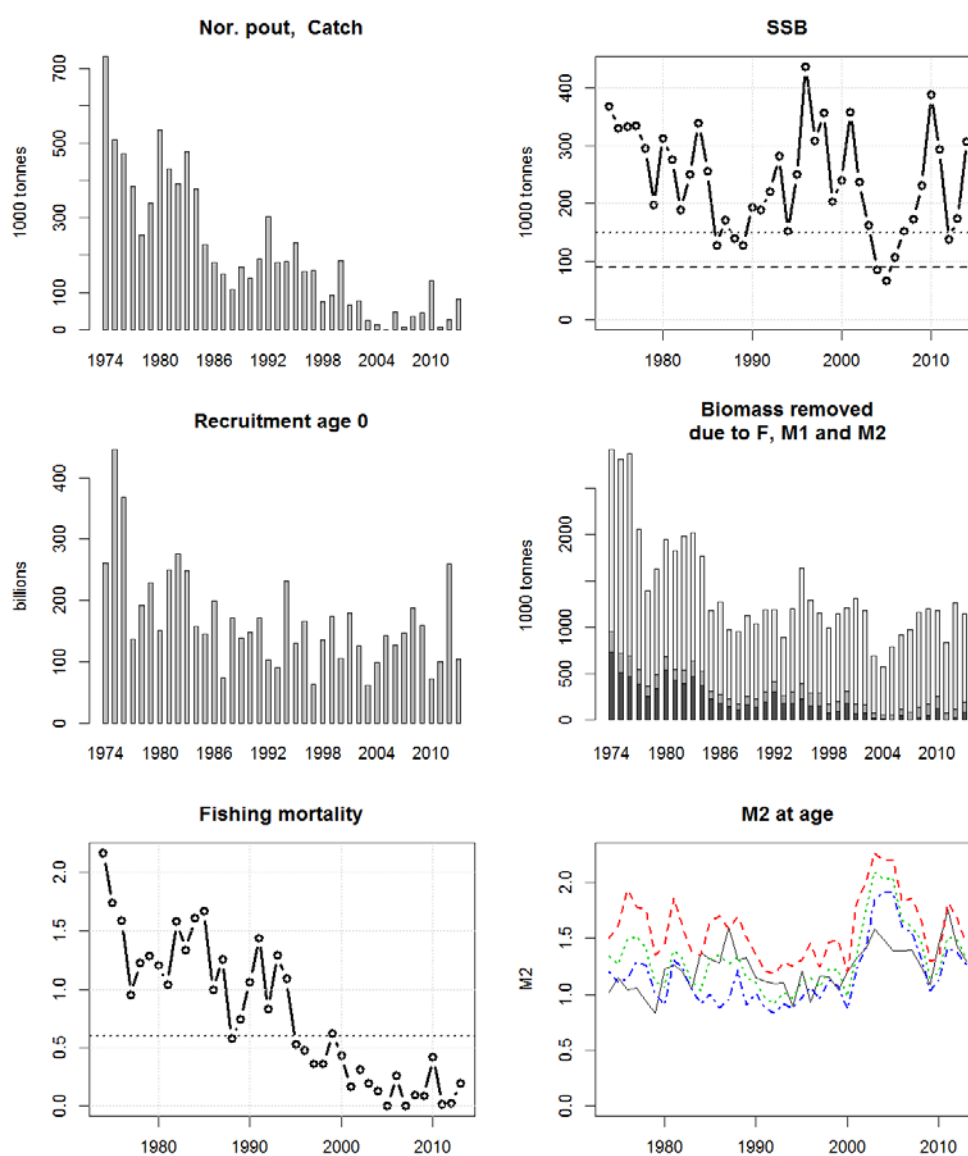
Figure 4.1.15. Comparison of estimates of predation mortality (M2) of cod from the 2011 and 2014 key runs.

Figure 4.1.15 cont. Comparison of estimates of predation mortality (M2) of whiting from the 2011 and 2014 key runs.

Figure 4.1.15 cont. Comparison of estimates of predation mortality (M2) of haddock from the 2011 and 2014 key runs.

Figure 4.1.15 cont. Comparison of estimates of predation mortality (M2) of herring from the 2011 and 2014 key runs.

Figure 4.1.15 cont. Comparison of estimates of predation mortality (M2) of Norway pout from the 2011 and 2014 key runs.

Figure 4.1.15 cont. Comparison of estimates of predation mortality (M2) of sprat from the 2011 and 2014 key runs.

Figure 4.1.16. Joint estimated sandeel SSB (northern plus southern)(left panel) and recruitment (right panel) from 2014 key run (purple) and 2011 key run with one stock (blue).

Figure 4.1.17. Predation mortality (M2) by prey species and age inflicted by predator species.

Figure 4.1.17. cont. Predation mortality (M2) by prey species and age inflicted by predator species.

Figure 4.1.17. cont. Predation mortality (M2) by prey species and age inflicted by predator species.

Figure 4.1.17. cont. Predation mortality (M2) by prey species and age inflicted by predator species.

Annex 6. Report from Joint WGSAM and WGMIXFISH workshop

Joint WGSAM-WGMIXFISH workshop

Thursday 23 October 2014

INTRODUCTION

ICES WGSAM and WGMIXFISH held a joint workshop in London on 23 October 2014. The aim was to further understanding of the links between the two groups work and identify future priorities which support development of ICES advice on multi-species and mixed fishery issues. The day was structured as a series of topical questions, with presentations from a number of participants, with discussion to solidify understanding of the major challenges.

OBJECTIVES AND QUESTIONS

The following broad objectives and associated questions were used to promote discussion at the workshop:

1. Identify the linkages between multi-species and mixed fisheries issues and describe what strategic (i.e. goal setting) or tactical advice is required from multi-species and mixed fishery model applications.

2. Identify where outputs of the multi-species or mixed fishery models could inform one another, or where benefits can be gained from coupling models or developing more holistic models dealing with both issues simultaneously.

    Questions:
    - Is it necessary, desirable, and possible to deal with multi-species and mixed fishery issues separately or together?
    - Over what time horizons do multi-species and mixed fishery issues manefest and what are the implications for fisheries management of any overlap?
    - Do the models need to be integrated, or can the mixed fisheries models use multi-species outputs?
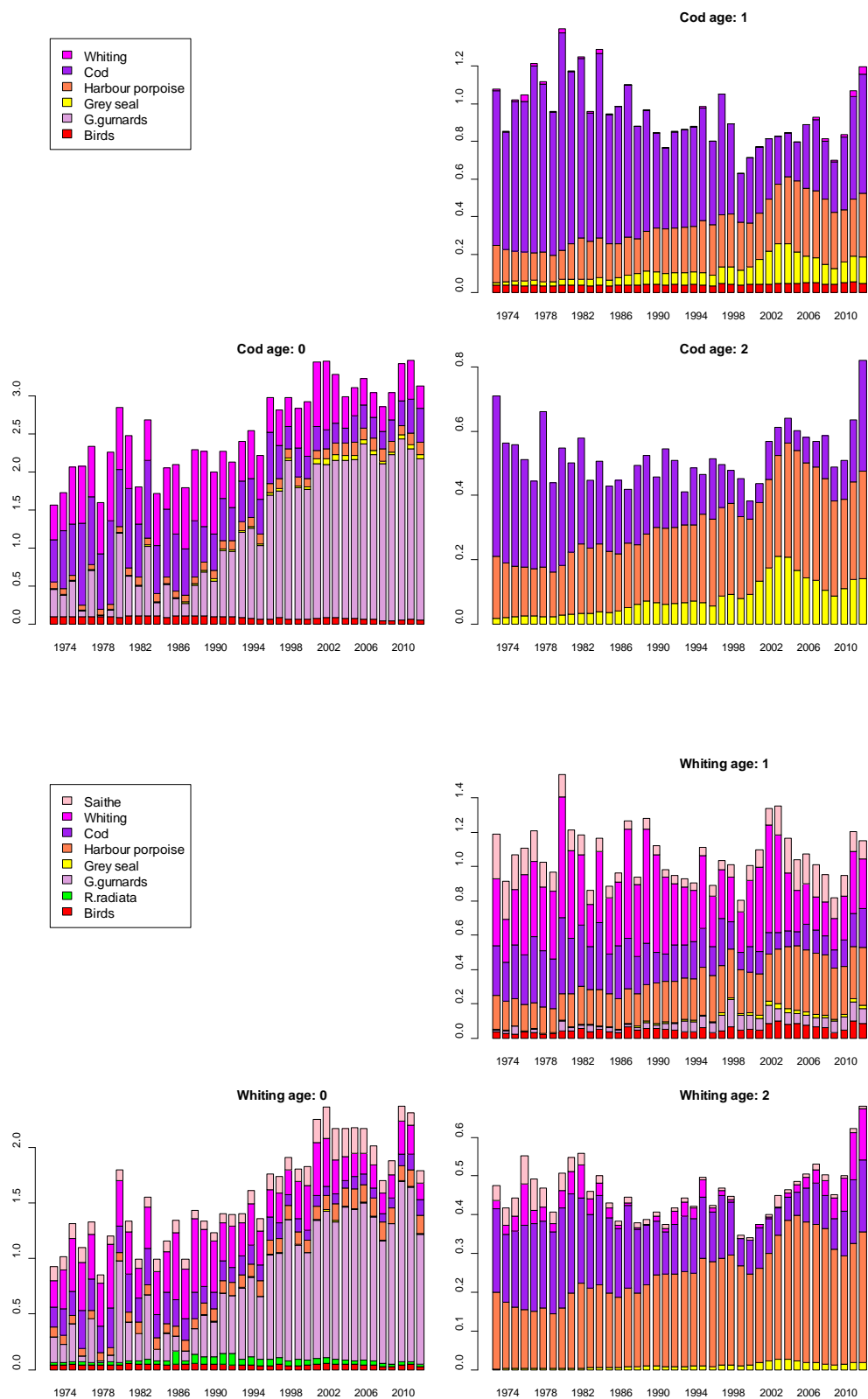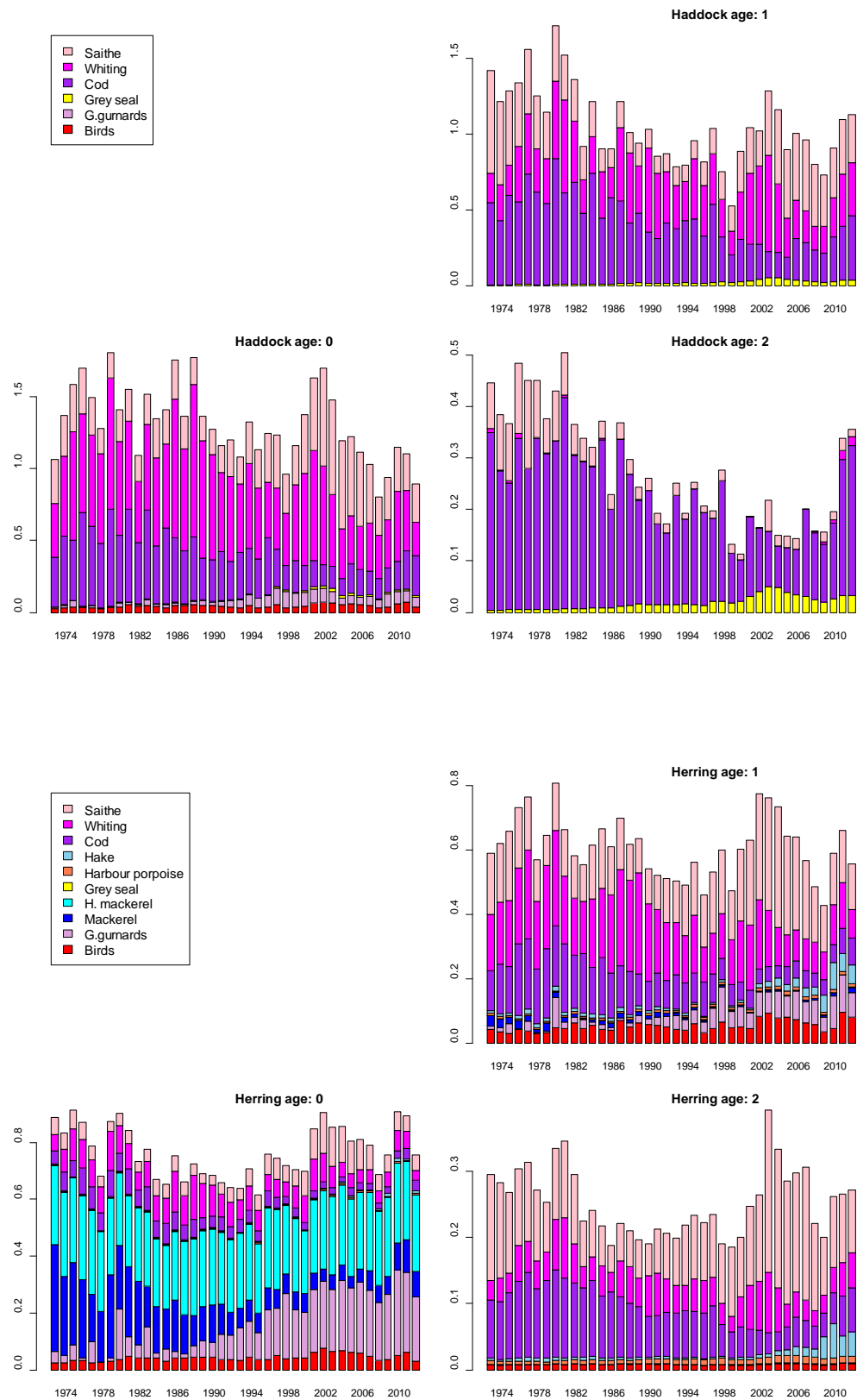   - Are multi-species models considered reliable enough to be setting fishing mortality target based on their outputs?
    - Can multi-species modelling be used to define ranges and limits on species fishing mortality associated with an MSY policy, which can be used in mixed fisheries models?
    - Where multiple fishing fleets are represented in multi-species models, how much fleet complexity is sufficient to capture the dynamics of fleets relevant to provide useful analysis of the impacts of mixed fisheries?
    - How can mixed fisheries models best predict changes in fleet behaviour? E.g. it is not known how the fishing fleet behaviour will changes in respond to the discard ban. How can models be developed to help predict possible changes?
    - Can the impact of choke species be evaluated using multi-species and mixed fishery models?

Several presentations were given pertaining to previous and current modelling work that simultaneously account for multi-species and multi-fleet mixed fishery interactions, and thus might be useful in addressing management requirements where the issues are tightly connected. These were used to promote discussion around the objectives (See Agenda in Appendix 1).

DEFINITIONS

Mixed fisheries 'issues' - Mixed fisheries issues covers two aspects, which occur simultaneously:

(a) where a single fleet exploits multiple stocks in the same fishing operations and thus has a direct effect on exploitation of the different stocks fished (i.e. multi-stock)

(b) where multiple fleets exploit a stock and indirectly have an effect on each other's potential yield (e.g. poor selectivity of cod in a *Nephrops* directed fishery impacts on the directed cod fishery yield; multi-fleet).

Mixed fisheries models (MF) – models where the consequences of multiple fleets exploiting multiple stocks concurrently are accounted for by explicitly modelling the link between the activity of the fleets in different métiers and thier exploitation of different stocks. Two basic concepts about the 'structure' of fishing activities are of primary importance when considering mixed-fisheries issues, the fleet (or fleet segment), and the métier:

- *A Fleet segment* is a group of vessels with the same length class and predominant fishing gear during the year. Vessels may have different fishing activities during the reference period, but might be classified in only one fleet segment.

- *A Métier* is a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern.

The FCube model currently used by ICES to provide mixed fisheries advice classifies the North Sea demersal fisheries into 37 fleets each fishing in up to 4 métiers (97 fleet*métier combinations).

Multi-species models – models where the interaction between species is accounted for through the estimation of the predation mortality of predators on their prey, and perhaps prey-dependent growth of the predators. Multi-species models focus on a limited number of species, principally those of commercial interest. Most multi-species models also represent multiple distinct fishing fleets and can thus consider mixed fishery interactions, though possibly in a more simplified form than dedicated mixed fisheries models. The SMS model currently used by ICES does not explicitly model different fishing fleets, but could if developed. Gadget models do explicitly model multiple fleets, but in a rather simplified manner compared to mixed fisheries models.

Ecosystem models – like multi-species models they represent the interactions among predators and prey, but include many more biological components from the ecosystem. Many ecosystem models represent multiple distinct fishing fleets and can thus consider mixed fishery interactions (E.g. Ecopath with Ecosim, Atlantis, various size spectra models). Some do not, but could.

PRINCIPAL OUTCOMES

1. WGMIXFISH to undertake a principle component analysis (PCA) on the métier data used by the group, to see how many aggregated fleets resulted and to show how the variance in catch composition changes with different levels of fleet aggregation.

2. WGSAM and WGMIXFISH participants agreed there was value in continued effort to integrate thinking in order to be able to provide consistent advice in the future. Each group extended an open invitation to one another for future meetings, and it was felt that a further joint session would be helpful, although this is unlikely to occur in 2015 due to the groups' prior commitments.

DISCUSSION ON ISSUES ARISING

1. Given CFP commitment (Article 9) tackling mixed fisheries management and tacking account of multi-species interactions, what types of models are needed to provide integrated advice to inform management?

The higher complexity, uncertainties and demands on modellers mean that MS models are not generally Multi-speciesable to replace single species stock assessments for giving TAC advice.

With this context in mind, two uses emerge for MS models. One use of multi-species and ecosystem models at present is as tools for assessing the impacts of single species advice on the wider ecosystem through an evaluation of the robustness and precautionary (risks) of management options in relation to possible ecosystem consequences. Such an evaluation would represent appropriate steps to adopting an ecosystem approach to advice, consistent with requirements in Article 2.3 of the CFP. In addition, MS models can give input into single species assessments on predator induced variable mortality (N. Sea, Baltic), or be used directly to give stock assessments (Barents Sea capelin). In none of these existing cases are mixed fisheries issues well integrated into the multi-species models.

ICES currently provide one-year-ahead scenario-based mixed fisheries management advice, integrating a fleet and fishery forecast model (FCube) with single stock assessment and forecasting methodology to advise on potential over- and under- exploitation of stocks against their single stock objectives, given mixed fisheries interactions. WGMIXFISH have been developing medium-term Management Strategy Evaluation (MSE) routines which can support evaluation of longer term objectives given mixed fisheries interactions, as required under the CFP. Other frameworks for bio-economic modelling (e.g. FISHRENT, FLBEIA – see Prellezo *et al.* 2012 for review), which have been developed to provide such advice are also available. However, they do not meet all the requirements for long-term management plan evaluation and generally no account is taken of multi-species interactions, except in

that they take single stock assessment inputs that may be informed by multi-species evaluations (i.e. historic M2 values for stocks in the North Sea from SMS). Generally, no account is taken of the ecosystem level system responses.

At present, MS and MF advice is given separately but one reason for bringing them together as integrated advice would be to avoid the situation where managers 'cherry pick' between two sets of advice. Furthermore, either class of models may indicate possible fisheries solutions which appear desirable when mixed fisheries or multi-species considerations are taken in to account, but which are not desirable when both mixed fisheries and multi-species issues are considered at the same time.

2. At which timescales are multi-species and mixed fisheries models most appropriate for giving advice?

Multi-species and fishery interactions occur at the same time and thus are both relevant to understanding how ecological and fishery interactions affect management. However, the timescales of the processes modelled becomes important in relation to their use in advice. The Fcube mixed fishery model presently used by ICES is a tactical management tool and most applicable at a 2 year time horizon, because of the underlying model assumption that fleet behaviour and species interactions in future years is the same as the present.

Multi-species and ecosystem models represent ecological processes that change over longer time scales, where it takes time to observe how changes in predator populations affect changes in their prey. Thus, one application is for longer term (5+ years) strategic evaluations of management options. In this context, ecosystem models give a wider perspective than MS ones, though at the cost of higher uncertainty. It is also possible to use MS models in short term assessment work, either through direct multi-species modelling (such as in the capelin fisheries off Norway), or by using the MS to give inputs into single species assessments (as in the SMS inputs to North Sea and Baltic assessments).

Models that represent both mixed fishery and multi-species interactions simultaneously are most relevant for strategic evaluation of management options over a medium timeframe. An important improvements in this area is working toward the integration of fleet dynamics models which can forecast changes in fleet effort allocation between métiers (e.g. dynamic state variable models, random utility models or markov models), because the assumptions of constant fleet behaviour become less appropriate over time. This is something that remains a challenge due to the complexity and scale at which fishers decisions take place.

In relation to what the overlap between multi-species and mixed fisheries modelling means for the integration of MF and MS advice in ICES, two logical suggestions arose: (i) it would make sense that in the same way that multi-species and ecosystem models can be used to evaluate the possible longer term consequences of advice on single species management targets, they could also be used to evaluate the consequences of technical interactions on these objectives, (ii) Integration of species interactions (or long term targets taking account of species interactions) in MF models might allow for further understanding of the "allowable management area" or "management space" which can help inform whether the current exploitation patterns arising from the multi-fleet multi-stock fisheries are consistent with management objectives in the medium-long term.

Such interactions could be in the form of an integrated model, perhaps by improving the current simplified multi-fleet implementations in MS models such as SMS and Gadget. Alternatively, the results of MS models, showing which combinations of fishing pressures give reasonable outcomes for the different species could be used as inputs for the MF models. The MF models would then have to constrain their results to the feasible regions defined by the MS models. Either approach would help to integrate the two classes of models and ensure that results were not presented which were only viable under one set of considerations.

3. *Can modelling be used to define optimum biomass and yields for all species?*

Participants discussed whether mixed fisheries, multi-species and ecosystem models could be used to define the optimum yield achievable across all species, and whether management measures that sacrificed achieving biomass targets for a choke species would be considered as a management option. Feedback from stakeholder consultations in the 'Myfish' project showed little support for tradeoffs that pointed to sacrifices by one species for the sake of maximising species aggregate yield, and no support for a closure of any fleets. What had been requested was for all species to be kept either in a 'safe area' (all species above species specific threshold biomass reference points) or in a 'MSY area' (all species fished near their species specific Fmsy) (e.g. Hilborn 2010).

Using models to explore the 'safe or msy areas' requires' consideration of how the biomass and yield of one species changes both in relation to the biomass of natural predators and fishery 'predators'. When different fisheries are considered, there is no one optimum because it becomes a matter of choice about how the yield is shared among fisheries and such choices are inherently political. The utility of models here is in illuminating what different levels of biomass and yield might be expected under different levels of fishing intensity by each fleet. This provides an assessment or analysis of possible trade-offs of policy options rather than pointing to some optimum. Optimisation can be undertaken where objective functions are clearly defined, such as maximum overall value of the fisheries portfolio, maximum economic yield or to prioritise some other objective such as biodiversity. However, because such objectives are rarely, if ever specified, optimisations for defined goals are mainly used in research to explore what possible options might be with little consideration of policy framework. Here we are more concerned about being able to provide useful scientific evidence to support the development of options within the policy framework.

4. What level of fleet aggregation is appropriate in multi-species models that include separate fishing fleets?

Currently, MS models include the capability to handle multiple fleet components, and for each fleet component to fish on multiple stocks. However this ability is, and is likely to remain, limited when compared to dedicated MF models. It would therefore be of great utility to investigate how much detail is required to adequately capture the dynamics of the fisheries of any given ecosystem.

The degree of aggregation needed depends on the questions being addressed. Participants considered that at present the best way to cope with uncertainty in fleet aggregation level desired was to provide the data at the most disaggregated level that is sensible based on the sampling frame at which biological information has been collected, allowing users to aggregate to the level desired. It was agreed that there

would be merit in having a defined process for moving from the most disaggregated level of data whose fidelity is preserved, to fleets aggregated at a level appropriate to address the questions of interest. Thus models could be tailored as necessary.

As an action arising, it was agreed that in the first instance, it would be useful to show how the variance in catch composition changes with different levels of fleet aggregation (ACTION to MIXFISH). This would at least provide an initial guide and promote better understanding about the utility of different levels of fleet aggregation. There are some simple rules of thumb that we know make sense and can help in avoiding inappropriate representation in models. For example, where two national fleets may have fishing effort using the same gear classification, (which might suggest the effort can be aggregated) but because of differences in location of fishing and fishing opportunities they can still have a very different species composition in the catch. The real world example cited was TR1 gear (which is in itself a broad aggregation of mesh sizes) used by Scotland to target haddock, cod and whiting and the Netherlands (plaice). Such choices are inevitably a compromise between the level of aggregation required to characterise activity and that which can accurately be done so by the data in a meaningful way.

Another useful suggestion was that MS models could also be run with different levels of fleet aggregation to test sensitivity of results to the level of fleet aggregation. Some of this work has begun already.

5. What factors determine Fmsy predictions (and their reliability) from multi-species models?

The fishing mortality that produces Maximum Sustainable Yield (F_{msy}) is determined based on assumptions about the biological productivity of species and the selection from the fisheries. Therefore different levels of fishing effort by different fleets in different métiers would change the population level selection pattern for the stock, requiring reconsideration of the appropriate Fmsy estimate. Such considerations would potentially be dynamic, and require simultaneously estimating the optimum Fmsy given multi-species interactions and changes to fleet effort. Integrated multi-species mixed fishery models could be used to explore such issues.

It should also be borne in mind that many of the considerations that lead to the desired outcome of near MSY fisheries for commercial stocks and safe biological status for non-commercial stocks are not directly to the amount of fishing pressure exerted (represented in models as fishing mortality. Rather, factors such as spatial and temporal closures, gear regulation and so on may be of critical importance in attaining these goals. Such factors are currently not well represented in any of the existing population/system level models (MS or MF).

CONCLUSIONS AND SUGGESTIONS

1. In the transition to multi-species and ecosystem advice, appropriately tested models are available to use in assessing the impact of single species advice in relation to consequences for commercial species, non-target species and fishing fleets, thus providing a risk assessment of the advice.
2. Where fishing fleets are explicitly represented in multi-species and ecosystem models, they could be used to assess the impact of mixed fishery advice, thus providing a risk assessment of management options.

3. Those using multi-species and ecosystem models need advice on the appropriate level of fleet aggregation to use.
4. Further integration of multi-species interactions into mixed fisheries models could be either through informing appropriate long-term exploitation targets or coupling of multi-species models with the existing mixed fishery framework.

References

Prellezo, R., Accadia, P., Andersen, J. L., Andersen, B. S., Buisman, E., Little, A. & Röckmann, C. (2012). A review of EU bio-economic models for fisheries: The value of a diversity of models. *Marine Policy, 36*(2), 423-431.

Hilborn, R. (2010). Pretty good yield and exploited fishes. Marine Policy, 34(1), 193-196.

Appendix 1. AGENDA

Overview and introduction to multi-species (WGSAM) and mixed fishery (WGMIXFISH) working groups	Steve Mackinson (Chair – WGSAM), Paul Dolder (Chair - WGMIXFISH)

Objective 1: Identify the linkages between multi-species and mixed fisheries issues and describe what strategic (i.e. goal setting) or tactical advice is required from multi-species and mixed fishery model applications.

Presentations

The problem of inclusion of multi-species biological relations into a multi-fleet system model (2 species - 2 different standard fleets)	Tatiana Bulgako-va, VNIRO Mos-cow, Russia
Re-structuring the mixed-fisheries management scheme to harmonize mixed-fisheries and ecological considerations	Axel Rossberg
Response surfaces for cheaply approximating the steady state response of age based Multi-species Models. Based on MAREFRAME work	John Pope

Objective 2: Describe what strategic (i.e. goal setting) or tactical advice is required using such models and whether it is necessary, desirable or possible to deal with multi-species and mixed fishery issues separately or together.
- *Do the models need to be integrated, or can the mixed fisheries models use multi-species outputs?*
- *Are the multi-species considered reliable enough to be setting fishing mortality target based on their outputs?*

Objective 3: Identify where outputs of the multi-species or mixed fishery models could inform one another, or where benefits can be gained from coupling models or developing more holistic models dealing with both issues simultaneously.
- *Can multi-species modelling be used to define ranges and limits on species fishing mortality associated with an MSY policy, which can be used in mixed fisheries models?*
- *Where multiple fishing fleets are represented in multi-species models, how much fleet complexity is sufficient to capture the dynamics of fleets relevant to provide useful analysis of the impacts of mixed fisheries?*

- *How to mixed fisheries models best handle planned and unplanned changes in fleet behaviour? E.g. it is not known how the fishing fleet behaviour will changes in respond to the discard ban. How can models be developed to help predict possible changes?*

Presentations

Including technical interactions in ecosystem models. Examples from Alaskan ecosim-type models as well as the beginnings of a length based multi-species model for Georges Bank.	Sarah Gachias, Woods Hole, USA (dial in)
Discuss simulations of idealised and historic "benthic", "demersal", and "pelagic fleets" and its link to MSFD. Seeking advice from WGMXFISH on the appropriate fishing selectivity and mortality to use to best characterise the fleets now and in the future if gear is "improved".	Robert Thorpe
Multi-species, risk-based evaluation of management policies: Tools for evaluating management strategies in an uncertain world	Steven Mackinson
Fleets and métiers – data, potentials and limitations	Clara Ulrich
How to display and communicate the outcomes and options of multi-species ?	Anna Rindorf
Summary of issues and points for discussion	Daniel Howell

Appendix 2. PARTICIPANT LIST

Name	Affiliation	email	Role
Tatiana Bulgakova	VNIRO, Russia	tbulgakova@vniro.ru	WGMIXFISH
Harriet Cole	Marine Scotland Science, UK	Harriet.Cole@scotland.gsi.gov.uk	WGMIXFISH
Sarah Davie	Marine Institute, Ireland	sarah.davie@marine.ie	WGMIXFISH
Paul Dolder	Cefas, UK	Paul.dolder@cefas.co.uk	WGMIXFISH (Chair)
Emma Hatfield	European Commission, Belgium	emma.hatfield@ec.europa.eu	Observer
Steven Holmes	JRC, Italy	steven.holmes@jrc.ec.europa.eu	WGMIXFISH
Mathieu Lundy	AFBNI, UK	mathieu.lundy@afbini.gov.uk	WGMIXFISH
Lionel Pawlowski	IFREMER, France	Lionel.Pawlowski@ifremer.fr	WGMIXFISH
Jan Jaap Poos	IMARES, Netherlands	Janjaap.Poos@wur.nl	WGMIXFISH
Marianne Robert	IFREMER, France	Marianne.Robert@ifremer.fr	WGMIXFISH
Clara Ulrich	DTU Aqua, Denmark	clu@aqua.dtu.dk	WGMIXFISH
Youen Vermard	IFREMER, France	youen.vermard@ifremer.fr	WGMIXFISH
Steve Mackinson	Cefas, UK	steve.mackinson@cefas.co.uk	WGSAM (co-chair)
Daniel Howell	Institute of Marine Research, Norway	danielh@imr.no	WGSAM (co-chair)
Alexander Kempf	Thuenen Institute of Sea Fisheries, Germany	alexander.kempf@ti.bund.de	WGSAM
Anna Rindorf	DTU-Aqua, Denmark	ar@aqua.dtu.dk	WGSAM
Andrea Belgrano	Swedish Institute for the Marine Environment, Sweden	andrea.belgrano@slu.se	WGSAM
Robert Thorpe	Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK	robert.thorpe@cefas.co.uk	WGSAM
Eider Andonegi	AZTI-Tecnalia, Spain	eandonegi@azti.es	WGSAM
Axel Rossberg	Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK	axel.rossberg@cefas.co.uk	WGSAM
Stefan Neuenfelt	DTU-Aqua, Denmark	stn@aqua.dtu.dk	WGSAM
Morten Vinther	DTU-Aqua, Denmark	mv@aqua.dtu.dk	WGSAM
Valerio	Swedish Institute for the	valerio.bartolino@slu.se	WGSAM

Bartolino	Marine Environment, Denmark		
John Pope	NRC (Europe) Ltd, UK	popejg@aol.com	WGSAM
Alfonso Perez Rodriguez	Institute of Marine Research, Denmark	perezra@imr.no	WGSAM