WGMIXFISH-METH 2014

ICES ADVISORY COMMITTEE

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Report of the Working Group on Mixed Fisheries Methods (WGMIXFISH-METH)

20-24 October 2014
Nobel House, London, UK

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Contents

Executive Summary

The ICES Working Group on Mixed Fisheries Methods [WGMIXFISH-METH] (Chair: Paul Dolder (UK)) met at Nobel House, London 20—24 October 2014 to:

- Develop medium term management strategy evaluation (MSE) methods using the FCube modelling approach, which may be suitable for advising on management plan development for North Sea fisheries.
- Develop an FCube model for the Celtic Sea gadoid fisheries as a basis for progressing mixed fisheries advice for the region.
- Undertake a joint workshop with the ICES multispecies working group (ICES WGSAM) to consider synergies and overlaps between modelling and advice on mixed/multispecies management issues.

In addition to these core issues, the working group also considered a recommendation from the methods working group (ICES WGMG) to develop a MICE (Models of Intermediate Complexity for Ecosystem Assessment), gave some initial thoughts on the scope of a potential future Term of Reference on including the impact of fisheries on vulnerable/bycatch species in mixed fisheries advice and considered the treatment of *Nephrops* Functional Units in mixed fisheries forecasts.

Medium term projections for North Sea demersal mixed fisheries were performed in a Management Strategy Evaluation (MSE) framework as part of development of the FCube methodology. Such an approach is likely to play an important role in supporting evaluations under the new CFP; where there is a requirement to implement regional multiannual management plans (MAPs) which take account of mixed fisheries interactions. Further work is likely to be progressed in the coming months, given the imperative policy driver.

The FCube short-term forecasting methodology was successfully applied to the Celtic Sea gadoid (cod, haddock and whiting) fisheries, and extended to include Sole VIIfg. It was considered that this could form the basis of operational mixed fisheries advice for the region in future years. However, further steps were also identified to develop its application. These include providing more disaggregated fleet data in response to the WGCSE-WGMIXFISH data call, considering what further stocks can/should be incorporated in forecasts and identifying the most appropriate timing for delivery of advice given the October release date for *Nephrops* advice for the ecoregion.

A workshop held jointly with WGSAM furthered mutual understanding of each groups work and identified areas where it would be beneficial to work more closely in future, as part of developing integrated ecosystem advice which takes account of both multispecies (biological) and mixed fishery (technical) interactions.

1 Introduction

1.1 Background

The mixed fisheries methods working group (WGMIXFISH-METH) was formed in response to the need to further develop how ICES provides mixed fisheries advice and to progress application of methods to areas other than the North Sea, independent of the annual advisory meeting (WGMIXFISH-NS; ICES, 2014). WGMIXFISH-METH met in London 20—24 October 2014 to consider the following issues:

- Development of medium term management strategy evaluation (MSE) methods using the FCube modelling approach, which may be suitable for advising on management plan development for North Sea fisheries.
- Develop an FCube model for the Celtic Sea gadoid fisheries as a basis for progressing mixed fisheries advice for the region.
- Undertake a joint workshop with the ICES multispecies working group (ICES WGSAM) to consider synergies and overlaps between modelling and advice on mixed/multispecies management issues.

In addition to these core issues, the working group also considered a recommendation from the methods working group (ICES WGMG) to develop a MICE (Model of Intermediate Complexity for Ecosystem Assessment; plagyanyi et al 2014), gave some initial thoughts on the scope of a potential future ToR on including the impact of fisheries on vulnerable/bycatch species in mixed fisheries advice and considered treatment of *Nephrops* stocks in mixed fisheries forecasts.

1.2 Terms of Reference

The terms of reference for WGMIXFISH-METH in 2014 were as follows

2013/2/ACOM23 The Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METH), chaired by Paul Dolder, UK, will meet in London, 20—24 October 2014 to:

a) Review progress on mixed fisheries methodologies and consider how they might be taken forward and incorporated into the advisory process. Issues to consider include; short-term catch forecasting methods, including methods to incorporate data-poor stocks taking account of uncertainties; medium term MSE approaches to mixed fisheries, in order to evaluate the performance of mixed-fishery models within a management strategy evaluation framework; alternative or additional indictors and metrics encapsulating key indicators from mixed fisheries outputs; scenarios incorporating more realistic assumptions in relation to fleet dynamics; and application of methodology to other ICES regions, fisheries and stocks.

b) In conjunction with WGSAM, consider how models providing advice on multi-species interactions and models providing advice on mixed fisheries interactions might complement or inform each other with a view to providing more holistic ecosystem advice.

1.3 Definitions

Two basic concepts are of primary importance when dealing with mixed-fisheries, the Fleet (or fleet segment), and the Métier. Their definition has evolved with time, but the most recent official definitions are those from the CEC's Data Collection Framework (DCF, Reg. (EC) No 949/2008), which we adopt here:

- ***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 characterized by a similar exploitation pattern.

In 2013 WGMIXFISH-METH requested data according to aggregations based on the definitions of the EU Data Collection Framework (DCF) and these terms are used consistently in this report.

1.4 Software

All analyses were conducted using the FLR framework (Kell *et al.*, 2007; www.flr-project.org) running with R2.15.1 (R Development Core Team, 2008). All forecasts were projected using the same fwd() function in the Flash Package. The FCube method is developed as a stand-alone script using FLR objects as inputs and outputs.

The FCube model has been presented and described in Ulrich *et al.* (2008; 2011). The basis of the model is to estimate the potential future levels of effort by a fleet corresponding to the fishing opportunities (TACs by stock and/or effort allocations by fleet) available to that fleet, based on fleet effort distribution and catchability by méti-er. This level of effort was used to estimate landings and catches by fleet and stock, using standard forecasting procedures.

2 Terms of Reference A

The overarching ToR for the meeting was kept deliberately broad in order to maximize participation and relevance of the work given the rapidly evolving policy drivers. Of particular relevance in this regard is the introduction of Multi Annual Management Plans (MAPs) under the reformed Common Fisheries Policy (CFP), with MAPs now required to take account of mixed fishery interactions (Article 9 of the CFP; Regulation (EU) 1380/2013). As such, under this ToR the work of the group primarily focused on two areas:

i) i. Application of mixed fishery forecasting methods to the Celtic Sea

ii) ii. Development of methods to evaluate mixed fishery management plans ("Management Strategy Evaluation" type approaches).

2.1 Application of mixed fishery forecasting methodology to further areas: Celtic Sea

2.1.1 Introduction

Annual mixed fishery advice is currently given for the North Sea ecoregion (ICES, 2012). The ICES strategy for Mixed Fisheries and Multispecies advice (ICES, 2013) envisages further development of methods for the provision of advice on technical interactions, including extension to the Bay of Biscay-Iberian and Celtic Seas fisheries the next few years. Such advice is required to meet the needs under the new Common Fisheries Policy (CFP) for regional based multistock management plans, allowing account to be taken of both technical and biological interactions between fisheries and stocks. In the past a lack of métier-disaggregated catch and effort data has limited the development of mixed fisheries approaches in the Celtic Seas. The increasing use of the ICES InterCatch for the transmission and processing of biological and catch data to assessment working groups, and a joint WGCSE-WGMIXFISH data call, with métier-disaggregated catch and effort data, provides the necessary data required to develop advisory methods to the ecoregion.

As a first step towards mixed fisheries advice for the Celtic Sea, a working document was submitted to WGMIXFISH-METH (Annex 4) applying the Fleet and Fishery Forecasting method "FCube" methodology (Ulrich *et al.*, 2011) to the three main demersal gadoid fisheries in the region. The "FCube" model has been used to provide advice on the potential catches of the main commercial fish stocks in the North Sea mixed demersal fisheries since 2012 (ICES, 2012). Its development has been progressive, with further stocks and fisheries included as analytical assessment outputs have become available, while further work is ongoing to include 'data-poor' stocks. During the 2014 WGMIXFISH-METH meeting further development of this model was attempted. A review of all stocks relevant to the Celtic Sea mixed fishery model was undertaken to assess the data availability and feasibility of inclusion. The work resulted in the inclusion of the VIIfg sole stock.

Each of stocks currently included in the FCube Celtic Sea model have analytical assessments, it was considered these were the most suitable initial candidates for the provision of mixed fisheries advice. However, given the highly mixed nature of the fisheries this should extend to further stocks. Further, it is noted that mixed fishery approaches are being developed elsewhere, in particular through the EC LOT1 project DAMARA (MARE/2012/22), using the FLBEIA framework (Garcia et al 2012) and such approaches may compliment or be substituted for the FCube methodology. Future work should therefore include comparison of the different available approaches to identify the suitability of the methods for meeting different advisory objectives (i.e. short-term advice, long-term management strategy evaluation etc.), as part of the general development of mixed fisheries advice.

2.1.2 Fisheries

The Celtic Seas ecoregion encompasses ICES divisions VIa (West of Scotland), VIIa (Irish Sea) and the inner (VIIfg) and wider (+VIIbc,hjk) Celtic Sea as well as the western English channel (VIIe) (Figure 2.1.2.1).

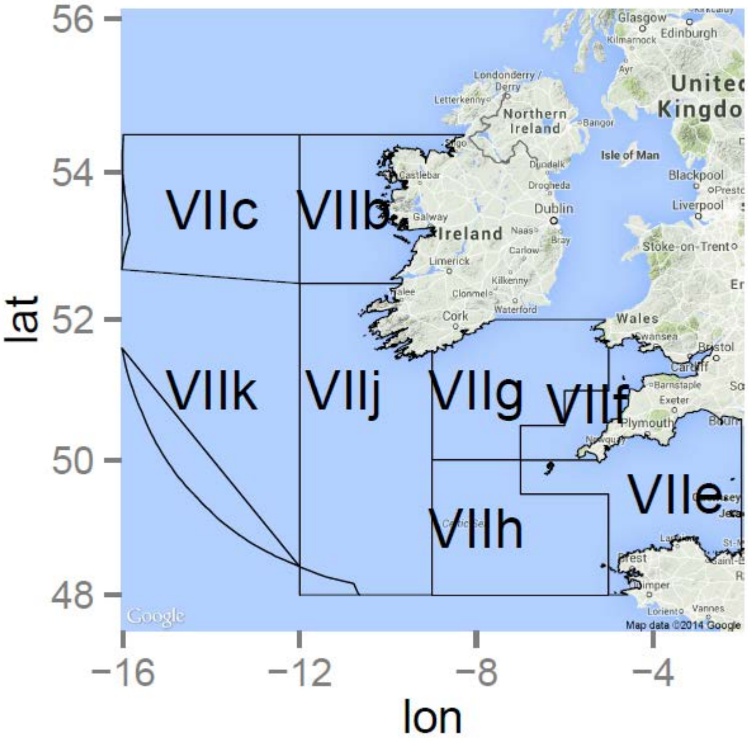

Figure 2.1.2.1. Map showing the inner (VIIfg) and wider (+VIIbc,e,hjk) Celtic Sea

Fisheries in the Celtic Sea are highly mixed, targeting a range of species with different gears. Otter trawl fisheries take place for mixed gadoids (cod, haddock, whiting), *Nephrops*, hake, anglerfish, megrims as well as cephalopods (cuttlefish and squid). Beam trawl fisheries target flatfish (plaice, sole, turbot), anglerfish, megrim and cephalopods (cuttlefish and squid) while net fisheries target flatfish, hake, pollack, anglerfish as well as some crustacean species. The fisheries are mainly prosecuted by French, Irish and English vessels though Belgian beam trawl fisheries target flatfish (in VIIe and VIIfg) while Spanish trawl and net fisheries target hake along the shelf edge (VIIhjk).

Fishing effort for the main gears (otter trawlers, beam trawlers) has been relatively stable over the past ten years, though there has been an increase in otter trawl effort since 2009 (STECF, 2014), particularly for the large mesh trawlers (>100 mm). Unlike other parts of the Celtic Seas (VIa, VIIa) and the North Sea and eastern English channel (IV and VIId) the Celtic Sea is not subject to effort control measures under the long-term management plan for cod (excepting beam trawlers and gillnetters in VIIe as part of the western channel sole management plan), and so the increase in effort may be due to limiting effort regulation in other areas.

The mixed gadoid fishery predominately takes place in ICES areas VIIf and VIIg with these areas responsible for >75% of the landings of each of cod, haddock and whiting (Annex 4, Figures 6-8). Catch per unit of effort for these stocks is much higher than in the wider Celtic Sea (STECF, 2013), which may reflect higher abundance and/or increased targeting in these areas. Landings are predominately by French and Irish vessels, though UK vessels also take significant landings.

Recent years have seen large but sporadic recruitment for the gadoid stocks (see section 2.1 of Annex 4) and high levels of exploitation which has resulted in significant fluctuations in the stocks. Incompatibilities between the quota available has resulted in regulatory discarding as well as highgrading in the mixed fisheries, creating significant challenges in managing the exploitation of the stocks and leading to the introduction of a number of technical gear measures designed to reduce discarding of under size and over quota fish. Understanding the strength of technical interactions and likely 'choke' stocks will therefore support design of management measures which provide greater consistency between quotas for the different stocks exploited in the mixed fishery. Industry reports of large incoming cod and haddock recruitments, which appear to be supported by observations in scientific surveys, indicate the need for such measures in the immediate future.

2.1.3 Data

With a view to expanding on the initial model run of cod (VIIe-k), haddock (VIIb-k), and whiting (VIIb-k) in the Celtic Sea (VIIb-k, exc VIId) mixed fisheries forecasts, a review of the assessment methods and the appropriateness of the data submitted, in response to the data call, was carried out for all other species for which ICES advice is given in the Celtic Sea (Table 2.1.3.1).

Table 2.1.3.1. Stocks for which ICES advise is given within the Celtic Sea (VIIb-k exc VIId).

Teleosts:

Stock	stock name	Accepted assessment	Assessement type	Issues
Anglerfish (Lophius budegassa) VIIb–k, VIIIa,b,d	anb-78ab	Trends	Survey trends-based, No forecast	Analytical assessment would be needed. Insuficent survey information. Ageing and species reporting issues. Stock area extends beyond Celtic Sea.
Anglerfish (Lophius piscatorius) VIIb–k, VIIIa,b,d	anp-78ab	Trends	Survey trends-based, No forecast	Analytical assessment would be needed. Insuficent survey information. Ageing and species reporting issues. Stock area extends beyond Celtic Sea.
Cod VIIbc	cod-7bc	No		Analytical assessment would be needed
Cod VIIe-k	**cod-7e-k**	**Yes**	**XSA**	**Included**
Grey gurnard VI VIIa-c VIIe-k	gug-celt	No		Analytical assessment would be needed. Poor species differentiation (Red/Grey). Uncertain stock areas. Stock area extends beyond Celtic Sea
Haddock VIIb-k	**had-7b-k**	**Yes**	**ASAP**	**Included**
Hake IIIa, IV-VI-VII, VIIIa,b,d		Yes	Length-based	Stock area extends beyond Celtic Sea
Megrim (Lepidorhombus whiffiagonis) VIIb-k,VIIIa,b,d	mgw-78	Trends		Analytical assessment would be needed. Stock area extends beyond Celtic Sea
Plaice VIIbc	ple-bc	No	-	Analytical assessment would be needed
Plaice VIIe	ple-echw	Yes	XSA	Could be included
Plaice VIIfg	ple-celt	Trends	Aarts and Poos	
Plaice VIIh-k	ple-7h-k	Trends	XSA, No forecast	No forecast although able to use a TAC target instead of F target. There is a mismatch between the assessment area (VIIjk) and the advice area (VIIh-k) with large landings in VIIh. Issue with VIIh-k area aggregated Intercatch submission
Pollack VI-VII	pol-celt	Trends	Depletion-Corrected Average Catch,	Analytical assessment would be needed. Poorly defined stock area. Stock area extends beyond Celtic Sea
Sea bass IVbc, VIIa, VIId–h	bass-47	Yes	Stock Synthesis 3	
Seabass VIaVIIb-VIIj	bss-wosi	No		Analytical assessment would be needed
Sole VIIbc	sol-7b-c	No		Analytical assessment would be needed
sole VIIe	sol-echw	Yes	XSA	Could be included
Sole VIIfg	**sol-celt**	**Yes**	**XSA**	**Included**
Sole VIIh-k	sol-7h-k	Trends	XSA, No forecast	No forecast although able to use a TAC target instead of F target. There is a mismatch between the assessment area (VIIjk) and the advice area (VIIh-k) with large landings in VIIh. Issue with VIIh-k area aggregated Intercatch submission
Striped red mullet VI, VIIa–c, e–k, VIII, IXa		No		Analytical assessment would be needed. Short time-series. Poorly defined stock area. Stock area extends beyond Celtic Sea.
Whiting VIIb-k	**whg-7e-k**	**Yes**	**XSA**	**Included**

Table 2.1.3.1. Continue.

Nephrops:

Stock	stock name	Accepted	Assessement	Issues
Nephrops VIIb (FU17)	Nep-VII-FU 17	Yes	UWTV & YPR	Agreed TAC advice only made available late in the year. Miss match between stock areas and TAC area
Nephrops VIIbcjk (FU16)	Nep-VII-FU 16	Yes	UWTV & catch size structure	
Nephrops VIIfg (FU22)	Nep-VII FU 22	Yes	UWTV & catch	
Nephrops VIIgh (FU2021)	Nep-VII FU2021	No		
Nephrops VIIjg (FU19)	Nep-VII FU19	Yes	UWTV & catch size structure	

Elasmobranches:

Stock	stock name	Accepted	Assessement	Issues
Common skates VI-VII (exc VIId)	rjb-celt	No		None of the Elasmobranch stocks, for which advice is given, has an analytical assessment. In a number of cases the stock areas extends beyond Celtic Sea
Thornback ray (Raja clavata) VIIa,f,g	rjc-celt	Trends	Survey trends-based, No	
Thornback ray (Raja clavata) VIIe	rjc-echw	No		
Small-eyed ray (Raja microocellata) VIId, e	rje-ech	No		
Small-eyed ray (Raja microocellata) VIIf, g	rje-7fg	Trends	Survey trends-based, No	
Shagreen ray (Leucoraja fullonica) VI-VII	rjf-celt	No		
Blonde ray (Raja brachyura) VIIa, f, g	rjh-7afg	No		
Blonde ray (Raja brachyura) VIIe	rjh-7e	No		
Sandy ray (Leucoraja circularis) VI-VII	rji-celt	No		
Spotted ray (Raja montagui) VI-VIIb,j	rjm-67bj	Trends	Survey trends-based, No	
Spotted ray (Raja montagui) VIIa, VIIe–h	rjm-7aeh	Trends	Survey trends-based, No	
Cuckoo ray (Leucoraja naevus) VI, VII, VIIIa,b,d	rjn-678abd	Trends	Survey trends-based, No	
Undulate ray (Raja undulata) VIIb,j	rju-7bj	No		
Undulate ray (Raja undulata) VIId, e	rju-ech	No		
Other skates VI-VII (exc VIId)	raj-celt	No		
Lesser-spotted dogfish (Scyliorhinus canicula) VI-VIIa–c, e–j	syc-celt	No		

All stocks with full analytical assessments were considered. Incorporating stocks having analytical assessment but no projection is possible using TAC targets instead of F targets as the rule in the forecast procedure (i.e. on the basis of a constant catch-rate assumption). Incorporation of some stocks which did have appropriate assessments was not possible, at present, due to data availability; Plaice VIIh-k and sole VIIh-k both have trends based assessments and could be incorporated within the FCube framework, however, issues relating to the TAC advice area (VIIh-k) and the assessment area (VIIjk) prevented their inclusion. Further, it was identified that in small number of cases there was a disagreement between the level of are aggregation in the data submitted to InterCatch for the assessment process and that data provided to WGMIXFISH, in response to the WGCSE-WGMIXFISH, data call. Inclusion of the 5 Nephrops stocks (FU16, FU17, FU19, FU20/21, and FU22) is at present not considered possible due to the later release date of advice and issues relating to the TAC area and assessment area, particularly given the importance of the Irish Sea functional units. The majority of other species fall within the data limited category, preventing formulation of analytical assessments though lack of information. Future development of the Celtic Sea model may work toward the inclusion of species without analytical assessment through the use of landings and effort to generate cpues and effort forecasts.

2.1.4 Results

The working document *WD: Celtic Sea mixed fishery analysis using FCube* (Annex 4) outlines the successful application of the FCube methodology to the mixed gadoid fishery in the Celtic Sea. A full description of FCube methodology is provided in Ulrich *et al.*, 2011 and ICES 2014a. Mixed fishery forecasts were performed for cod, haddock and whiting based on the scenarios used in the North Sea advice (excepting the effort management scenario), these scenarios are:

- *min*: Fishing stops when the catch for any one of the stocks considered meets the single-stock advice. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks.
- *max*: Fishing stops when all stocks considered have been caught up to the ICES single-stock advice. This option causes overfishing of the single-stock advice possibilities of most stocks.
- *stock*: All fleets set their effort corresponding to that required to land their quota share of the named stock, regardless of other catches.
- *status quo effort*: The effort is set equal to the effort in the most recently recorded year for which landings and discard data are available.

The TAC year landings under the mixed fisheries scenarios are summarized in Figure 11 (in Annex 4), with the forecast fishing effort by fleet in Figure 12 (in Annex 4) and the SSB in 2016 relative to the baseline in Figure 13 (in Annex 4).

The 'max' scenario results in over-quota landings of both cod (2006t overshoot) and haddock (6922t overshoot) Figure 11. This is a consequence of whiting being the least restrictive quota in 2015 for all fleets, and as the assumption in the scenario is for effort to be set according to the least restrictive stock, there is a resultant increase in fishing effort on 2013. The fishing effort under this scenario is higher than that required to catch either the cod or haddock quotas. Under this scenario fishing mortality is forecast to be at F_{msy} for whiting, but well above for cod (F=0.66) and above F_{lim} for haddock (F=1.05), and therefore not considered precautionary. The haddock SSB is forecast to be little over half that forecast by the single-stock advice in 2016, while the cod SSB is forecast to be around 70% of the single-stock advice.

Under the 'min' scenario, all the single-stock TACs are forecast to be undershot in 2015, with cod landings forecast at 1766 t below the TAC advice, haddock landings at 416 t below the TAC advice and whiting landings at 9185 t below the TAC advice. The most limiting stock for all fleets is haddock, as can be seen from the fact that the 'had-cs' and 'min' scenario are the same. Under this scenario fishing effort is forecast at less than half the level in 2013 for each of the fleets. Fishing mortality is forecast to be below F_{msy} for cod (F=0.21) and whiting (F=0.1) but consistent with F_{msy} for haddock (F=0.33).

The sq_E scenario results in overshoots of both the cod (overshoot = 1213 t) and haddock (overshoot = 5521 t), while there is an under-shoot of the whiting TAC (-1936 t). Fishing mortality is estimated to be above F_{msy} for cod (F=0.55), above F_{msy} and F_{lim} for haddock (F=0.88) but below F_{msy} for whiting (F=0.27). Due to the higher exploitation rates, SSB is forecast at below the single-stock advice level in 2016 for both cod and haddock, while being slightly higher than the single-stock advice for whiting (Figure 13).

During WGMIXFISH-METH group 2014, VIIfg sole was included in the model. The outputs of the model are considered to show negligible change with the inclusion of this forth stock compared to those described above. Indeed, the fleets/métiers targeting sole and gadoids species are quite distinct, Belgium TTB and French-Irish OTB/OTT respectively, resulting in the absence of technical interactions between these two fisheries. Nevertheless, further consideration should be given to incorporation of further economically important stocks which drive the dynamics of the fisheries, in order to more accurately represent the fishery dynamics and full range of technical interactions. The approach outlined here should be considered a first step in meeting the advisory needs for mixed fisheries in the Celtic Sea, as part of a progressive development of the advice framework in accordance with the ICES mixed fishery and multispecies advice strategy.

2.1.5 Conclusions

From the experience of this methods group it is believed that it would be possible to generate Celtic Seas mixed fisheries considerations in 2015 for 2016 based on the model focused on the three main gadoid species targeted in the Celtic Sea. However, it should be noted that further work is needed to take into account other important species that are caught simultaneously with gadoid species such as *Nephrops*, anglerfish and megrims with further developments of the models planned during future WGMIXFISH-METH meetings. In order to operationalize the mixed fisheries advice requires the development of an advice sheet and stock annex – these should be considered at the next advisory meeting (May 2015).

2.1.6 Recommendations

The experience of applying FCube within the Celtic Sea has highlighted a number of issues which, to progress the mixed fisheries assessment further, must be addressed.

Data issues

A number of distinct data sources are used to run FCube model: the stock assessment input (InterCatch), assessment data (catch-at-age, fishing mortality, SSB, R and forecast hypothesis) and the data from the MIXFISH data call (catch and effort by DCF métier, vessel length category and mesh size). These data sources are combined to provide the biological model components and to characterize the fishery through fleet and métier parameters such as effort share and catchability. An important step in the model definition is to link catches used in the assessment of each species to fleet/métier efforts. This process relies on consistency of the levels of aggregation and uniformity of codification between InterCatch and Mixfish data calls.

The following recommendations are made toward further improvement of the next joint data call WGCSE-MIXFISH:

- The importance of accurate reporting of disaggregated data into Intercatch must be stressed: Areas should not be reported in an aggregated form but area by area. If area aggregations must be made they should not be beyond the assessment area of individual stocks; which sometime differs from the stock area (e.g. sole VIIh-k is assessed in only VIIjk and therefore the maximum aggregation should be VIIjk). A table defining the stock area and the assessed area should be provided in the data call.
- Some of the candidate stocks to be incorporated have a wide distribution area and are not assessed by the WGCSE, e.g. anglerfish, megrim and hake

in VII and VIII. Therefore similar advice should be made to the WGBIE group.

- The reporting of data within the MIS-MIS Intercatch métier should be minimized. Large volumes of catches in the MIS-MIS category hinders the ability to describe and characterize the technical interactions in the fisheries.
- Submission of dominant métiers should be minimized / eliminated, especially in relation to mesh size ranges distinguishing between 70-99mm and ≥100mm in particular. The main point underlying this request is that effort management regulation is often relater to TR1, TR2, BT2… As such, métier definition is FCube model is mainly based on mesh size ranges.
- Provide when possible input and output data of the assessment in an .RData format on the sharepoint.

Guidance from WGCSE

The WGMIXFISH-METH group would like to request guidance from WGCSE as to the priority of stocks for inclusion into the FCube mixed fisheries assessment. Given that it is possible to develop and include effort forecasts and applied cpues for species without assessment but which have landings and effort available, which ancillary/associate species are considered top priorities?

Further work is required to develop fleet definitions appropriate to the Celtic Sea, whether this be in the form of the gear categories of the cod long-term management plan as applied within the presented FCube analysis or whether these are too coarse and DCF métier level 5 (i.e. gear-species) would be more appropriate.

2.2 Development of methods for evaluation of Multi-Annual Management Plans from a mixed fishery perspective

2.2.1 EC mixed fisheries MAP concept

The WGMIXFISH has been focusing some of its work on what a mixed-fisheries MAP for the North Sea could look like, on the basis of the outcomes of the second EC consultation workshop held in Brussels on 29—30 September 2014. The minutes of this workshop state that:

"Multiannual plans should define the optimal strategy for each stock to be exploited at maximum yield and maintain sustainable biomass levels. However, each stock has a different optimal strategy, and any deviation from this because of mixed-fisheries considerations implies suboptimal management of that stock. How can these mismatches be reduced in the framework of a mixed fisheries plan? The use of FMSY ranges instead of point estimates would provide greater flexibility in the definition of the target to be reached for each stock, allowing for greater scope for overlap in range areas between stocks than there would be with point estimate targets. Coherence between the TACs of the various stocks managed under the future MAP, and ensuring that no stock is exploited above precautionary levels; is how we would move from a sum of single-stock management strategies to a mixed fisheries management strategy. FMSY ranges are not the only instrument that can help address mixed fisheries considerations. Technical measures also have an important role to play in helping to decouple fisheries (in other words, to reduce the extent to which different fisheries overlap in their catch compositions). Used in combination they should prove sufficient without the need for effort restrictions.

The consultation tended towards a simple plan, which focuses on the "big 6" stocks (cod, haddock, whiting, saithe, sole, and plaice) in areas IV, VIId and IIIaN. Recognizing that cod recovery would remain a priority, the group discussed how the mixed fisheries plan could improve the current situation, where the North Sea fisheries are predominantly driven by the conservation requirements for cod. One idea was to include a simple rule, whereby the TAC for any stock that was below precautionary biomass levels must be set at a level that would lead to a forecast increase in SSB of at least a certain percentage."

WGMIXFISH did try to work out how such a plan could work over the next 10 years for the main stocks of the North Sea. The interpretation of the group is as follows:

- Strict Harvest Control Rules as known from the current single-species LTMP (including a deterministic target F, a cap on interannual variability (IAV) in TAC and, in many cases, a sliding rule imposing a reduced target F when the stock is evaluated to be below Bpa /or MSY $B_{trigger}$) would not exist anymore
- Instead, the main rule would be a F_{msy} Target with a range
- Additional constraints should ensure that sustainable biomasses are maintained.

This approach to mixed-fisheries MAP takes clearly inspiration from the ideas formulated by the WGMIXFISH group over the years. It builds on the idea that independent HCR create mismatches in the system when quota increases for some stocks and decreases for some others, and that a better alignment of fishing opportunities could reduce some of the incentives to discard.

2.2.2 WGMIXFISH considerations – short-term recovery issues for North Sea cod

The WGMIXFISH group has now the necessary tool and data to proceed to simple and rapid evaluations of various options, and some of the preliminary results were already presented to the NSAC in July 2014 (Joint MYFISH/SOCIOEC meeting, July 7th 2014). These thoughts were also discussed at the Brussels EC, workshop, and further analysed during this Working Group meeting.

As noted above, the situation in the North Sea for the "big 6" stocks should in reality be characterized as "big 5 plus cod", given how low the cod stock still is compared to its biomass target, which is not the case for the other five stocks. WGMIXFISH underlines that this is likely the biggest challenge to a mixed-fisheries plan now, which would be much easier to design if all stocks were already around sustainable biomass levels. The plan aims to "maintain sustainable biomass levels", whereas the cod is still largely in a situation of recovery towards such a sustainable level.

Despite the increase observed over the last years, the cod SSB is still estimated to be around B_{lim}, half of MSY $B_{trigger}$. Recruitment is continuously poor without any signs of improvement, and the stock is mainly present in the Northern area of the North Sea, but much less in the South compared to historical distributions.

This situation means that under the current cod LTMP, F in 2015 should be halved, corresponding to a 20% decrease of the TAC. In comparison, F in 2015 is advised to be close to or even larger than F in 2013 for the other "big 5". Since all demersal fleets in the North Sea do catch some cod (ICES MIXFISH 2014 data), the mixed-fisheries considerations have indicated that assuming constant catchabilities, discards proportions and relative distributions of effort across métiers within each fleet between 2013 and 2015, fishing effort should be almost halved to stick to the cod plan, leading to foregone yield for the other stocks ("cod-ns" and "min" scenarios in the mixed-fisheries advice sheet). Alternatively, it was also simulated that a decrease of 40 to 50% of the cod catchability (through improved avoidance of cod catches) would be necessary to achieve some balance in the exploitation of the other stocks without reduction of effort, if the predicted cod catches should be as required by the plan (reduced levels of estimated over- and undershoot of potential 2015 landings – Figure 2.2.2.1).

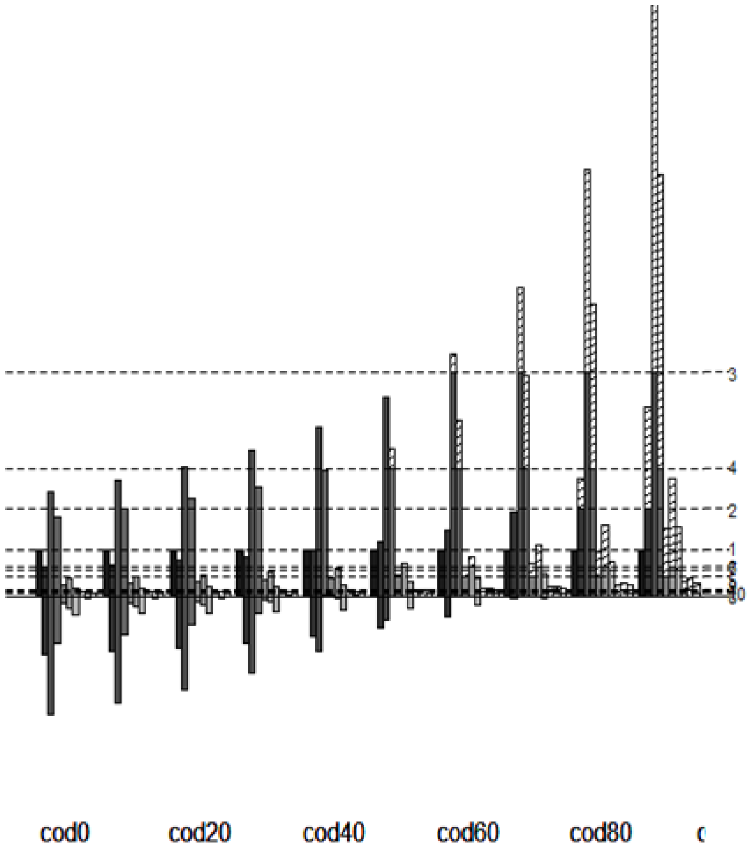

Figure 2.2.2.1: MIXFISH standard advice barplot, for alternative scenarios picturing 0 to 90% reductions of cod catchability in all fleets and all métiers (From MIXFISH-NS June 2014). Bars under 0 are under-shoot of potential 2015 landings by stock, hatched bars are overshoot.

This analysis illustrates clearly that cod acts as a very strong "choke species", leading to predictable political disputes around the future TAC level to be agreed on. But it illustrates also clearly that any "flexibility" around the cod target would in reality likely mean higher cod TACs than would be prescribed in the current cod LTMP plan over the next few years. The risk that such higher TAC represent to the cod stock should be carefully evaluated.

2.2.3 A simple MSE tool for medium-term HCR projections

The WGMIXFISH runs a very simplified MSE, allowing quick comparison of alternative management scenarios on the "big 6" stocks plus turbot over the short-and medium term (10 years). The runs performed during the workshop include the following features:

- Conservative Hockey-Stick Stock–recruitment relationships (stochastic recruitment fluctuating around the historical average but not increasing with increasing biomass, and reduced recruitment below a given SSB threshold);

- Random deviation of future recruitment around this SRR for future recruitment (mean-corrected lognormal distribution using the standard deviation of residuals)
- No estimation error in the catch, and no assessment error (assumption of perfect stock knowledge)
- Mimic of a 2 years short-term forecast at each time-step, using constant F assumption for the intermediate year, and the HCR to be tested in the following year, leading to a catch advice in the TAC year
- Perfect implementation of this catch advice in the operating model, leading to an estimate of the actual fishing mortality in the next year given actual stochastic recruitment.

It must be noted that this simple MSE model is different from the more comprehensive MSE model used for the evaluation of North Sea cod HCR regularly used by ICES, and a detailed comparison of the assumptions and results between both models could not be conducted during the meeting. This implies that simulation outcomes may differ to some extent.

It was discussed which SRR is the most relevant to use for cod. On the one hand, a standard hockey-stick fitted over the whole period fits reasonably well (Fig 2.2.3.1, left), with the recent low recruitments being interpreted as arising from recent low SSB. On the other hand, the recent residuals are all negative, indicating that recent recruitments have been lower than predicted by this fit and no improvement in recruitment has yet been seen for cod over the last few years. So an alternative pessimistic SRR was also fitted, as a hockey stick fitted on the recent years only (since 1998, figure 2.2.3.1, right). The results presented below were run with the pessimistic scenario, as a worse case investigation.

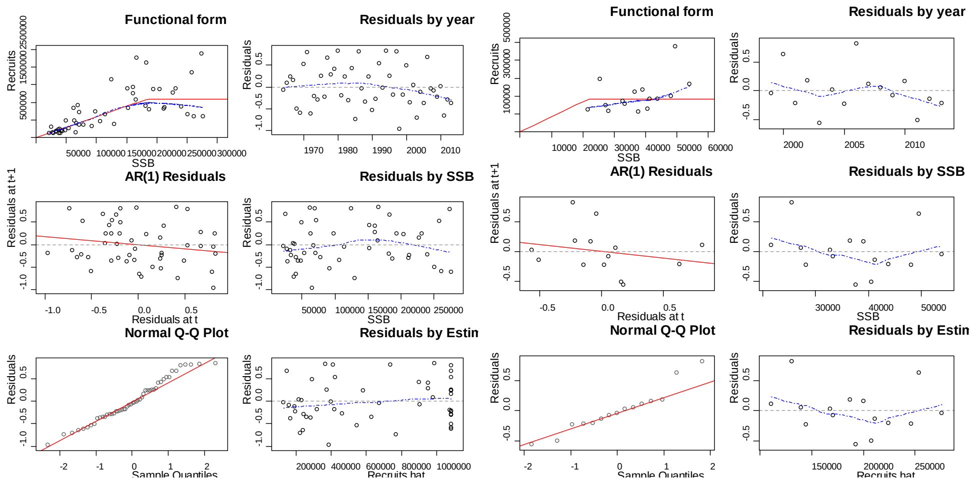

Figure 2.2.3.1: Hockey Stick SRR for North Sea cod. Left: fitted on the full time-series. Right: fitted on recruitment since 1998.

Additionally to running such MSEs in parallel for the “big 6” stocks (plus turbot), the Fcube model can be plugged in (or switched off) as an implementation error between bullet points 3 and 4 above. For example, if the “max“ Fcube scenario is run, then the actual fishing mortality by stock in the following year is replaced by a higher F corresponding to the higher level of fishing effort and over-quota catches as estimated by the Fcube model, with a corresponding lower biomass.

An alternative set up was operated assuming perfect implementation of a landings obligation, with all catches being landed and full quota uplift in 2014. The WG did not have sufficient time to set up an operating model with imperfect implementation (discards still occurring but not being recorded), since such an assumption implies also a module of imperfect assessment (assessment error), which cannot be easily parameterized without the use of a real assessment model.

DISCLAIMER: During the Working Group, some errors were discovered in the FLR package Flash when using a biomass-based target, as this feature has not been used very often and was not fully proof-checked, so corrections had to be performed after the meeting. Due to a general heavy workload for the scientists involved in the Fcube modelling, it has been difficult to allocate additional time for completing this work. Therefore, the results should be still considered as preliminary and illustrative. In particular, it was later noted some discrepancies between the single-species runs and the mixfish "min" run, whereas these should display similar patterns. These will be corrected as part of the ongoing Mixed-fisheries management plan.

2.2.4 Single-species runs of alternative rules

As a starting point, WGMIXFISH compared a number of single-species runs over 10 years. For the purpose of proof checking, runs have first been produced for 10 iterations only (10 alternative recruitment draws), thus reducing computing time. Extensions to 100 iterations were run after the meeting. The purpose of this is to assess the potential trajectories of the stocks under perfect implementation of alternative rules, as an "ideal" reference under which mixed-fisheries scenarios can be compared.

- HCR 1 : current single-stocks HCR including a target F, a % TAC IAV cap and a sliding rule reducing target F when SSB is below Bpa
- HCR 2 : F_{msy} target, with TAC IAV cap but no sliding rule
- HCR 3 : proxy for F_{msy} upper range (F high), with IAV cap but no sliding rule
- HCR 4: same as 3 but without IAV cap
- HCR 5 : same as 4, but adding a requirement when SSB at the beginning of the TAC year is below MSY $B_{trigger}$ for at least 20% increase in SSB or SSB reaching MSY $B_{trigger}$ at the end of the TAC year
- HCR 6 : same as 5, but adding a requirement that the TAC cannot decrease if the SSB is increasing (SSB in TAC year>SSB in Intermediate year>SSB in last assessment year)

So far, F_{msy} ranges are not provided for all stocks, so for the purposes of the exercise, proxies were used as follows:

Stock	hcr 1 target	f_{msy}	f_{msy}-high	basis
COD-NS	0.4	0.19	0.42	ICES estimate
HAD	0.35	0.35	0.385	F_{msy}+10%
PLE-NS	0.3	0.25	0.3	ICES estimate
POK	0.3	0.3	0.33	F_{msy}+10%
SOL-NS	0.2	0.22	0.25	ICES estimate
TUR	0.33	0.33	0.36	Proxy +10%
WHG-NS	0.15	0.15	0.165	F_{msy}+10%

It must be noted that ICES WKMSYREF met after the WGMIXFISH meeting, and estimated appropriate MSY ranges for these stocks, which will replace the proxy values used above. However, this should not dramatically affect the conclusions presented.

The summary results of the HCR are displayed on Kobe Plots, showing trajectories of median F and median SSB by stock, relative to MSY reference points. As no MSY $B_{trigger}$ is defined for turbot and whiting, Bloss (lowest observed biomass) was used as a proxy. Additionally, Confidence Intervals on F and SSB can be displayed on the graphs with bars.

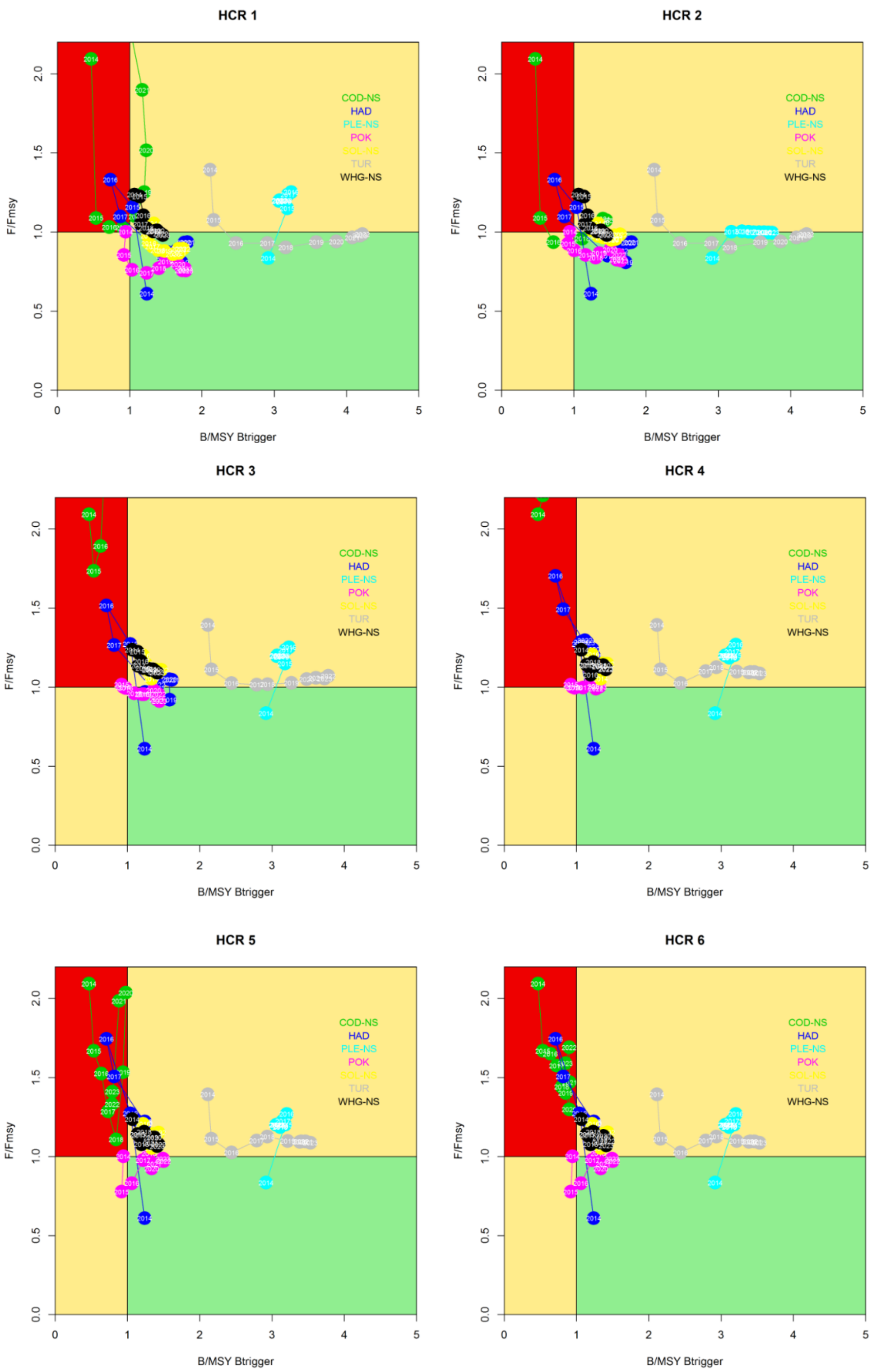

Figure 2.2.4.1. Kobe Plot of Single species HCR 1-6, median stock trajectories from 2014 to 2023

In all the HCRs plaice and turbot SSB were well above the biomass trigger. The five other stocks were more sensitive to the harvest control rule. Whiting, saithe, haddock and sole oscillated around the trigger points in HCRs 3 to 6. The difference between HCR 3 and 4 is the presence/absence of the IAV cap, which affects haddock and saithe more significantly. A TAC constraint of 15% is a narrow buffer, especially for species with a relatively quick growth, where changes in stock numbers linked to variation in

F significantly affect biomass estimates. The TAC applies to a biomass /volume, so a constraint can have strong limiting effects on changes in F.

The most dramatic effects were observed on cod, which is the stock starting from the poorest state (F above F_{msy}, SSB below MSY $B_{trigger}$) in 2014. HCR 3 and 4 did not bring the stock near any reference points during the simulation runs (Figure 2.2.4.1).

The current management plan (HCR 1) with a target HCR of 0.4 and a sliding rule manages to, on average, bring the stock up to the biomass trigger by lowering F, but as soon as the trigger is reached then F is allowed to increase back to 0.4 and the stock decreases again. This indicates that under the pessimistic scenario of sustained low recruitment, the current F target of 0.4, or the F_{msy}-high range (0.42) are not sustainable. The results of HCR 5 and 6 with biomass targets are interesting. HCR 5 is similar to HCR1, in the sense that it forces F down to increase biomass – though over 4 years against 1 year in HCR1. However, once SSB reaches the biomass trigger, then the F_{msy}-high target applies, which increases F and reduce SSB quickly, and then the biomass constraints apply again etc. This leads to a cyclic median trajectory, consistently above F_{msy} and below MSY $B_{trigger}$. The HCR 6 show similar results but much more damped because of the catch constraint acting on top of the SSB constraint. As TAC cannot decrease if biomass increases, then the annual changes in F and SSB are much slower, and average recovery above MSY $B_{trigger}$ is reached in 5 years. This indicates that the constraints of SSB increase could be potentially helpful in bringing cod recovery from its initial low state with less drastic catch reductions than the current LTMP. But after the recovery, a lower target than F_{msy} high range should be applied to avoid a biomass decrease afterwards.

Of course, it is also necessary to keep in mind the variability of the results linked to the uncertainty on e.g. future recruitments, therefore the results of HCR 5 and 6 are also displayed with 95% confidence interval bars, illustrating that biomass can potentially not increase although predicted as such in the short-term forecast. If the true recruitment is lower than assumed in the forecast, then the predicted F has a stronger impact on the stock and biomass increases less or can even reduce.

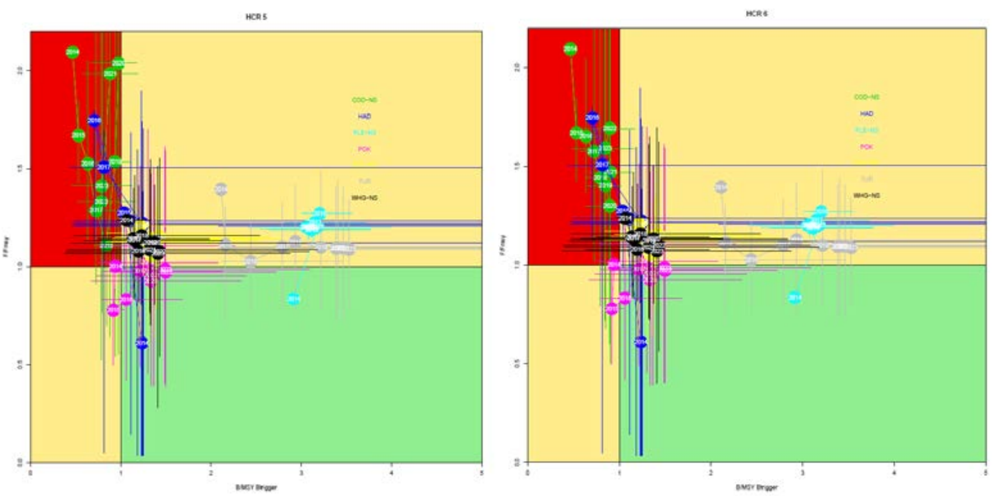

Figure 2.2.4.2. Single-species HCR 5 and 6 with confidence intervals shown

2.2.5 FCube MSE runs

The runs presented above were subsequently run including FCube as an implementation error – i.e. with the actual catches and fishing mortality of the Operating model being defined by FCube. For the purpose of the analyses, the results for HCR 1 (LTMP) and 6 are shown.

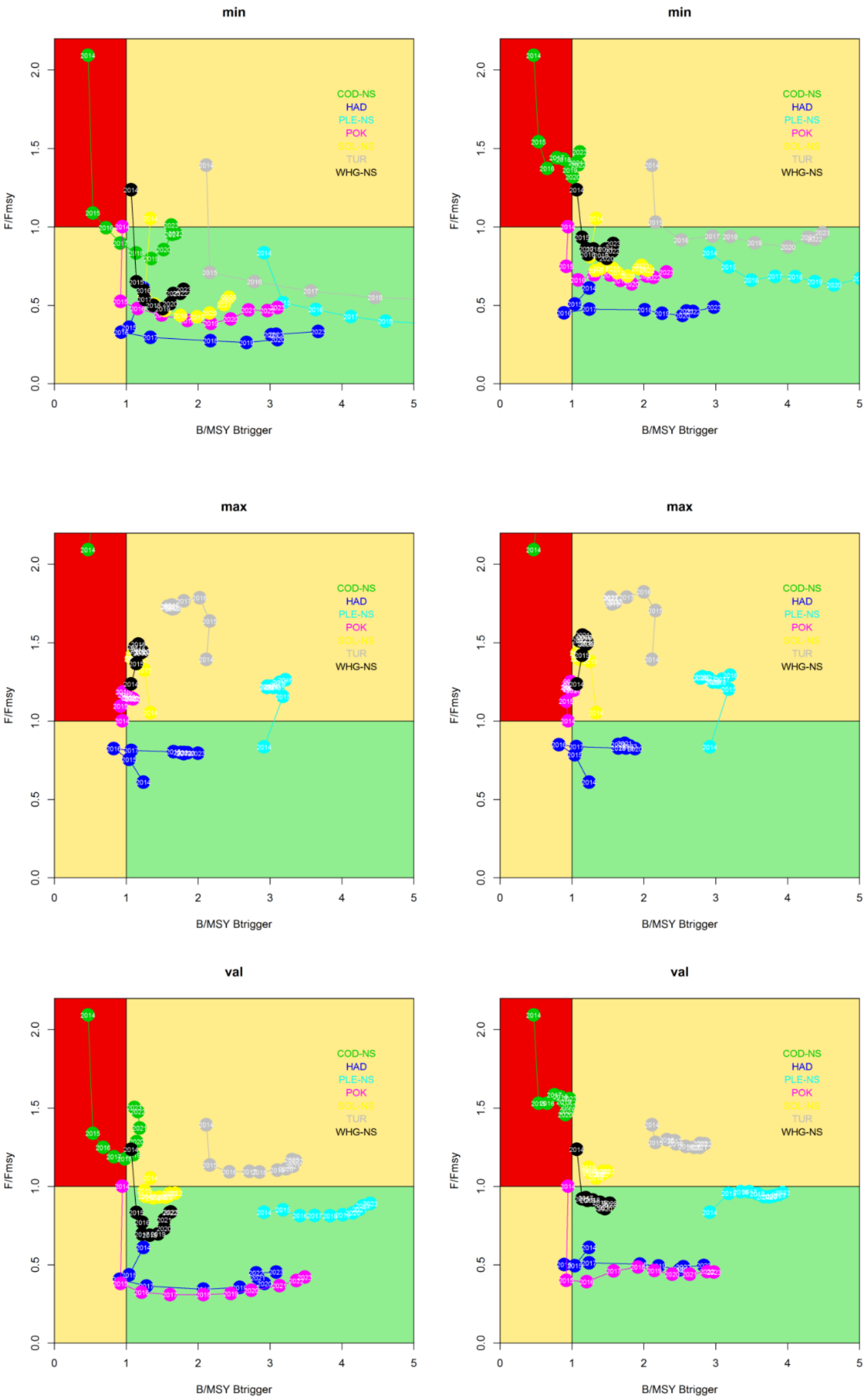

Figure 2.2.5.1. “min”, “max” and “val” median stock trajectories with HCR 1 (left) and 6 (right).

There are no differences in the HCR for the “max” scenario, whereas the “min” scenario displays similar contrasts as the single-species runs. As mentioned above, there might still be some slight inconsistencies in the code that will be corrected in future developing application of the model.

2.2.6 Conclusions

This work demonstrates the kind of simulation results that can be obtained with the Fcube MSE. A lot more options could be explored, including e.g. economic data or age-specific selectivity. Data and algorithms for those are in principle available, but some time is necessary to perform the code development.

Since the MIXFISH group met in October 2014, further developments have taken place regarding the European Commission's vision of a mixed-fisheries plan for the North Sea, so this work will expand over the coming months into operational results.

3 Terms of Reference B

3.1 Joint WGMIXFISH – WGSAM workshop on mixed fisheries and multispecies issues

A joint session of two ICES Working Groups, WGMIXFISH-METH and WGSAM, was held on 23 October in London, in accordance with point b) of the Terms of Reference:

"b) In conjunction with WGSAM, consider how models providing advice on multi-species interactions and models providing advice on mixed fisheries interactions might complement or inform each other with a view to providing more holistic ecosystem advice".

The aim of the workshop was to further understand the links between the two groups work and identify future priorities which support development of ICES advice on multispecies and mixed fishery issues. The day was structured as a series of topical questions, with presentations from a number of participants, and discussion to solidify understanding of the major challenges.

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

1. Identify the linkages between multispecies and mixed fisheries issues and describe what strategic (i.e. goal setting) or tactical advice is required from multispecies and mixed fishery model applications.
2. Identify where outputs of the multispecies or mixed fishery models could inform each other, or where benefits can be gained from coupling models or developing more holistic models dealing with both issues simultaneously.

Under objective [1] presentations (see Annex 6, Appendix 1 for details) were received from participants detailing the incorporation of technical interactions into multispecies models to highlight the inherent complexities when considering the issues together but the ability to identify the "management space" which achieves highest long-term yields given multispecies and mixed fishery interactions. Objective [2] saw a number of presentations using foodweb and multispecies models which are able to incorporate simplified multifleet structures to model whole system responses and explore the strength of interactions between and among biological and technical interactions. Finally, presentations and discussion explored issues around fleet definition in models and how to communicate complex model results to stakeholders and managers.

The workshop concluded that:

- In the transition to multispecies 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.
- Where fishing fleets are explicitly represented in multispecies and ecosystem models, they could be used to assess the impact of mixed fishery advice, thus providing a risk assessment of management options.
- Those using multispecies and ecosystem models need advice on the appropriate level of fleet aggregation to use.
- Further integration of multispecies interactions into mixed fisheries models could be either through informing appropriate long-term exploitation targets or coupling of multispecies models with the existing mixed fishery framework.

The groups agreed to continue dialogue through cross-participation in the respective working groups, with a further meeting on integrating multispecies and mixed fisheries advice when work schedules allow (likely in 2016).

A full report of the workshop has been included at Annex 6.

4 Additional issues considered

4.1 Recommendation from the methods working group (ICES WGMG) to develop a Model of Intermediate Complexity for Ecosystem advice (MICE)

The working group on methods of fish stock assessment (WGMG), which met in Reykjavik, Iceland on 30 September – 4 October 2013, made the following recommendation jointly to WGMIXFISH and WGSAM (the working group on Multispecies Assessment Methods):

"Consider developing a minimum realistic model (e.g. MICE) to serve as an operating model in order to evaluate the performance of mixed-fishery models within a management strategy evaluation framework."

Response from WGMIXFISH-METH:

Models of Intermediate Complexity for Ecosystem (MICE) assessments are intermediate in complexity between traditional single-species stock assessments and whole-of-ecosystem models (Plagányi *et al.*, 2014). MICE attempt to provide 'tactical advice' by explaining ecological processes for a limited group of populations subject to fishing and other anthropogenic pressures. Hence, MICE are a candidate for use in mixed fisheries and multispecies advice.

MICE include at least one explicit representation of an ecological process, for instance interspecific interaction or spatial habitat use (Plagányi *et al.*, 2014). Collaboration with WGSAM seems to a natural way to achieve the development of MICE for mixed fisheries advice.

MICE are designed based on data available to parameterize the model. Parameter estimation can be done through optimization methods such as ADMB (Fournier *et al.*, 2011). A MICE model for mixed fisheries can be constructed by starting from the populations of the main commercial species in the fisheries, then adding species and complexity to adequately explain the system dynamics.

In MICE, those populations are modelled by age, length and stage, or at a more coarse resolution (Plagányi *et al.*, 2014). Currently FCube, the main tool in modelling tactical mixed fisheries advice, uses a biomass aggregated catch model, with age-structured population models. However, development is underway to move to modelling catch at the age-structured population level in FCube. The structured information could also be used in future MICE models.

Inclusion of human behaviour comes naturally in MICE models: just like the explicit ecological dynamics of the stocks are modelled, the economic dynamics should be modelled. MICE can either use estimates of empirically modelled fleet dynamics, or use theoretical models of fleet dynamics.

4.2 Possible future ToR on inclusion of vulnerable/bycatch advice in mixed fisheries

In the lead up to the meeting the following information was received from ICES Secretariat:

"The development of fisheries management plans plus the discussion around Elasmobranch advice this year has highlighted the need to differentiate in a mixed fisheries context between

a) those fish stocks which are seen as an economic contribution to the fisheries and where a yield perspective therefore is relevant and

b) *those stocks where the main concern is in relation to the ecosystem impacts, say in relation to biodiversity, foodwebs and habitats.*

*ICES has discussed with advice clients the idea to move towards a risk-based advice for bycatch stocks which are not seen as important from a yield / economic perspective but must nevertheless be considered in fisheries policy from a biodiversity, foodweb and habitats perspective. Such advice would not deliver quantitative TAC advice linked to MSY for these stocks but would rather be based on first a risk assessment and then, for those stocks assessed to be at risk, **advice regarding potential mitigation measures which would make the fisheries measures conform with, say, MSFD GES targets regarding biodiversity, foodwebs and habitats**. ICES may consider to develop such advice as 'demonstration advice' in a similar way as 'considerations' have been offered to foster dialogue regarding multispecies and mixed fisheries issues in recent years. Such demonstration advice could then be a basis for discussions regarding how the CFP and MSFD may be integrated, supported by scientific advice in the future. At the same time such advice would address the bycatch problems inherent in the upcoming fisheries management plans.*

WGMIXFISH may be interested in considering an approach along these lines in its work. Since this is last minute input please consider this 'food for thought', any comments on if/how this can be done are welcome but it is certainly not a ToR."

WGMIXFISH-METH discussed the contribution it could make to ICES advice on the impact of fisheries on species of conservation concern (so-called, PET Protected-Endangered-Threatened species) that are not the target stocks in fisheries but caught alongside other, target, stocks. The group had the following considerations/ conclusions:

Assessment of populations considered "at-risk" would take place in other ICES working groups with more specialist knowledge of the biology of the populations and exploitation pattern.

In the case that the fisheries interaction with the species of concern is *particular to a métier, spatial or temporal dimension* the mitigation measures would also be best placed to be designed outside WGMIXFISH, with appropriate knowledge of the relevant factors and data at the right spatial and temporal scale, rather than at the scale of "supra-métiers" currently provided to and used by WGMIXFISH in mixed fisheries forecasts. This is particularly true where catches of the species of concern may not be (fully) recorded in logbooks. Such advice could be incorporated in mixed fisheries advice through additional considerations.

Application of models which best contribute to advice provision for the management measures for vulnerable populations would likely be on a case-by-case basis as part of an impact assessment of the specific measures being proposed, from a mixed-fishery context. That is, being able to assess the likely impacts on catches of other target stocks for the vessels affected given restrictions imposed (spatial/temporal closures, gear or effort regulation) to protect the vulnerable populations of non-target stocks. Current operational models are not suitable for such advice given the scale (finer spatial and/or temporal) at which the management measures are likely to be implemented. Fleet behaviour models to inform where the displaced fishing effort may allocate in future, and therefore likely impact on catches for the fleets, are available (e.g. Bastardie et al 2013; Tidd et al 2012) but are not part of the operational advice approach used by WGMIXFISH (with the difficulties of incorporating in full-scale MSE type evaluation highlighted previously – see Andersen et al 2010). The group considered these models are not currently in a position to be integrated into the macroscale models (i.e. FCube (Ulrich *et al.*, 2011), FLEBEIA (Garcia *et al.*, 2012)) – and therefore at present are more suitable when applied on a case-specific basis with a particular objective in mind rather than as part of a routine advice process.

In the case that the fisheries interaction with the species of concern is more spatially and temporally widespread for particular métiers (and information is available on such catches) the currently available tools may be suitable for application of the 'what-if' type scenarios currently used to provide mixed fisheries advice. For example, to highlight potential foregone yield from fisheries in short-term projections with management measures (e.g. effort limitations) imposed to ensure catches of the vulnerable stock remain at a level advised for the population. Such methods have been under development in the EC project MYFISH and may be applicable to be integrated into the mixed fishery advice process.

One possible first step would be to develop a matrix detailing the strength of interactions between métiers and vulnerable species, and relate this to the potential effort changes under mixed fisheries scenarios.

WGMIXFISH suggests that, as a next step, the appropriate expertise be identified and invited to discuss with the group how this could be made operational within the advice.

Foodweb and ecosystem effects are considered outside the scope of the group but could be considered with further integration of mixed fishery and multispecies/ecosystem models.

4.3 Treatment of Nephrops Functional Units (FUs) in mixed fishery forecasts

Mixed fishery advice provided by ICES for the North Sea (ICES, 2014) concluded that cod, followed by *Nephrops* in Functional Unit 6 (Farn Deeps) would be the most limiting stocks (i.e. those for which quotas would be reached first) for fisheries operating in 2015. This is because for these stocks the largest reduction in fishing mortality and harvest ratio, respectively, is required to achieve their single-stock exploitation targets, and hence the largest reduction in fishing effort in the mixed fisheries.

During the STECF plenary (STECF 14-02; STECF, 2014b) the following statement was recorded:

> "STECF notes that for several stocks the ICES advice sheets make the following statement with regard to mixed fisheries: "*Assuming fishing patterns and catchability in 2014 and 2015 are unchanged from those in 2013, Cod and Nephrops in FU6 are the limiting species for 73% and 27% respectively for the fleets in the North Sea demersal fisheries in 2015*". STECF notes that these results are an artefact of the way the model has been formulated. STECF advises that the percentages given in the above statement are erroneous and should not be used for management purposes."

WGMIXFISH-METH reviewed the issues raised and considered the implications of this statement for future advice formulation. It was considered that this statement could have arisen from four possible sources:

1. *Because, while Nephrops advice is given according to separate functional units, management takes place at the wider North Sea area under a single TAC, and therefore no single FU would cause the fisheries to be limited,*
2. *Because the fleet definitions used by WGMIXFISH cover a broad range of fishing activities, while Nephrops FU6 may be the limiting stock for some of the Scottish otter trawl fleet*

(which represents the bulk of the 23% effort limited by Nephrops FU6), it is not likely to be limiting for the entire fleet (as in the model), as the fleet includes vessels that either do not fish for Nephrops at all, or do not fish in FU6,

3. *Because the mixed fisheries advice was mistranslated to the single-stock advice sheets, or,*
4. *Because the limiting stock for each fleet is the product of past behaviour, which is unlikely to remain constant in future years.*

The following provides a response to each of these points in perceived descending order of importance.

1. *Because, while Nephrops advice is given according to separate functional units, management takes place at the wider North Sea area under a single TAC, and therefore no single FU would cause the fisheries to be limited.*

The issue of how to deal with *Nephrops* in mixed fisheries forecasts has been subject to a number of discussions. At present, *Nephrops* FUs are treated as individual stocks in the same way as finfish stocks, with a target Harvest Ratio consistent with the ICES single-stock advice (following the method adopted by ICES (2009b)). In this way, each FU can potentially limit (or choke) the fishery. In the past two years, landings of *Nephrops* from FU6 (Farn Deeps) have increased considerably (so that they're now 2-3 times higher than advised) and landings of FU7 (Fladen) have decreased (with landings now much lower than advised). A consequence of this is that the *Nephrops* FU6 quota becomes exhausted at a low level of fishing effort, while in practice vessels can continue fishing under the single North Sea *Nephrops* quota.

The group considered there was no "correct" way of treating *Nephrops* in this circumstance. The current approach treats the stocks consistently with the ICES FU advice and reflects the fact that in order to keep within the advised FU limits, fishing effort would require a reduction in the overexploited FU. Assuming fixed effort shares between FUs implies effort overall is required to reduce. Conversely, reflecting current management arrangements (i.e. a single TAC) in the model would allow fishing effort to be much higher – by allowing fisheries to fish the entire North Sea TAC for *Nephrops* irrespective of the catch of individual FUs - but with resultant overexploitation of individual FUs. This highlights the current problem with *Nephrops* where management is not implemented at a level consistent with the advice (i.e. at FU level). It was suggested that at the next advisory meeting in May 2015 the following options could be considered and contrasted:

- The mismatch between the spatial scale of *Nephrops* TAC and *Nephrops* advice is made explicit in the limiting stock statement in the MIXFISH advice.
- *Nephrops* are aggregated into a North Sea wide stock (in terms of TAC) and final year catchability. The projections consider the effort required to take the TAC. Then the landings taken from each FU are calculated using the proportions from the final year data.
- Both of the above.

This would allow comparison of the options and the outcomes for the fisheries-based forecasts to be contrasted.

2. *Because the fleet definitions used by WGMIXFISH cover a broad range of fishing activities, while Nephrops FU6 may be the limiting stock for some of the Scottish otter trawl fleet (which represents the bulk of the 23% effort limited by Nephrops FU6), it is not likely to be limiting for the entire fleet (as in the model), as the fleet includes vessels that either do not fish for Nephrops at all, or do not fish in FU6:*

Defining fleets appropriately in mixed fisheries forecasts is an ongoing iterative process, which strikes a balance between having the right amount of contrast to capture the major differences between the fleets and having each vessel represented individually (which is infeasible given available data). Inevitably vessels will need to be aggregated to some level, and in the process of such aggregation there will be an averaging of vessel characteristics. The Scottish otter trawl fleet is a good example of this issue as, while there are vessels that use both TR1 gear (large mesh otter trawls targeting whitefish) and TR2 gear (small mesh otter trawls targeting *Nephrops*) there are also vessels that use only one or the other.

Table 4.3.1 shows the effort and catch by Scottish otter trawl fleets in 2013 as represented in the North Sea FCube model, while Figure 4.3.1 shows the effort share among métiers. As can be seen, the >=24m fleet largely prosecutes a whitefish fishery with most effort in TR1. However, the <24m fleet is much more evenly split between the *Nephrops* fishery (TR2; 67 % of effort) and a whitefish fishery (TR1; 33 % of effort).

Table 4.3.1. Effort and catch by Scottish Otter trawl fleets in 2013 represented in the North Sea mixed fisheries advice

FLEET	MÉTIER	EFFORT	CATCH
SC_Otter<24	OTH	2	2
	TR1.4	2 291	12 218
	TR2.4	4 570	14 479
SC_Otter>=24	OTH	146	50
	TR1.4	4 364	27 832
	TR2.4	638	1 279

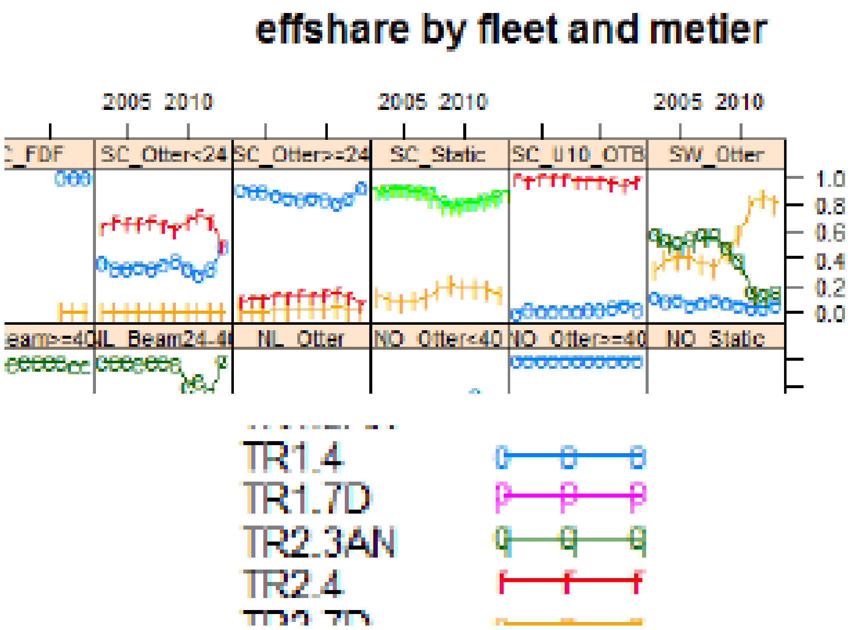

Figure 4.3.1. Effort share between métiers for the Scottish otter trawl fleets.

Examining the <24m fleet more closely (Table 4.3.2 – data provided by Marine Scotland Science) indicates that approximately 17 % of vessels use only TR1 gear, 47 % use only TR2 gear, while 36 % use both.

Table 4.3.2. Gear switching between Scottish vessels < 24m length

	Gear use	Permitted
TR1	40	57
TR2	111	139
TR1 TR2	86	44
BT2 TR2	1	0
TR1 TR3	1	0
TR2 TR3	1	0
	240	240

A possible solution to better characterize this fleet in the short term may therefore be to consider Scottish <24m otter trawls as three separate fleets: a whitefish fleet, a Nephrops fleet and a mixed whitefish/Nephrops fleet. Such a change could be implemented – but would require a change to the way in which data are submitted to WGMIXFISH.

A more long-term solution to the problem would be to better align the economic data call (for the STECF Annual Economic Report; STECF, 2014c) with the biological data. This would allow a greater ability to map individual vessels to their activity in terms of gear use and catches of species. If in answering biological data calls data can be linked to individual vessels then a completely accurate linking of economic and biological variables should be possible, allowing better characterization of the fleets. An STECF workshop has been convened in Zagreb, Croatia 19—23 January 2015 to look at this issue with WGMIXFISH members in attendance. The outcome and conclusions from that meeting will therefore be of interest to the future work of the group.

3. *Because the mixed fisheries advice was mistranslated to the single-stock advice sheets:*

Where it said "*the limiting species for 73% and 27% respectively for the fleets in the North Sea demersal fisheries...*" it should in fact have said (as per the mixed fisheries advice sheet) "*for fleets representing 73% and 27%* ***of the effort in 2013*** *respectively*". The subtle difference in wording clarifies the fact that it is in fact only a small number of fleets (primarily UK otter trawl fleets) that are limited by *Nephrops* FU6 – but that they represent a large share of the overall effort - and not a large number of the fleets in the model.

4. *Because the limiting stock for each fleet is the product of past behaviour, which is unlikely to remain constant in future years:*

While true that the assumptions of constant catchability, effort share between métiers and quota share in the model determine – to a significant degree – the limiting quotas for the fisheries in the following year, the advice is intended to characterize and quantify the likely consequences of such constant behaviour given single-stock management advice. Clearly a simplifying assumption, but in the absence of an operational fleet behavioural model (which may be able to predict changes in the fleets behaviour in response to management measures) it is a necessary simplification and for this reason the advice is provided in the form of scenarios rather than catch advice. Such an assumption is likely to continue to be the basis for the advice in the short to medium term, until such a time a validated operational effort allocation model is available.

5 Conclusions and Recommendations

The working group met 20—24 October in London and progressed three key issues:

Medium term projections for North Sea demersal mixed fisheries were performed in a Management Strategy Evaluation (MSE) framework as part of development of the FCube methodology. Such an approach is likely to play an important role in supporting evaluations under the new CFP; where there is a requirement to implement regional multiannual management plans (MAPs) which take account of mixed fisheries interactions. Further work is likely to be progressed in the coming months, given the imperative policy driver.

The FCube short-term forecasting methodology was successfully applied to the Celtic Sea gadoid (cod, haddock and whiting) fisheries, and extended to include Sole VIIfg. It was considered that this could form the basis of operational mixed fisheries advice for the region in future years. However, further steps were also identified to develop its application. These include providing more disaggregated fleet data in response to the WGCSE-WGMIXFISH data call, considering what further stocks can/should be incorporated in forecasts and identifying the most appropriate timing for delivery of advice given the October release date for *Nephrops* advice for the ecoregion.

A workshop held jointly with WGSAM furthered mutual understanding of the groups work and identified areas where it would be beneficial to work more closely in future, as part of developing integrated ecosystem advice which takes account of both multi-species (biological) and mixed fishery (technical) interactions.

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Annex 2: Recommendations

Recommendation	For follow up by:
WGMIXFISH-METH consider it would be possible to provide mixed fisheries advice for the Celtic Sea gadoid fisheries (cod, haddock and whiting) based on successful trial application. This could be done following WGCSE in May/June (during the WGMIXFISH-ADVICE meeting) but to incorporate advice on *Nephrops* would require waiting until after the October Celtic Sea *Nephrops* stocks advice is released. ACOM should advise on when advice should be produced, i. Including only the finfish stocks with a June release date ii. Including finfish stocks and *Nephrops* stocks based on the most recent available abundance estimates with a June release date, with the potential for updated advice in October with the new *Nephrops* survey information [group preference]*, or;* iii. Including both finfish and *Nephrops* stocks only in October.	ACOM
Revise WGCSE –WGMIXFISH datacall so as to make clear: - The importance of supplying area-disaggregated catch data to InterCatch and WGMIXFISH in a consistent manner. Where possible, areas should not be reported in an aggregated form but area by area. If area aggregations must be made they should not be beyond the assessment area of individual stocks. - Reporting of data within the MIS-MIS Intercatch métier should be minimized, as it hinders the ability to effectively model the fishery interactions. - Submission of dominant métiers should be minimized / eliminated, especially in relation to mesh size ranges distinguishing between 70-99mm and ≥100mm in particular.	WGCSE/WGMIXFISH
The WGMIXFISH-METH group would like to request guidance from WGCSE as to the priority of stocks for inclusion into the FCube mixed fisheries assessment.	WGCSE
Provide, when possible, output data from the final assessment in an .RData format directly to WGMIXFISH Chair.	WGNSSK/WGCSE
Take note of WGMIXFISH comments on 'possible future ToR on inclusion of vulnerable/bycatch advice in mixed fisheries' in WGMIXFISH-METH report (2014)	ACOM
Consider comparison of alternative approaches to dealing with *Nephrops* Functional Unit managment advice in mixed fisheries forecasts.	WGMIXFISH-ADVICE
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	WGMIXFISH, WGSAM

Annex 3: Proposed ToR for 2015 WGMIXFISH Meetings

WGMIXFISH-ADVICE – Working Group on Mixed Fisheries Advice

2014/#/ACOM## The **Working Group on Mixed Fisheries Advice** (WGMIXFISH-ADVICE), chaired by Paul Dolder, UK, will meet at ICES Headquarters, 25–29 May.

a) Carry out mixed demersal fisheries projections for the North Sea taking into account the single species advice for cod, haddock, whiting, saithe, plaice, sole, turbot, *Nephrops norvegicus*, sole VIId and plaice VIId that is produced by WGNSSK in XXXX 2015, and the management measures in place for 2016;

b) Carry out mixed demersal fisheries projections for the Celtic Sea taking into account the single species advice for cod, haddock, whiting and sole 7fg that is produced by WGCSE in XXXX 2015, and the management measures in place for 2016; and further develop advice for the region. In particular, it should consider how advice released for *Nephrops norvegicus* issued in October could be taken into account in mixed fisheries projections;

c) Carry out mixed fisheries projections for the Iberian waters taking into account the single species advice for hake, four-spot megrim megrim and white anglerfish that is produced by WGBIE in XXXX 2015, and the management measures in place for 2016; and further develop advice for the region. In particular, how advice for Horse mackerel produced by WGHANSA meeting in XXXX 2015 can be incorporated into the mixed fishery forecasts;

Produce a draft mixed-fisheries section for the ICES advisory report 2015 that includes a dissemination of the fleet and fisheries data and forecasts for the North Sea, [and where possible the Celtic Sea and Iberian waters];

WGMIXFISH will report by ## ### 2015 for the attention of ACOM.

Supporting Information

Priority:	The work is essential to ICES to progress in the development of its capacity to provide advice on multispecies fisheries. Such advice is necessary to fulfil the requirements stipulated in the MoUs between ICES and its client commissions.
Scientific justification and relation to action plan:	The issue of providing advice for mixed fisheries remains an important one for ICES. The Aframe project, which started on 1 April 2007 and finished on 31 March 2009 developed further methodologies for mixed fisheries forecasts. The work under this project included the development and testing of the Fcube approach to modelling and forecasts. In 2008, SGMIXMAN produced an outline of a possible advisory format that included mixed fisheries forecasts. Subsequently, WKMIXFISH was tasked with investigating the application of this to North Sea advice for 2010. AGMIXNS further developed the approach when it met in November 2009 and produced a draft template for mixed fisheries advice. WGMIXFISH has continued this work since 2010.
Resource requirements:	No specific resource requirements, beyond the need for members to prepare for and participate in the meeting.
Participants:	Experts with qualifications regarding mixed fisheries aspects, fisheries management and modelling based on limited and uncertain data.
Secretariat facilities:	Meeting facilities, production of report.
Financial:	None

Linkages to advisory committee:	ACOM
Linkages to other committees or groups:	SCICOM through the WGMG. Strong link to STECF.
Linkages to other organizations:	This work serves as a mechanism in fulfilment of the MoU with EC and fisheries commissions. It is also linked with STECF work on mixed fisheries.

WGMIXFISH-METH – Working Group on Mixed Fisheries Advice Methodology

2014/X/ACOMXX The Working Group on Mixed Fisheries Advice Methodology (WGMIXFISH-METH), chaired by Paul Dolder, UK, will meet in London, 19—23 October 2015 to:

a) Review progress on mixed fisheries methodologies and consider how they might be taken forward and incorporated into the advisory process. In particular, focus should be given to the following priorities:
   a) Short-term catch forecasting methods, including methods to incorporate data-poor stocks taking account of uncertainties;
   b) Incorporation of advice on protected, endangered and threatened (PET) species into mixed fisheries advice;
   c) Incorporation of F_{msy} ranges into forecasting procedure to provide advice which minimizes incompatibility between management advice for multiple stocks exploited in mixed fisheries. This may be developed through robust medium term Management Strategy Evaluation approaches,
   d) Application of methodology to other ICES regions, fisheries and stocks.
b) Undertake a Principle Components Analysis (PCA) on the MIXFISH métier data used in North Sea mixed fishery forecasts to inform a minimum fleet aggregation for use in ecosystem models

WGMIXFISH-METH will report by XX November 2015 for the attention of ACOM.

Supporting Information

Priority:	The work is essential to ICES to progress in the development of its capacity to provide advice on multispecies fisheries. Such advice is necessary to fulfil the requirements stipulated in the MoUs between ICES and its client commissions.
Scientific justification and relation to action plan:	The issue of providing advice for mixed fisheries remains an important one for ICES. However, in practice all recent advice in this area has resulted from the work and analyses done by subgroups of STECF rather than ICES. The Aframe project, which started on 1 April 2007 and finished on 31 March 2009 developed further methodologies for mixed fisheries forecasts. The work under this project included the development and testing of the Fcube approach to modelling and forecasts. In 2008, SGMIXMAN produced an outline of a possible advisory format that included mixed fisheries forecasts. Subsequently, WKMIXFISH was tasked with investigating the application of this to North Sea advice for 2010. AGMIXNS further developed the approach when it met in November 2009 and produced a draft template for mixed fisheries advice. WGMIXFISH has continued this work in 2010 to 2012.
Resource requirements:	No specific resource requirements, beyond the need for members to prepare for and participate in the meeting.
Participants:	Experts with qualifications regarding mixed fisheries aspects, fisheries management and modelling based on limited and uncertain data.
Secretariat facilities:	Meeting facilities, production of report.
Financial:	None
Linkages to advisory committee:	ACOM
Linkages to other committees or groups:	SCICOM through the WGMG. Strong link to STECF.
Linkages to other organizations:	This work serves as a mechanism in fulfilment of the MoU with EC and fisheries commissions. It is also linked with STECF work on mixed fisheries.

Annex 4: WD on application of FCube to the Celtic Sea gadoid fisheries

WD: Celtic Sea mixed fishery analysis using FCube

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Summary

This working document outlines the successful application of the FCube methodology to the mixed gadoid fisheries in the Celtic Sea. The model is seen as a first step in developing an approach for providing short-term advice on the consequences of technical interactions in Celtic Sea demersal fisheries. Mixed fishery forecasts are performed for cod, haddock and whiting based on the scenarios used in the North Sea advice (excepting the effort management scenario). These are:

- *min:* Fishing stops when the catch for any one of the stocks considered meets the single-stock advice. This option is the most precautionary option, causing under-utilisation of the single-stock advice possibilities of other stocks.
- *max:* Fishing stops when all stocks considered have been caught up to the ICES single-stock advice. This option causes overfishing of the single-stock advice possibilities of most stocks.
- *stock:* All fleets set their effort corresponding to that required to land their quota share of the named stock, regardless of other catches.
- *status quo effort:* The effort is set equal to the effort in the most recently recorded year for which landings and discard data are available.

The mixed fishery scenarios indicate that there is inconsistency between the fishing opportunities for cod and haddock on the one hand, and whiting on the other. This suggests efforts are required to provide consistency between exploitation patterns for the gadoid stocks caught in the mixed fishery - through better alignment of fishing opportunities and/or techncial measures which decouple cod and haddock catches from catches of whiting. Industry reports of large incoming cod and haddock recruitments, which appear to be supported by observations in scientific surveys, indicate the need for such measures in the immediate future.

The mixed fisheries in the Celtic Sea are complex and driven by a number of roundfish (cod, haddock, whiting, hake, pollack, anglerfishes), benthic flatfish (sole, plaice, turbot, megrims) and invertebrates (*Nephrops*, cuttlefish, squid). This document demonstrates the successful application of the FCube methodology to the gadoid fisheries. However, further consideration should be given to incorporation of further economically important stocks which drive the dynamics of the fisheries, in order to more accurately represent the fishery dynamics and full range of technical interactions. The approach outlined here should be considered a first step in meeting the advisory needs for mixed fisheries in the Celtic Sea, as part of a progressive development of the advice framework in accordance with the ICES mixed fishery and multispecies advice strategy.

1 Introduction

The ICES strategy for Mixed Fisheries and Multi-species advice (ICES, 2013) envisages further development of methods for the provision of advice on technical interactions, including extension to the Bay of Biscay-Iberian and Celtic Seas fisheries the next few years. Such advice is required to meet the needs under the new Common Fisheries Policy (CFP) for regional based multi-stock management plans, allowing account to be taken of both technical and biological interactions between fisheries and stocks. For mixed fisheries, the European Commission has requested the advice to include, inter alia:

- quantification of catches and discards (where relevant) at a sufficiently detailed level to support analysis of technological interactions between the main demersal fisheries;
- development of mixed-fisheries TAC advice, where annual TAC advice is provided that is consistent with conforming to the MSY framework for all species in the mixed fisheries, taking account of plausible ranges in the choice of MSY targets;
- development of multiannual plans with harvest rules governing the setting of TACs for the species in a mixed fishery and (where appropriate) effort levels for the relevant gear types.

A lack of métier-disaggregated catch and effort data has limited the development of mixed fisheries approaches in the Celtic Seas. However, the increasing use of the ICES Intercatch for the provision of biological and catch data to assessment working groups, and inclusion of a request for métier-disaggregated catch and effort data through the joint WGCSE-WGMIXFISH data call provides an opportunity to develop application of advisory methods to the ecoregion. In 2014, all stocks assessed by the Celtic Sea working group included data provided through Intercatch (WGCSE, 2014a), and complimentary métier-disaggregated data was also provided to WGMIXFISH.

The Fleet and Fishery Forecasting method "FCube" (Ulrich *et al*, 2011) has been used to provide advice on the potential catches of the main commercial fish stocks in the North Sea mixed demersal fisheries since 2012 (ICES, 2012). The main objective of the modelling approach is to provide information on potential 'choke' stocks in the fisheries, given the range of quota and effort limitations, management measures and past observed characteristics of the fisheries (with respect to the distribution of effort between fisheries, catchabilities within the different fisheries and recent discarding patterns etc.). Its development has been progressive, with further stocks and fisheries included as analytical assessment outputs have become available, while further work is ongoing to include 'data-poor' stocks.

As a first step towards mixed fisheries advice for the Celtic Sea, this document sets out the application of the FCube methodology to the main demersal gadoid fisheries in the region. As these stocks all have analytical assessments, it was considered these were the most suitable initial candidates for the provision of mixed fisheries advice, but in time this should extend to further stocks given the highly mixed nature of the fisheries. Further, it is noted that mixed fishery approaches are being developed elsewhere, in particular through the EC LOT1 project DAMARA (MARE/2012/22), using the FLBEIA framework (Garcia *et al* 2012) and such approches may compliment or be substituted for the approach outlined here. Future work should therefore include comparison of the different available approaches to identify the suitability of the methods for meeting different advisory objectives (i.e. short term advice, long-term management strategy evaluation etc..), as part of the general development of mixed fisheries advice.

1.1 *Celtic Sea fisheries*

The Celtic Seas ecoregion encompasses ICES divisions VIa (West of Scotland), VIIa (Irish Sea) and the inner (VIIfg) and wider (+VIIbc,hjk) Celtic Sea as well as the western english channel (VIIe) (Figure 1). Fisheries in the Celtic Sea are highly mixed, targetting a range of species with different gears. Otter trawl fisheries take place for mixed gadoids (cod, haddock, whiting), *Nephrops*, hake, anglerfishes, megrims as well as cephlopods (cuttlefish and squid). Beam trawl fisheries target flatfish (plaice, sole, turbot), anglerfishes, megrims and cephalapods (cuttlefish and squid) while net fisheries target flatfish, hake, pollack, anglerfishes as well as some crustacean species. The fisheries are mainly prosecuted by French, Irish and English vessels though Belgian beam traw fisheries target flatfish (in VIIe and VIIfg) while Spanish trawl and net fisheries target hake along the shelf edge (VIIhjk).

Fishing effort for the main gears (otter trawlers, beam trawlers) has been relatively stable over the past ten years, though there has been an increase in otter trawl effort since 2009 (STECF, 2014), particularly for the large mesh trawlers (>100 mm). Unlike other parts of the Celtic Seas (VIa, VIIa) and the North Sea and eastern english channel (IV and VIId) the Celtic Sea is not subject to effort control measures under the long-term management plan for cod (excepting beam trawlers and gillnetters in VIIe as part of the western channel sole management plan), and so the increase in effort may be due to limiting effort regulation in other areas.

The mixed gadoid fishery predominately takes place in ICES areas VIIf and VIIg with these areas responsible for >75% of the landings of each of cod, haddock and whiting (Figures 6-8). Catch Per Unit effort for these stocks is much higher than in the wider Celtic Sea (STECF, 2013), which may reflect higher abundance and/or increased targetting in these areas. Landings are predominately by French and Irish vessels, though UK vessels also take signficant landings.

Recent years have seen large but sporadic recruitment for the gadoid stocks (see section 2.1) and high levels of exploitation which has resulted in signficant fluctuations in the stocks. Incompatibilities between the quota available has resulted in regulatory discarding as well as high-grading in the mixed fisheries, creating significant challenges in managing the exploitation of the stocks and leading to the introduction of a number of technical gear measures designed to reduce discarding of under size and overquota fish. Understanding the strength of technical interactions and likely 'choke' stocks will therefore support design of management measures which provide greater consistency between quotas for the different stocks exploited in the mixed fishery. Industry reports of large incoming cod and haddock recruitments, which appear to be supported by observations in scientific surveys, indicate the need for such measures in the immediate future.

2 Data

The following section describes the input data used for the mixed fishery forecasts. This includes a description of the assessment outputs from WGCSE (ICES, 2014a), including stock trends and a description of the fleet and métier catch and effort data.

2.1 *Stock data*

The following stocks were included in the Celtic Sea FCube model:

- Cod: ICES divisions VIIe-k
- Haddock: ICES divisions VIIb-k
- Whiting: ICES divisions VIIbc,e-k

Each of the stocks is assessed annually by the ICES assessment working group on the Celtic Sea ecoregion (WGCSE, 2014a) and currently have full-analytical assessments with quantitative advice (the extent of the assessment are summarised in Table 1). There are currently no management plans in place for the stocks, and so in keeping with its advisory approach ICES provides single stock catch advice according to the ICES MSY approach.

The following section briefly summarises the status of the stocks.

2.1.1 *Cod VIIe-k*

The cod stock has increased recently on the back of a very strong 2010 year-class, but poor recruitment and increased exploitation has resulted in the stock declining in the most recent year (Figure 2). Fishing mortality is currently above the Fmsy target, having increased from the lowest level in 30 years in 2011.

2.1.2 *Haddock VIIb-k*

The 2009 haddock year-class was the highest in the time-series, and consequently the stock increased rapidly in 2011 before declining to levels typically seen over the time-series (Figure 3). The 2013 year-class is also estimated to be strong, at around half the level of that in 2009, and expected to contribute signficantly to the spawning stock in 2015. Fishing mortality has been above the Fmsy value over the entire length of the time-series, and has increased sharply in recent years - currently being three-times the MSY exploitation rate.

2.1.3 *Whiting VIIbc,e-k*

Whiting in the Celtic Seas has a relatively short assessment time-series. In contrast to cod and haddock, whiting has had a relatively low exploitation rate in recent years, being below Fmsy since 2011, and SSB has increased since 2008 before leveling off in the past two years (Figure 4). The 2013 year class is estimated to be strong, being the second highest in the time-series.

2.1.4 *Assessment and forecast methods:*

The FCube methodology builds on single stock assessment outputs, combining the results with information on catches and effort by the fisheries to forecast future catch based on fishing effort and catchability (or exploitation per unit of effort) for each of the stocks, in a single consistent framework. A prerequisite of this approach is available an assessment output in order to inform the analysis. Cod, haddock and whiting all have age-based analytical assessments (summary in Table 1) that can be incorporated in the standard forecasting procedures used by the FCube methodology and code (developed in the Fisheries Library in R software (Kell *et al*, 2007)).

2.1.5 *Single Stock advice*

ICES advice for cod, haddock and whiting is provided in accordance with the ICES MSY approach framework (ICES, 2014a). As such, advice is provided to achieve the exploitation rate associated with the maximum sustainable yield (MSY), or where the spawning stock size (SSB) is estimated to be below the MSY Btrigger in the year of the application of the TAC, according to an exploitation rate reduced on a sliding scale between Fmsy at the stock size Bmsy trigger and zero at some level below Blim. The 2015 TAC advice for cod, haddock and whiting and the basis for it are summarised in Table 2.

Table 1. Single species forecast and assessment methods

stock	assessment	forecast
COD-CS	Age-based analytical assessment (FLR 2.x XSA)	FLR STF
HAD-CS	ASAP (Age-Structured Assessment Programme; NOAA toolbox)	MFDP1a
WHG-CS	Age-based analytical assessment (XSA)	MFDP1a

Table 2. ICES single stock advice for cod VIIe-k, haddock VIIb-k and whiting VIIbc,e-k in 2015

stock	Rationale	Cat	Lan	Dis	Basis	FCat	FLan	FDis	SSB	SSB.Chg	TAC.Chg
cod VIIe-k	MSY approach		4024		Fmsy * SSB2015 / MSYBtrigger		0.37		10687	+13%	-41%
haddock VIIb-k	MSY approach	10434	5605	4829	Fmsy	0.33	0.3	0.03	37251	+13%	-41%
whiting VIIbc,e-k	MSY approach	18501	14230	4271	Fmsy	0.32	0.26	0.06	77208	-4%	

2.2 *Fleet data*

2.2.1 *Catch and effort data*

The joint WGCSE-MIXFISH data call requested métier-based biological, catch and effort data according to Data Collection Framework level 6 defintions for the first time in 2014, covering the year 2013. As part of that data call, vessel length-disaggregated landings and effort data were also requested, and received from Belgium, France, Ireland, United Kingdom (England and Wales) and United Kingdom (Northern Ireland). Vessek length-disaggregated data were not available from Spain or United Kingdom (Scotland), but as these contribute to only a small part of the overall landings of the gadoid stocks, it was not considered a hinderence to developing the approach outlined here.

The data were treated much the same as in developing the North Sea mixed fisheries advice and the detailed approach taken can be reviewed in ICES (2014b). Briefly: discards for the vessel length-disaggregated data are first raised by applying the landings to discards ratio from the Intercatch data (which was not disaggregated by vessel length, but included estimated discards raised by individual stock coordinators within WGCSE). That is;

$$D_{m,l,a} = L_{m,l,a} * (D_{m,a} / L_{m,a})$$

Where $D_{m,l,a}$ are the discards estimated for metier m at length l in area a, and $L_{m,a}$ and $D_{m,a}$ are the landings and discards respectively, across all vessel lengths within the area (provided by the Intercatch data).

Secondly, a check for consistency between the vessel length disaggregated data and the stock assessment data in undertaken by comparing the sum of the landings and the sum of the discards in the métier-based data and the landings and discards from the assessment. As can be seen in Table 4, the data were consistent with 96 - 100 % of the stock landings in the métier-based data, while the data covered 78 - 96 % of the discards. Some of the difference is catch is likely to be due to the lack of Spanish and Scottish métier-based data. To ensure consistency in the FCube forecasts the difference between the métier-derived catch and stock assessment derived catch were pooled into an "others" fleet representing any catch not explictly included in the fleets.

As the DCF level 6 métier definitions are at a level of disaggregation not needed for the FCube mixed fishery analysis, the métiers landings, discards and effort were then aggregated into the broader métier definitions used by STECF, and deriving from the cod long-term management plan (TR1, TR2, BT1 etc. . .), However, an area definition was retained in the métier classification so that activity within ICES areas VIIbc, VIIe, VIIfg and VIIhjk were treated seperately.

Finally, any fleets that were found to land <1% of any of the stocks in the analysis they were pooled in an "others" fleet (denoted OTH_OTH), while any métier that accounted for <1% of the fleets landings of any stock were also pooled into an "others" métier ("OTH"). Fleets that had effort and not landings of any of the stocks included in the analysis were removed.

2.2.2 *Fleet and métier defintions*

Following the processing steps described above, the final model included the following fleets and métiers:

Fleets

- Belgian:
  - Beam trawlers 24<40m
- English:
  - Beamtrawlers <24<40m
  - Otter trawlers 10<12m, 12<18m and 18<24m
  - Static gears <10m, 12<18m and 18<24m
- French:

  - Otter trawlers 10<24m and 24<40m
  - Other gears 10<24m and 24<40m
- Irish:
  - Beam trawlers 24<40m
  - Otter trawlers 10<24m, 24<40m and all other lengths
  - Static gears all lengths
  - Other gears all lengths
- Northern Irish:
  - Otter trawlers 24<40m
- Others:
  - All other countries, gears and vessel sizes

Métiers:

- TR1: Otter trawlers with a mesh size >100mm
  - VIIbc, VIIe, VIIfg, VIIhjk
- TR2: Otter trawlers with a mesh size of 70-99mm
  - VIIbc, VIIe, VIIfg, VIIhjk

- BT2: Beam trawlers with a mesh size of <120mm
  - VIIe, VIIfg, VIIhjk
- GN1: Gillnets all mesh sizes
  - VIIbc, VIIe, VIIfg, VIIhjk
- GT1: Trammel nets all mesh sizes
  - VIIe, VIIfg, VIIhjk
- LL1: Longlines all mesh sizes
  - VIIe
- OTH: All other gears
  - VIIe, VIIfg, VIIhjk

3 Model set-up

3.1 *Software*

All analysis undertaken in R 2.15.1 (R Core team, 2014) and FLR 2.5.0 (Kell *et al*, 2007), using FLCore 2.5.0, FLXSA 2.5.0 and FLash 2.5.0 as well as adapting code developed by Ulrich et al (2011).

3.2 *Forecast settings*

This section describes the forecast procedures used in projecting the stocks, as well as the procedures in developing FCube baseline runs against which the mixed fisheries scenarios are compared.

3.2.1 Stock forecast setting

The FCube model allows comparison between forecasts of catch based on different assumptions of fishing activity (i.e. effort) by fleets and métiers. As such, it is important to first compare the ability of the software to replicate the single stock advice so that the mixed fishery scenarios are comparable to the ICES TAC advice. As a first step, we ensured that the stock forecast settings used in the FCube analysis were the same as those used in the single stock advice, and that the same or similar landings, catch, fishing mortality and ssb estimates could be replicated using the single FLR framework.

Further input parameters included the Biological Reference Points (BRPs) for the stocks (as detailed in the single stock advice, and summarised in Table 5). The 2014 TACs (Table 6) were also used as input parameters to limit the allowed landings in the FCube model runs and classify landings proportions into legal-landings and over-quota landings. For whiting, as the TAC area (VIIb-k) includes part of the North Sea stock of whiting (ICES area VIId), an adjustment was made to the quota in VIIb-k in accordance with the proportion of the catch which is considered to derive from the North Sea stock (20% of the total IV and VIId landings are considered to derive from VIId, and so this value was similarly used here).

Tables 7, 8 and 9 summarise the input parameters to the stock forecasts, which were collated from the WGCSE report (ICES, 2014a), and their basis. Recruitment, stock and catch weights-at-age and selectivity patterns were set to the setting used for the single stock advice.

3.2.2 FCube baseline forecast settings

Rather than running the mixed-fishery scenarios for two consecutive years (intermediate and TAC years), we applied a status quo effort assumption in the intermediate year, with the mixed-fishery scenarios operating in the TAC year only. This assumption is closer to the single stock forecast assumption, and the trends observed in the fisheries in recent years, and so was considered to be more appropriate.

3.3 *FCube runs*

A full description of the FCube methodology is provided in Ulrich *et al* (2011) and ICES (2014b) and so is not repeated here. In keeping with the North Sea advice, as a first step in developing an approach for the Celtic Sea we run the following FCube scenarios:

- *min:* Fishing stops when the catch for any one of the stocks considered meets the single-stock advice. This option is the most precautionary option, causing under-utilisation of the single-stock advice possibilities of other stocks.
- *max:* Fishing stops when all stocks considered have been caught up to the ICES single-stock advice. This option causes overfishing of the single-stock advice possibilities of most stocks.
- *stock:* All fleets set their effort corresponding to that required to land their quota share of the named stock, regardless of other catches.
- *status quo effort (sq_E):* The effort is set equal to the effort in the most recently recorded year for which landings and discard data are available.

As only three stocks were included in the model, it was decided to run the stock-limited scenario for each of the stocks: cod (cod-cs), haddock (had-cs) and whiting (whg-cs). The effort management scenario undertaken for the North Sea was not considered as the effort regulation does not apply to the Celtic Sea.

4 Results

4.1 *Consistency with single species advice*

Table 10 compares the single stock forecasts of landings, catch, fishing mortality and SSB in 2014 (the intermediate year) and 2015 (the TAC year) as well as the SSB forecasts in 2016 (TAC year+1). In general, the forecasts were very consistent with the single stock advice. Small differences in catch for cod (-1%/-30 t in 2014 and -1%/ -38t in 2015), and the ratio of discards to landings for whiting (-5%/116 t discards and +2%/+223 t landings in 2014 and -4%/151 t discards and +2%/341 t landings in 2015) were not considered to have signficantly affected the analysis.

4.2 *FCube runs*

4.2.1 *Intermediate year analysis*

The intermediate year assumption of status quo effort used in the FCube run results in a slightly higher forecast for fishing mortality than the single stock advice (Table 13). This is because the cod, haddock and whiting single stock advice all assume F in 2014 is an arithmetic (unscaled) mean F over the period 2011 - 2013, and as F has been increasing over this period, the resultant F from status quo effort would be higher (being equivilent to the most recent data years F, 2013). Consequently, landings (and catch) in the intermediate year are forecast to be higher than in the single stock advice. However, landings are still forecast to be below the TAC for each of the stocks (Figure 11, top panel). This suggests a conservative intermediate year F assumption has been used in the single stock advice, given trends in recent effort in the fisheries and so the assumption of status quo effort is a plausible alternative.

A consequence of the status quo effort assumption in the FCube intermediate year projection is that catches of cod are higher, and consequently SSB is projected to be lower in the TAC year. As the ICES MSY approach harvest rule is dependent on the SSB at the start of the year of the application of the TAC (i.e. 2015), the cod F target for that year is revised to 0.34 (Table 16), resulting in a lower TAC advice (Table 17: 3525 t, compared to 3986 t in the FCube baseline run).

4.2.2 *TAC year analysis*

The TAC year landings under the mixed fisheries scenarios are summarised in Figure 11, with the forecast fishing effort by fleet in Figure 12 and the SSB in 2016 relative to the baseline in Figure 13.

The **'max'** scenario results in over-quota landings of both cod (2006 t overshoot, total landings = 6030 t) and haddock (6922 t overshoot, 12527 t total landings) - Figure 11, Table 20. This is a consequence of whiting being the least restrictive quota in 2015 for all fleets, and as the assumption in the scenario is for effort to be set according to the least restrictive stock (Figure 12), there is a resultant increase in fishing effort on 2013. The fishing effort under this scenario is higher than that required to catch either the cod or haddock quotas.

Under this scenario fishing mortality is forecast to be at Fmsy for whiting, but well above for cod (F=0.66) and above Flim for haddock (F=1.05), and therefore not considered precautionary - Table 16.

The haddock SSB is forecast to be little over half that forecast by the single stock advice in 2016, while the cod SSB is forecast to be around 70% of the single stock advice (Figure 13).

Under the **min** scenario, all the single stock TACs are forecast to be undershot in 2015, with cod landings forecast at 1766 t below the TAC advice, haddock landings at 416 t below the TAC advice and whiting landings at 9185 t below the TAC advice (Table 20). The least limiting stock for all fleets is haddock (as can be seen from the fact that the 'had-cs' and 'min' scenario are the same). Under this scenario fishing effort is forecast at less than half the level in 2013 for each of the fleets (Figure 12). The reason the TAC for haddock is not reached under this scenario, despite it being the least limiting stock for all fleets, is because the higher intermediate year fishing mortality results in a lower stock size in 2015, and consequently results in lower catches for the same F in 2015. Further, SSB is still forecast to be below the single stock advice in 2016 under this scenario (Figure 13).

Fishing mortality for cod is forecast to be below Fmsy for cod (F=0.21) and whiting (F=0.1) but consistent with Fmsy for haddock (F=0.33) - Table 16.

The **sq_E** scenario results in overshoots of both the cod (overshoot = 1213 t, total landings = 5237 t) and haddock (overshoot = 5521 t, total landings = 11126 t), while there is an undershoot of the whiting TAC (-1936 t).

Fishing mortality is estimated to be above Fmsy for cod (F=0.55), above Fmsy and Flim for haddock (F=0.88) but below Fmsy for whiting (F=0.27) - Table 16. Due to the higher exploitation rates, SSB is forecast at below the single stock advice level in 2016 for both cod and haddock, while being slightly higher than the single stock advice for whiting (Figure 13).

5 Conclusions and recommendations

This paper documents a successful application of the FCube methodology to the mixed gadoid fisheries of the Celtic Sea. The results show there is significant conflict between the advised single stock catch limits for cod and haddock on the one hand, and whiting on the other. This suggests efforts are required to provide consistency between exploitation patterns for the gadoid stocks caught in a mixed fishery - either through better alignment of fishing opportunities and/or techncial measures which decouple cod and haddock catches from catches of whiting.

The mixed fisheries in the Celtic Sea are complex and target a number of roundfish (cod, haddock, whiting, hake, pollack, anglerfishes), benthic flatfish (sole, plaice, turbot, megrims) and invertebrates (*Nephrops*, cuttlefish, squid). This working document illustrates the successful application of the FCube methodology to the Celtic Sea fisheries considering the main gadoid stocks only; further consideration should be given to incorporation of economically important stocks which drive the dynamics of the fisheries in order to more accurately represent the fishery dynamics and full range of technical interactions. Nevertheless, this is a first step in meeting the advisory needs for mixed fisheries in the Celtic Sea, in accordance with the ICES mixed fishery and multispecies advice strategy.

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7 Annex

Figures:

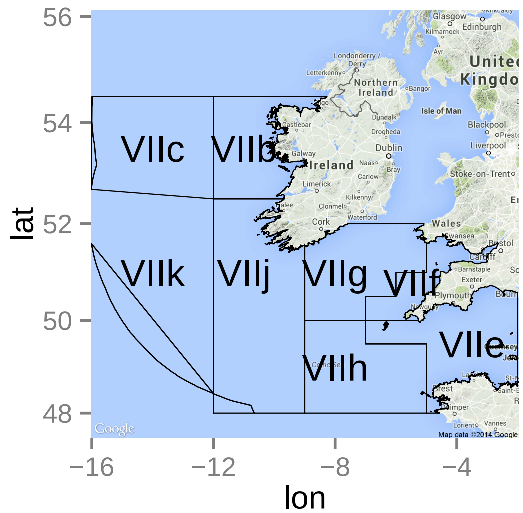

Figure 1: Map showing the inner (VIIfg) and wider (+VIIbc,e,hjk) Celtic Sea

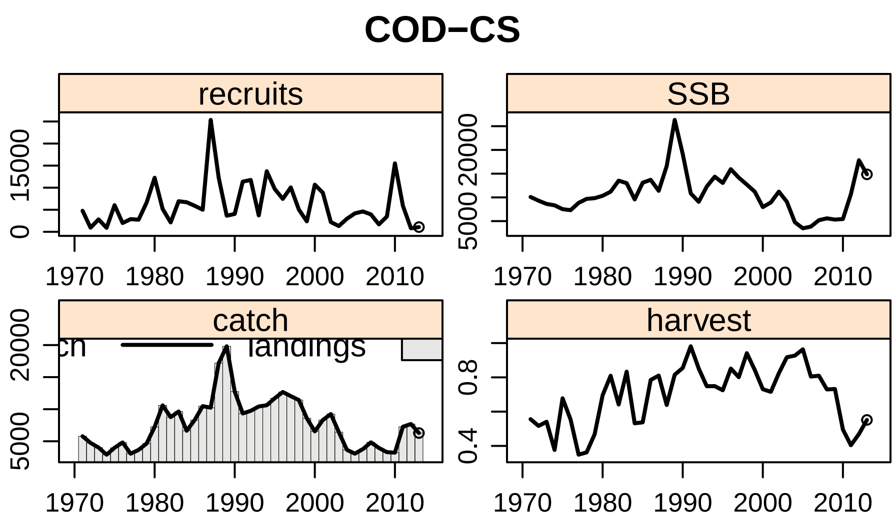

Figure 2: WGCSE2014 Cod assessment summary plot

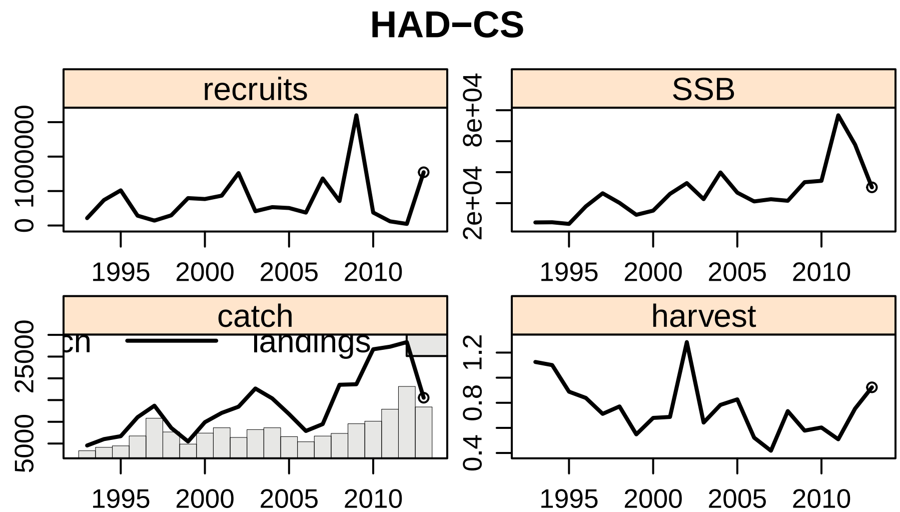

Figure 3: WGCSE2014 Haddock assessment summary plot

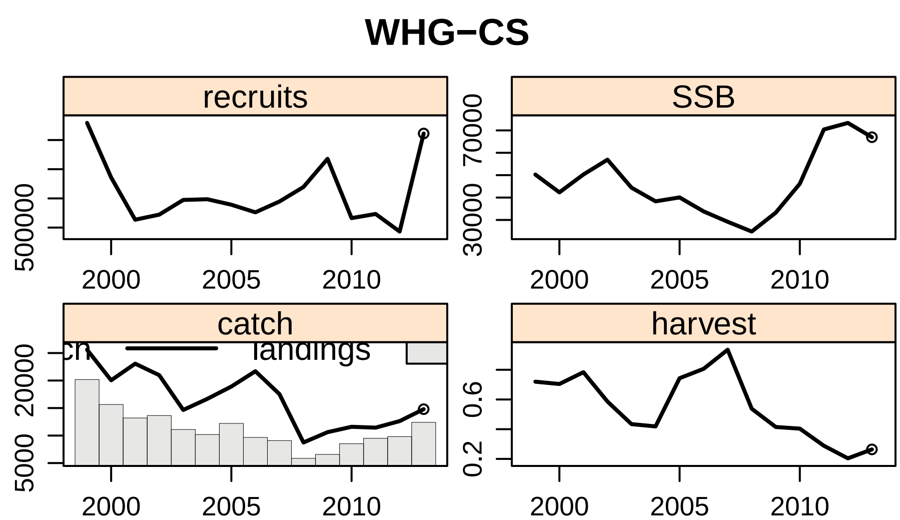

Figure 4: WGCSE2014 Whiting assessment summary plot

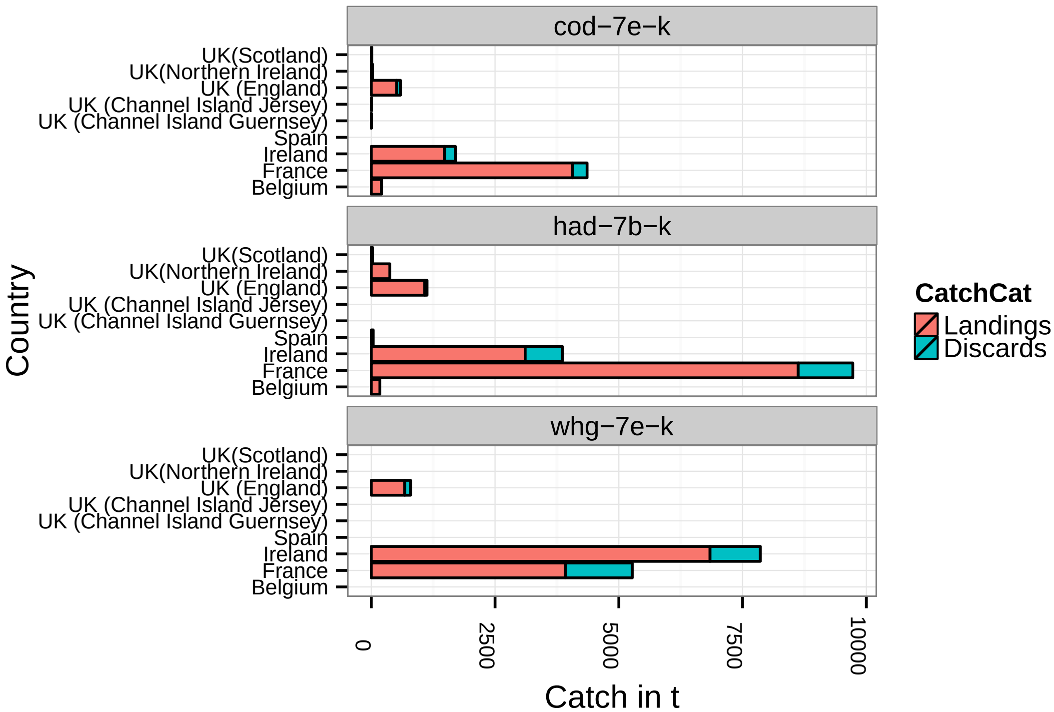

Figure 5: Catch estimates by Country from InterCatch (2013)

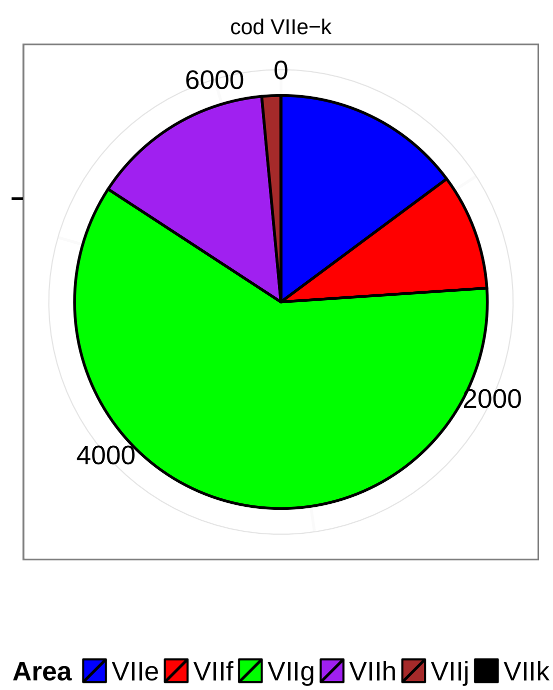

Figure 6: Catch by ICES area for cod VIIe-k

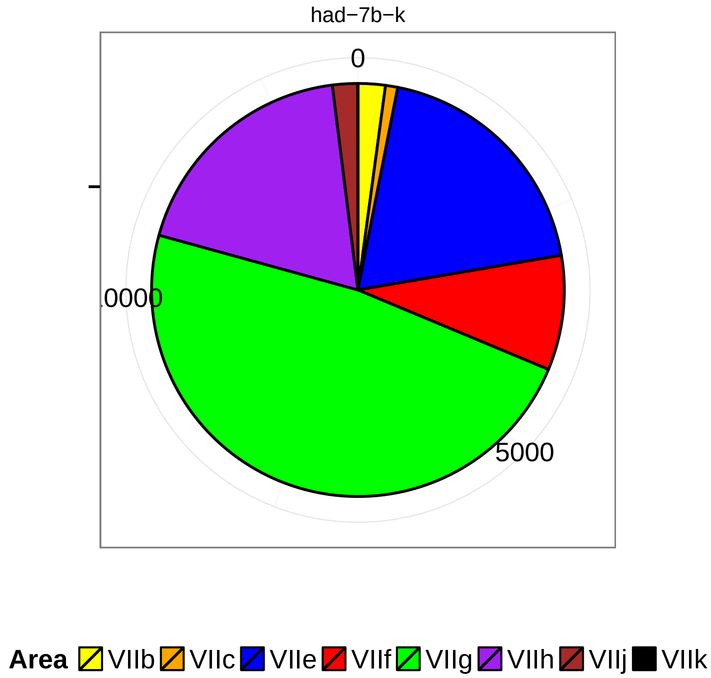

Figure 7: Catch by ICES area for haddock VIIb-k

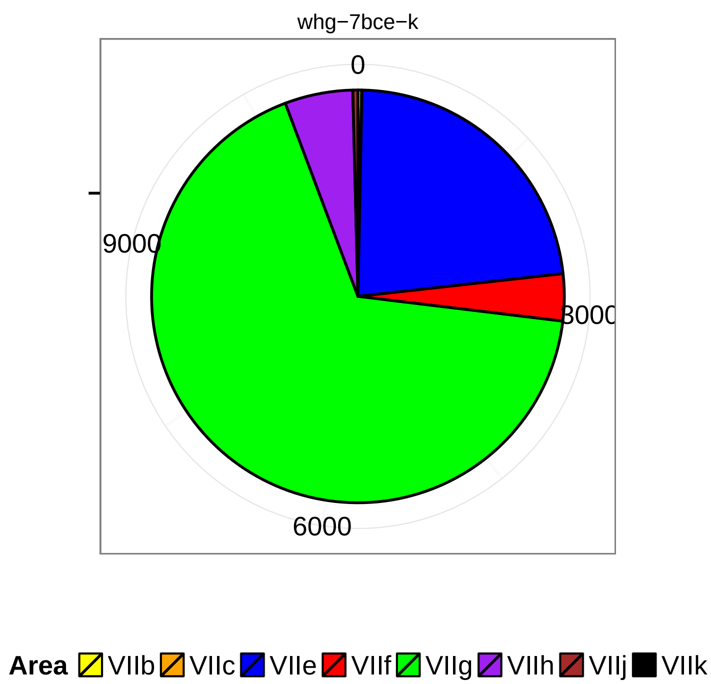

Figure 8: Catch by ICES area for whiting VIIbc,e-k

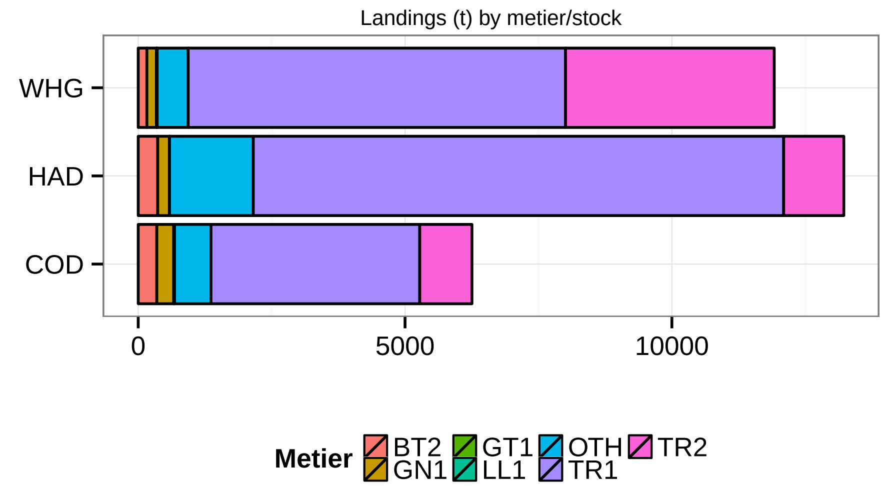

Figure 9: Landings (t) by Metier for each of the stocks: cod VIIe-k, haddock VIIb-k, whiting VIIbce-k. Metier definitions are those used in the final model runs after aggregation

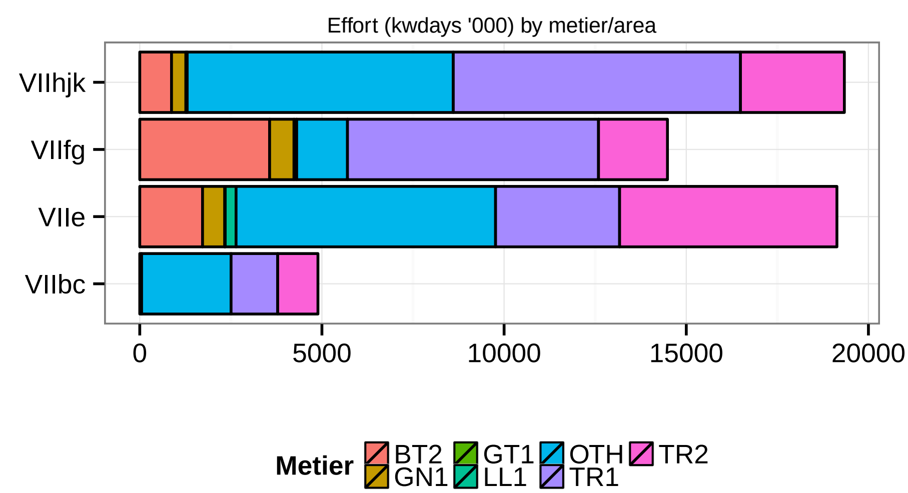

Figure 10: Effort (kwdays) by Metier for each area. Metier definitions are those used in the final model runs after aggregation

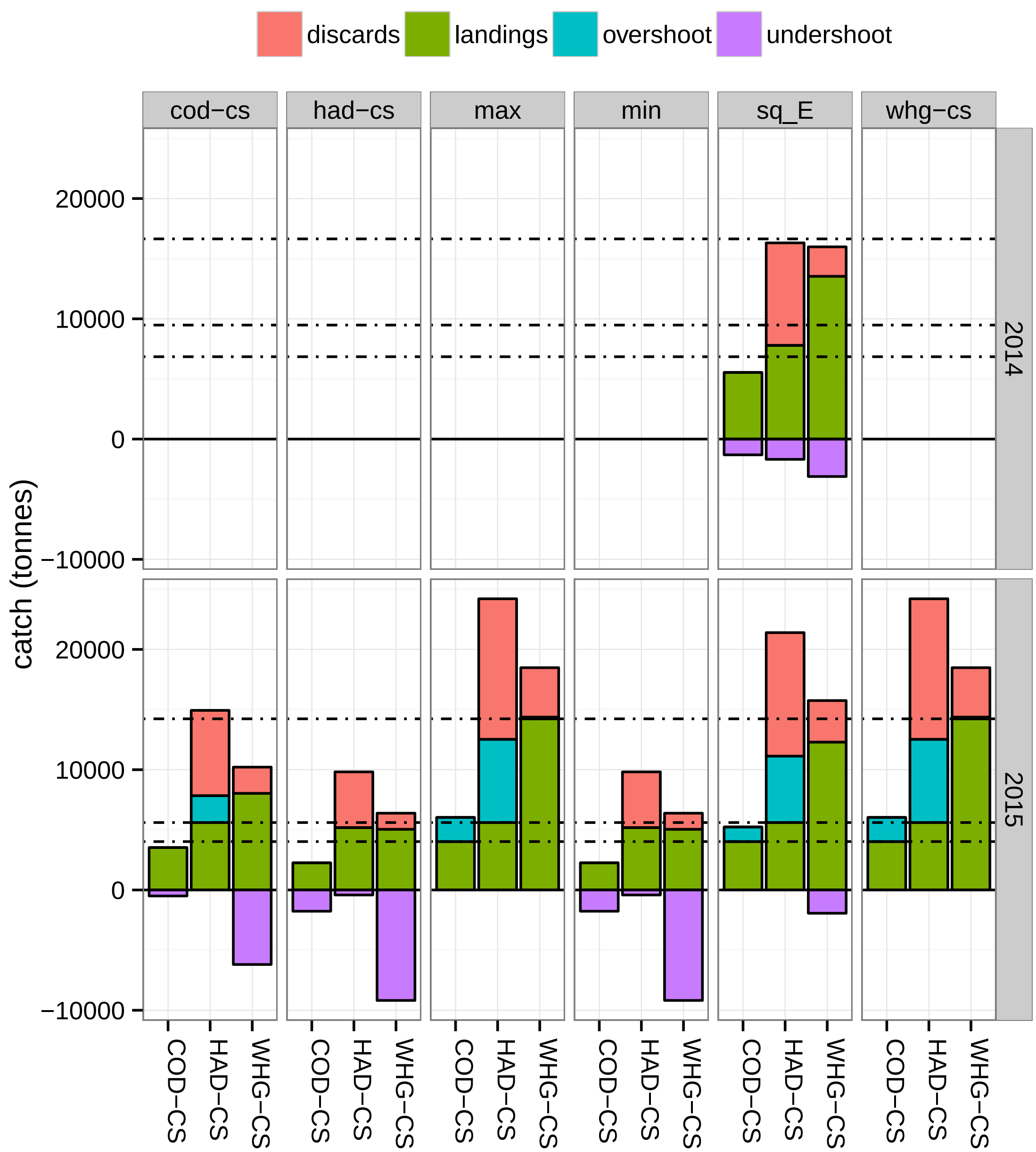

Figure 11: Overview plot of mixed fisheries scenarios for the Celtic Sea showing Intermediate year (2014) and TAC year (2015) landings and discards. Dashed lines indicate single stock TAC advice (top=whiting, middle=haddock,bottom=cod)

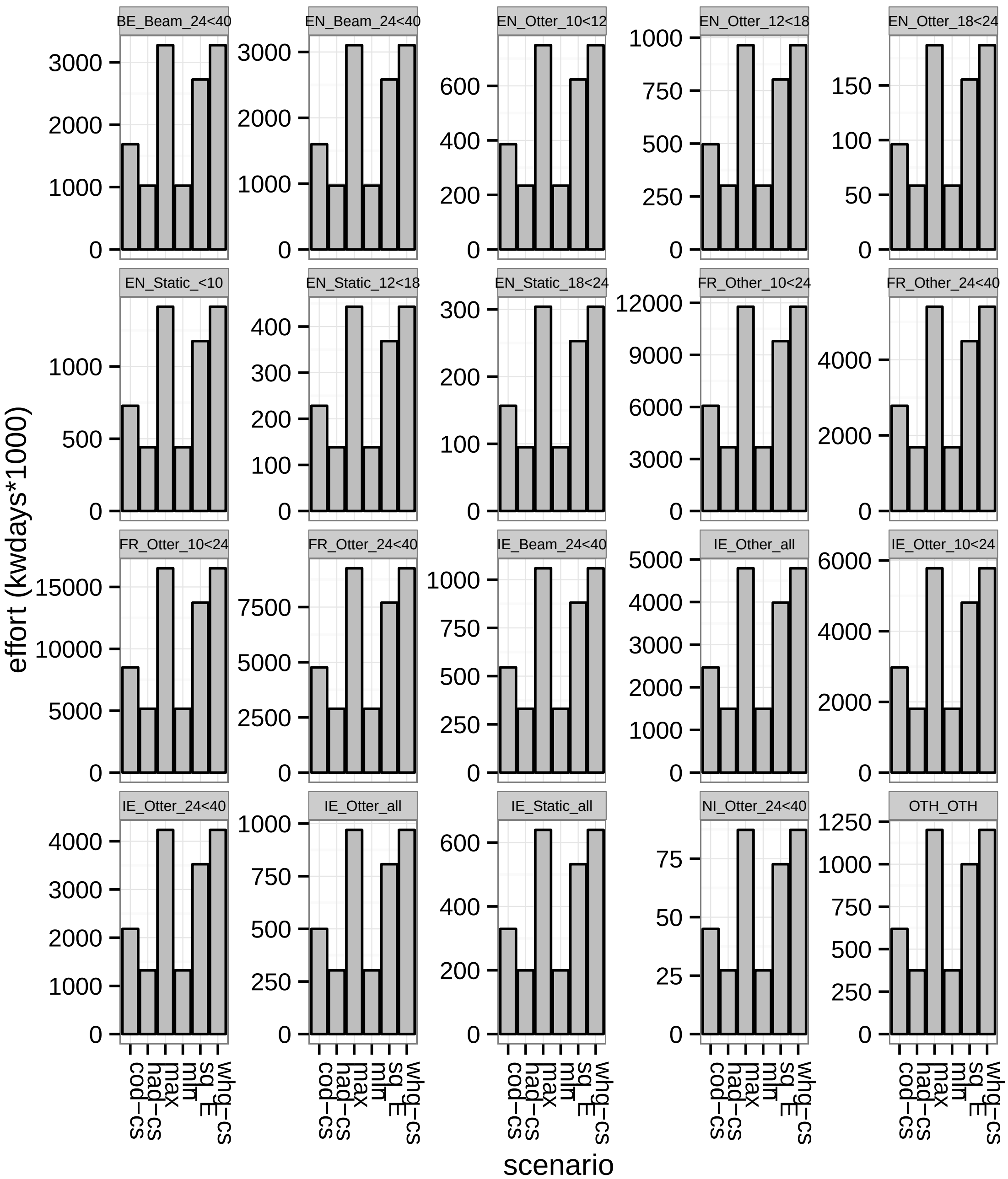

Figure 12: Effort by fleet under each mixed fishery scenario in 2015

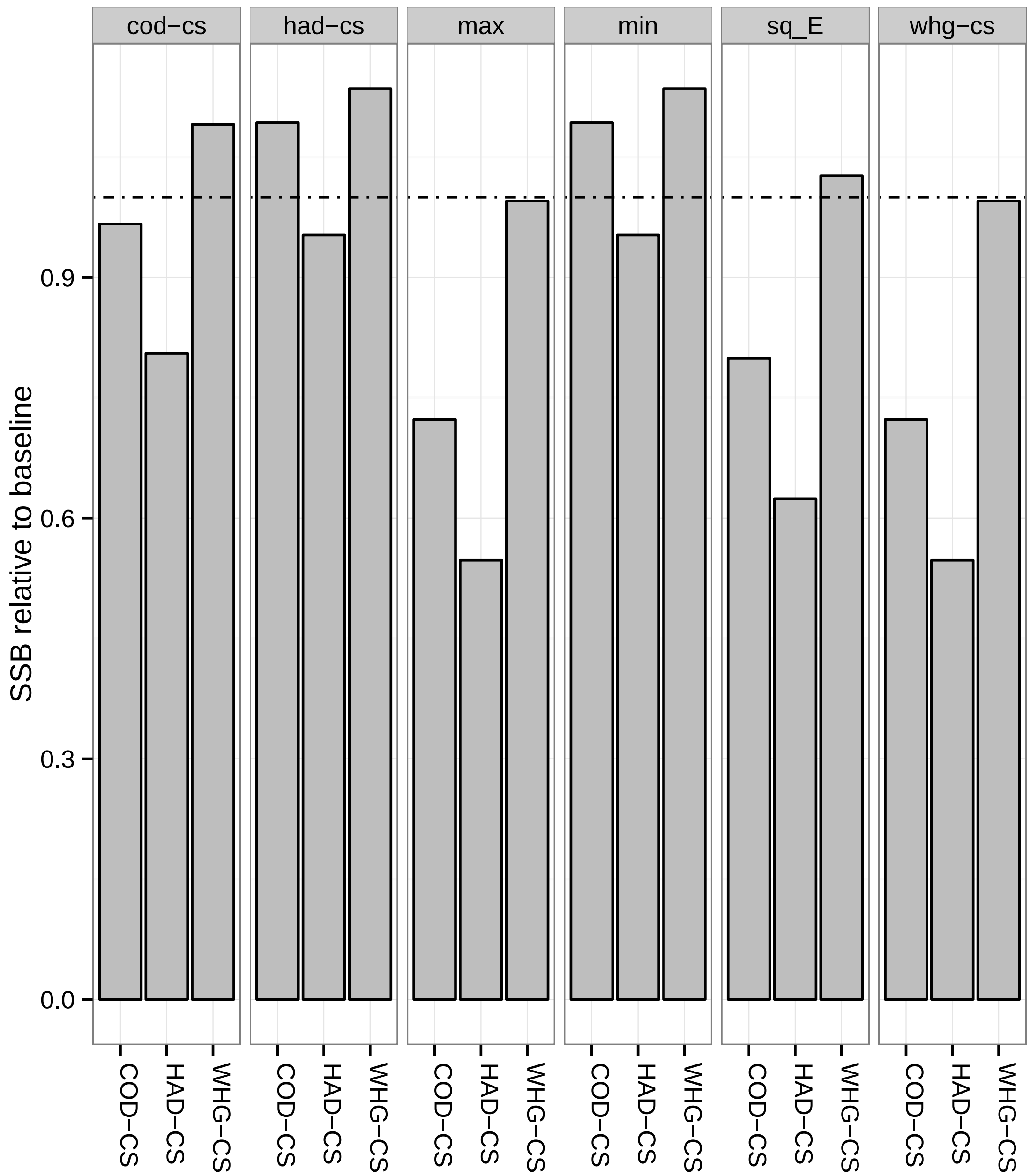

Figure 13: Change in SSB2016 compared to the baseline under each mixed fishery scenario. Dashed line represents the baseline SSB change.

Tables:

Table 3. Summary stock information for stocks considered in Celtic Sea mixed fishery analysis

	min	max	plusgroup	minyear	maxyear	minfbar	maxfbar
COD-CS	1	7	7	1971	2013	2	5
HAD-CS	0	8	8	1993	2013	3	5
WHG-CS	0	7	7	1999	2013	2	5

Table 4. Comparison between landings and discards in Fleet data and stock object

year	stock	WG.land	WG.disc	ratio.l	ratio.d	land	diff.
2013	COD-CS	6282	0	1	Inf	6253	-29
2013	HAD-CS	13424	2114	0.98	0.78	13222	-201.8
2013	WHG-CS	12401	2512	0.96	0.87	11918	-483.4

Table 5. Biological Reference Points

	Flim	Fpa	Fmsy	Blim	Bpa	Bmsytrigger
COD-CS			0.4	7300	10300	10300
HAD-CS			0.33			7500
WHG-CS	0.5		0.32	25000	40000	40000

Table 6. Total Allowable Catch limits in 2014

COD-CS	6848
HAD-CS	9479
WHG-CS	16645

Table 7. Forecast setting used for cod in the FCube baseline run (as per single stock advice)

Stock	Year	Parameter	Value	Basis
COD-CS	2014	R	4829	GM(1971-2011)
COD-CS	2015	R	4829	GM(1971-2011)
COD-CS	2016	R	4829	GM(1971-2011)
COD-CS	2014	Fbar	0.475	meanF(2011-2013)
COD-CS	2015	Fbar	0.37	MSY approach: Fmsy * (SSB2015/MSYBtrigger)
COD-CS	2014	landings	4835	
COD-CS	2014	discards	0	
COD-CS	2014	catch	4835	
COD-CS	2015	landings	4024	
COD-CS	2015	discards	0	
COD-CS	2015	catch	4024	
COD-CS	2014	ssb	11985	
COD-CS	2015	ssb	9470	

Stock	Year	Parameter	Value	Basis
COD-CS	2016	ssb	10687	

Table 8. Forecast setting used for haddock in the FCube baseline run (as per single stock advice)

	Stock	Year	Parameter	Value	Basis
15	HAD-CS	2014	R	295159	GM(1993-2010)
16	HAD-CS	2015	R	295159	GM(1993-2010)
17	HAD-CS	2016	R	295159	GM(1993-2010)
18	HAD-CS	2014	Fbar	0.73	meanF(2011-2013)
19	HAD-CS	2015	Fbar	0.33	Fmsy
20	HAD-CS	2014	landings	6820	
21	HAD-CS	2014	discards	7242	
22	HAD-CS	2014	catch	14062	
23	HAD-CS	2015	landings	5605	
24	HAD-CS	2015	discards	4829	
25	HAD-CS	2015	catch	10434	
26	HAD-CS	2014	ssb	13016	
27	HAD-CS	2015	ssb	32900	
28	HAD-CS	2016	ssb	37251	

Table 9. Forecast setting used for whiting in the FCube baseline run (as per single stock advice)

	Stock	Year	Parameter	Value	Basis
29	WHG-CS	2014	R	931630	GM(1999-2012)
30	WHG-CS	2015	R	931630	GM(1999-2012)
31	WHG-CS	2016	R	931630	GM(1999-2012)
32	WHG-CS	2014	Fbar	0.252	meanF(2011-2013)
33	WHG-CS	2015	Fbar	0.32	Fmsy
34	WHG-CS	2014	landings	12696	
35	WHG-CS	2014	discards	2444	
36	WHG-CS	2014	catch	15140	
37	WHG-CS	2015	landings	14230	
38	WHG-CS	2015	discards	4271	
39	WHG-CS	2015	catch	18501	
40	WHG-CS	2014	ssb	57200	
41	WHG-CS	2015	ssb	80058	

	Stock	Year	Parameter	Value	Basis
42	WHG-CS	2016	ssb	77208	

Table 10. Comparison between the Single Stock advice forecast output and the FCube baseline output for year 2014 (landings, discards, catch, ssb and Fbar)

				stock	
			COD-CS	HAD-CS	WHG-CS
	type	variable	value	value	value
2014	catch	single_species	4835.000	14062.00	15140.000
		baseline	4805.000	14066.00	15199.000
		Perc.diff	− 1.000	0.00	0.000
	discards	single_species	0.000	7242.00	2444.000
		baseline	0.000	7245.00	2328.000
		Perc.diff	NaN	0.00	− 5.000
	Fbar	single_species	0.475	0.73	0.252
		baseline	0.460	0.73	0.250
		Perc.diff	− 3.000	0.00	− 1.000
	landings	single_species	4835.000	6820.00	12696.000
		baseline	4805.000	6821.00	12919.000
		Perc.diff	− 1.000	0.00	2.000
	ssb	single_species	11985.000	13016.00	57200.000
		baseline	11985.000	13016.00	57198.000
		Perc.diff	0.000	0.00	0.000

Table 11. Comparison between the Single Stock advice forecast output and the FCube baseline output for 2015 (landings, discards, catch, ssb and Fbar)

	type	variable	stock COD-CS value	HAD-CS value	WHG-CS value
2015	catch	single_species	4024.00	10434.00	18501.00
		baseline	3986.00	10448.00	18442.00
		Perc.diff	−1.00	0.00	0.00
	discards	single_species	0.00	4829.00	4271.00
		baseline	0.00	4836.00	4120.00
		Perc.diff	NaN	0.00	−4.00
	Fbar	single_species	0.37	0.33	0.32
		baseline	0.37	0.33	0.32
		Perc.diff	0.00	0.00	0.00
	landings	single_species	4024.00	5605.00	14230.00
		baseline	3986.00	5613.00	14571.00
		Perc.diff	−1.00	0.00	2.00
	ssb	single_species	9470.00	32900.00	80058.00
		baseline	9511.00	32895.00	80057.00
		Perc.diff	0.00	0.00	0.00

Table 12. Comparison between the Single Stock advice forecast output and the FCube baseline output for 2016 (ssb only)

		variable	stock COD-CS value	HAD-CS value	WHG-CS value
2016	ssb	single_species	10687	37251	77208
		baseline	10814	37227	77176
		Perc.diff	1	0	0

Table 13. Intermediate year (2014) Fishing mortality from the baseline run (single stock advice) and FCube status quo effort assumption

stock	Baseline	sq_E
COD.CS	0.46	0.55
HAD.CS	0.73	0.88
WHG.CS	0.25	0.27

Table 14. Intermediate year (2014) landings from the baseline run and FCube status quo effort assumption

stock	baseline	FCube Int yr
COD.CS	4805	5538
HAD.CS	6821	7795
WHG.CS	12919	13532

Table 15. Intermediate year (2014) catch from the baseline run and FCube status quo effort assumption

stock	baseline	FCube Int yr
COD.CS	4805	5538

stock	baseline	FCube Int yr
HAD.CS	14066	16313
WHG.CS	15199	15984

Table 16. TAC year (2015) Fishing mortality forecast comparison between single stock advice and FCube scenarios

stock	baseline	cod-cs	had-cs	max	min	sq_E	whg-cs
COD.CS	0.37	0.34	0.21	0.66	0.21	0.55	0.66
HAD.CS	0.33	0.54	0.33	1.05	0.33	0.88	1.05
WHG.CS	0.32	0.16	0.1	0.32	0.1	0.27	0.32

Table 17. TAC year (2015) landings forecast comparison between single stock advice and FCube scenarios

stock	baseline	cod-cs	had-cs	max	min	sq_E	whg-cs
COD.CS	3986	3525	2258	6030	2258	5237	6030
HAD.CS	5613	7842	5189	12527	5189	11126	12527
WHG.CS	14571	8033	5045	14372	5045	12294	14372

Table 18. TAC year (2015) catch forecast comparison between single stock advice and FCube scenarios

stock	baseline	cod-cs	had-cs	max	min	sq_E	whg-cs
COD.CS	3986	3525	2258	6030	2258	5237	6030
HAD.CS	10449	14933	9818	24211	9818	21395	24211
WHG.CS	18691	10213	6383	18482	6383	15748	18482

Table 19. TAC year+1 (2016) ssb forecast comparison between single stock advice and FCube scenarios

stock	cod-cs	had-cs	max	min	sq_E	whg-cs
COD.CS	10453	11818	7817	11818	8641	7817
HAD.CS	29983	35475	20380	35475	23237	20380
WHG.CS	84182	87620	76803	87620	79235	76803

Table 20. Summary of TAC landings, undershoot, overshoot and discards in the TAC year (2015) for the mixed fisheries scenarios

sc	cat	COD-CS	HAD-CS	WHG-CS
cod-cs	landings	3525	5605	8033
cod-cs	overshoot		2237	
cod-cs	undershoot	-499		-6197
cod-cs	discards		7091	2180
had-cs	landings	2258	5189	5045

sc	cat	COD-CS	HAD-CS	WHG-CS
had-cs	undershoot	-1766	-416	-9185
had-cs	discards		4629	1338
max	landings	4024	5605	14230
max	overshoot	2006	6922	142
max	discards		11684	4110
min	landings	2258	5189	5045
min	undershoot	-1766	-416	-9185
min	discards		4629	1338
sq_E	landings	4024	5605	12294
sq_E	overshoot	1213	5521	
sq_E	undershoot			-1936
sq_E	discards		10269	3454
whg-cs	landings	4024	5605	14230
whg-cs	overshoot	2006	6922	142
whg-cs	discards		11684	4110

Annex 5: WD: The problem of inclusion of multispecies biological relations into a multifleet system model (2 species - 2 different standard fleets).

Working document for ICES WGMIXFISH-METH

20-24 October, 2014, London

The problem of inclusion of multispecies biological relations into a multifleet system model (2 species - 2 different standard fleets).

Bulgakova Tatiana, VNIRO Moscow, Russia

Let us take as an example the model of two biologically interactive homogeneous populations produced many years ago (Pope and Harris, 1975). The model is actually a system of two differential equations; in a general case the populations can interact along the prey-predator pattern, or compete for food, while the type of interaction depends on parameter C_1 and C_2 signs. The model was applied to a system of two fish populations in the Southeast Atlantic competing for food (pilchard and anchovy: P is a pilchard biomass, R is an anchovy biomass in the equations below).

$$\frac{dP}{dt} = P(A_1 - B_1P - C_1R) - F_pP$$

$$\frac{dR}{dt} = R(A_2 - B_2R - C_2P) - F_RR$$

Parameters A, B and C are constant; where B- are parameters of intraspecies relations, C are interspecies ones; F are fishing mortality rates. The authors used single species VPA time-series P(t), R(t) and F(t) as the input information for parameters estimation, provided the system is sustainable (i.e. dP/dt=dR/dt= 0). The six constant parameters A, B, C were evaluated using the regression technique. Such a method to find parameters is not quite accurate because the single species VPA disregards interspecies relations, hence might cause bias in stock assessment.

A similar model for two species was suggested somewhat later (surplus production model with due regard to biological relations) (Bulgakova, Kizner 1986); parameters of this model were determined differently, disregarding the sustainability condition, and using fisheries statistics.

International fisheries data collected off Namibia in 1974-1983 were used to parameterize the model. Vessels of various types from different countries equipped with diverse gears were employed in the area. The major fishing species in the area were horse mackerel and hake. The data from trophology experts (Krzeptowski, 1982; Konchina, 1986) showed that the species in the local community interacted as predator–prey while some age groups of those species might compete for food.

The problem of mixed fisheries in this case was resolved by selecting for each of the two species the most representative “fleet” as a standard, followed by standardization of the fishing effort by the method of J.Gulland (1956). Soviet big trawlers (BMRT) with midwater trawls were chosen as the first standard fleet. The same Soviet trawlers with bottom trawl were taken as the second standard fleet. The first fleet targeted at horse mackerel with some bycatch of hake, the second fleet worked on hake with bycatch of horse mackerel.

The above made it possible to obtain equations describing theoretical (modelled) dynamics of a two species community retrospectively, and then to consider different options of fishery management for projections. The two species dynamic model equations fitted for stock indices (cpue for each species u_i in this case) are as follows:

$$\frac{\dot{u}_i}{u_i} = a_i - b_i u_i - c_i u_j - q_i f_i$$

i,j =1, 2

where f_1 and f_2 are values of a standard fishing effort for horse mackerel (the first species) and for hake (the second one) respectively. The input information for the model involved two time-series of catch per unit of effort ui *(t)* for a standard vessel, and two time-series of standard fishing effort $f_i(t)$. Besides, another one time-series was built for each species reflecting the stock index variations which is relative change of cpue:

$$\frac{\Delta u_i}{u_i(t)} = \frac{u_i(t) - u_i(t-1)}{u_i}$$

i=1,2

The unknown constant parameters of the model a_i,b_i,c_i, were evaluated by the method of multiple regression while the above time-series were used as basic information. The biological meaning of the model coefficients is: b_i are intraspecific competition or density-dependent factors; c_i are interspecific relations; a_i are the species reproduction rates component independent of the abundance of the species; q_i are catchability rates. Parameters q_i were estimated in advance, as proportion coefficients of single species VPA stock biomass estimates and u_i for each species.

Therefore, the model parameters are with due regard to the variability of population biomass. That is why the model belongs to the class of dynamic model for interacting species. In order to obtain a more reliable procedure for evaluating model parameters the input catch-per- effort series were smoothened (Figure1).

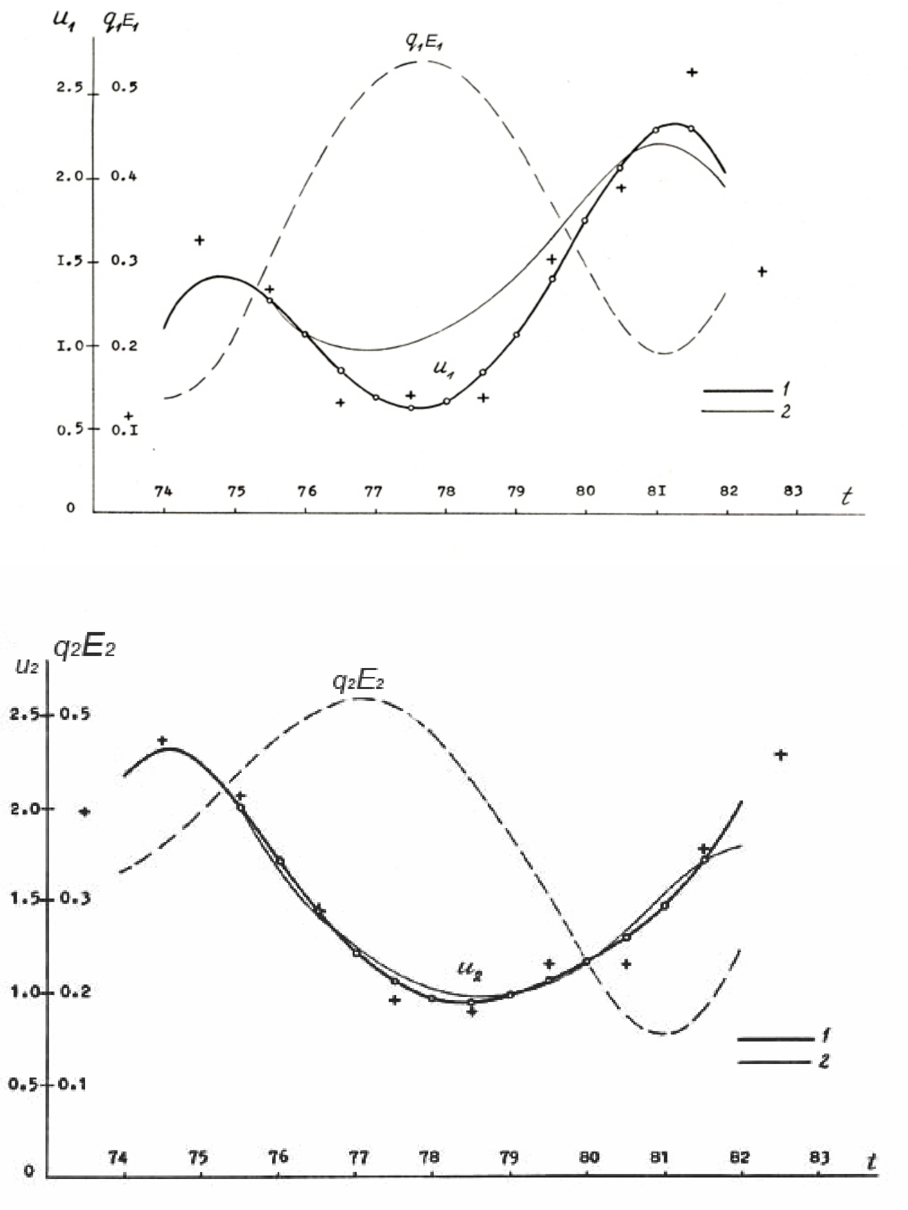

Figure 1. cpue and fishing rate F=qE as function on year index for horse mackerel (upper figure) and for hake (bottom figure). Crosses are the initial data, curve 1 is smoothened initial data, curve 2 is modelled u(t) after parameter assessment; the dashed lines are Fi (t).

The signs of the obtained parameter values show a much greater role of predation than that of competition : the coefficient c_1=0,9 was obtained as positive, while c2= - 0,2 as negative; the parameter b_1 was close to zero which shows that intraspecific competition does not exist in horse mackerel population. The b_2 is estimated at 0,34, it confirms a quite important role of cannibalism in hake abundance dynamics.

After estimating the parameters the model was used to describe dynamics of the populations accounting for their biological interactions in the forecast period of time followed by reviewing various management strategies. Our analysis showed, for example, that in choosing a sustainable yearly catch strategy this dynamic system is not stable. On the other hand, if the fishery is conducted with invariable effort, but the one not beyond the allowable management range, any equilibrium state of the system will be sustainable. The results are given as plots in a phase plane. (Figure 2)

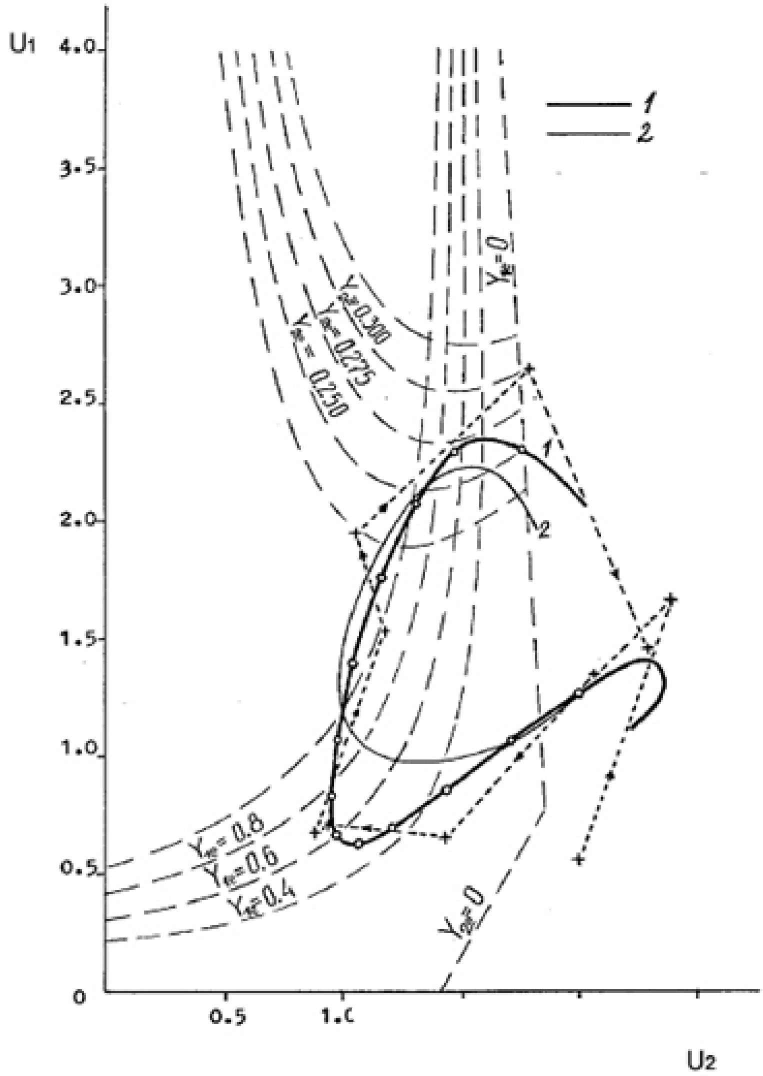

Figure 2. The phase diagram of the horse mackerel-hake system. The thin dash lines are the equilibrium catch isolines. Crosses are the initial data, curve 1 is smoothened initial data, curve 2 is model testing after parameter assessment; ui [t/hour trawling]

The author suggests to apply this approach to those elements of the integrated multispecies/multifleet model for which no disaggregated information is available on the age composition of catches for different metie or fleets.

This dynamic approach makes it unnecessary to apply the status-quo conditions to model coefficients of the forecast period.

This paper did not consider the problem of allocating fishing effort among various fleets in the projected years. All conclusions pertained only to the level of standardized effort in respect of each species. In general, such an approach would be true in working out a long-term management strategy. In short-term forecasting a mixed fishery advice for standard fishing effort is not sufficient. The recommended effort has to be distributed among the fleets and even metie, with due regard to the technological interaction of species in the fishery.

Besides, an additional difficulty may arise if biological relations are engaged in the model since this would affect the allowable management area for each system element (Bulgakova,1999).

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Annex 6: Report of joint WGMIXFISH – WGSAM workshop on mixed fisheries and multispecies issues

Joint WGSAM-WGMIXFISH workshop

Thursday 23rd October 2014

Report

Introduction

ICES WGSAM and WGMIXFISH held a joint workshop in London on 23rd 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 multispecies 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 multispecies and mixed fisheries issues and describe what strategic (i.e. goal setting) or tactical advice is required from multispecies and mixed fishery model applications.
2. Identify where outputs of the multispecies or mixed fishery models could inform each other, 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 multispecies and mixed fishery issues separately or together?*
- *Over what time horizons do multispecies 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 multispecies outputs?*
- *Are multispecies models considered reliable enough to be setting fishing mortality target based on their outputs?*
- *Can multispecies 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 multispecies 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 multispecies and mixed fishery models?*

Several presentations were given pertaining to previous and current modelling work that simultaneously account for multispecies and multifleet 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, 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; multifleet).

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 characterized 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).

Multispecies 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. Multispecies models focus on a limited number of species, principally those of commercial interest. Most multispecies 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 multispecies 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 each other 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 multispecies 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 Multispecies able to replace single species stock assessments for giving TAC advice.

With this context in mind, two uses emerge for MS models. One use of multispecies 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 multispecies 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 bioeconomic 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 multispecies interactions, except in that they take single-stock assessment inputs that may be informed by multispecies 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 multispecies considerations are taken in to account, but which are not desirable when both mixed fisheries and multispecies issues are considered at the same time.

2. *At which time-scales are multispecies and mixed fisheries models most appropriate to giving advice?*

Multispecies and fishery interactions occur at the same time and thus are both relevant to understanding how ecological and fishery interactions affect management. However, the time-scales of the processes modelled becomes important in relation to their use in advice. The Fcube mixed fishery model currently 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.

Multispecies 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 multispecies 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 multispecies interactions simultaneously are most relevant for strategic evaluation of management options over a medium time frame. 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 on which fishers decisions take place.

In relation to what the overlap between multispecies 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 multispecies 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 multifleet multistock 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 multifleet 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, multispecies 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 trade-offs that pointed to sacrifices by one species for the sake of maximizing 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 F_{msy}) (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. Optimization can be undertaken where objective functions are clearly defined, such as maximum overall value of the fisheries portfolio, maximum economic yield or to prioritize some other objective such as biodiversity. However, because such objectives are rarely, if ever specified, optimizations 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 multispecies 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 characterize 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 F_{msy} predictions (and their reliability) from multispecies 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 F_{msy} estimate. Such considerations would potentially be dynamic, and require simultaneously estimating the optimum F_{msy} given multispecies interactions and changes to fleet effort. Integrated multispecies 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 etc. 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 multispecies 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 multispecies 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 multispecies and ecosystem models need advice on the appropriate level of fleet aggregation to use.
4. Further integration of multispecies interactions into mixed fisheries models could be either through informing appropriate long-term exploitation targets or coupling of multispecies models with the existing mixed fishery framework.

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Appendix 1. AGENDA

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

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

Presentations

The problem of inclusion of multispecies biological relations into a multifleet system model (2 species - 2 different standard fleets)	Tatiana Bulgakova, VNIRO Moscow, Russia

Restructuring 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 Multispecies Models. Based on MARE-FRAME 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 multispecies outputs?*
- *Are the multispecies considered reliable enough to be setting fishing mortality target based on their outputs?*

Objective 3: Identify where outputs of the multispecies or mixed fishery models could inform each other, or where benefits can be gained from coupling models or developing more holistic models dealing with both issues simultaneously.

- *Can multispecies 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 multispecies 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 multispecies 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 characterize the fleets now and in the future if gear is "im-proved".	Robert Thorpe
Multispecies, risk-based evaluation of management policies: Tools for evaluating manage-ment 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 multispecies ?	Anna Rindorf
Summary of issues and points for discussion	Daniel Howell

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