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1. Introduction and scope

This report presents progress towards fleet and area based management of fisheries of the North Sea within AFRAME, whose main objective is the development of a fleet and area based framework for fisheries management. Within AFRAME, the demersal fisheries of the North Sea represent a data rich area, with few important commercial species, subject to routine assessments, in contrast to other case studies, which have higher numbers of target species and less stock assessment information. The North Sea, relatively simple and data rich, thus represents a best case scenario for workpackages on developing the Fleet and Area Framework Fcube (WP4), Indicator Approaches (WP5) and Stakeholder Perceptions and and Institutional Implication (WP6).

Within chapters 2-7 we both present work at the intersections between the North Sea and WP4 (chapter 2: Fcube analyses for the North Sea demersal fisheries, chapter 3:Economic Modelling in the North Sea Case study, and Chapter 4: A Full Feedback Model of fleet and area based mixed fisheries in the North Sea), between the North Sea Case study and WP5 (chapter 5: Effort indicators for North Sea demersal fisheries), and with WP6 Chapter 6(North Sea fleet definitions and stakeholder perceptions). Chapters 2 and 4 will be revised for suitability for submission to peer reviewed journals and/or presentation to ICES Annual Science Conference. Furthermore, the work developed in Chapter 2 will be the basis of future mixed-fisheries ICES advice under the future ICES WKMIXFISH workshop (26-28 august 2009). In addition Chapter 7 explores the Fleet and Fishery structure of Scottish mixed demersal North Sea fisheries.

Below follow exectutive summaries of chapters 2-7

Chapter 2: Fcube analyses for the North Sea demersal fisheries

This chapter present the extended analyses that were performed for the North Sea demersal fisheries using the Fcube methodology developed within WP4. This case study has supported the basis of methodological development from the early beginning (ICES MIXMAN, 2006), and there has thus been a constant feedback between the method and the results obtained for the North Sea. In particular, a lot of testing and exploratory Fcube runs have been performed with the North Sea data, leading to an improved understanding of the model and of its behavior, strengths and limitations. The model was found out to be quite robust to a number of sources of uncertainties, of which the variability of catchability is the most important The conditions for providing timely and operational mixed-fisheries advice based on single-stock assessment data were reproduced, in order to best achieve the full consistency of the method.

Some important results were also obtained. The base case analysis showed that the single-species TACs implemented for 2007 in the North Sea were not consistent with each other, mostly with regards to cod, thus leading to high risks of overquota discarding for this stock. In addition, hindcasting scenarios were run to investigate some plausible proxies for fleet behaviour, and these showed that the value-driven estimate reflecting some sort of economic behaviour was the most accurate for most fleets. All model findings could be supported by qualitative evidence or external knowledge.

All outcomes are summarised and discussed in the present deliverable.

Chapter 3: Economic Modelling in the North Sea Case study

The Fcube framework bases the effort distribution on fleets on a combination of fleet catchabilities and fish stock preservation considerations. As fisheries management has a significant impact on human behaviour as well as on ecosystem development, management solutions should, however, also take into account the behaviour and economic interests of humans, as well as resource preservation. Therefore an extension of Fcube has been constructed, where the management decision is based on the two former criteria combined with economic optimisation considerations for the harvesting agents. As such the final effort distribution on fleets and metiers is based on constrained maximisation of fleet profits, the constraints being the single species quotas. The economic optimisation module allows effort to be distributed on metiers freely, contrary to the original Fcube framework, in which the effort distribution on metiers is assumed constant. Moreover the optimisation module may also allow the fleet capacity (number of vessels) to change, as opposed to the original Fcube framework.

Using the optimisation framework it has been shown that the fishery may benefit significantly economically, i.e. obtain significantly higher profits, while still complying with the set TACs and quotas, when compared with the Fcube minimum scenario, by firstly re-distributing effort between metiers and secondly by allowing the capacity to change. This is a highly important result seen from that management perspective that includes socio-economic as well as biological considerations.

Chapter 4: A Full Feedback Model of fleet and area based mixed fisheries in the North Sea

Plaice (Pleuronectes platessa) and sole (Solea solea) stocks in the North Sea are mainly caught by Dutch and UK demersal beam trawl fleets. The main problem with this mixed fishery is the unsynchronized exhausting of plaice and sole (country) quota due to the fixed relative stability of TAC-shares, the spatial distributions of fish stocks and the size selective characteristics of demersal beam trawls, resulting in a considerable amount of plaice that is caught but discarded.

This study developed a generic full feed back simulation model to investigate the impact of alternative management measures on a fisheries with mixed species The model contains several modules. The operating module simulates the true states of the stocks and the dynamics of the fishing fleets. An observation module models the indices of the stocks. A stock assessment module, using the XSA procedure produces the perception of the stocks in terms of stock numbers and fishing mortality rates per age groups. Given a set of harvest control rules based on certain management scenario's the management module calculates TAC's and quota for the stocks for the TAC year.

The fleet structure was simplified to 2 separate fleets with 2 métiers each. The behaviour of these fishing fleets was simulated by using two extreme scenarios. In the first scenario it is assumed that overquota catches, in case the first quota are exhausted, will be discarded or misreported until the quota of the other species is fished up. Under the second scenario it is assumed that overquota catches are avoided by fishers for instance by directed fishing for a particular species. Besides these two scenario's, the harvest control rule / management measures and setting quota's were also simulated using Fcube.

Simulations were run using the multiannual EC plan for fisheries exploiting stocks of plaice and sole in the North Sea as management. Results show that the objectives of this plan, reduction of the fishing mortalities to Fmsy, are on average reached within 7-10 years after the implementation. of the harvest control rule. Simulating the harvest control rule using Fcube results in lower allowed fishing effort and lower landings of plaice. The simulations also show that results for plaice are very sensitive for the assumptions on overquota fish caught.

Chapter 5: Effort indicators for North Sea demersal fisheries

The substantial changes in both effort and fishing mortality that have occurred in the North Sea demersal fisheries since the introduction of effort management make this case study a useful 'experiment' on the linkages between effort applied at the level of fleet or fishery, and the resultant impacts on the target stocks. An indicator that uses effort and catchability by fishery to derive an overall proxy for fishing mortality shows promise as a way of linking fleet activity to the impacts of that activity. The indicator is independent of stock assessment information, so could potentially be used to provide information on change sin exploitation on unassessed stocks. The short time series of effort data currently available limits the ability to explore further the link between changes in effort and fishing mortality. While such an indicator would be useful in itself to allow fishing activity to be linked to its impacts, further analysis would also be desirable to investigate the links between management actions and fleet activity.

Chapter 6:North Sea fleet definitions and stakeholder perceptions

This chapter seeks to compare the fleet definitions applied in the AFRAME Fcube models with the North Sea stakeholder's perceptions of group of boats. It argues that the stakeholders way of thinking about groups do in fact confirm many of the Fcube assumptions about gear, size and species as relevant criteria. But the chapter also argues that stakeholders may have some very specific ideas as to why these criteria are relevant which are grounded not only in considerations of 'type of fish being caught' but also in broader considerations of existing management categories and occupational specialization. Last but not least, the chapter sums up a range of alternative criteria that fishermen also used in addition to gear, species and size when grouping the boats. They relate to both work organization, quota management systems, fishing area, time at sea, processing possibilities, marketing and management impact in terms of the upcoming of new types of fisheries.

Chapter 7: Fleet and Fishery structure of one Scottish mixed demersal North Sea fishery

For this project it was impossible to consider the whole Scottish demersal fleet targeting the North Sea for this case study. Therefore one specific area which covered a number of traditional Scottish mixed demersal fishing grounds was identified for the study. The fleets targeting these grounds comprises of two distinct sub-grounds one targeting whitefish species and the other targeting Nephrops with a fish by-catch. The main data source for fleets operating in the study area was provided by the Fisheries Information Network (FIN) managed by the Scottish Ministry of Fisheries. This database contains the information recorded by all Scottish skippers on the official EU logbook. The main fishing method for each vessel held on FIN was validated using data collected by the Laboratories observer programme, expert knowledge and the information recorded on mesh size and catch landed for each fishing voyage. It should be noted that main engine power was not used as a parameter during this case study due to the common under reporting of actual engine power of many vessels.

On investigation it was found that most vessels on FIN the main fishing methods were incorrectly coded as whitefish trawl when they were actually using small mesh Nephrops gears. Furthermore, some pair trawling and twin trawl whitefish vessels were also being incorrectly coded as single trawl. Also noted were a number of Nephrops vessels abusing the two net-rule whereby they claim to fish with larger mesh sizes when in reality only ever use the smaller mesh size. However, it was found that using a combination of expert knowledge and utilising other FIN data fields it was possible to validate the actual main method being used by vessels within this CS study area. One objective of this study was to define a metier to better describe fleets without using the main fishing method recorded on FIN. Unfortunately it was found that without expert knowledge of the vessels being studied and an understanding of the regulatory processes (i.e. by-catch limits) used to manager their fishery, developing a metier using FIN data alone would be problematic. One solution would be to ensure vessel main method is correctly recorded onto the EU logbook.

2. Fcube analyses for the North Sea demersal fisheries (DTU Aqua)

2.1. Introduction

This document present the extended analyses that were performed for the North Sea demersal fisheries using the Fcube methodology developed within WP4. This case study has supported the basis of methodological development from the early beginning (ICES MIXMAN, 2006), and there has thus been a constant feedback between the method and the results obtained for the North Sea. This was acknowledged by ICES, which has set up a new Workshop for Mixed-Fisheries Advice for the North Sea (ICES WKMIXFISH), starting in august 2009, based on the Fcube methodology.

In particular, a lot of testing and exploratory Fcube runs have been performed with the North Sea data, leading to an improved understanding of the model and of its behavior, strengths and limitations. In addition, the conditions for providing timely and operational mixed-fisheries advice based on single-stock assessment data were reproduced, in order to best achieve the full consistency of the method. The base case scenario investigated the consistency of the single-species TACs implemented in 2007 and quantified the risks of overquota discarding occurring in the fishery. We also investigate various plausible proxies for fleet behvaiour through hindcasting analyses. All outcomes are summarised and discussed in the present deliverable.

2.2. Material and methods

2.2.1. Data

The data collected for running Fcube analyses in the North Sea were presented in deliverables 1.1 and 4.1. Some difficulties were encountered to insure full consistency in fleets and métiers definition across countries and the reasons are explained in deliverable 4.1.

Over the end of the project, additional testing and analyses were performed in order to further check the data, correct some inconsistencies and propose updated classification.

In particular, the inspection of data after aggregation still revealed the presence of a number of minor métiers and fleets, which did not contribute significantly to the catches of any of the eleven stocks (cod, haddock, saithe, whiting, plaice, sole, Nephrops FU 6,7,8,9 and others FU).

2.2.2. Base case run (ICES SGMixMan 2008)

The base run followed throughout the exploratory process is the one presented and discussed during ICES SGMixMan (2008). Time shortage [2] has prevented updating the database with the most recent catch and effort information and stock assessment results. This run has been extensively discussed during the ICES study Group and was therefore a “known” basis for further analysing the behaviour of the Fcube model. Furthermore, a global update of the data will take place in August 2009 during the forthcoming ICES WKMIXFISH workshop for mixed-fisheries advice, and all runs will be actualised accordingly.

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[2] *Due to the absence of the main scientist responsible for that work during 2008, see management report.*

This run intended to mimic some “real-time” examples of what could be a mixed-fishery advice for the North Sea. The choice was made to evaluate the potential outcomes of the true single-species TAC regulating the demersal fisheries in 2007 under a number of scenarios detailed below. As such, this run did not link to the single-stock advice provided by ICES, but to the evaluation of the actual TACs agreed as a result of negotiations between EU Commission, Norway and the Council of Ministers in December 2006.

The 2007 TACs were used as a landings constraint in single-stock short-term forecasts, using assessment settings and recruitment estimates from the May 2007 ICES WGNSSK (ICES, 2007b). FLR forecast methods were used to estimate the corresponding level of landings and fishing mortality in 2007. These were used as target F in Fcube inputs (expressed as Fbar). North Sea cod represents a slightly specific and difficult case. North Sea cod stock assessment is performed with the B-Adapt method, which estimates some levels of unallocated catches and fishing mortality, to the difference of other stock assessed with XSA (Darby and Flatman, 1994) which assumes perfect information about catches. This created some conceptual and technical issues in the generic use of forecast methods, because the estimated levels of harvest do not match with the input landings and discards. Some proxies had to be used to circumvent this issue, leading to minor difference between the estimated target F and the initial TAC. The base case for comparison for cod was thus set at a TAC of 23,722 tonnes instead of the initial TAC of 19,957 tonnes in 2007.

The Nephrops TAC is set up for the whole North Sea and not by Functional Unit (FU). However, to take Nephrops into account in the analyses it was necessary to estimate targets by stock and therefore it was assumed that the TAC was shared across FU according to 2006 landings average from the database. For the FU 6 to 9, 2007 abundance was assumed equal to 2006, and the target F was estimated as the 2006 harvest rate time ratio of 2007 TAC divided by 2006 landings. No assumption was made about the NEPoth, which gathered all Nephrops FU for which no abundance estimates are available.

An interesting feature with this choice of real 2007 TAC was that the cod TAC appeared as very restrictive (as a relatively high estimated 2005 year-class would allow high catches of age-2 cod in 2007 according to single-stock forecast), while on the opposite whiting TAC was set much higher than recent landings average, and appeared not restrictive at all, leading to high levels of fishing mortality necessary to take the TAC up. In that sense, the scenarios were contrasted according to management objectives and assumptions on fleet behaviour.

A 3-years average (2004-2006) was used for estimating Fcube inputs, i.e. mean catchability by fleet and métier, mean effort distribution by fleet across métiers, and mean share of landings by fleet and stock (as a proxy for relative stability and stable distribution patterns across and within member states). Visual inspection of data showed that effort distribution and landings share were fairly stable over the most recent years, while catchability estimates was noisier, although the time-series were too short to detect any trends (see results below).

A number of alternative scenarios were run :

- “max” : underlying assumption is that the fleets go on fishing until their last quota is exhausted. The difference between the estimated landings and the actual TAC for the other stocks is considered as overquota.
- “min” : underlying assumption is the opposite, the fleets stop fishing as soon as their first quota is exhausted, and do not catch up the whole of their quota for the other stocks.
- “val” : underlying assumption is that the global effort of each fleet is influenced by the monetary value that each fleet can get from its quota share across stocks. The value of

the quota share (quota share * mean price by fleet and stock) is thus used as a weighting factor of the estimated effort necessary to catch each quota share. The final level of effort is set at the level of this weighted mean.

- “statusquo_E” : underlying assumption is that the global effort of the fleets is not affected by the single-stock quotas, and fleets effort in 2007 is set at the 2006 level
- “DAS_reduction” : this scenario mimics the imposed reduction in Days_at_sea limitation that occurred between 2006 and 2007. This reduction was different across gears and mesh sizes, as Nephrops trawling (<90 mm) was reduced by 10%, demersal trawling between 90 and 120mm as well as beam trawling were reduced by 8%, and large mesh size demersal trawling (>120mm) was reduced by 7%. In this scenario, the effort of each metier within each fleet was reduced accordingly compared to its 2006 level.
- “cod” : this scenario is run specifically to investigate what would be necessary to avoid overquota catches of cod. Underlying assumption is that fleets set their effort at the level corresponding to their cod quota share, regardless of other stocks. Similar scenarios could be run for addressing the same issue for other stocks, but were not displayed here.

For each scenario, landings (as opposite to undersize discards, not to official landings) fishing mortality by stock was then recalculated as the sum of partial F by fleet and metier, i.e. effort by fleet * effort share by metier * mean catchability * landings selectivity. This fishing mortality was thus used to re-run single-stock forecast using the same methods and settings as in the base case, and the difference between estimated landings and base case landings was referred to as overquota landings.

This Base Case, which results are presented below, was then used as a reference case for all subsequent exploratory runs, which aimed at understanding the behaviour of the model under various conditions and assumptions.

2.2.3. Exploratory runs

Using KWdays

Days at sea are a simple measure of effort, which is easily measurable and available for most fleets through logbooks declaration. But it describes poorly the effective level of effort and is often poorly correlated with fishing mortality. Attempts to improve the definition of fishing effort and the correlation to fishing mortality has often involved detailed analysis at the trip level (Marchal et al., 2006) or precise information on effort descriptors (Marchal et al.,2007), which cannot be easily collected across large scale supranational métiers on a routine basis. The alternative measure of KWdays represents an alternative simple measure to correct for some differences in fishing power linked to the size and engine power of the vessels. Improved correlation to fishing mortality has been shown for some selected towed gears, whereas the inclusion of engine power in a nominal capacity expression for passive gears did not improve the linkage to effective capacity (Marchal et al., 2002). This is perhaps not so not so surprising as the coupling of engine power to gear size to increased catch rate is straight forward (the more engine power, the larger a trawl you can drag through the water), whereas a direct linkage between vessel engine power and the gear volume of passive gears (e.g. length of gill nets or number of hooks fished) is much less direct. In the case of passive gears, any improved linkage between effort and Fishing mortality from using KWdays instead of fishing days, is probably more a result of engine power being a reasonable indicator of vessel size. In conclusion, one would expect a substantial improvement in the linkage between effort and mortality for towed gears by using KWdays instead of fishing days, but more limited results for vessels using passive gears.

The effect of Nephrops

Because of the economic importance of Nephrops, all efforts were done to account for this species in our calculations. However, Nephrops is a problematic case, both in terms of management and in terms of assessment. Management issues arise from the fact that the TAC is set up for the whole North Sea and not by Functional Unit (FU), although each FU is considered as an independent population. Furthermore, landings data by country are provided by management area only, which is a grouping of FU within a larger area (ICES, 2007b).

Assessment issues arise from the fact that usual age-based stock assessment models are not relevant for this shellfish, both because growth and age cannot be established with sufficient precision and because its variable catchability (due to variable emergence from burrows) makes difficult the use of trawl catch rates as abundance indices. According to ICES WGNSSK (2007b), judgments about the states of the Nephrops populations in the various FU are based on three main approaches : (i) consideration of basic catch, landings and effort data; (ii) length composition and mean size; and (iii) for FUs where a reasonable time-series of underwater television survey (UTV) data is available, this is used as the principle indicator of stock condition (this is currently the case for FU6 to FU 9 in the North Sea).

Furthermore, our data format did not authorize to implement the length-based short-term forecasts as done by the ICES WGNSSK (2007b), and therefore a simpler harvest rate was estimated based on assessment data.

Therefore, the inclusion of Nephrops in the Fcube forecasts necessitated a number of proxies and simplifications. The translation of national landings data by management area into landings by fleet and FU included some expert guess in the fleet effort, in particular in the case of smaller and larger Scottish trawlers (S. Holmes, pers. comm.). For the FU 6 to 9, 2007 abundance was assumed equal to 2006, and the target F was estimated as the 2006 harvest rate time ratio of 2007 TAC divided by 2006 landings. No assumption was made about the NEPoth, which gathers all Nephrops FU for which no abundance estimates are available.

In consequence, the inclusion of five uncertain Nephrops stocks in the Fcube runs may imply large sources of uncertainty added to the model, compared to the more usual age-based forecasts for demersal fish stocks. This may affect the outcomes of the runs involving the “max”, “min” and “val” scenarios. Therefore, these three scenarios were run with the database including and excluding Nephrops from the Fcube effort estimate by fleet, all other parameters being equal.

Sensitivity to input parameters

Like for any forecast, Fcube analyses are based on a number of assumptions on the future values of parameters, which are unknown by definition. Traditional single-species TACs assume a relationship between landings and fishing mortality, provided hypotheses about future biological parameters (weight at age, recruitment) and fisheries parameters (selectivity, discarding patterns). The uncertainty of these parameters plays a major role in the potential failure of the TAC system to manage F.

Since Fcube aims at analyzing the consistency of single-species TAC, it is entitled the same range of uncertainties as those underlying these single-species TAC. Beside these, additional fleet-based parameters are used as inputs in the Fcube runs. They include hypotheses about future levels of (i) effort share by fleet and métier, (ii) landings share by fleet and stock and (iii) catchability by fleet, métier and stock. Some of these parameters show strong variability from year to year, catchability in particular.

We investigated the relative importance of the various sources of uncertainties by running a number of hindcasting exercises, i.e. by running the model back in time with some known input parameters, in order to evaluate the difference between predicted and observed values.

The analysis was conducted for the year 2006. In all analyses, the observed 2006 landings were used as the proxy for the TAC and the model was run as for the Base Case. Following validation analyses were run :

- “No error” : all 2006 parameters are known without error. Stock numbers at age, weight at age and selectivity data are those estimated for 2006 by the ICES Working Group in 2007; fleet-based parameters are those from the database.
- “Avg effort share” : all 2006 parameters are known without error, except effort share by fleet and métier, which is calculated as a 3 years average 2003-2005.
- “Avg TAC share” : all 2006 parameters are known without error, except landings share by fleet and stock, which is calculated as a 3 years average 2003-2005.
- “Avg catchability” : all 2006 parameters are known without error, except catchability by fleet, métier and stock, which is calculated as a 3 years average 2003-2005.
- “Forecast stock” : all 2006 fleet-based parameters are known without error, but stock-based parameters are calculated using a standard short-term forecast procedure. Selectivity and weight at age are calculated as a 3 years average 2003-2005. Only 2006 recruitment estimates are known from assessment data.
- “Full forecast” : all of the above. All input parameters are calculated using 3 years average as would be the case in a forecast procedure.

All these validation scenarios were run for a number of strategies scenarios, in a similar manner as for the Base case, in order to evaluate if the choice of the strategy itself is a factor of additional uncertainty. The scenarios were

- “max”
- “min”
- “Status quo_E”
- “val”
- “cod”
- “had”. The “had” scenario investigate the effort necessary to catch up the quota of haddock.

Outcomes in terms of estimated landings by stock, fleet and métier and effort by fleet and métier were synthesized through their relative variation compared to observed data, expressed in percentage.

Hindcasting analyses of strategies

A similar exercise was conducted in order to investigate the importance of the fishing strategies. A generic key issue for managing mixed-fisheries is that fishermen adjust their effort to resource availability, but also to market condition and regulation. This is a highly complex process of human behavior which is extremely difficult to apprehend and quantify, even at the level of the individual trip and fishing vessel. A fine simulation of the actual fishing strategies of the fleets is not possible to implement at such a large scale as the North Sea. In that sense, the Fcube method works at the level of the “broad picture” and aims at extracting simple proxies that could eventually be indicative of large trends.

Given the mismatch between the amounts of effort that a fleet may need to catch its various quota shares, a key issue is to estimate the final amount of effort that the fleet will use, based on the balance between these shares. As shown in the base case run, the Fcube model allows us to explore a variety of scenarios, but doesn’t provide evidence of which scenario is the most plausible. No endogenous behavior assumption is included in the model, i.e. we do not assume implicitly that the fleets will choose the maximum of the effort, or the one which maximizes their income. Such economic assumptions have been explored in another version of the model, the FcubEcon (Hoff and Frost, UCPH, D1.2).

In the present case, we have extended the previous hindcasting method to explore the recent time-series 2004-2006. For each of these three years, hindcasting were conducted using both “No error” and “Full forecast” validations. “No error” validations used the true value of input parameters effort share, catchability, stock numbers and landings share for the hindcasted year, while “full forecast” used the standards projections for these parameters using the average of previous observed years as input data. For each combination of year and validation, the effort by fleet corresponding to each stock’s TAC was output, as well as the corresponding scenarios “min”, ”max” and “val”. Then these results were compared with the true effort observed for the hindcasted year.

Stochastic runs

All exploratory runs described above involved variations around the deterministic Base Case run. But ultimately, the Fcube model was intended to be fully compatible with a general and generic MSE (management Strategy Evaluation) framework, which usually involves stochastic MCMC (MonteCarlo Markov Chain) procedures. Therefore, the Fcube scripts and functions were modified to account for the “iteration” dimension in all objects and perform the calculation accordingly.

Based on the results of the sensitivity analysis, we conducted some stochastic runs with uncertainty on the catchability input parameter, considering that this key parameter, linking the fishing effort with the fishing mortality, was the most variable. However, the shortness of the time series (four years) did not allow an in-depth analysis of the internal variability of the catchability parameter for all combination of fleet, métier and stock, and neither of their covariance. Furthermore, catchability here is only considered at a yearly average fleet level, and as such encompasses all individual trip-based processes which are related to complex individual fishing behavior (e.g. Marchal et al., 2006). Therefore, it was not possible to investigate the causal effects of the high variability observed, and neither to propose alternative methods for improving the input estimates.

The sensitivity of the model to catchability uncertainty was thus tested by adding a lognormal error on the three-years average catchability estimates, all other parameters being equal to the Base Case run. The error term was given a standard deviation of 0.3, which is the value commonly used for stock index uncertainty in MSE applications (e.g. STECF, 2007a, Hamon et al., 2007, Kell et al., 2007, Bastardie et al., 2009). This value is much lower than the actual sd estimated out of four points in many of our categories, but is still creating sufficient uncertainty in the model to inspect its robustness. Trials with 1000 iterations created memory troubles in R, due to the large size of the fleets objects. The analysis was then run with 100 runs only and this did not lead to memory or processing time issues. Larger numbers of iterations could potentially be achieved by running successive sets of simulations and combining them in the final results.

2.2.4. Short-term Advice

In all the exploratory runs explained above, we have used observed data for some years (2004-2006) to forecast fleets and stocks for the following year (2007).

However, key issue when delivering timely short-term advice is the intrinsic two-years lag existing between the last data known and the TAC. An ICES Working Group will meet during one year, and will use the data from the previous year to provide advice for the following year. Recent simulation studies have shown that the uncertainty about the intermediate year is a key factor affecting the short-term advice and the consistency of TAC with the precautionary approach (e.g. STECF, 2007a, Bastardie et al. 2009). ICES WGNSSK (2007b) often assumes statusquo F for the intermediate year, partly because mixed-fisheries issues prevent considering the more optimistic scenarios of F constrained by TACs.

This question is a major issue to address before considering the method as being fully operational for advice. Therefore, we modified the scripts used in the previous analyses to explore alternative scenarios comparing usual single-stocks approaches with mixed-fisheries approaches.

We run some forecast exercises with the same fleets data used in the exploratory runs (up to 2006), aiming at providing advice for 2008 TAC. Nephrops stocks were not considered here, because of the difficulty to provide stock-based forecast, so only the six fish stocks were included.

All scenarios focused on the intermediate year, estimating levels of landings and biomass for 2007. Then Advice for 2008 was subsequently based on a simplified Harvest Control Rule, similar across all scenarios, aiming at F2008 being below Fpa and not increasing for each stock *s*:

$$\text{Fmult2008}_s = \min(\text{Fbar2007}_s, \text{Fpa}_s) / \text{Fbar2007}_s.$$

We ran the following scenarios :

- “Sq_F” : Traditional stock-based short-term forecast. F in the intermediate year is assumed constant and equal to a three years average 2004-2006.
- “TAC_cstr” : Stock-based short-term forecast using a TAC constraint on landings on the intermediate year. The 2007 TAC as input in the Base Case were used.
- “Sq_E” : In the intermediate year, F by stock is determined by the Fcube status quo strategy. The difference with the traditional forecast is that E 2007 is equal to E 2006, while catchability is estimated with 3 years-average. Thus F2007 may differ slightly from the “sq_F” scenarios

- “val” : In the intermediate year, F by stock is determined by the Fcube “val” strategy, i.e. the effort of fleet is influenced by the financial value of the single-stock quota shares. This scenario was chosen based on the results of the hindcasting analysis (see below), as a plausible proxy for the expected resulting effort of the fleets. Therefore, this scenario was run as a simple scenario for what may likely happen in the reality in 2007.
- “cod” : In the intermediate year, F by stock is determined by the Fcube “cod” strategy, i.e. the fleets are strictly constrained by the cod quota in 2007, and this corresponds to the perfect implementation of a cod recovery plan in our simulated fishery, even though this implies a very restrictive management according to our Base Case analyses.

This represents only a subset of all possible runs that could be envisaged, since Fcube scenarios could also be run for 2008 instead of stock-based HCR. But this would be set up in a similar way as for the exploratory runs and would not require much additional programming. Therefore, such results were not investigated here, although they may be conducted during ICES WKMIXFISH (august 2009).

2.2.5. Management Strategies Evaluation

Ultimately, a final goal was to include Fcube scenarios into a broader MSE framework for North Sea demersal fisheries. Major steps in this direction were previously achieved by running simultaneous stochastic cod-haddock single-species projections linked by simple “min-max” fleet rules (Hamon et al., 2007).

It is intended to include Fcube into this MSE model and extend it to all demersal fish stocks. This ultimate linkage was a major driver in the setup and technical development of the Fcube programs, in order to achieve best compatibility, consistency and genericity with the MSE approaches.

Unfortunately, time shortage has prevented the full completion of this task at the end of the AFRAME project. Initial trials were successfully performed in February 2009, but it has not been possible to analyse this further, and no results are presently available. This task is still ongoing, and will be completed at a later stage.

However, comparable work was developed by IMARES during this project (see chapter 4) for sole and plaice fisheries.

2.2.6. Summary

In conclusion, a number of exploratory and trial runs were performed with the same dataset. For the readability of the document and the linkages with following results, these analyses are briefly summarized in the table below :

Type of analysis	**Description**	**Purpose**
1. Data exploration	a. fleets objects b. Trends	Overview over fishing units Parameterization of the Fcube model
2. Base Case	Analysis of the consistency of 2007 TACs	
3. Sensitivity and Exploratory analyses	a. Effect of effort measure	Comparison Days at Sea with KW days

	b. Effect of Nephrops	Inclusion/exclusion of Nephrops stocks
	c. Sensitivity to input uncertainty	Predicted vs. observed for 2006 data
	d. Hindcasting analysis of strategies	Analysis of preferred strategies by fleet
	e. Stochastic runs	Effect of uncertainty in catchability
4. Short-Term Advice	Advice on 2008 TAC	Effect of the Intermediate year in the forecast.

2.3. Results

2.3.1. The Fcube North Sea database

Compared to the data presented in deliverable 1.1, additional trials were performed to evaluate the relative importance of the various units (country * fleet segment * métier) and the loss of information when aggregating minor units into the "OTH" categories. (Figure 1)

Figure 2.1 (left) indicates that most fleets included in the database are fairly robust to the threshold, i.e. most of them catch more than 1000 tonnes per year of at least one stock. Increasing the threshold only leads to a marginal fleet aggregation, covering mainly the Belgian demersal trawler fleet, the English static fleet, and to a lesser extent the Norwegian beam trawler fleet. It must be kept in mind that this Norwegian fleet appeared in the database until 2006, although evidence exists that this fleet disappeared in 2007 (I. Huse, IMR, pers. com.) and will thus likely be removed from the database when it is updated with the most recent data.

On the contrary, Figure 2.1 (right) indicates that the métier aggregation within the fleets follows a fairly constant continuous stream. Increasing the threshold value leads to a number of métiers being pooled together and some loss of information on the actual fishing patterns of fleets.

It was therefore decided to keep the threshold at 300 tonnes per year instead of 100 tonnes as described in D1.1. This threshold was chosen corresponding to 5% of total fleets landings weight (all species together) being aggregated into the "OTH" categories and the two minor fleet segments mentioned above being pooled in the "OTH" fleet.

It is to be remembered that these total landings do not correspond to the total landings by stock as provided by ICES (WGNSSK 2007b), due to (i) the absence of some countries in our database, (ii) the extension of some stocks distribution beyond the North Sea, and (iii) the restricted definition to North Sea vessels within each country, removing the share of national landings taken by vessels mainly involved in other type of fisheries. The difference between the total landings by stock and the landings allocated to the fleets is allocated to the "OTH_OTH" fleet in order to include all fishing mortality in the data.

In conclusion, the updated Fcube North Sea database includes 16 fleets plus the "OTH_OTH" one, and 52 fishing units (fleet * métier) [against 19 and 62 respectively in the earlier version of the database], Table 2.1.

Table 2.1. Fleets and Métiers in the final Fcube North Sea database.

Fleet	Métier
BE_Beam	OTH
	TBB_120+
	TBB_80-89
DK_Beam	OTH
	TBB_120+
DK_DSeine	DSB_100-119
	DSB_120+
	OTH
DK_DTrawl<24	OTB_070-099
	OTB_100-119
	OTB_120+
	OTH
DK_DTrawl24_40	OTB_070-099
	OTB_100-119
	OTB_120+
	OTH
DK_Gillnet	GNS_120+
	OTH
EN_Beam	OTH
	TBB_DEM_100-119
	TBB_DEM_120+
	TBB_DEM_80-99
EN_DTrawl	OTB_CRU_80-99
	OTB_DEM_120+
	OTH
	PTB_DEM_120+

Fleet	Métier
NL_Beam<24	OTH
	TBB_DEM_80-99
NL_Beam>=24	OTH
	TBB_DEM_100+
	TBB_DEM_80-99
NO_Beam	OTH
	TBB_DEF_080
	TBB_DEF_120
NO_DTrawlRnd	OTB_DEF_100
	OTB_DEF_120
	OTB_DEF_130
OTH_OTH	OTH
SC_Beam	TBB_100-119
	TBB_120+
	TBB_80-89
SC_DSeine	DSB_120+
	OTH
SC_DTrawl<24	OTB_100-119
	OTB_120+
	OTB_70-89
	OTB_90-99
	OTH
SC_DTrawl>=24	OTB_100-119
	OTB_120+
	OTB_70-89
	OTH

2.3.2. Time series

Effort

The Fcube North Sea database provides a very useful overview of the global trends over the recent years. The database covers the period 2003-2006, which has witnessed major changes in the North Sea demersal fisheries. A strong driver has been the enforcement of restrictive management actions in the purpose of cod stock recovery, including among others days at sea limitations (e.g. STECF 2007b). The database includes simple annual figures of catches and effort by fleet and métier, and summary figures help describing main features.

The largest fleets in terms of effort (Figure 2.2) are the Scottish demersal trawls less than 24m (~ 30 000 days in 2006), and the Dutch Beam trawlers larger than 24m (~ 20 000 days). English demersal trawlers, Scottish large trawlers, Danish gillnetters and Danish large trawlers are of same effort scale (~ 10 000 days), while the other fleets are of minor importance. The least important fleets in this database are both the Danish and the Norwegian beam trawlers (which, as mentioned above, disappeared in 2007).

There has been a general decreasing trend in effort since 2003, comprised between 15 to 40% for most fleets. The effort of smaller Danish trawlers has though decreased more steadily. But as for beam trawlers, this trend is more indicative of a shift in effort from North Sea to Skagerrak rather than an absolute decrease (Bo S. Andersen, pers. com.).

The distribution of effort across the various métiers within a fleet shows some stability in the fishing patterns (Figure 2.3), in spite of métier-based days at sea regulation which may have enforced stronger reductions in some particular gear and mesh size categories. This is consistent with STECF (2007b) findings, showing that major changes have taken place in 2003 when days at sea were enforced, but subsequent adjustments in regulations have not affected yearly fishing patterns significantly. Most fisheries dealt with here are entitled days at sea limitations due to cod catches, and are thus following similar trends in management adjustments.

Landings time series

A key feature in the management of mixed-fisheries in European waters is the principle of relative stability which allocates a fixed share of single-species TAC to each country. Then the national quotas are spread over the fisheries in specific ways, which varies from country to country. Some countries have enforced ITQ systems, while other countries operate with competitive quotas, periods, quota allocation to PO etc. Furthermore, the national quotas are also traded and exchanged between countries in order to best address national interests. All this system is highly complex and cannot be quantified. It is not possible to simulate the true process of quota allocation. Nevertheless, the amount of quota available is likely a key driver in fisherman behavior, and must be accounted for. The simplest proxy is to assume that the main fleets by country get a constant share of the national quota, which can thus be approximated by the recent average. Over the last years, the landing share by fleet has indeed been relatively constant (Figure 2.4), although few changes have taken place. Scotland owns the largest quota share for haddock, but within the country, the share of large trawlers has increased meanwhile it decreased for the seiners fleet.

Base Case run – (ICES SGMixMan 2008)

The 2007 TAC corresponded to an overall variation in F (Fmult) between 0.4 and 2.7 compared to its 2004-2006 average:

COD	HAD	PLE	POK	SOL	WHG	NEP
0.40	1.02	0.95	1.00	1.08	2.73	1.12

The various scenarios showed very contrasted results, as displayed in the table 2.2 and figure 2.5

Table 2.2 : Estimated 2007 landings by stock corresponding to the various Fcube scenarios

	COD	HAD	PLE	POK	SOL	WHG	NEP6	NEP7	NEP8	NEP9	NEPoth
TAC2007	19957	54640	50261	123250	15020	23800	5487	12713	2887	2112	2945
fwd	23722	54640	50261	123249	15020	23800	5487	12713	2887	2112	NA
max	93816	146153	104195	308273	27953	24343	7291	24833	5577	4427	NA
min	23722	29713	24121	54907	6314	5212	1219	4004	897	712	NA
val	49545	65298	52293	120710	14182	12268	4498	11395	2617	2077	NA
statusquo_E	49255	62808	48531	118471	13390	11476	3141	9046	2018	1602	NA
DAS_reduction	47121	55829	44877	112046	12103	10764	2759	7459	1659	1317	NA
cod	23722	29713	24121	54907	6314	5212	1219	4004	897	712	NA

Maximum and minimum scenarios represent the two extreme bounds of the range of possibilities, and because of the co-occurrence of a very restrictive cod TAC and a very unrestrictive whiting TAC, the maximum was estimated four or five times higher than the min. Thus the max did not appear a plausible scenario here, especially given the low monetary value of whiting.

On the other hand, the scenarios of no or limited reduction of effort provided results closer to previously observed patterns. Indeed, under these scenarios, there is a fairly close match between the TAC in place and the estimated landings for haddock, plaice, saithe and sole (less than 15% difference). Only cod showed large overquota catches, (of the order of magnitude of the TAC itself), while whiting TAC was taken at 50%, and Nephrops at 70-75% only.

The simulated days at sea reduction showed only a reduction of 4.5% of estimated landings compared to the statusquo scenario, although the effort in most fisheries catching cod was reduced by 7 to 10%. This was partly due to the non linear relationships between effort and catches, but also to the large share of cod landings allocated to the “OTH” fleet (and gathering cod catches from French and German fleets as well as cod catches taken in Skagerrak and English Channel). This “OTH” was not reduced in the present scenario, whether assuming a global 10% reduction of the effort of that fleet also would lead to a 9% reduction of cod catches.

An interesting result was the consistency observed between the “val” (“value”) scenario and scenarios of status quo effort. In the “val” scenario, fleets are assumed to set their effort as a weighted mean of the relative value of their quota shares, i.e. they would focus more on catching the quota share for the species giving the maximum value, while under- or over-catching the quota share for the species giving less value. This scenario is a simple but very rough proxy for economy-driven fleet behaviour, but was indeed the one giving the results closest to the observed historical patterns for most fleets (Figure 2.6). The main difference was that the quota uptake was estimated higher for sole (93%) and Nephrops (89%) in that scenario compared to the statusquo scenario (89% and 70% respectively), indicating a higher focus towards high-valued species.

Finally, the “cod” scenario investigated which TAC reduction for the other stocks would be necessary to avoid overquota catches of cod. Because of the large effort reduction required by the very restrictive TAC and the incoming of the larger 2005 year-class at age 2 in 2007, dramatic TAC reductions would be necessary in the other fisheries, in the magnitude of 50% for haddock and plaice, 60% for saithe and sole, 70% for Nephrops and 80% for whiting. For all fleets, it is clear that the effort necessary to take up their own quota share of cod was much lower that what is necessary for taking up the quota of the other species (Figure 2.7). This scenario was indeed equivalent to the “min” scenario. In the current situation, it was thus expected that large overquota catches of cod have indeed taken place in 2007.

Furthermore, the use of the B-Adapt assessment method for cod provides a valuable tool to compare with our findings. B-Adapt estimates an amount of “missing catches”, that were removed from the stock but not recorded in the inputs landing and discards. These unallocated removals are interpreted as the likely overquota catches due to restrictive TACs and mixed-fisheries effects. The estimated amount of these removals varies across years, but was estimated around 17 to 20 000 tonnes over 2004-2006. The results obtained from Fcube runs are very consistent with these findings, since we estimated overquota catches being around 25 000 tonnes in 2007 in the three scenarios “val”, “statusquo_E” and “DAS_reduction”. In that sense, Fcube provided an interesting process-based modelling of the dynamics of overquota discarding, and this was supported by the findings of independent analyses as done here with B-Adapt.

2.3.3. Exploratory runs

Using KWdays

We have tested whether using KWdays would affect our results and reduce the uncertainty on the catchability estimates. The same run as the TAC07 was performed using KWdays at sea instead of days at sea, and the outcomes were compared (Figure 2.8)

It appears clearly that using KWdays or days at sea did not affect the outcomes of the results in this case. The estimated landings by stock were very similar. minor differences in the estimated variation of effort may be observed, but mostly for the smallest fleets with little relevance here.

Such similarity in estimated landings indicates that F estimates by fleet were identical and thus, that the observed patterns in catchability were similar. Both measures of effort displayed the same trends, indicating that the internal size structure of the fleet has not changed over the period.

In addition, using KWdays did not contribute to reduce the variability in catchability estimates by fleet and metier (Figure 2.9). Standard deviation of Log catchability residuals are very high in most combinations of fleets, metiers and stocks, underlying the major incertainty in this parameter.

Effect of Nephrops

We tested the influence of Nephrops in the outcomes of the runs by removing all Nephrops FU from the database and re-running the “min”, “max” and “val” scenarios from the Base Case. We observed no effect of this removal in the “min” and “max” scenarios (Figure 2.10).

Indeed, the figure 2.7 above had evidenced that although the estimated effort necessary to catch the fleets Nephrops quota did vary from fleet to fleet, it was in all cases estimated higher than the minimum effort across stocks (which corresponded to cod) and lower than the maximum (which corresponded to whiting). This result is not surprising, since in the absence of reliable age-based assessment the stocks of Nephrops were modeled in a fairly conservative way in our model. This led to little variability in the abundance in the short-term, and therefore corresponding effort estimates close to the status quo.

The “val” scenario is a simple proxy for an economically-driven behavior, where the resulting fleet effort is a simple mean of the effort weighted by the monetary value of the landings. This scenario shows some effect of the exclusion of Nephrops, with lower effort estimates mainly for the English, small Scottish and large Danish trawlers (22%, 21% and 12% lower respectively). However, these differences are smoothed out at the stock level, since only minor changes in the landings estimates are observed, and only for haddock and whiting (-7%).

Sensitivity to input parameters

The hindcasting exercise comparing observed and predicted 2006 values under a number of scenarios is presented on figure 2.11, both with focus on the type of uncertainty and the type of scenario. The visual inspection of the summary plots underline the potential large variability between predicted and observed data.

Looking at the type of uncertainty (Top figure), it is clear that in the absence of uncertainty (“No error”), the model outcomes are close to the observed data for most scenarios, except for the cod stock, which landings are systematically overestimated. The model seems also robust to uncertainty around future effort share, since this parameter has not varied much over the years 2003-2006.

Obviously, the largest uncertainty comes from the catchability parameters, for all stocks and strategies, as well as from the uncertainty about stock forecast, which is equivalent to the level of uncertainty traditionally included in stock-based forecast. Beside, the uncertainty about relative TAC share may affect significantly the results as well. This is particularly evident looking at the "had" strategy results. For this stock, the relative TAC share has decreased within the Scottish seiners fleet and has increased within the Scottish trawlers fleet, and because of the size of these fleets this impacts significantly the outcomes of the model. Though, all these sources of uncertainties interact and counteract each other, and the final level of uncertainty taking into account the combined sources is not larger than with the uncertainties considered individually.

This perception is slightly different when looking at the results by type of strategy (Bottom figure). It appears clearly that some scenarios predict observed data better than some others, regardless of the sources of uncertainty, and this provides with some indications that these strategies do not reflect what has happened in the reality. In particular, the strategy "max" is performing poorly under all scenarios, and the strategy "had" is also very sensitive to model misspecification. On the contrary, a striking result is that the strategy "val" seems quite robust to the various sources of uncertainties introduced, and provided a fairly good fit to observed data, except for some overestimation of cod landings.

These outcomes were refined by extending the analyses to a larger hindcasting period.

Hindcasting

The same exercise as the base run was conducted for the years 2004 to 2006, both by using 3-years average for the input parameters as in the base case ("Full forecast" validation) and by using the true observed value of parameters ("No error" validation). For all years, the observed landings were used as the management objective, as a proxy for the TAC.

The resulting Fmultiplier necessary to achieve the single-stocks objective were less variable than in the Base Case. This was expected, since the Base Case runs with some high whiting TAC for 2007, which does not constrain the landings. However, the large drop in F observed for haddock in the 2003-2005 period in the assessment data used in the present work acted as a highly restrictive landings constraint for 2004 and 2005 when using a standard 3-years average short-term forecast as we did here. Whiting did also show large fluctuations in F and landings over the recent years, with a large decrease in 2004 and an increase again in 2006 (Table 2.3).

Table 2.3. Fmultiplier by year necessary to land the observed landings data by year, used as input for Fcube hindcasting 2004-2006.

	COD	HAD	PLE	POK	SOL	WHG
2004	0.69	0.38	0.94	0.88	0.83	0.47
2005	0.92	0.82	0.78	1.11	0.88	0.84
2006	0.90	1.20	0.81	1.05	0.94	1.77

The comparison of observed versus predicted effort for all years and both validation runs is presented figure 2.12. The fleet effort corresponding to each stock quota share (stock-specific effort) is displayed, as well as the "max", "min" and "val" scenarios. Although "max" and "min" are by definition corresponding to the maximum and minimum across stock-specific effort by stock, plotting them has been a valuable tool for tracking errors in the code and has contributed to improved quality checking.

This comparison brought very interesting results. The “No error” run (Figure 2.12, top) shows that all strategies gave close results, and that the model was able to reproduce observed patterns fairly well, knowing the true values of stock and fleet input parameters. This result was logically expected, since the observed values of effort and landings were initially used to estimate catchability and landings share. As such, it was expected that using these values of catchability and landings share would in turn estimate levels of effort close to the observed ones. Only for 2004 where F for haddock has decreased at a larger scale, the corresponding effort estimates are lower than for other stocks, but for 2005 and 2006 all strategies are consistent. This result, although not very informative about the true observed behavior of the fleets, provides confidence in the model’s consistency and ability to reproduce observed patterns.

More interesting are the results obtained with the “Full forecast” validation run (Figure 2.12, bottom and figure 2.13), which uses 3-years average of past input data to estimate future levels of effort by fleet. Stock-specific efforts by fleet are more spread than in the “No error” run. However, the single-species objectives and Fmultipliers were not fully inconsistent with each other, as they were around similar scales (Table 2.3), except for haddock in 2004. In consequence, resulting stock-specific effort are not very different for many of the fleets. However, Figure 2.13 clearly shows that the actual observed effort (red “x” symbols) was neither at the maximum (blue “M” symbols) nor at the minimum (green “m” symbols) for almost all fleets. However, the “val” strategy (red “V” symbols) seems to be a fairly close proxy for many of the fleets of importance. In particular, the fit is best for the Dutch beam trawlers, which are of very high importance in the North Sea. The only fleet for which this proxy doesn’t seem to reflect the observed effort is the largest fleet of all, the Scottish demersal trawlers less than 24m, where the observed effort was systematically below the “val” forecast. For this fleet, the closest consistent proxy appears to be “cod”, since the effort of this fleet has been close to the effort necessary to catch the cod quota share regardless of other stocks. This fleet gets a large amount of revenue from the Nephrops fisheries, which are poorly modeled and forecasted, and this may explain the high estimates for the “val” scenarios.

Some mismatch also appears for the Danish trawlers less than 24m. However, this fleet is poorly defined in our case, because it has shifted a large part of its activity from the North Sea to the Skagerrak, leading to some inconsistencies in the effort estimates. Similar reserves apply for the Danish and English beam trawlers, which have experienced other trends but which importance at the North Sea level is limited.

This relatively good fit of the “val” scenario was not expected, since this proxy is only a simple mathematical metric which is very loosely based on some rough economic consideration, but does not include explicit economic behavior such as revenue- or profit optimization. Its interest lies on its computational simplicity. This result is very valuable for the further use of the Fcube method for advice and forecast, since it provides with a plausible hypothesis about future levels of effort.

Stochastic runs

Finally, the last exploratory exercise was conducted using the stochastic features available in FLR through the “iter” dimension of all objects. We applied a lognormal error with 0.3 sd to all catchability estimates for 2007 and ran 100 such iterations for all scenarios.

Figure 2.14 shows that this error propagates into the model outcomes, especially in the “max” scenario. And because of the static conservative model we have implemented for Nephrops stocks, the uncertainty in model estimates is the largest for these stocks (table 2.4). On the other hand, the age-based models for demersal fish stocks include some non-linear relationships between effort and landings, which tend to decrease the confidence interval in the landings estimate.

Table 2.4 : coefficient of variation in the landings estimates by stock and strategy with a lognormal random error on catchability with sd 0.3.

	max	min	val	sq_E	cod
COD	0.08	0.02	0.11	0.11	0
HAD	0.11	0.17	0.07	0.13	0.2
NEP6	0.27	0.27	0.09	0.22	0.27
NEP7	0.28	0.27	0.12	0.21	0.27
NEP8	0.28	0.27	0.25	0.23	0.28
NEP9	0.31	0.32	0.28	0.28	0.33
PLE	0.08	0.14	0.11	0.09	0.14
POK	0.14	0.22	0.09	0.15	0.23
SOL	0.15	0.23	0.07	0.16	0.23
WHG	0.03	0.17	0.1	0.12	0.18

Conclusions on exploratory runs

The goal of these exploratory runs was to gain increased knowledge about the Fcube model, and to come up with our best expert choice for the settings of the final Fcube run. The main findings obtained were:

- Giving the correct set of input parameters (perfect knowledge), the Fcube model was able to reproduce the observed effort and landings patterns. This contributes to enhance the credibility and the usefulness of the approach for real advice purposes.

- Over the 2003-2006 period, using KW days instead of days at sea does not improve the model, as it does not contribute to reduce the uncertainty around the relationship between fishing effort and fishing mortality. More advanced work would be necessary to improve the standardization of effort.

- This uncertainty about catchability is the most important source of uncertainty. It reduces significantly the predictive power of the model, although main differences between scenarios are still clear in a noisy simulation framework.

- Nephrops stocks are poorly addressed in this model, which can best address issues related to traditional age-based single stock approaches. However, it was possible to combine data-poor and data-rich stocks within the same framework using simple proxies and conservative models, allowing taking in consideration all stocks of high economic importance. Furthermore, we showed that the model outcomes were highly robust to the inclusion / exclusion of Nephrops.

- Hindcasting the model on previous years and comparing predicted values with observed ones helped formulating “best expert choices” for future scenarios and advice. A major finding was the evidence that for the period 2004-2006, the simple metric used in the “val” strategy, which loosely relates to some economic considerations, appeared as a valuable proxy fitting relatively closely with observed patterns for most fleets. Only for the largest fleet did this not seem to apply, but for this fleet the quota for cod may have been a stronger driver.

2.3.4. Short-term advice

This chapter intends to mimic what could be a situation of real advice, where mixed-fisheries interactions must be quantitatively considered on top of single-species assessment and short-term forecast. In all cases, advice for 2008 is based on the single-stock objective of F being at or below Fpa and must not increase.

Based on the results of the Base Case analysis, we chose some scenarios likely to give very different results on the likely development of stocks in the short-term (Table 5). And indeed, it is clear here that completely opposite pictures can be given based on what is expected to happen during the intermediate year. The scenarios of “sq_F” (traditional single-stock forecast with status quo F) and “sq_E” (status quo effort by fleet) give close results for all stocks, as was expected. They would lead to an increase in the cod stock biomass, a decrease of haddock and whiting, and some stable biomass of saithe, plaice and sole.

As shown in the Base Case, 2007 TAC were not strongly constraining the haddock, saithe, plaice and sole landings, and the “TAC_cstr” scenario provides thus similar results for these stocks. However, it is very unrestrictive for whiting, being set at 23 000 tonnes while status quo landings would be around 12 000 tonnes. Such high landings, if they were taken (which is little plausible with the current fleet capacity) would logically lead to a strongly reduced whiting stock by 2009. On the opposite, the 2007 cod TAC was set at a very restrictive level (corresponding to a reduction of 60% of effort), which, if it was perfectly implemented, would lead to major recovery of the cod biomass. As for the Base Case, these results underline significantly the large inconsistency that has taken place in 2007 between the TAC for cod in the one hand, the TAC for whiting in the other hand, and the TACs for haddock, saithe, plaice and sole in between.

Finally, the “val” scenario represents our most plausible “expert guess” on the likely level of fisheries in 2007, and the corresponding effect on the stocks for 2008. General findings are close to the “sq_E” results. For cod, this implies that a higher TAC would have been necessary to avoid overquota catches in 2007, but this would be at the price of a lower biomass increase in 2008 and 2009 and thus a slower recovery than would have been expected if the perfect implementation of the TAC was achievable.

Table 2.5 – Short term advice in landings, Fmultiplier (from $Fbar_{04-06}$ to $Fbar_{07}$ and from $Fbar_{07}$ to $Fbar_{08}$) and SSB by stock following various scenarios for the intermediate year.

Landings		COD	HAD	PLE	POK	SOL	WHG
2007	sq_F	37920	53521	52271	123085	14142	10983
	TAC_cstr	18907	54640	50261	123249	15020	23800
	cod	18907	29713	24121	54907	6314	5212
	sq_E	36858	62808	48531	118471	13390	11476
	val	36069	60791	51712	119694	14165	11416
2008	sq_F	33743	62467	51680	116518	14904	8370
	TAC_cstr	62759	63303	50750	116624	16564	6478
	cod	62759	40368	31190	61234	8648	4648
	sq_E	42583	68887	49886	113481	15168	8621
	val	43467	67592	51429	114296	14895	8591

Fmult		COD	HAD	PLE	POK	SOL	WHG
2007	sq_F	1	1	1	1	1	1
	TAC_cstr	0.4	1.02	0.95	1	1.08	2.73
	cod	0.4	0.52	0.41	0.41	0.4	0.44
	sq_E	0.96	1.2	0.91	0.96	0.94	1.05
	val	0.93	1.16	0.99	0.97	1	1.05
2008	sq_F	0.74	1	1	1	0.91	1
	TAC_cstr	1	1	1	1	0.99	0.46
	cod	1	1	1	1	1	1
	sq_E	0.78	1	1	1	0.97	1
	val	0.8	1	1	1	0.91	1

SSB		COD	HAD	PLE	POK	SOL	WHG
2008	sq_F	38313	295582	200304	310532	31825	51636
	TAC_cstr	62920	293996	203994	310377	30980	31947
	cod	62920	329717	252397	375382	39413	60832
	sq_E	39648	282472	207172	314884	32550	50857
	val	40644	285308	201330	313730	31802	50953
2009	sq_F	55808	236799	216700	298612	33711	40046
	TAC_cstr	67967	234193	224207	298346	31131	26786
	cod	67967	298065	337507	421323	48243	53210
	sq_E	46013	215869	230796	306152	34227	39032
	val	46973	220280	218772	304142	33694	39156

Ideally, these findings should be included in a full Management Strategy Evaluation framework, in order to fully test the consequences of these scenarios in the medium and the long-term, so as to evaluate if the cod stock may recover even if higher TACs are implemented. Such a work is still ongoing and the results are not yet available, but they will likely be finalized during the incoming ICES WKMIXFISH in August 2009.

2.4. Discussion

2.4.1. Summary

All analyses presented here have lead to very interesting results. We have gained valuable knowledge about the Fcube model. We have also developed increased confidence about its consistency and behavior, as well as about its usefulness for operational mixed fisheries advice in real situations. We have also demonstrated the flexibility of the method to address a large variety of issues, since all results were obtained with only limited changes to the Base Case R scripts. This has also given us a major technical training in developing R and FLR programs and visualizing complex data involving several units of fleets, métiers and stocks.

Second, this work has provided us with a highly valuable quantitative knowledge about the North Sea demersal fisheries. They have been considered here as a whole, regardless of national differences. In spite of their complexity and heterogeneity, we have been able to output simple metrics and graphs helping understanding “the broad picture” of the technical interactions occurring in the fisheries.

It is also important to point out that the use of North Sea data has been highly beneficial for the overall development of the Fcube method and simulation scripts. The complexity of the data structure, where métiers differ from fleet to fleet and where not all stocks are caught by all fleets nor by all métiers within a fleet, has driven the needs for improved quality checking and genericity of the programs. A lot of testing and controls have been necessary at all steps of the computations. Reciprocally, improvements in data visualization have helped identifying inconsistencies and errors in the data. Conducting all these analyses has been a computer-intensive and highly time-consuming process, but this has lead to major improvements in the Fcube method, and significant contribution to the whole issue of mixed-fisheries management.

Though, a number of issues have been encountered throughout the advancement of the work, both on the data side and on the conceptual and technical side. These issues are summarized below.

2.4.2. Data issues

Some issues we encountered with regards to input data, and in particular:

- As described in more details in the deliverable D4.1, it has not been possible to obtain national data consistent across countries with regards to fleet and métiers definition. In consequence, each fleet must be considered as an independent unit, and it is not relevant to proceed to métiers-based analyses regardless of the fleet. Even for métiers defined according to similar criteria across fleets (e.g. OTB_100-119), it is not appropriate to consider them as a regional métier since catch composition will differ significantly between e.g. Danish trawlers and Scottish trawlers engaging in this activity. We consider thus that the fleet should be the basis of any analysis, rather than the métier or the country.

- Stock distribution. In the North Sea, some stocks are strictly related to the North Sea (plaice, sole, Nephrops), while others extend beyond the North Sea, in the Skagerrak and the English Channel or on the West of Scotland. This has created some problems when collecting the data since other métiers should have been considered for these areas, with different exploitation patterns and exploiting other stocks than North Sea stocks. Here we chose then to limit our fleet-based data collection to the area IV only, but this had the consequence of allocating a large part of the stock-based landings to the "OTH" fleet.

- More generally, this "OTH" fleet got a major share of the total landings (mostly for cod, saithe and whiting). This is partly due to the stock distribution advocated above, but two other factors influence this as well : the missing data from France and Germany, and the differences that may occur between the sum of fleets landings by country and the official landings by country. This arises from the fact that landings by country include also landings with missing trip information and landings from the fleets not considered as North Sea fleets (an important issue for Denmark, Belgium and Norway at least). While the size of the "OTH" fleet doesn't affect the behavior of each individual fleet (which reacts only to its own set of quota share), this may have important consequences for the results obtained at the stock level. For research purpose, this did not prevent developing the tool and performing some analysis, but additional effort should be made to reduce the size of the "OTH" fleet when dealing with real advice.

2.4.3. Conceptual and technical issues

The Fcube method in itself was considered appealing by ICES SGMixMan (2006, 2007, 2008) because it was conceptually simple. Indeed, the core of the method itself, linking target F with effort by fleet, is rather straightforward.

However, a number of technical and conceptual issues have revealed themselves during the development of the analyses and their application to North Sea data. In particular, the following points were raised :

- The distinction between landings, discards and overquota at each time step of the computation is error-prone and requires careful thinking. Available discards data mostly relate to size-based processes of selection and minimum landings size, and are therefore disentangled from the issue of overquota discards that we are addressing here. High grading is not addressed here neither. Fcube calculations are therefore based on landings and landing mortality constraints, rather than on catch F. In the database, mean catchability estimates relate to catch F, therefore targets are estimated using landings selectivity at age. But stock dynamics is influenced by catch F, and hence the Fmultiplier estimated with Fcube on landings is applied to both the landings and discards component, assuming a fixed pattern between both components. This issue is not specific to Fcube and may be tackled in a similar manner for any forecast exercise, but is it important to keep this in mind in the programming.

- More difficult was the issue of cod. All demersal stocks are currently assessed with the XSA method, which assume perfect knowledge of all catches, landings and discards. But cod is assessed with the B-Adapt method, which estimates an amount of unallocated catches beside landings and discards. In particular, these catches are assumed to include the overquota catches, i.e. the share of oversized fish that was regularly caught but could not be landed because of restrictive quota. The B-Adapt method was exactly developed to circumvent the bias in the assessment due to TAC management. In that sense, B-Adapt estimates the same component of catches as Fcube aims at modeling. This creates a number of conceptual issues when using cod assessment data in Fcube, among others (i) catchability estimates are estimated base on official landings, and therefore may underestimate the true levels of landings, (ii) fishing mortality summed over fleets is not consistent with stock-based fishing mortality, and this affects the whole stock forecast and requires modifications of the traditional catch equation, (iii) modeled changes in effort and TAC will eventually affect the level of landings F, but no simple assumption can be made to relate this to the unallocated mortality in the stock forecast. In consequence, a number of assumptions had to be made specifically for cod, and the results obtained should be interpreted with more caution.

2.5. References

Bastardie, F., Nielsen, J.R., and Kraus, G. 2008. Management Strategy Evaluation framework for the Eastern Baltic cod fishery to test robustness of management against environmental conditions and fleet response scenarios. (Accepted ICES J. Mar. Sci.)

Darby, C.D., and Flatman, S., 1994 Virtual Population Analysis: Version 3.1 (Windows/DOS) User Guide. Information Technology Series, No. 1(MAFF, Directorate of Fisheries Research, Lowestoft) 85 pp.

Hamon, K., Ulrich, C., Hoff, A., and Kell, L. T., 2007. Evaluation of management strategies for the mixed North Sea roundfish fisheries with the FLR framework. In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp. 2813-2819.

ICES. 2006. Report of the Workshop on Simple Mixed Fisheries Management Models (WKMixMan), 9–13 January 2006, ICES Headquarters. ICES Document CM 2006/ACFM: 14. 47 pp.

ICES. 2007a. Report of the Study Group on Mixed Fisheries Management (SGMixMan), 15–19 January 2007, ICES HQ, Copenhagen, Denmark. ICES Document CM 2007/ACFM: 02. 565 pp.

ICES. 2007b. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 1-8 May 2007, ICES Headquarters. ICES Document CM 2007/ACFM: 35. 1160 pp.

ICES. 2008. Report of the Study Group on Mixed Fisheries Management (SGMixMan), 14–18 January 2008, ICES, Copenhagen, Denmark. ICES Document CM 2008/ACOM: 23. 65 pp.

Kell, L. T., Mosqueira, I., Grosjean, P., Fromentin, J-M., Garcia, D., Hillary, R., Jardim, E., et al. 2007. FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science, 64: 640−646

Marchal P., Ulrich C., Korsbrekke K., Pastoors M. Rackham B., 2002. A comparison between three indices of fishing power relative to some demersal fisheries of the North Sea. ICES J. Mar. Sci. 59, 604-623.

Marchal, P., Andersen, B., Bromley, D., Iriondo, A., Mahévas, S., Quirijns, F., Rackham, B., Santurtun, M., Tien, N., Ulrich, C., 2006. Improving the definition of fishing effort for important European fleets by accounting for the skipper effect. Canadian Journal of Fisheries and Aquatic Sciences, 63(3), 510-533.

Marchal, P., Andersen, B., Caillart, B., Eigaard, Guyader, O., Hovgaard, H., Iriondo, A., Le Fur, F., Sacchi, J., and Santurtun, M. 2007. Impact of technological creep on fishing effort and fishing mortality, for a selection of European fleets. ICES Journal of Marine Science, 64, 192–209.

STECF 2007a. STECF / SGMOS-07-07. Working Group report on evaluation of “policy statement” harvest rules report, Copenhagen, 10-14 september 2007.

STECF 2007b. STECF / SGRST – 07-02 and 07-04. Working Group report on assessment of fishing effort regime, Lisbon, 21-25 june 2007, Ispra, 24-28 september 2007, 282 pp.

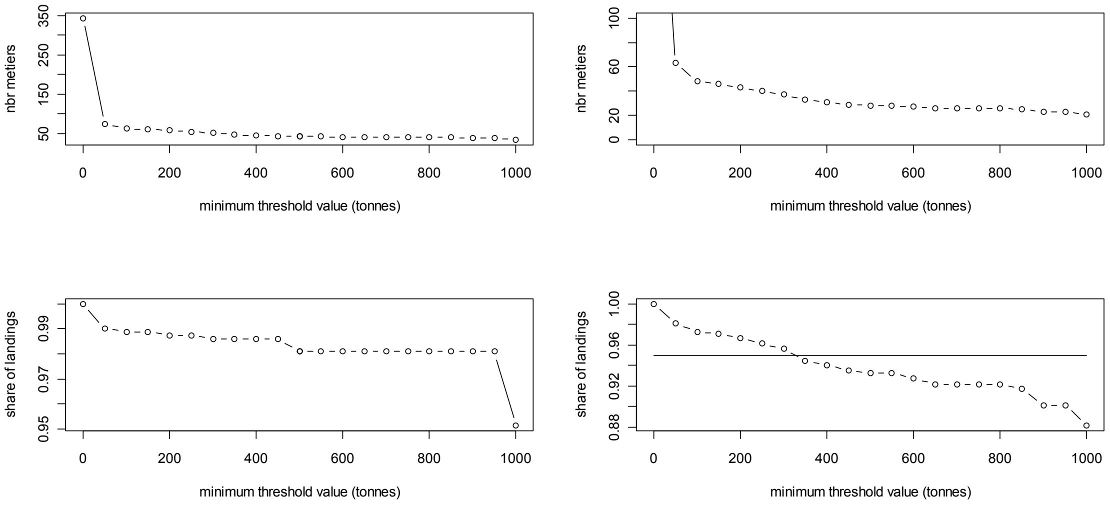


Figure 2.1 : Number of units and percentage of allocated landings explained with regards to the threshold value. All métiers within a fleet catching less than the threshold for any of the eleven stocks are merged into the “OTH” métier within the fleet. All fleets having all of their métiers under the threshold are merged into the general “OTH_OTH” fleet. Left : number of units not being in the “OTH_OTH” fleet (including “OTH” métiers). Right : number of units not being in the “OTH_OTH” fleet and not being merged into the “OTH” métier by fleet

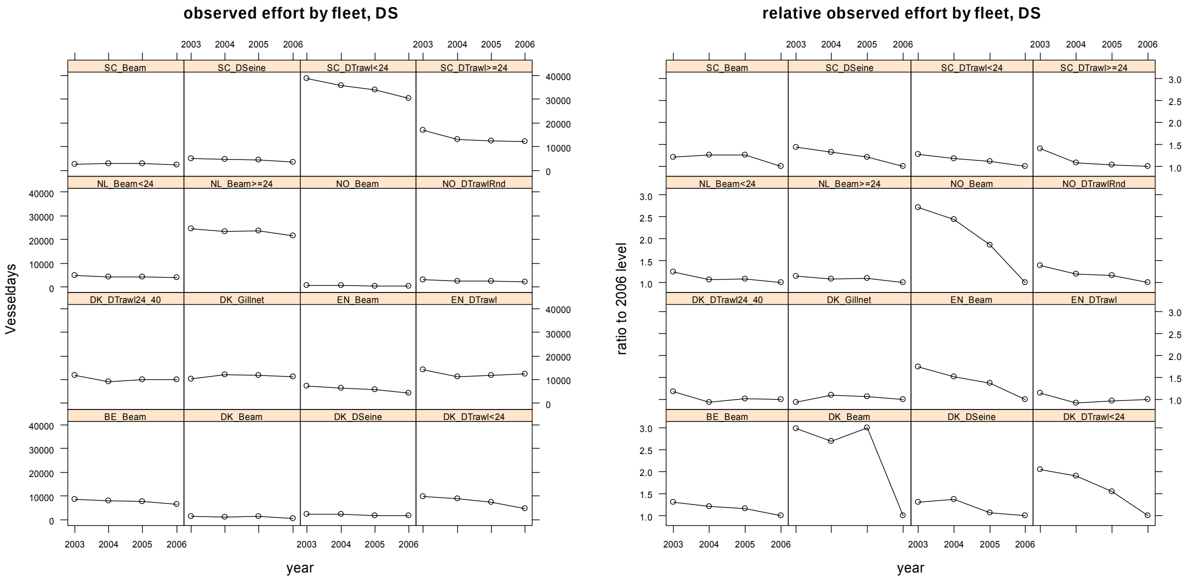


Figure2.2. Observed effort by North Sea fleet, 2003-2006. Left : Total numbers of days at sea. Right : relative variation of effort, value=1 in 2006.

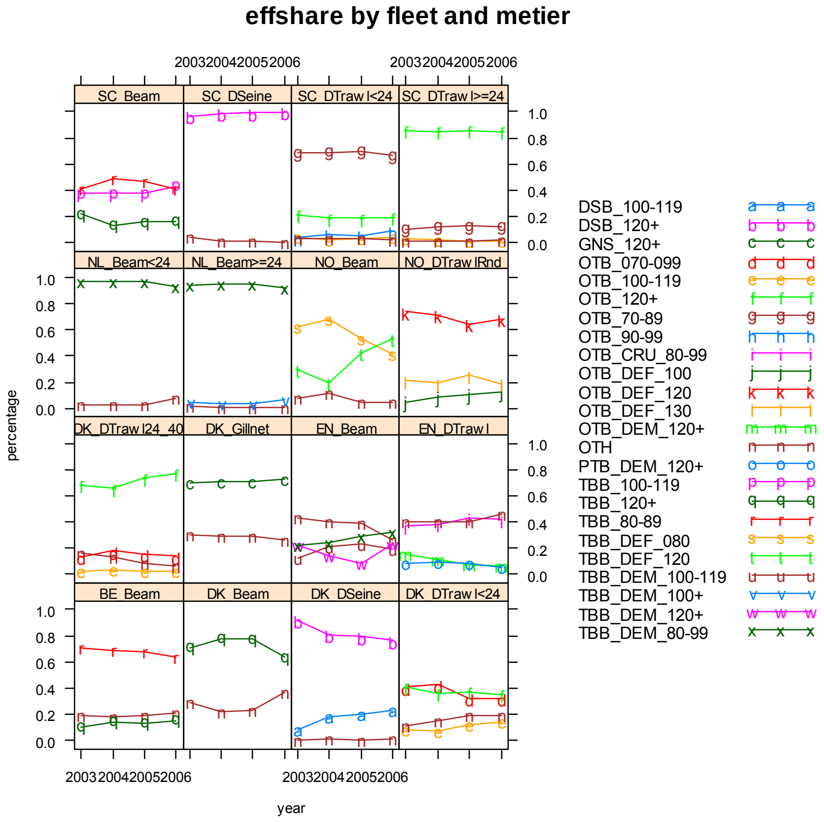


Figure 2.3. Percentage of fleet effort by métier, 2003-2006.

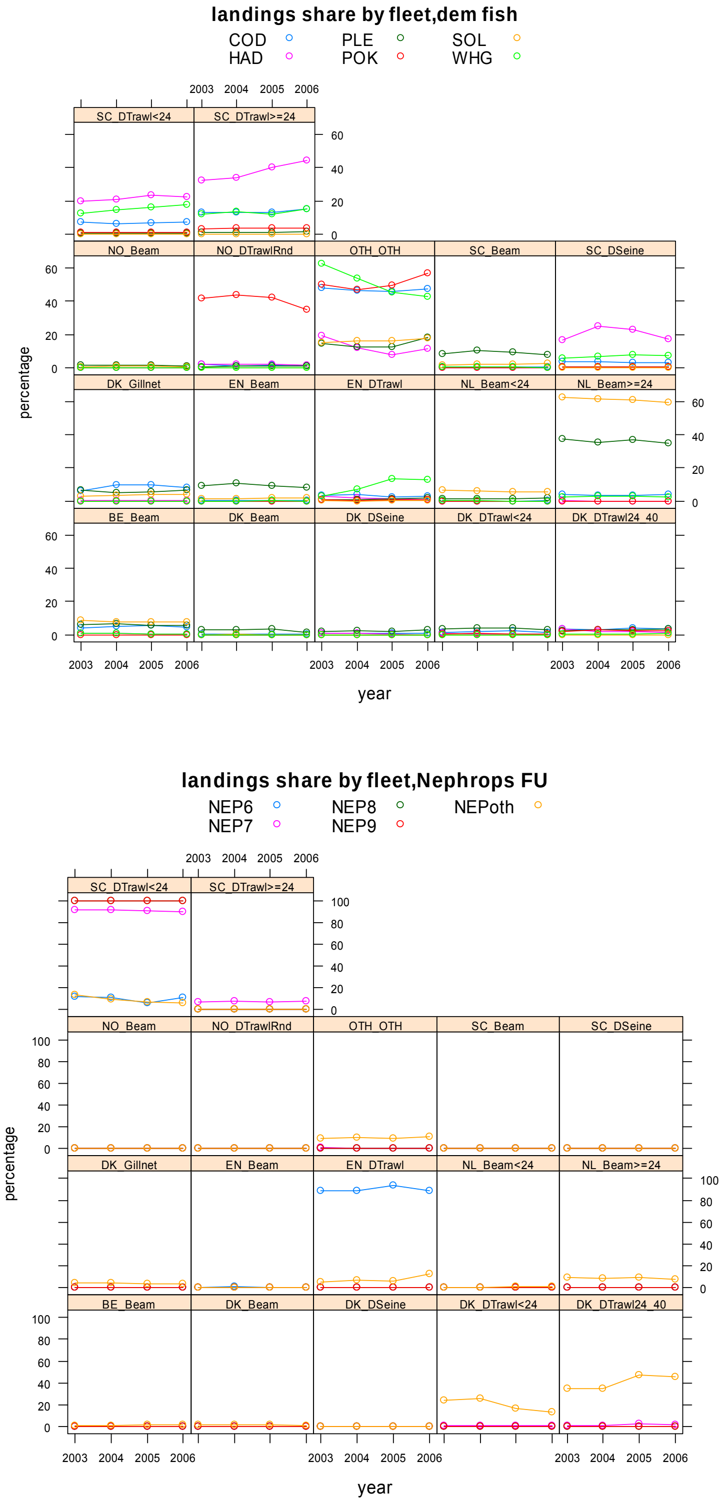


Figure 2.4. Time series of landings share by fleet and stock.Top : demersal stocks. Bottom : Nephrops

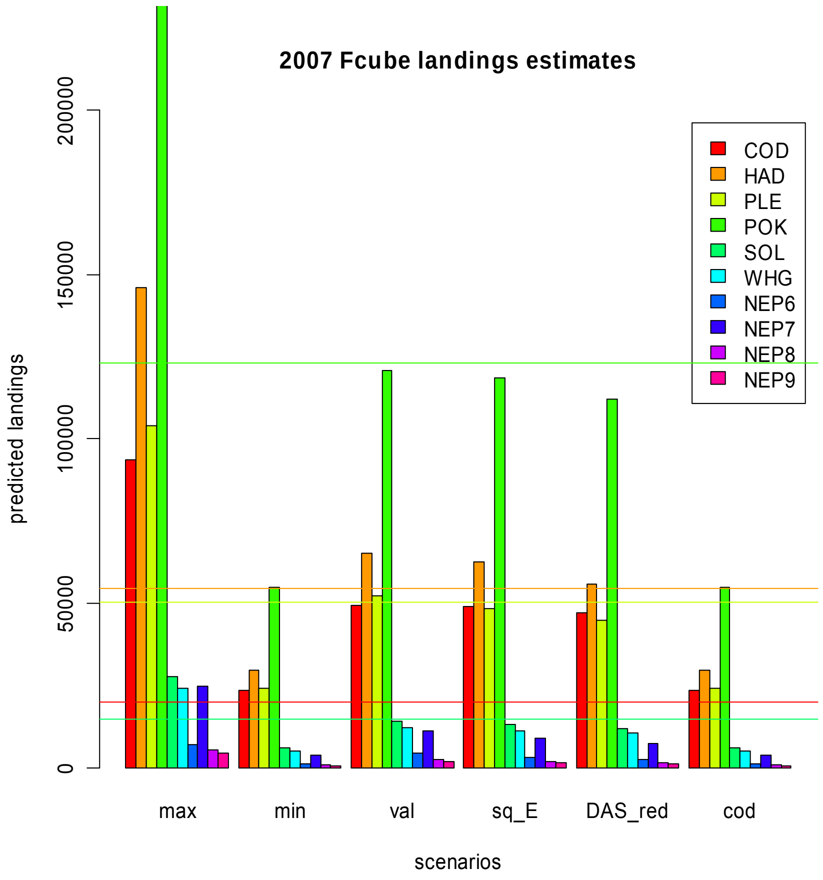


Figure 2.5 – estimated 2007 landings by stock for the various Fcube scenarios. Horizontal lines correspond to base case TAC for cod, haddock, plaice, saithe and sol respectively (whiting TAC being close to cod TAC level).

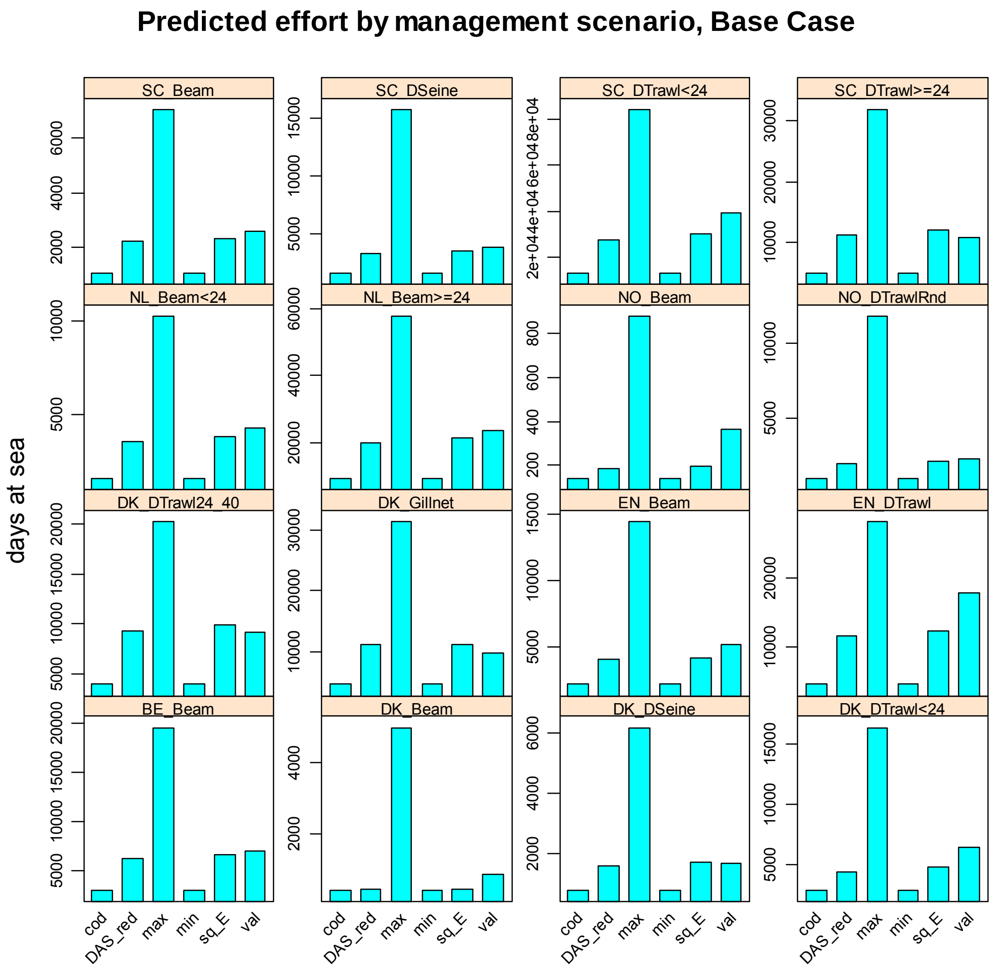


Figure 2.6. Predicted effort by fleet corresponding to the various scenarios. Plots are not all at the same scale. Fleet OTH_OTH not shown

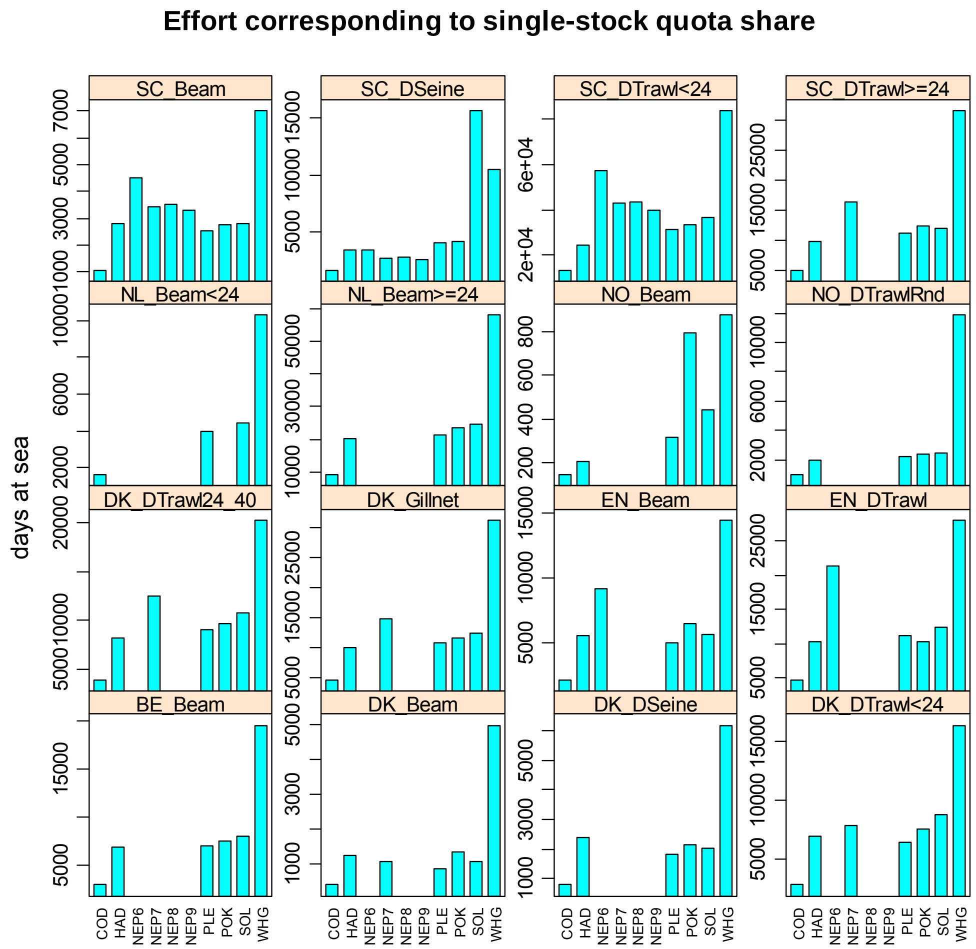


Figure 2.7 – Fcube estimates of the level of effort by fleet necessary to take up the fleet's quota share by stock. Plots are not all at the same scale. Fleet OTH_OTH not shown.

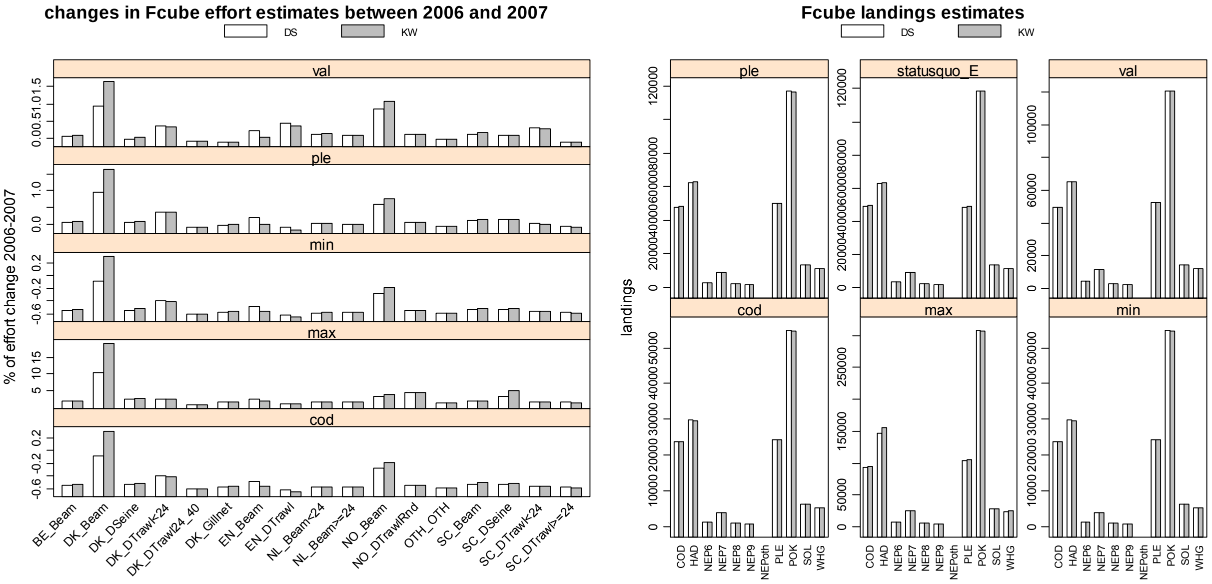


Figure 2.8 Comparison of Fcube results using Days at sea or KWdays

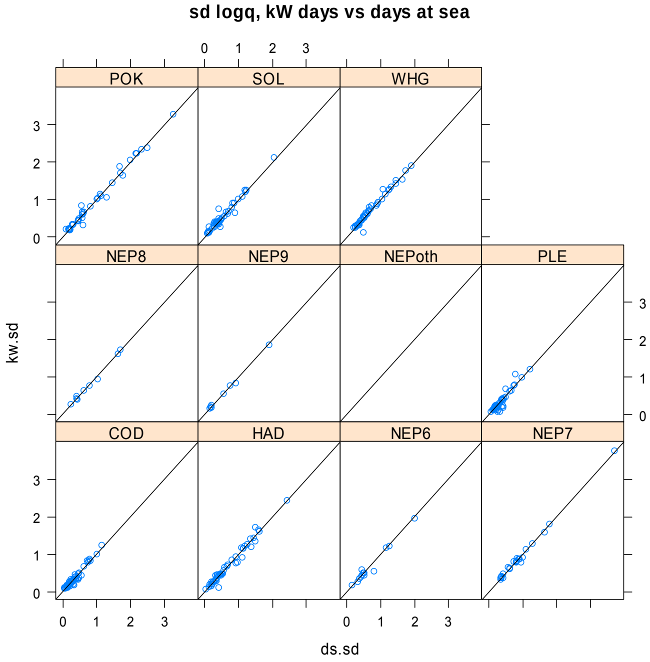


Figure 2.9. Pairwise comparison of log catchability residuals for effort measured in days at sea vs. kwdays. Each point represent a metier. Straight line is the regression line of slope 1.

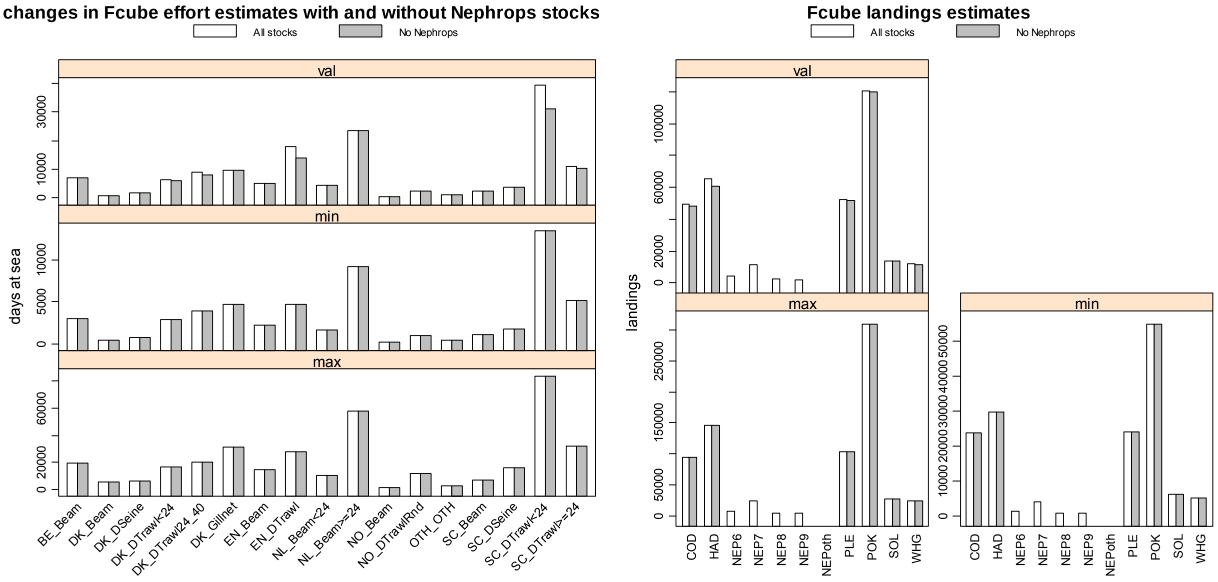
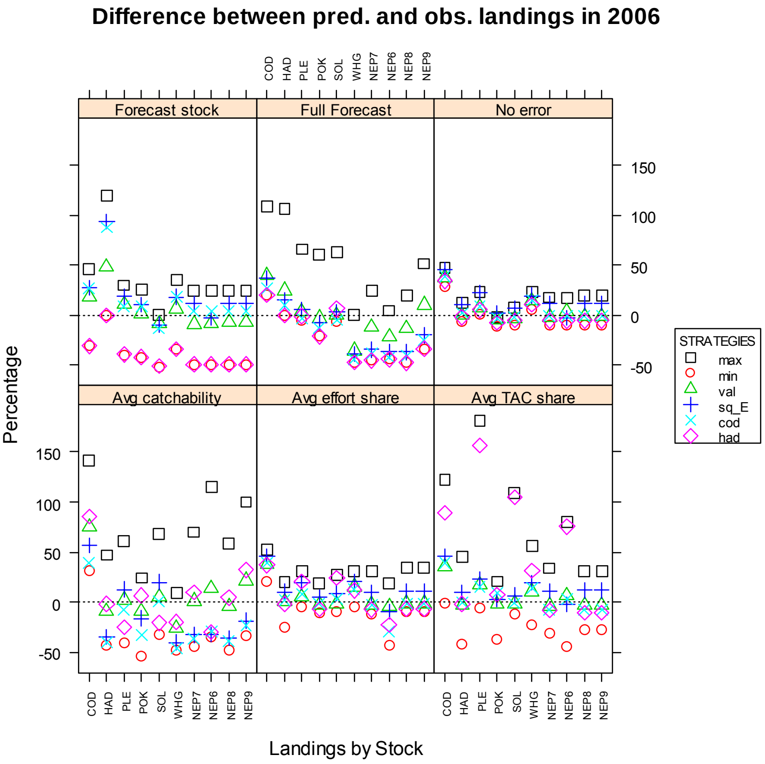


Figure 2.10. Comparison of Fcube results with or without Nephrops stocks.



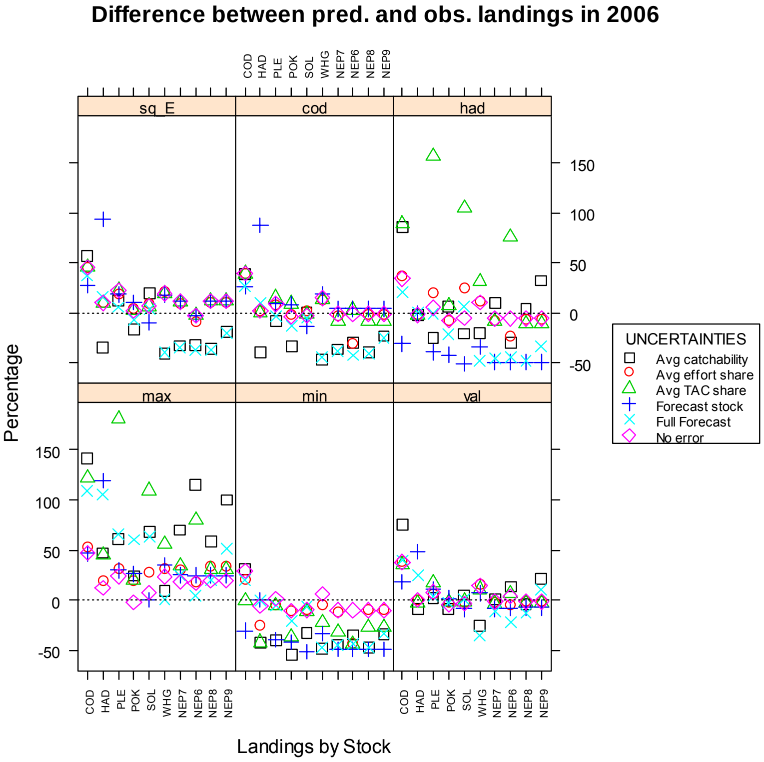


Figure 2.11. Differences between predicted and observed landings in 2006, with various sources of uncertainty and assuming various strategies.

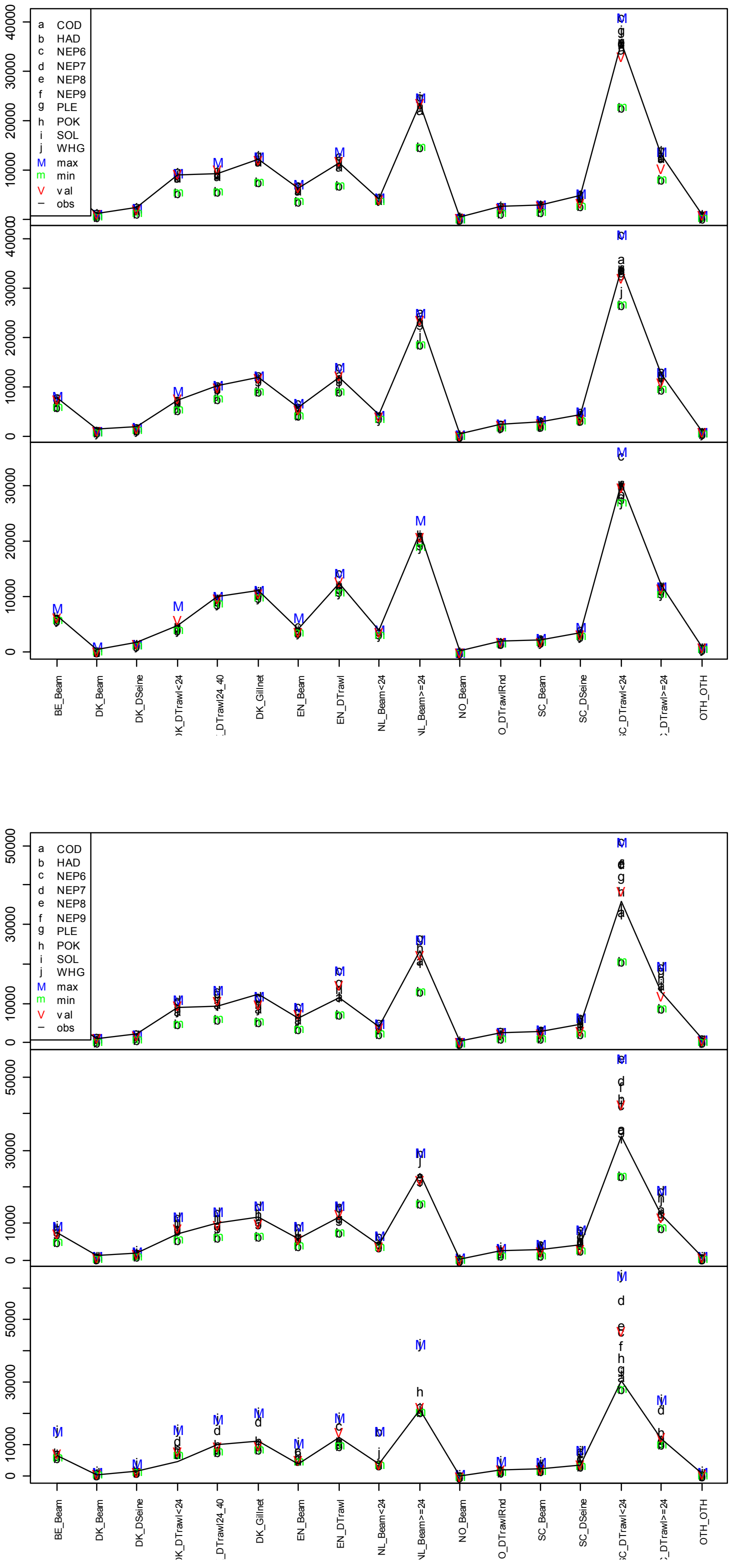


Figure 2.12. 2004-2006 Hindcasted effort for the various scenarios. Top : “no error” validation, all known input parameters. Bottom : “Full forecast” validation, all predicted input parameters. Plots are by year, top=2004, Middle=2005,Bottom=2006.

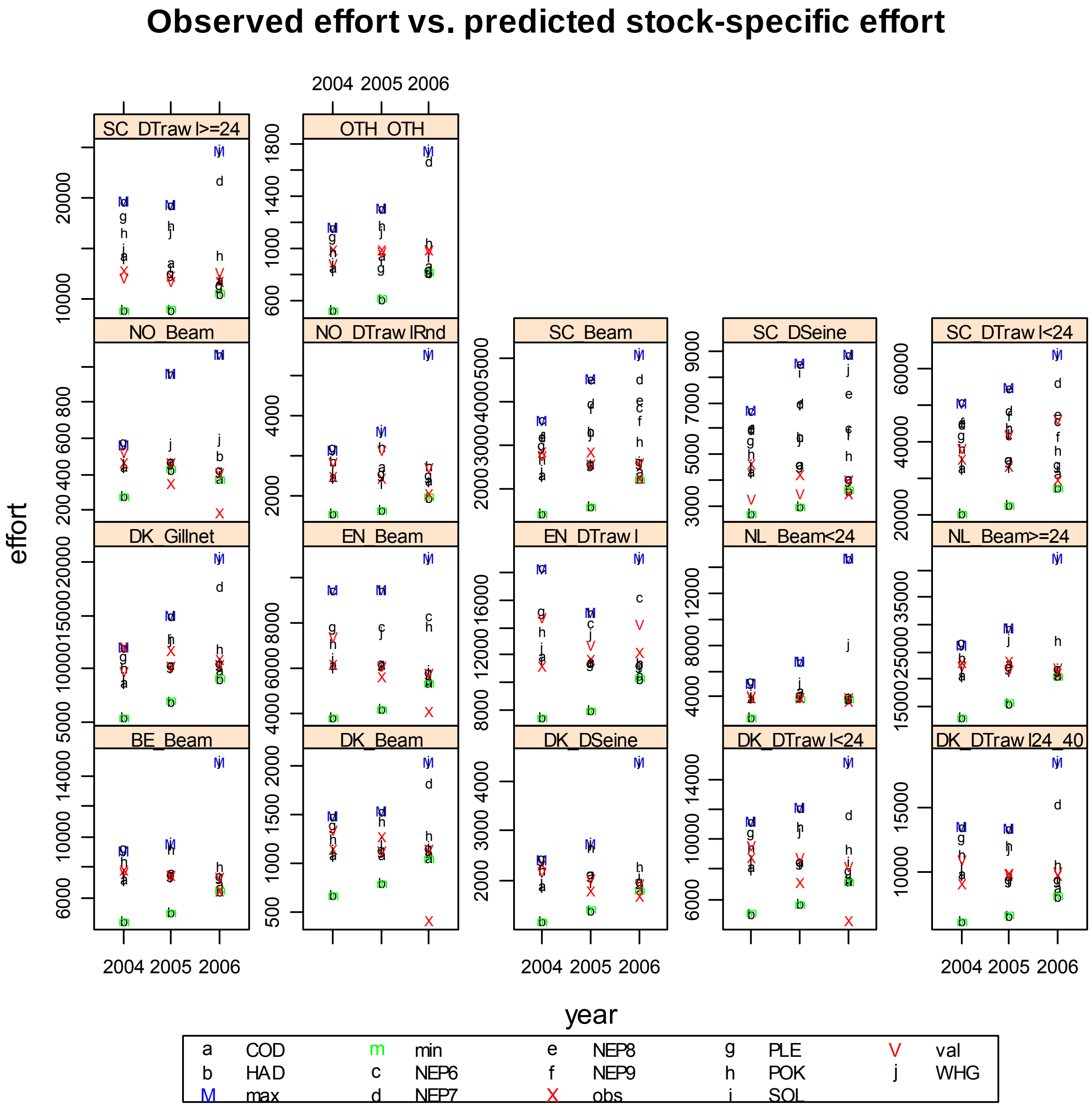
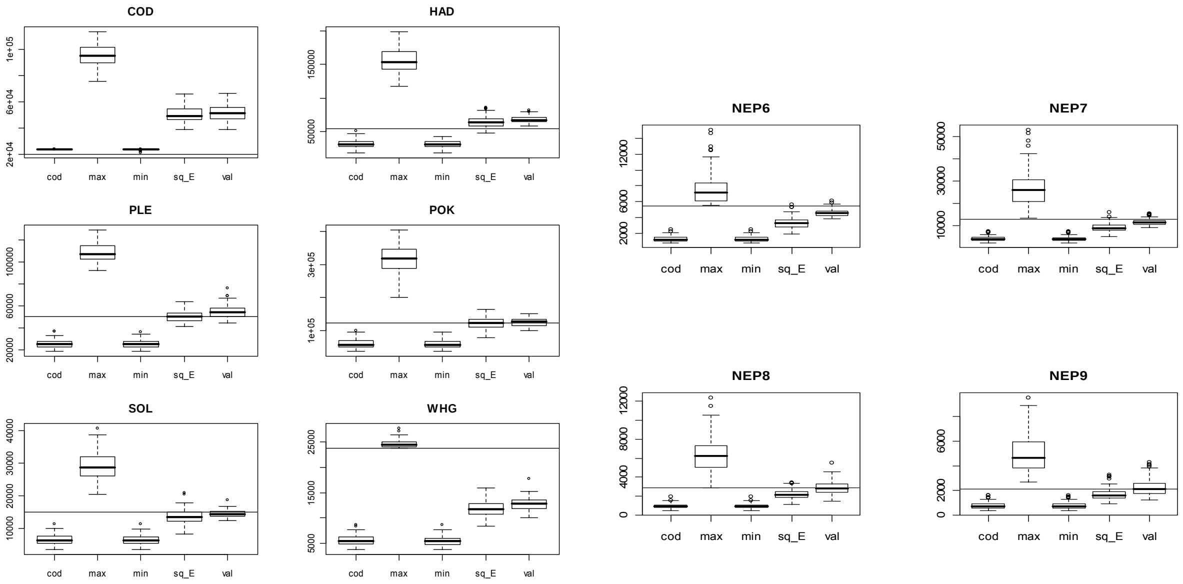


Figure 2.13. 2004-2006 Hindcasted effort for the various scenarios, Full forecast validation. (Same data as in previous figure but with different display).



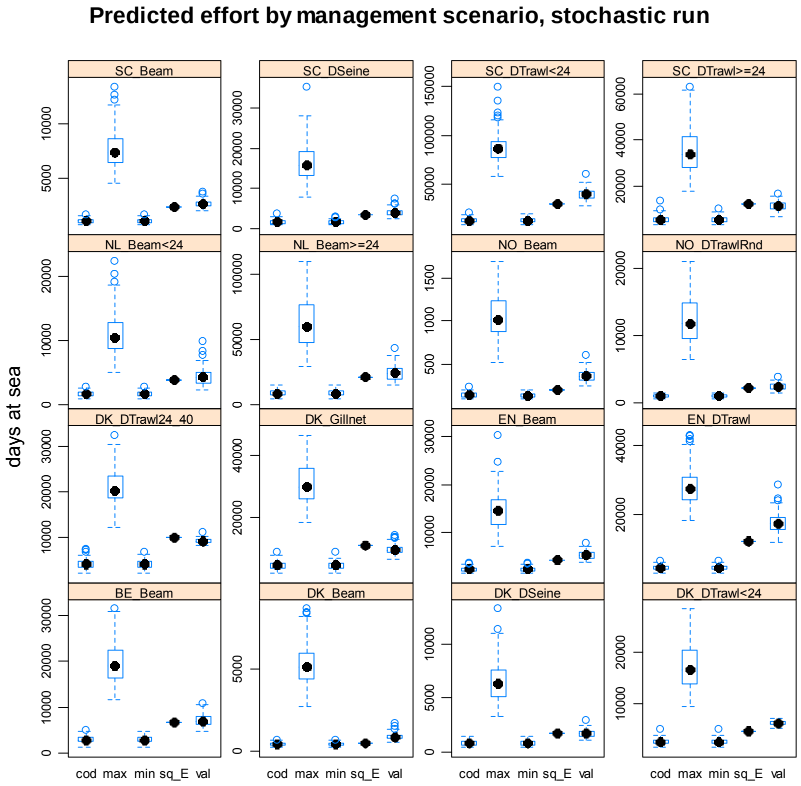


Figure 2.14. Variability of Base Case results to uncertainty in catchability, using a lognormal random error on catchability with sd 0.3. Top : Landings by stock. Bottom : effort by fleet. Fleet OTH_OTH not shown

3. Economic modeling in the North Sea case study (UCPH)

The basic principle of Fcube is to set future levels of effort by fleet based on knowledge of catchability, effort distribution by metier and TAC forecast by stocks (ICES, 2006). Thus Fcube applies a number of exogenously fixed efforts with a fixed catch composition to produces catches of different species. These catches are then evaluated against an exogenous TAC vector. This procedure allows for an explicit evaluation of discards that can be positive (overfishing) or negative (underfishing). As such Fcube has explicit focus on over- and underfishing of the TAC/quotas. This is, however, based on an explicit value judgement (a sort of harvest control rule) of which effort to apply. This effort may correspond to the most binding TAC, the least binding TAC or something in between. One specific way to determine the effort is to use fleet economics as the foundation for choosing the effort, e.g. through constrained maximization of profit. This makes it possible to compute an economically optimal effort distribution in terms of number of vessels, sea days, landings and discards.

As is well known Fcube is implemented in FLR, which is well suited for simulating stock and catch projections together with economic assessments of fleet economics based on the projected catches. Optimisation routines are, however, still under development in R as well as in FLR, so to perform the economic optimisation scenarios it has been necessary to use other software, the choice being Excel that include a Solver software for constrained linear as well as non-linear optimisation. Thus, implementing Fcube in Excel (creating the so-called FcubEcon model), the following economic optimisation scenario has been performed in the North Sea case:

$$\max_{U,V} \ \Pi = \left[(p^0 \cdot h^1 - o^0) \cdot U^1 - R^0\right] \cdot V^1 \qquad ; \qquad h^1 \cdot U^1 \cdot V^1 \leq H^1$$

Where *Π* is total fleet profit, *U* is the vector of fleet efforts per vessel, *V* is the vector of fleet capacities (number of vessels), *p* is the vector of species prices, *h* is the vector of fleet harvests of the different species, *o* is the vector of variable costs and *R* is the vector of fixed costs.

Two kinds of economic optimisation approaches have been performed; FcubeOpt and CPUEOpt. The former is a direct extension of the FcubeMax/FcubeMin approach, i.e. based on biological projections of stocks and catches, that take into account the economics of the fleets and finds the economically optimal allocation of sea days and vessels, given a number of restrictions. CPUEOpt is an alternative to FcubeOpt, where the catches are based on CPUE as opposed to fishing mortalities. This is an advantage in data-poor fisheries, where stock data are not known. When correctly calibrated, the two approaches should yield the same results.

In the present context, the FcubEcon model has been applied to the demersal fishery in the North Sea. This model includes 19 fleet segments, 8 metiers and 11 species. The data used to calibrate (initialise) the model are retrieved from ICES as regards fish stocks, and from the Annual Economic Report as regards fleet landings and costs and earnings. Because economic data is missing (or very uncertain) for 6 of the 19 fleet segments (BEL_OTTER, DEN_BEAM, ENG_STATIC, NOR_BEAM, NOR_roundfish, OTH_OTH) these are not included in the economic assessments and optimisations. This leaves 13 segments for the economic calculations. All segments are, however, included in the calculations of the landings, in order to be able to compare with the quotas. For the segments not included in the economic optimisations, a choice must be made for their number of seadays. In the present context the number of seadays calculated in the FcubeMin scenario are applied, i.e. the number of seadays corresponding to the most restricting quota for the fleet segment in question. The reason for choosing the FcubeMin effort as opposed to the FcubeMax effort is that if the latter is used the catches of the non-economic segments alone will exceed the TACs for some species.

Of the eleven species included six are subject to stock assessments, namely cod, haddock, plaice, pollock, sole and whiting. Moreover Nephrops are included, for which TAC's and fishing mortalities are estimated based on historical catches and landings.

In the example FcubeOpt and CPUEOpt have been run alongside FcubeMax and FcubeMin and fleet economics for these different scenarios have been compared together with allocation of seadays. In the optimisation scenarios the fleet segments are firstly allowed to re-allocate the seadays freely between their metiers while keeping the number of vessels (capacity) constant, i.e. it is not assumed that the allocation of effort between metiers is constant but that the capacity on the contrary is constant (short run version). Secondly a scenario is run with FcubeOpt where both number of seadays and number of vessels are allowed to vary freely (long run version). Moreover all optimisation scenarios include the extra constraint that the total landings must be less than the quotas. In this way it is investigated whether there is an economically optimal allocation of effort and of effort and capacity between fleets and metiers, complying with the given quotas, as opposed to the FcubeMax and FcubeMin scenarios where a constant allocation of effort between metiers and constant capacity are assumed, and where quota compliance is not automatically fulfilled.

All scenarios use the basic assumption that the number of seadays per vessel must not exceed 365 days. This is of course an unrealistic upper limit, seeing that all vessels will naturally be in port for some part of the year. This upper limit should as such be changed when the models are used for real assessments, but as the present example is only aimed at presenting the FcubeEcon models and comparing these with the original FcubeMax and Min models, 365 days is kept as an upper limit in the present context. It should be noted that the FLR program for Fcube does not at present include this constraint, which is the reason why results from the FcubEcon Excel model may differ from results produced by the FLR model for the FcubeMax and FcubeMin scenarios.

Two scenarios are carried out. In the first (base) scenario all TACs are kept at their 2007 level, while the cod TAC is reduced with 20% relative to the 2007 TAC in the second scenario. Tables 3.1 and 3.2 show the results of the evaluations, including total landings value and cash flow for the entire fleet, together with the percentage difference between catch and quotas for each of the target species.

The two tables firstly show that the FcubeOpt with no capacity variation and the CPUEOpt (that is only run without capacity variation) scenarios differ a bit, indicating that the calibration of Catch Per Unit Effort (CPUE) values against fishing mortalities is not optimal yet. It is generally a difficult task to calibrate these perfectly against each other, and it is an ongoing discussion of which approach, i.e. the biological using catch and stock projections or the economic using production functions to evaluate catches, is the most appropriate. It is clear that future work should focus on optimal calibration of each method, so the one will always be able to replace the other, given the data quality and availability.

This said the FcubeOpt with and without capacity variation and CPUEOpt scenarios both show interesting results when compared to the FcubeMin scenario. All give significantly higher landings values and cash flows when compared with the FcubeMin scenario, in both TAC cases, and at the same time higher TAC exploitations, but still without discards. The FcubeMin scenario is aimed at complying with all TACs, which is accomplished by applying the lowest of the efforts corresponding to each quota for each fleet segment. It is however assumed that this effort is distributed between the metiers according to a constant distribution key based on historical efforts. In the economic optimisation scenarios it is also required that all TACs must be complied with, but the effort distribution between metiers is left open. This thus shows that the fishery may benefit economically while still complying with the set TACs, but re-distributing effort between metiers in a new way and by varying the capacity, which is a very important result seen from a management perspective. It is further noticed that the FcubeOpt scenario with capacity change yields significantly higher cash flows than the FcubeOpt scenario without capacity change, while the landings values do not differ much. The noticeable change in cash flow is caused by most fleets being shut down in the case where the capacity is allowed to change, while the remaining viable fleets (DEN_GILLNET, SCO_BEAM, SCO_DEM_SEINE, SCO_DEM_TRAWL_<24) take the total catch. As such much less effort is used to land the same amount, thus reducing the variable costs considerably. This is quite a controversial result, seeing that it is highly improbable that most of the European fleet stops fishing, but it still points to the important fact that many European fisheries with great possibility are not economically viable in the long run, if the present state of the fishery persists.

Contrary to this, the FcubeMax scenario shows that a higher economic benefit can be gained if the fishery does not comply with the set TACs, which is to be expected. Non-compliance can, however, be expected to lead to depletion of the fish-stocks, and thus to decreased economic gains in the long run, and should as such not be considered as a real option.

Finally comparison of the two tables show that the economic gains of the fishery will of course go down in the TAC compliance scenarios when the quota of one (or more) species are reduced. This may, however, lead to long-term gains, as the reduction of TACs means restoration of the stocks.

Table 3.1. Base TAC scenario: All TACs equal to the 2007 level

		FcubeOpt Constant capacity	**FcubeOpt Varying capacity**	**CPUE Opt**	**Fcube Max**	**Fcube Min**
Total Landings Value (Mill Euro)		431	427	454	1041	217
Total Fleet Cash Flow (Mill Euro)		124.5	187.5	155.7	140.3	42.2
	Quota (tonnes)	**(Catch – Quota) /Quota**				
Cod	19957	0.00	0.19	0.32	-3.12	0.00
Haddock	54640	0.39	0.00	0.00	-1.07	0.55
Nephrops6	5487	0.73	0.94	0.78	-0.28	0.79
Nephrops7	12713	0.05	0.10	0.00	-0.53	0.74
Nephrops8	2887	0.08	0.09	0.11	-0.56	0.74
Nephrops9	2111	0.00	0.00	0.06	-0.69	0.72
Nephropsoth	2944	0.86	0.94	0.00	0.75	0.96
Plaice	50261	0.00	0.00	0.00	-0.80	0.60
Pollock	123250	0.64	0.98	0.84	-1.24	0.63
Sole	15020	0.00	0.00	0.00	-0.63	0.65
Whiting	23800	0.72	0.72	0.58	0.02	0.80

Table 3.2.TAC scenario 1; original cod TAC reduced with 20%

		FcubeOpt Constant capacity	FcubeOpt Varying capacity	CPUE Opt	Fcube Max	Fcube Min
Total Landings Value (Mill Euro)		392	427	451	1041	172
Total Fleet Cash Flow (Mill Euro)		112.3	187.1	156.1	140.3	33.9
	Quota (tonnes)	**(Catch – Quota) /Quota**				
Cod	15966	0.00	0.00	0.15	-4.16	0.00
Haddock	54640	0.64	0.00	0.00	-1.07	0.64
Nephrops6	5487	0.78	0.94	0.78	-0.28	0.83
Nephrops7	12713	0.13	0.10	0.00	-0.53	0.80
Nephrops8	2887	0.08	0.09	0.11	-0.56	0.80
Nephrops9	2111	0.00	0.00	0.06	-0.69	0.78
Nephropsoth	2944	0.87	0.94	0.00	0.75	0.97
Plaice	50261	0.00	0.00	0.00	-0.80	0.68
Pollock	123250	0.72	0.98	0.84	-1.24	0.70
Sole	15020	0.00	0.00	0.00	-0.63	0.72
Whiting	23800	0.79	0.72	0.58	0.02	0.84

References

ICES (2006) WKMIXMAN report 2006

4. A Full Feedback Model of fleet and area based mixed fisheries in the North Sea (IMARES)

4.1. Introduction

The plaice (Pleuronectes platessa) and sole (Solea solea) stocks in the North Sea are mainly caught by Dutch and UK demersal beam trawl fleets, which adds up to over 50 and 70 percent of the total North Sea plaice and sole landings respectively. Plaice is caught in a directed beam trawl fishery north of 56°N using 120 mm mesh. In the southern North Sea sole is caught in a mixed fishery with plaice using 80 mm meshed codend. Current management of North Sea plaice- and sole stock is characterized by a single-species approach with single species Total Allowable Catches, TACs and some additional technical measures. The TAC options are based on full analytical assessments (EC, 2009).

The main problem with this fishery is the unsynchronized exhausting of plaice and sole (country) quota due to the fixed relative stability of TAC-shares, the spatial distributions of fish stocks and the size selective characteristics of demersal beam trawls, resulting in a considerable amount of plaice that is caught but discarded.

According to the annual assessment (ICES, 2008) fishing mortality (F per year) for plaice increased, with considerable variation in the annual estimates, from circa 0.4-0.5 per year around 1970 to circa 0.7 to 0.8 per year in the period from 1998 to 2003. The fishing mortality for sole increased with large variation as well, from circa 0.4-0.5 per year around 1970 to 0.5 to 0.6 per year in the period from 1998 to 2003. The spawning stock biomass (SSB) of plaice declined from 1970 onwards but showed a temporal increase in the 1980s when both recruitment and growth rate were high. The SSB of plaice has, with the exception of 2 years, been below Bpa for the entire period 1998-2003. Bpa is the precautionary biomass limit below which the probability that the population will drop below Blim becomes unacceptably high The spawning stock biomass of sole varied around the Bpa level over a longer period. A series of strong year-classes caused the spawning stock biomass of sole to increase for around five years in the early 1990s. Recruitment estimates for all year classes since 2001 of both species are below the long term averages except for year class 2006 of plaice and year class 2005 of sole. In 2006 both stock SSBs were in between Blim and Bpa.

In June 2007 a multiannual management plan for fisheries exploiting stocks of sole and plaice in the North Sea that was adopted (EC, 2007) and it was implemented for the first time in 2008 (EC, 2008). The plan is a result of the new approach adopted in the reform of the Common Fisheries Policy, CFP, in 2002 (EC, 2003) with the intention of replacing short-term management decisions by a long-term approach allowing multiannual measures. The plan consists of setting annual TAC’s, such that the corresponding fishing pressure expressed as fishing mortality is reduced by 10% until the target F’s are reached. Target F is a proxy for Fmsy in order to meet the commitments arising from the acceptance of the Declaration of the World Summit on Sustainable Development in Johannesburg (2003) in order to restore fish stocks to levels that produce maximum sustainable yields (MSY). In 2008 the management plan was evaluated (Machiels et al., 2008).

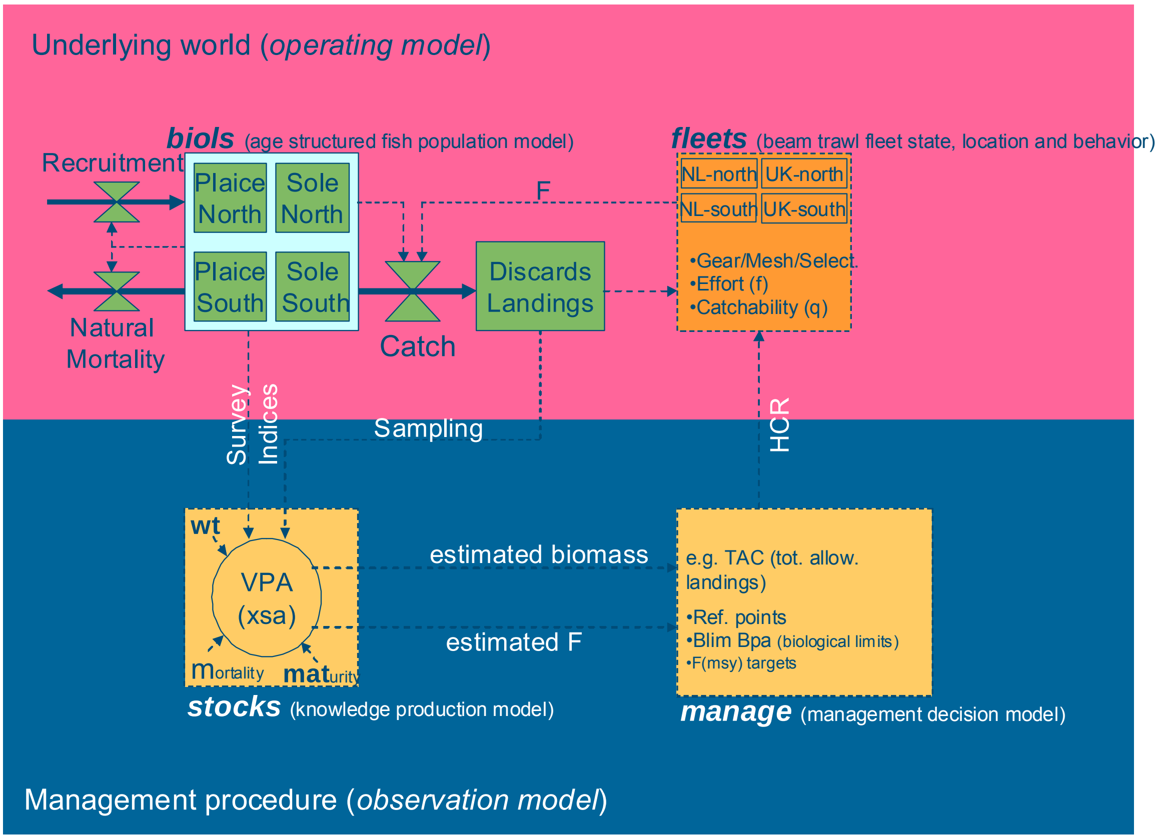
In 2006 an alternative method for mixed-fishery management was introduced (Ulrich et al., 2006) that focuses on fisheries and fleets rather than on stocks using fleet based data. The principle of Fcube is to predict the future level of effort by fleet given the TAC and fishing pressure by stock, known catchability and the effort distribution by fleet métiers.

The objective of this study is to develop a generic full feed back simulation model to investigate the impact of alternative management measures on a fisheries with mixed species harvests and taking into account the spatio-temporal dynamics of the fish populations interacting with fleets through fishers behaviour in response to applied management measures. Additionally the incorporation of the Fcube approach in the application of the harvest control rule in the long-term management procedure was implemented and tested..

4.2. Model

The model numerically simulates the interplay between the biological dynamics of the fish stocks as resources, the economic dynamics of fleets and fisher behavior, the perceived information on stock states and fisheries and the implementation of harvest control rules based on management regulations or policies. A relational diagram of the full feedback model is presented in Figure 4.1. The operating model represents the true state of the system. The observation model represents the perception of this true state by scientist and managers based on data collection, stock assessment and application of harvest control rules

Figure 4.1. Relational diagram of the simulation model with 4 main modules: 'biols' and 'fleets' represent the OM while 'stocks' and 'manage' represent the MP (our perception of the true state)



The operation model consists of an age structured population model, which includes the stock dynamics and other biological characteristics of the plaice and sole stocks. The parameter values used in the model are presented in Table 4.1. Recruits, stock number at age 1, are generated based on constant recruitment with random noise added as a stochastic factor based on observed historical variation of recruitment (ICES, 2008). Future recruitment can also be related to stock size by a Ricker or Beverton & Holt stock recruitment relationship. Growth of fish stocks is simulated by a weight at age relationship based on a von Bertalanffy model (K, L_∞ and t_0) for length combined with a length weight key based on a power function.

$$l_t = l_\infty (1 - e^{-k(t-t_0)})$$

$$W_t = \alpha \cdot l_t^{\beta}$$

As is used in the routine ICES assessments, the mature fraction is assumed to be 1 from age 4 onward for plaice and from age 3 onwards for sole. Survivors at age are calculated given the mortalities at age. Natural mortality is assumed 0.1 (yr^{-1}) for all age classes (ICES, 2008). Fishing mortality depends on fishing effort through fleet capacity and activity, métier effort share, gear selectivity and catchability. The survivors have a distribution pattern, fixed per age group, over the area's north and south. Older plaice is found more in the north and young plaice is concentrated in the southern area. All age groups of sole are mainly found in the south.

A fleet is defined as a physical group of vessels and the fleet's effort is the actual activity of these vessels during a time period (e.g. days at sea). The fleets operating model contains two fleets fishing for the two stocks and generates a fishing mortality on these stocks, depending on fishing behavior. The two fleets, NL and UK, represent the exploitation of the two stocks in total The fishing effort of NL fleet covers 60% of the total effort in combination with 70% of the sole TAC and 50% of the plaice TAC. So, the UK fleet covers 40% of the total effort combined with quota covering 30% of the sole TAC and 50% of the plaice TAC. Fleets and fish populations are linked through the relationship between (nominal) fishing effort and effective fishing effort or fishing mortality (F,yr^{-1}). A fishing effort of a fleet métier that is allocated to a particular area is calculated based on the total fleet capacity and activity combined with effort shares allocated to métier-area combinations. The two fleet métiers that are distinguished in the two fleets are based on the codend mesh sizes used namely 120 mm in the north and 80 mm in the southern areas. The effort share of the 80 mm métiers of the NL fleet is 75% and 35% for this métier of the UK fleet. The fishing mortality per age group is a function of the fishing effort in combination with size dependent trawl selectivity and catchability. Trawl selectivity is simulated using a logistic model based on a trawl selection factor, S, for both species and selection ranges SR. S represents the ratio of L50, the mean selection length (cm) and M, the codend meshsize (cm) [S·M=L50]. At a given mesh the logistic equation for selectivity at length (S_L) is:

$$S_L = \frac{1}{1 + e^{\left(SR - SR/_{L50} \cdot L\right)}}$$

Catchability is defined as the probability that a fish, present in the exploited area, is caught by a standard unit of effort, using a non selective gear. In this way mesh size dependent selectivity is distinguished from mesh size independent catchability. Fishing mortality for every fleet métier area combined and summed to a total fishing mortality for an area. Catchability varies due to technical, environmental and behavioral factors (van Oostenbrugge et. al. 2008). A possible increase of effectiveness of the fleets over time, or technological creep, has not been taken into account in the current model. The number of fish that are caught by the fleets in each area is estimated by using the catch equation.

Perception on the status of the plaice and sole simulated stocks by scientist is modelled through the inclusion of stock assessment procedures for both stocks. Commercial catches (landings and discards) at age are recorded with added random noise of 15 % and two survey fleets sample the stocks with a constant fishing effort. These survey catches with additional added random noise of 15 % are linearly related to stock abundance resulting in a survey index on the status of the stocks. The information from commercial catches (landings and discards) and survey indices are input data for the XSA assessment procedures (Darby and Flatman,1994). Default stock assessments input and control options are selected. Inclusion of stock assessment procedures takes into account possible errors generated by this procedure. It should be realized that stock assessment results in fishing mortality estimates for the year preceding the year in which the assessment takes place and the harvest control rule (HCR) result applies to the year following this assessment year. This means that assessment output and short-term forecast predictions might deviate from the true population characteristics as modeled in the biological operating procedure because of uncertainty in recruitment and the introduction of various types of errors. The management part of the model expected F's, given the estimated and forecasted stock numbers at age, results in TAC's and this affects the state and behavior of the fleets. Changes in F are proportional to changes in effort

Management measures or policy options that are considered originate from the European North Sea flatfish long-term management plan (EC, 2007) with a conventional TAC and some effort control. The plan is designed to gradually adjust the level of fishing pressure to achieve greater landings, larger and more stable fish stocks and a more profitable fisheries in the long term. The TACs applied will match up with a predicted fishing mortality that will be reduced by 10% year-on-year based on the most recent stock assessment until both stocks have returned to safe biological limits in the first phase or reached the target fishing mortalities in the second phase. The maximum deviations from TACs applied one year earlier is limited to 15% up or down. According to article 5 of the Regulation the Council will amend the agreed plan when the stocks of plaice and sole have been found to have returned to safe biological limits for two years in succession. For sole the safe biological limits are fishing mortality below 0.4 per year and an estimated spawning biomass exceeding 35 000 tons. For Plaice these limits are F below 0.6 and spawning biomass larger then 230 000 tons

The HCR that was implemented for each species looks step-wise as follows:

1) Assume F in the running year to be equal to the F estimate in the preceding year (the last data year), F status quo (Fsq, age 2-6)
2) Calculate a multiplication factor for a F reduction of 10% (= 0.9)
3) Calculate a multiplication factor to reach Fmsy = 0.3 (for plaice) or Fmsy = 0.2 (for sole) (Fmsy/Fsq)
4) Take for each species the maximum result of step 2 and 3 and estimate the stock size and TAC given the resulting multiplication factor.
5) Compare the resulting TAC with the current TAC and if the difference exceeds 15%, estimate a new multiplication factor so that the resulting TAC is just within these 15% bounds.
6) Estimate the (fleet)effort needed to yield the fleet quota (derived from TAC in combination with relative stability of the country fleets) and fleet métier contingents, or alternatively use the Fcube procedure. Compare the estimates of both species, thus revealing constraints in exploiting both fish stocks. It is assumed that fishing continues until the last TAC (or quota) is caught and the maximum effort estimate is selected.
7) Sometimes the quota for a species are lower than the simulated catch using the effort estimate selected in step 6. The surplus is to be regarded as overquota catch.

The first year for which the TAC is simulated according to the HCR is 2009; the TACs in previous years are the agreed TACs (ICES, 2008b).

Results of the HCR procedure in terms of TAC/quota or effort restrictions results in changes in the exploitation levels and modifies the fishing effort levels. In this instance changes in overall fishing effort are proportionally distributed over the various fleets, métiers and areas. To account for fishers response to the annual management measures two scenarios (A and B) were used. Under scenario 1 fishers will continue fishing until both plaice and sole quotas are exhausted, while discarding the overquota catches. Under scenario 2 fishers will also fish up both quota but avoid catching overquota fish through directive fishing. It is assumed that information on landings and discards on an annual basis to be incorporated in the assessment is available.

4.3. Simulations

A number of Monte Carlo realizations were run with process error in the biological part by adding random noise around the recruitment generated and observation error in the management part by the inclusion of random sampling errors around the observed (true) fleet and survey catches. In reality there are more sources of error (e.g. mortality rates). In the current simulations spatial variation in fish abundance and fishing effort is not included because the (XSA) observation model and the Fcube estimates of fishing effort do not include spatial variation.

The fishing behavior as the response to the annual management was formulated as two alternative scenarios. The fleets will fish up both plaice and sole quota while avoiding catching over-quota fish, or, continue fishing until both quota are exhausted while discarding the over-quota catch of the species whose quota is exhausted first.

The model was developed using the FLR package / simulation framework (Kell, et al. 2007), a collection of data types and methods written in the R language as part of the EU EFIMAS-COMMIT-FISHBOAT project cluster. FLR is an Open-Source project meaning that the source code is available to the users.

4.4. Results

The stochastic model was run for 100 iterations of 15 successive assessment years (2010-2025). Figures 4.2 to 4.9 show time series of TACs, landings, discards, perceived and implied fisheries mortalities SSB for both scenarios using the TAC management measure. The figures show the probability distributions of these results by their 5th, 25th, 50th, 75th and 95th percentiles

The (average) TAC of sole initially decreased from 12 500 ton/year to 11 000 ton/year 7 years after implementing the management rules under scenario 1 (overquota catches discarded or misreported). Under scenario 2 average TAC's reduced on average to 11 500 tons per year and increased thereafter to 13 000 tons per year towards the end of the simulated period after 15 years. The actual average landings of sole followed the TAC pattern but showed higher variation and average landings under scenario 1 at the end of the simulation period were lower then the average TAC levels. Average sole landings varied between 10 000 and 13 000 tons depending on the scenario and the year of simulation (Figure 4.2). Including Fcube into the management harvest control rule showed similar results as without during the first 5 years. Thereafter TAC and landings of sole were approximately 2000 tons less compared to the “regular” management regime. Actual simulated landings using Fcube were between 8 500 and 9 000 tons per year. Sole discards at the start of the simulation were on average around 3 500 tons and gradually decreased to about 2 000 tons after 15 years but at the same time the overquota catches increased from on average 5 000 tons in 2010 to 15 000 tons at then end of the simulated period (see Figure 4.3). Applying the Fcube approach resulted in similar amounts of discards but lower overquota catches (from 2000 to 4000 tons per year).

Yearly recruitment and SSB biomass of sole time series are shown in Figure 4.4. Average recruitment was a production of on average 93 million one year old sole per year and SSB biomass increased from 40 000 tons to 60 000 tons. Using the Fcube approach resulted in a similar recruitment and average SSB biomass levels up to 70 000 tons after 15 years of simulation. The observed fishing mortality of sole reduced with approximate 9% per year from 0.34 to 0.2 (per year) during the first 5 year after the management rule implication. F reduced from 0.4 to 0.2 (per year) in 7 to 10 years (Figure 4.5).

The average TAC of plaice under the conditions of scenario 1 increased from 67 000 tons to 100 000 tons after 14 years. Landings were on average 10% lower then the yearly TACs. Under scenario 2 TAC increased to levels of 120 000 tons at the end of the simulated period and landings matched better with the TAC levels (Figure 4.6). Simulating scenario 1 under a Fcube management scenario show a reduced TAC increase to around 70 000 tons with 10% lower landings (in comparison to the TAC) at the start and 40% lower yearly landings at the end of the simulation. Although the final TAC and landing levels for scenario 2 were slightly higher the differences between TAC and landings were relatively the same.

Discards of undersized plaice was initially 46 500 tons and dropped to 31 000 tons after 10 years and increased thereafter to 36 000 tons. Discards under scenario 2 were much higher. Initially approximately 70 000 tons undersized plaice was discarded and this amount dropped to 50 000 tons toward the end of the simulated period (Figure 4.7). The overquota discarded plaice under scenario 1 increased to around 75 000 tons from initially 60 000 tons at the start of the simulation. Using the Fcube procedure as management procedure showed discards of undersized plaice of about 50 000 tons at the start towards 20 000 tons at the end of the simulation for scenario 1 and from 60 000 to 30 000 for scenario 2. Overquota plaice increased from 65 000 ton towards 160 000 tons after 15 years of simulation.

SSB biomass levels were initially low, 200 000 tons and increased to 420 000 tons (figure 4.8). Under the Fcube approach, simulating scenario 2, a similar result was obtained for SSB levels, but simulation scenario 1 resulted in SSB levels from 200000 tons initially to 270 000 tons after 15 years. F reduced from 0.5 to 0.3 after 8 years under scenario 1 with an average yearly reduction of about 7% and remained stable around 0.3 per year. F levels under scenario 2 were higher and these reduced from 0.7 to 0.4 in 15 years, meaning a reduction of 5% per year on average (figure 4.9). Under the Fcube approach F levels and reductions were found to be similar.

4.5. Discussion

This study aims to indicate the changes in the fishery and fish stocks and their magnitude which may be expected under the simulated management with the accompanying simplifications and assumptions made. It is not intended to predict what happens exactly after implementing the management procedures under various assumed scenario-options. The results indicate a direction of the effect after the implementation including an indication of a time frame needed to achieve possible management objectives. The simulations are repeated 50-100 times to take into account the expected variation of model parameters, such as recruitment, sampling errors and observation errors. The results are presented as averages being the modal values of the repeated realizations and the percentiles defining the ranges of probabilities in which most realizations occurred. The results of individual runs indicate that output mainly varies, pending the occurrence of exceptional good or poor year classes. Here the risk associated with the harvest control rules and the other stochastic processes should be kept in mind. Communicating the risks associated with all these processes is a challenge to scientists, managers and administrators.

When evaluating the model, assumptions and simplifications had to be made at different levels in the process. The fleet operating model assumes that the two fish stocks are targeted by only two country fleets, each with two métiers that characterizes the codend mesh sizes used. In reality fishers from at least 6 EC countries are fishing for North Sea flatfish and much more different métiers can be distinguished. Including all these fleet-métiers would make the simulation model too complex, which would probably produce unrealistic results. A simple fleet structure, by simulating the North Sea flatfish fishery by one fleet with combined métier has the advantage of using the ICES working group data to calibrate the catchabilities for the two species (Machiels et.all. 2008). In this study a compromise of 2 fleets with 2 métiers each was chosen/

If the major assumptions are very different from the true situation, the effect of the measures are probably different from those indicated by the evaluation. In some cases it may be possible to demonstrate that making one or another assumption does have little effect on the final outcome of the evaluation. In that case we can conclude that the measure is robust to this assumption. As shown in the results the variation of the outcome between individual runs is to a large extent related to the stochastic recruitment pattern and related year class strengths. Previous simulation results show model sensitiveness to the commonly used stock-recruitment relationship, because, depending on the function chosen, on average more or less recruits are generated given a certain amount of stock biomass (Machiels at al., 2008). The Ricker function generates more recruits compared with the Beverton and Holt function while the SSB is less than 50 000 and 320 000 tons for sole and plaice respectively. When SSB is larger the Beverton and Holt function generates more recruits. Given the large uncertainty in the true stock-recruitment relationships, runs for the simulation presented her were executed using a constant recruitment level equal to the long term recruitment average with imposed stochasticity and thus simulate an overall average recruitment pattern.

The implementation of this management agreement means a change in management strategy from a risk avoidance strategy (to stay within safe biological limits) to a strategy of optimal harvesting of the resource. It can be envisaged that management of other stocks in EU waters will follow and be adjusted using a similar management approach as currently used for plaice and sole. This means a change from conservation or limit reference points to target reference point that are intended to meet management objectives. The concept of using the precautionary biomass threshold (Bpa) as a trigger for management action has disappeared in the present management. The management action is only conditional to the fishing mortalities estimates by the fishery scientists based on stock assessments. The assumptions made in the assessment procedure should be clear, together with the methods used to monitor the status of the stocks.

The main difference between the agreed plan currently evaluated and Fcube scenarios is that the HCR under Fcube results in (direct) effort management. So the overruling European management system of TAC and quota is implemented via effort restrictions. In reality fishers will only favor such a system under the conditions of eliminating the TAC/quota management. Moreover the effects of effort measures are difficult to predict on the medium term because limiting fishing effort mostly results in changes of the catchabilities. These changes may also occur when fishers will allocate their fishing effort to other areas and seasons due to economic optimizations. Also technological creep will lead to higher fishing mortality and lower fish biomass. The key question remains: how will the fleet or fishers behave in the future. Ultimately the assumed linear relationship between Fishing mortality and fishing effort is no longer valid (van Oostenbrugge et al. 2008). The limitations of fishing effort may also increase the risk of input substitution towards fish species with are not regulated by TACs and quota.

The effort level in the agreed plan is set at such a level that both TACs can be exhausted with an upper limit of the 2006 level. The effect of the lack of the linkage has not been investigated in detail in this study. It would be interesting to investigate how errors in one assessment may affect the performance of the HCR for the other species, particularly in case the observed fishing mortalities are low.

Most important are the assumptions on the behavior of fishers in response to the measures. The avoidance scenarios assume that fishers can avoid one target species and continue to fish on the other species after the TAC of the first species is exhausted. It is noted that the Regulation aims to control landings and not catch. Fishermen have the choice either to stop fishing when their quotas are depleted, or to discard over quota fish. Both scenarios must be considered as extremes. This behavior of discarding is not illegal in waters under European Community legislation. To some extent, it may be possible to avoid catches of a target species, by selecting different fishing grounds or periods, or by modification to the gear but it is doubtful whether full avoidance, as assumed in some of the scenarios, is possible. The avoidance assumption is considered less realistic but is included to assess the sensitivity of the simulation for the extreme assumptions. The simulations show that results found for the plaice stock in terms of TAC and landings are sensitive for the assumption on overquota fish.

The differentiation between fleets takes into account overquota fish resulting from assigning plaice and sole quotas to multiple fleets in ratios which differ from the overall plaice and sole TACs ratio and results in behaviors that differs from fleet to fleet. A similar problem may occur under an individual transferable quota system where the individual quota ratios of species vary between fishers.

4.6. References

Darby, C.D. and Flatman, S. 1994. Virtual Population Analysis User Guide. MAFF Directorate of Fisheries Research. IT report 1 85 pp.

EC, 2007 Council Regulation (EC) No 676/2007 of 11 June 2007 establishing a multiannual plan for fisheries exploiting stocks of plaice and sole in the North Sea.

EC, 2008 Council Regulation (EC) No 40/2008 of 16 January 2008 fixing for 2008 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required.

EC, 2009. Council Regulation (EC) No 43/2009 of 16 January 2009 fixing for 2009 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required

ICES WGNSSK (2008) Report of the Working Group on the assessment of the Demersal Stocks in the North Sea and Skagerrak.

Kell, L. T., Mosqueira, I., Grosjean, P., Fromentin, J-M., Garcia, D., Hillary, R., Jardim, E. et al. 2007. FLR: an open-source framework for the evaluation and development of management strategies. ICES Journal of Marine Science, 64: 640–646.

Machiels, M. A. M., Kraak, S. B. M. and Poos, J. J. 2008. Biological evaluation of the first stage of the management plan for fisheries exploiting the stocks of plaice and sole in the North Sea according to Council Regulation (EC) No 676/272. Wageningen-IMARES Report C031/08. IJmuiden, the Netherlands.

van Oostenbrugge, H.J.A.E., Powell, J.P., Smit, J.P.G., Poos, J.J., Kraak, S.B.M., and Buisman, E.F.C. 2008. Linking catchability and fisher behaviour under effort management. Aquat. Living Resour. Vol. 21(3), pp. 265-273.

Ulrich, C., Andersen, B. S., Hovgård, H., Sparre, P., Murta, A., Garcia, D., and Castro, J. 2006. Fleet-based short-term advice in mixed-fisheries – the F3 approach. ICES Symposium on

Fisheries Management Strategies, June 2006, Galway. http://www.ices06sfms.com/presentations/index.shtml

Table 4.1: Model parameters of the population dynamics of plaice and sole stocks.

	Plaice	Sole
Recruitment	915 000	93 400
Growth		
k (yr^{-1})	0.3	0.54
l_∞(cm)	41	33
t_0(yr)	-0.5	-0.2
Length-weight		
α	0.030	2.7
β	0.18	2.15
Trawl selectivity		
S_l (-)	2.2	3.7
SR (cm)	3.3	3.6
Minimum landing size (cm)	27	24
Natural mortality (yr^{-1})	0.1	0.1
Catchability (day^{-1}·yr^{-1})	0.000031	0.000026

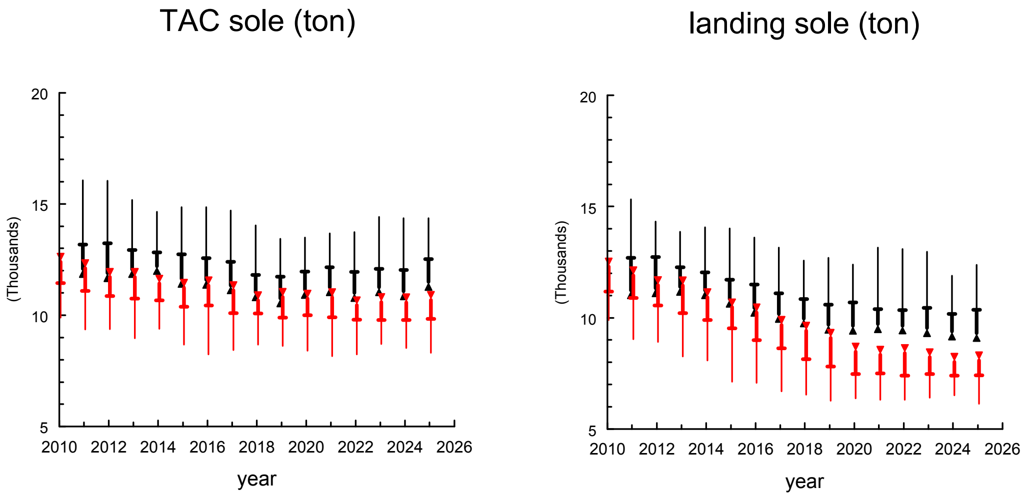


Figure 4.2. The sole TAC and landings (in thousand tons) over time. Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided). Triangles: medians. Thick lines end at the 25th (red) and the 75th (black) percentile respectively. Thin lines end at the 5th (red) and 95th (black) percentile respectively. For scenario 1 only the downward variation and for scenario 2 only the upward variation are shown, but the variability is expected to be similar between the scenarios.

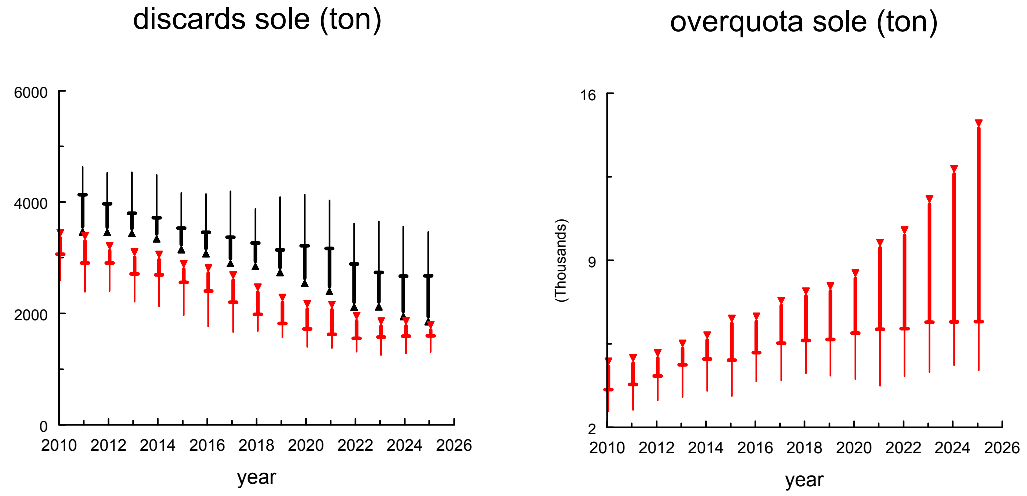


Figure 4.3. The discards and overquota catches (in thousand tons) over time. Only scenario 1 is shown, because in scenario 2 overquota catches are avoided. Symbols and lines, see Figure 4.2.

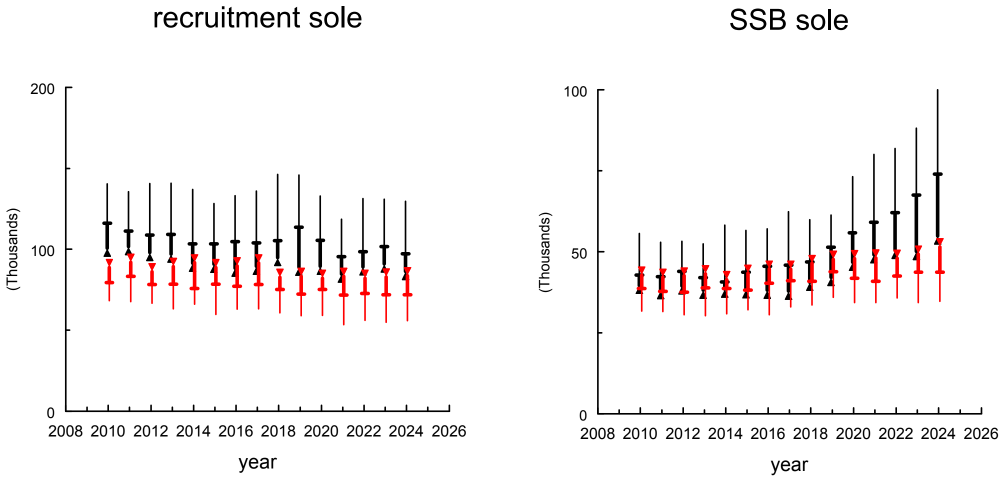


Figure 4.4. The number of sole recruits (in million over time) and SSB (in thousand ton). Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided). Symbols and lines, see Figure 4.2.

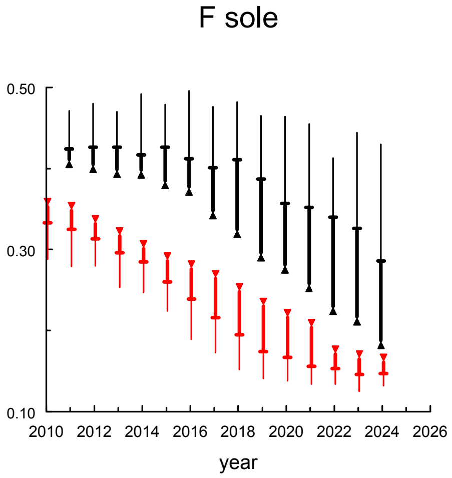


Figure 4.5. The sole fishing mortality (F) over time. Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided)., see Figure 4.2.

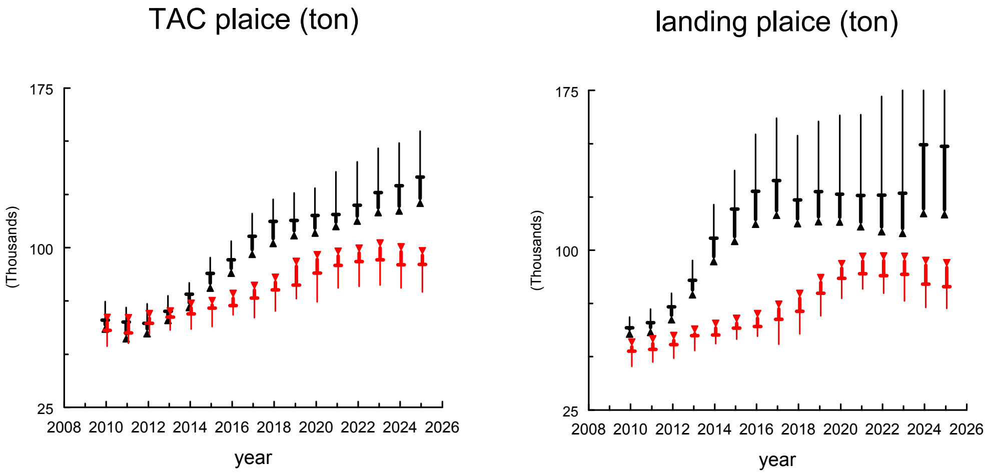


Figure 4.6. The plaice TAC and landings (in thousand tons) over time. Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided). Triangles: medians. Thick lines end at the 25th (red) and the 75th (black) percentile respectively. Thin lines end at the 5th (red) and 95th (black) percentile respectively. For scenario 1 only the downward variation and for scenario 2 only the upward variation are shown, but the uncertainty is expected to be similar between the scenarios

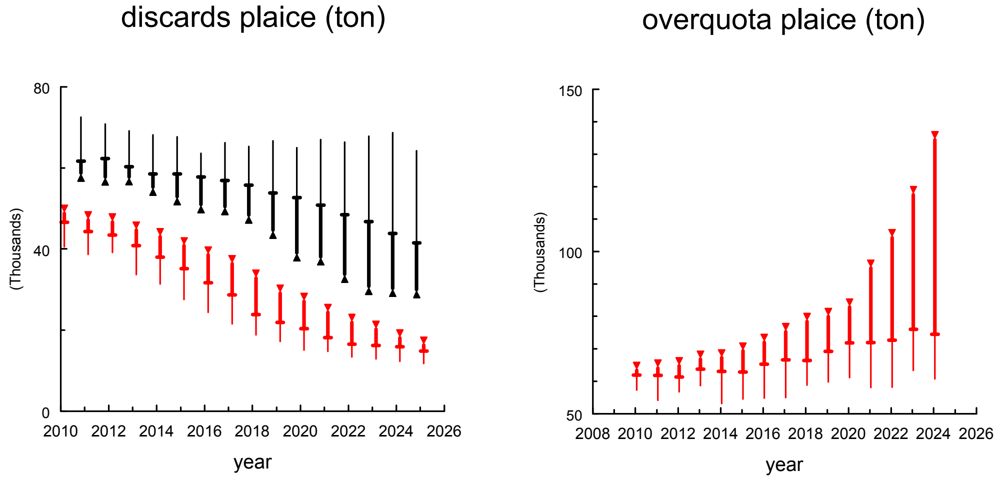


Figure 4.7. Plaice undersized discards (in thousand tons) and the overquota catches (in thousand tons) over time. Only scenario 1 is shown for overquota, because in scenario 2 overquota catches are avoided Symbols and lines, see Figure 4.6.

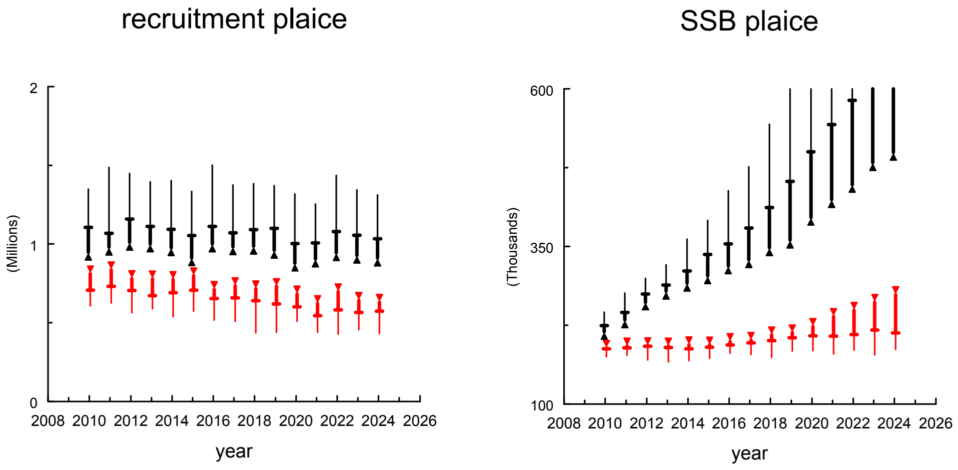


Figure 4.8. The number of plaice recruits (in million over time) and SSB (in thousand ton). Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided). Symbols and lines, see Figure 4.6.

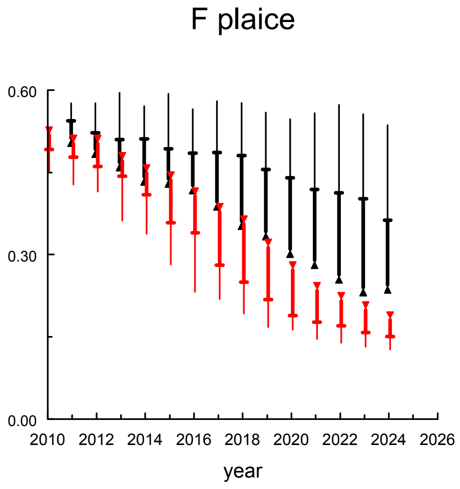


Figure 4.9. The plaice fishing mortality (F) over time. Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided). The circles and squares connected by solid lines (right) represent the implied or expected F under the HCR-measure. The triangles (left) represent the F as estimated two years later by XSA. Vertical lines, see Figure 4.6.

5. Effort indicators for North Sea demersal fisheries (CEFAS)

The current interest in fleet- and fishery-based approaches to fisheries management advice has its origins around 2002, when the conflicting states of the various demersal stocks in the North Sea made the limitations of the traditional, single-species approach to advice particularly apparent. At that point the North Sea cod stock was in such a bad state that ICES advised a closure of all fisheries for cod as a targeted species or bycatch (ICES, 2002). At the same time, North Sea haddock was at its highest level for 30 years, following the recruitment of a very strong 1999 year class. Nonetheless, on the basis that haddock is taken mostly with cod and whiting, ICES advised that “Unless ways to harvest haddock without by-catch or discards of cod can be demonstrated fishing for haddock should not be permitted.”

This situation is the classic mixed-fishery problem of how to restrict fishing on one or more stocks without restricting fishing on other stocks taken in the same fishery. The initial scientific response to this situation came in an approach first implemented for use within a meeting of a subgroup of the European Commission’s Scientific, Technical and Economic Committee for Fisheries (STECF). What became known as the MTAC approach (after Mixed-species TAC; Vinther *et al.*, 2004) was developed with the intention of making use of quantitative information on the extent to which different species are caught together, and of making the priorities assigned to the different species explicit.

The end result of applying the MTAC approach is a set of mixed-species TACs that represent a compromise between the single-species TACs based on the priorities assigned to the different species, and the information on the extent to which the species are caught together. Full details of the approach are given in Vinther *et al*. (2004). The approach was used by STECF subgroups in the autumns of 2002, 2003 and 2004, with the intention that the results could be used to inform European Commission proposals for TACs for the following years. For various reasons, however, the results were never actually used in this way, so this approach to accounting for the effects of a mixed fishery had no direct impact on the management of the North Sea fisheries.

In the absence of an accepted approach to providing mixed-species TACs, the European Commission had been seeking to ensure recovery of the North Sea cod stock through other measures. Notably, the agreed TAC for 2003 was set at a level consistent with a 65% reduction in fishing mortality, and for the first time restrictions on fishing effort were also introduced. These effort restrictions were applied to broad gear/mesh size categories and are listed in Table 1.

With the advent of effort management as part of the cod recovery plan, information on fishing effort by fleet in the North Sea is now compiled on a routine basis in order to assess the effects of the regulations (STECF, 2008). Although this is a relatively recent initiative, it has already produced some interesting results. In particular, there has been a substantial reduction in effort by trawlers in the North Sea. This has been accompanied by a switch from the directed roundfish fishery towards the *Nephrops* fishery, presumably as a result of the greater allocation of days at sea available in the latter fishery.

The substantial changes in both effort and fishing mortality that have occurred in the North Sea demersal fisheries since the introduction of effort management make this case study a useful ‘experiment’ on the linkages between effort applied at the level of fleet or fishery, and the resultant impacts on the target stocks. In particular, if an indicator of fleet activity, such as fishing effort, can be linked to stocks through fishing mortality, this opens up the possibility of providing fishery management advice on a fleet or fishery basis and describing its implications for the target stocks.

5.1. Data & methods.

The Fcube approach (Ulrich *et al* , in prep) is based on

$$F_{species} \approx \sum\nolimits_{Fleet,metier} \left(Effort_{Fleet,metier} q_{metier,species} \right) \quad (1)$$

where q indicates catchability. If

$$CPUE_{\text{métier, species, year}} = Catch_{\text{métier, species, year}} / Effort_{\text{métier, year}} \quad (2)$$

Then it also follows that:

$$CPUE_{\text{métier, species, year}} = q_{\text{métier, species}} . Biomass_{\text{species, year}} \quad (3)$$

Then

$$CPUE_{\text{métier, species}} / CPUE_{\text{ref, species}} = q_{\text{métier, species}} / q_{\text{ref, species}} \quad (4)$$

i.e. dividing the CPUE of a given métier/species combination by the CPUE of a reference métier for that species gives an estimate of relative catchability. This approach means that relative catchability can be estimated without the need for an assessment of the stock

If $rq_{\text{métier, species}}$ is the mean relative catchability for a given species and métier across all years of data, then a simple indicator of the effective effort on a given species is given by:

$$I_{species,year} = \sum\nolimits_{metiers} Effort_{metier,year} rq_{metier,species} \quad (5)$$

In effect, the total effort by gear category multiplied by the mean relative catchability for that gear can be summed across all gears to provide a an indicator that is a proxy for fishing mortality which is independent of stock assessment results.

The data used in this study reflect the management units in place for the North Sea Demersal fisheries. These are not statistically defined métiers, and the vessels involved cannot be considered as homogeneous fleets. Instead the effort management categories are defined by a combination of a gear type and a mesh size range, for example otter trawlers using 80-99mm mesh. While these categories do not include any explicit definition of target species, existing legislation meant that there were already restrictions on the percentages of different species that could be caught with each gear type. Additional allocations of days at sea were also available for vessels using a specific gear type if they met certain special conditions, such as using a more selective gear, or having a track record of landing less than 5% cod.

Landings and effort data for the gear categories used in the effort management scheme are as summarised in STECF (2008). Discard data are also available for some species and gears, but for reasons of limited coverage these are not considered further here. The data used cover the period 2002 to 2007. To investigate the link between recent fishing effort and fishing mortality, LPUE data from STECF (2008) were used to calculate the indicator summarised in equation 5 for a range of species. The LPUE data were aggregated to broad gear category, i.e. including all nations and special conditions within that gear category. The species included both assessed species, to allow comparison with trends in fishing mortality, and non-assessed species. Gear category 4aii (Otter trawls with mesh size 70-89mm) was used as the reference gear as it is a widely used and relatively unspecialised gear.

5.2. Results

Recent trends in effort for major gear types in the North Sea demersal fisheries are shown in Figure 5.1. Figure 5.2 shows recent trends in fishing mortality for the main assessed stocks in the area. The latter are presented scaled to the maximum value of each series and presented on the same plot in order to place emphasis on the trends and to make the link with fleet activity rather than treating F as an attribute of each stock individually.

Figures 5.3 to 5.8 compare the F-proxy effort indicators with estimated fishing mortality for each species where the latter information is available. The comparisons are given both as time trends and as correlations. In the case of the latter, the short time series of consistent effort data available means that possible correlations should be interpreted with caution. To give a rough indication, with the number of data points presented here, a relationship has a probability of less than 5% of occurring by chance if the r-squared is in excess of 0.53. Figure 5.9 shows trends in the relative effort indicator for three species where the corresponding information on fishing mortality is not available.

For cod (Figure 5.3), the effort indicator seems to be a good predictor of fishing mortality. In addition, cod are caught by a wide range of gears, rather than one or two specific gears, hence the composite effort indicator is not driven by a single gear but reflects changes in effort across a wide range of gears.

The correlation between the effort indicator and fishing mortality for haddock is apparently significant but negative (Figure 5.4). This anomaly presumably results from the short time series used as the apparent increasing fishing mortality over 2002 to 2007 follows a very sharp drop from 2000. The reasons for this are not immediately clear, and merit further examination. However, it may be relevant that the drop in fishing mortality followed the recruitment of the very strong 1999 year class to the stock. Catchability has been demonstrated to be inversely related to population size for haddock (Crecco & Overholtz, 1990), hence it seems possible that the reduction in fishing mortality was a result of the substantial increase in population size. Under such conditions, the changes in catchability due to density dependence may have been sufficiently large to swamp the changes in F due to effort.

There is little or no link between the effort indicator and estimated fishing mortality for whiting (Figure 5.5) or saithe (Figure 5.6). For whiting the assessment is problematic and is not accepted for use as the basis of scientific advice. In addition, the species is subject to high discarding. For saithe, the lack of a relationship is to be expected, as the effort indicator covers only EU fleets, whereas Norway accounts for the majority of the landings from the North Sea. In addition the assessment area includes the West of Scotland as well as the North Sea.

For both plaice (Figure 5.7) and sole (Figure 5.8), there seems to be a reasonably good link between the effort indicator and fishing mortality. The correlation is stronger for the sole stock, but this should be interpreted with caution as the large majority of sole are caught with a single gear type (4bi, beam trawlers using 80 to 89mm mesh) so effort by this gear type is highly influential in the composite effort indicator.

Hake caught in the North Sea are considered to form part of the Northern Hake stock which covers a much wider geographical area. Similarly, Anglerfish in the North Sea also form part of a larger stock, for which an analytical assessment is not currently available. In contrast, *Nephrops norvegicus* in the North Sea consists of a number of discrete populations. The management advice on this species is based on abundance estimates from underwater TV surveys, hence again no direct estimates of fishing mortality are available. Composite effort indicators for these three species are given in Figure 5.9. Indicators for all three species show a general decline, although that Nephrops is later and less marked than the other species, presumably reflecting the switch to targeting Nephrops that was one consequence of the introduction of effort management.

5.3. Discussion

For all species investigated here, the effort indicator shows a general declining trend. In the case of cod, plaice and sole trend this appears consistent with recent trends in fishing mortality. In the case of whiting and saithe, there is no clear link between the trends in effort and those in fishing mortality, although in the case of saithe at least, limitations in the available data means that any such link would be unlikely to be apparent. The results for haddock however, are problematic. The effort indicator does not give a meaningful insight into fishing mortality on the species over the period considered. This may be a result of specific biological conditions in the stock at that time. The effort indicator used here is relatively simple, and intended to capture only broad changes in technical aspects of exploitation. While it may be possible to develop more case-specific approaches which could address complexities such as the haddock case, the strength of the simple approach is in its generality. In principle, if such a simple indicator is found to be an effective predictor of fishing mortality in the majority of cases where the latter information was available, this would give some confidence in the use of the indicator as a measure of fishing pressure on non-assessed species.

The exploratory application of the effort indicator to anglerfish and hake highlighted issues relating to using an effort indicator that covers only part of the distribution of a stock. In such cases, the indicator should be interpreted as relating to the fleets concerned rather than being an attribute of the stocks or species. Hence, the general decline indicated for both hake and anglerfish could be interpreted as a decrease in fishing pressure on these species in the North Sea, irrespective of the stock identity. This information should be useful for management, as it reflects the wider impacts of the fleets concerned. Under a more traditional, stock-based approach it would also be desirable also to have corresponding information for the remainder of the stock area in each case.

The short time series of effort data currently available limits the ability to explore further the link between changes in effort and fishing mortality over the recent period in the North Sea. As further years of data become available it will be desirable to explore the approach further and investigate for example whether using data at a finer degree of disaggregation (e.g. gear/special condition/nation rather than just gear) improves the link with fishing mortality. From this initial analysis however, the approach shows promise as a way of linking fleet activity to the impacts of that activity. While this would make it a useful indicator in itself, further analysis is also required to establish the link between management actions and fleet activity. This would require disentangling the various contributions of, for example, effort restrictions, vessel decommissioning, and changes in targeting to the observed changes in effort. If this can be done, it would open up the possibility of linking management actions to impacts on target species which would provide a powerful way of incorporating fleet and fishery effects alongside traditional stock-based approaches to management advice.

5.4. References

Crecco, V. and Overholtz, W.J. (1990) Causes of Density-dependent Catchability for Georges Bank Haddock Melanogrammus aeglefinus. *Canadian Journal of Fisheries and Aquatic Science*, **47**, 385-394.

ICES (2002) Report of the Advisory Committee for Fisheries Management, 2002. ICES Cooperative Research Report, 255.

STECF (2008) Report of the SGRST-08-03 Working Group on the Fishing Effort Regime 1 – 5 September, Lysekil, Sweden.

Vinther, M., Reeves, S. A. and Patterson, K. R. (2004) From single-species advice to mixed-species management: taking the next step. ICES Journal of Marine Science 61, 1398–1409.

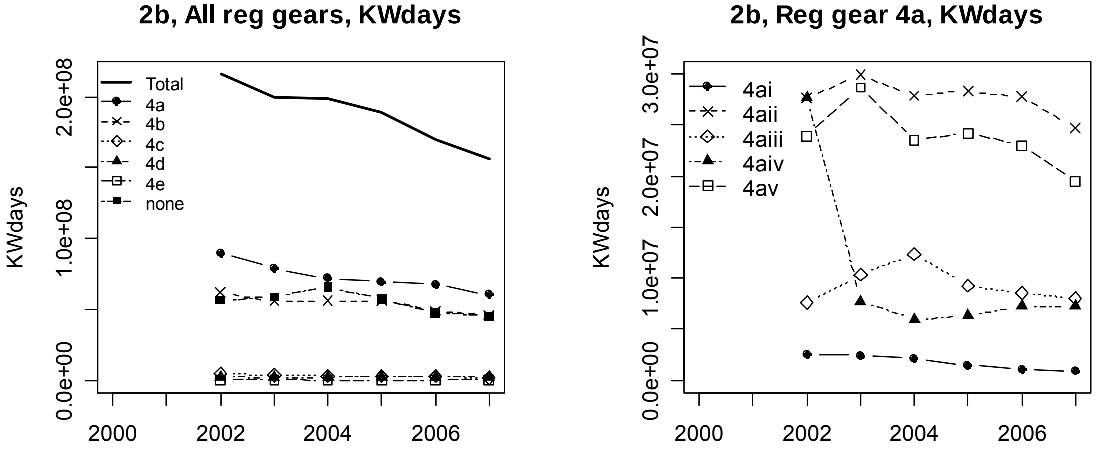


Figure 5.1; Trends in fishing effort in North Sea demersal fisheries

A, Effort by gear type (4a = Otter trawls; 4b = beam trawls; 4c = Gillnets; 4d = Trammel nets; 4e = longlines)

B, Effort by mesh size category for otter trawls (4ai = 16-32mm; 4aii = 70-89mm; 4aiii = 90-99mm; 4aiv = 100-119mm; 4av = >=120mm)

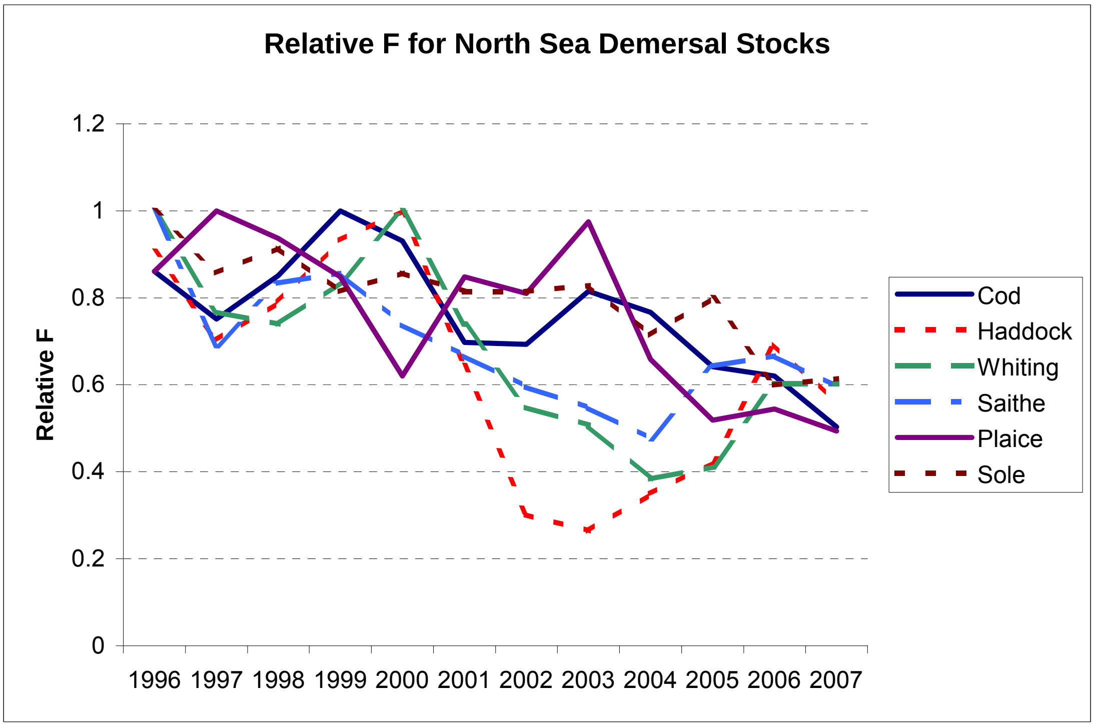
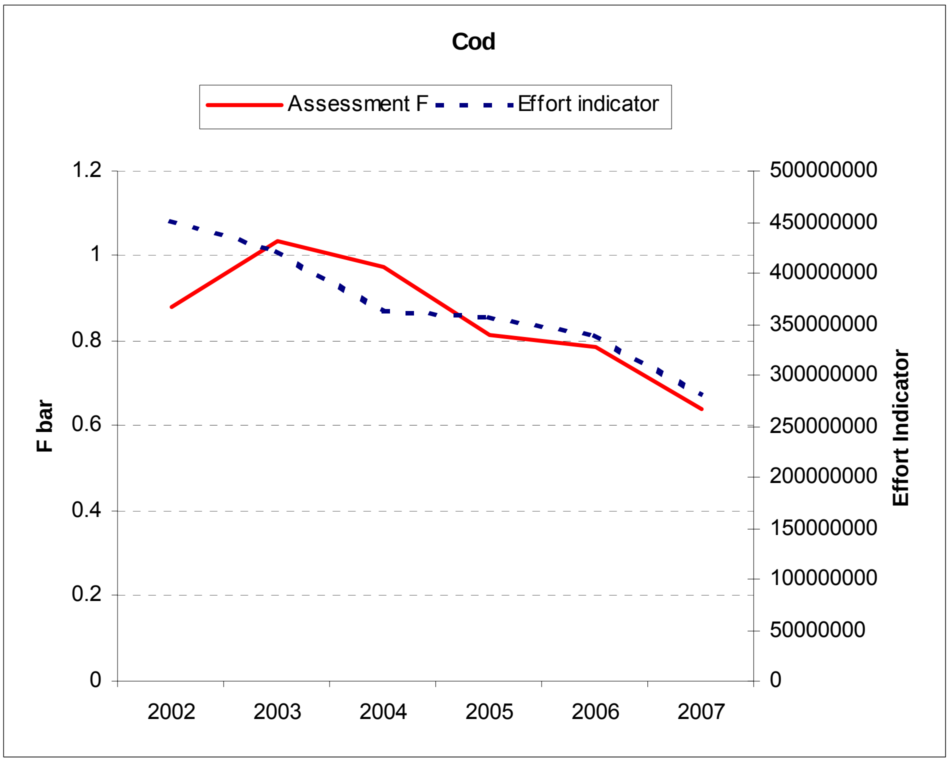


Figure 5.2; Recent fishing mortality for North Sea stocks.



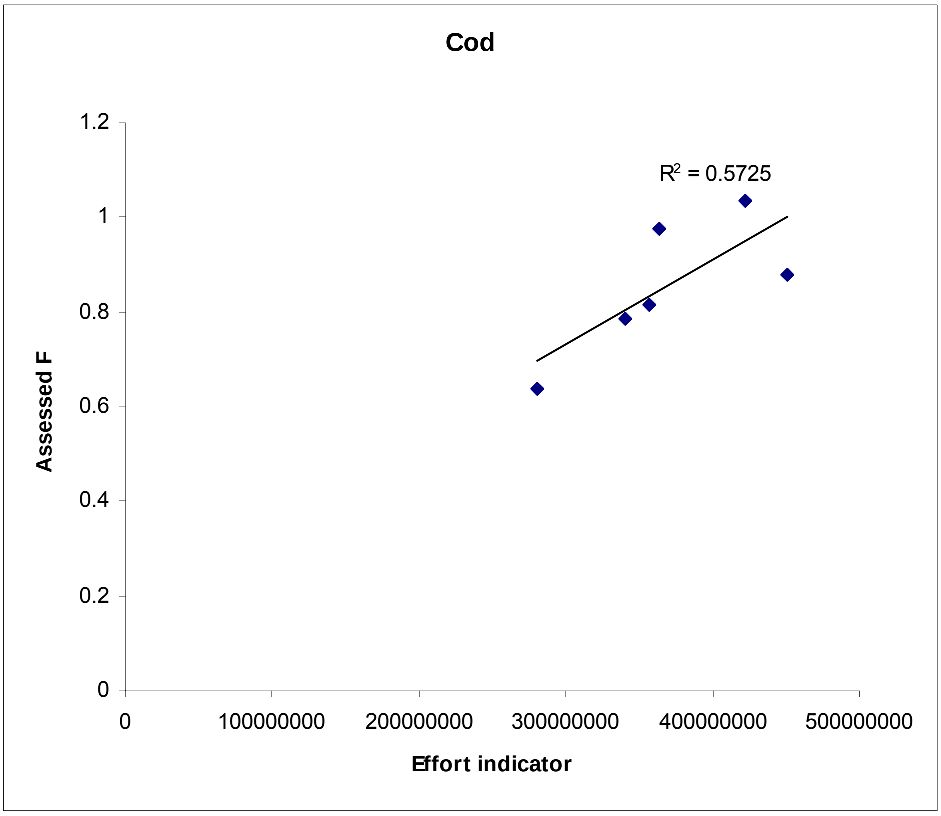
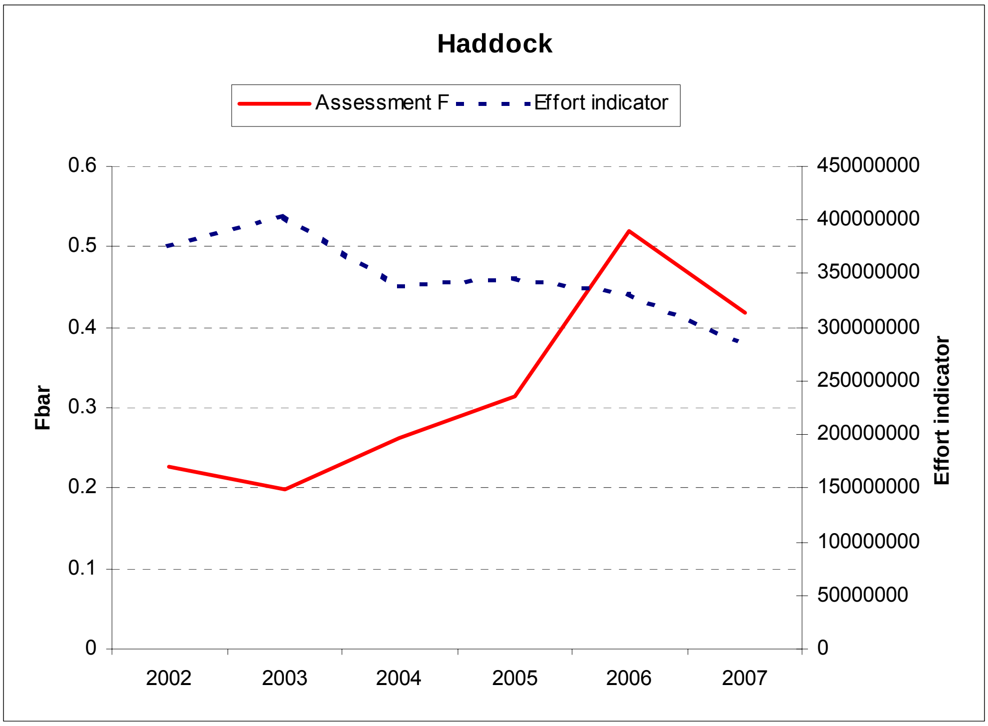


Figure 5.3; Comparison between fishing mortality and a composite effort indicator for North Sea cod



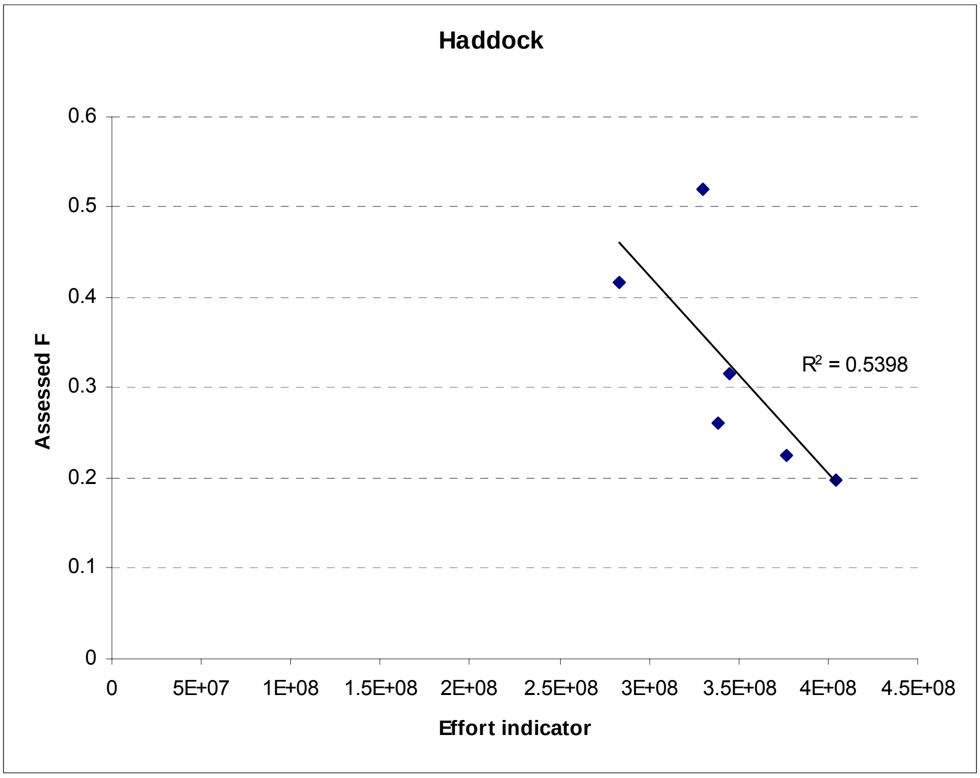
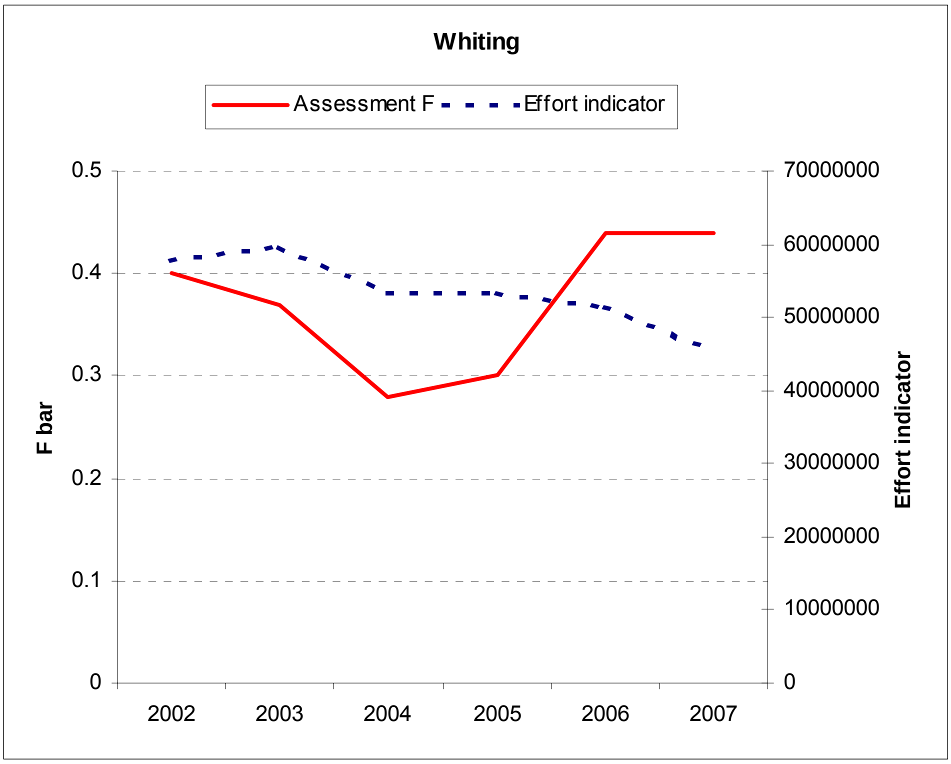


Figure 5.4; Comparison between fishing mortality and a composite effort indicator for North Sea haddock



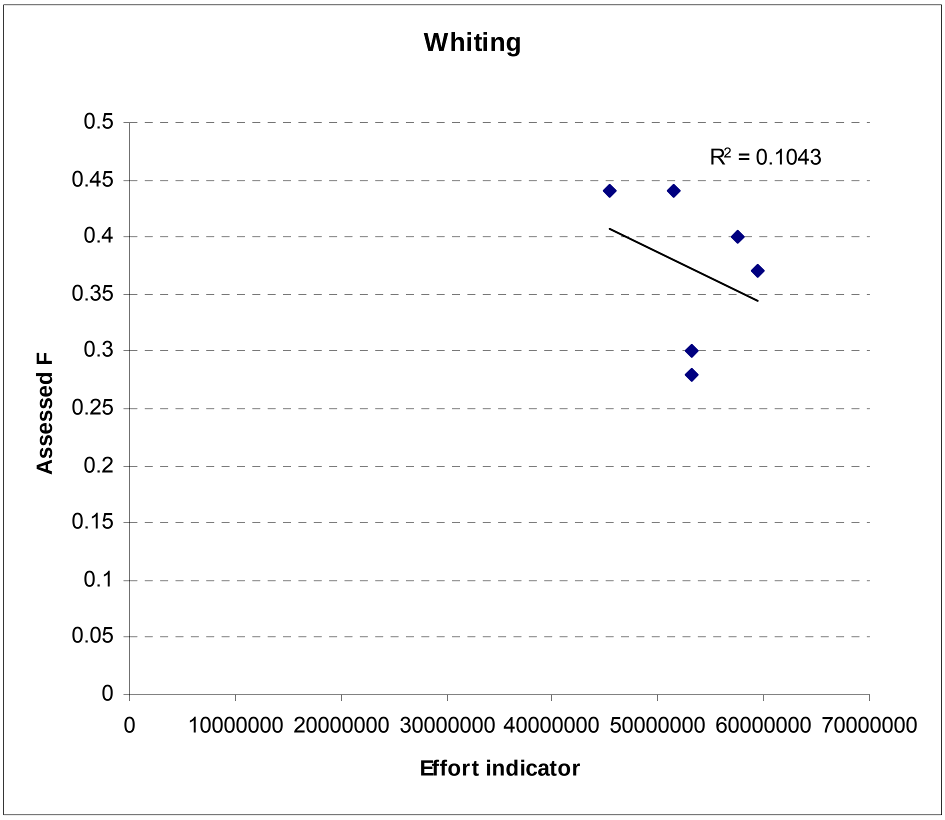
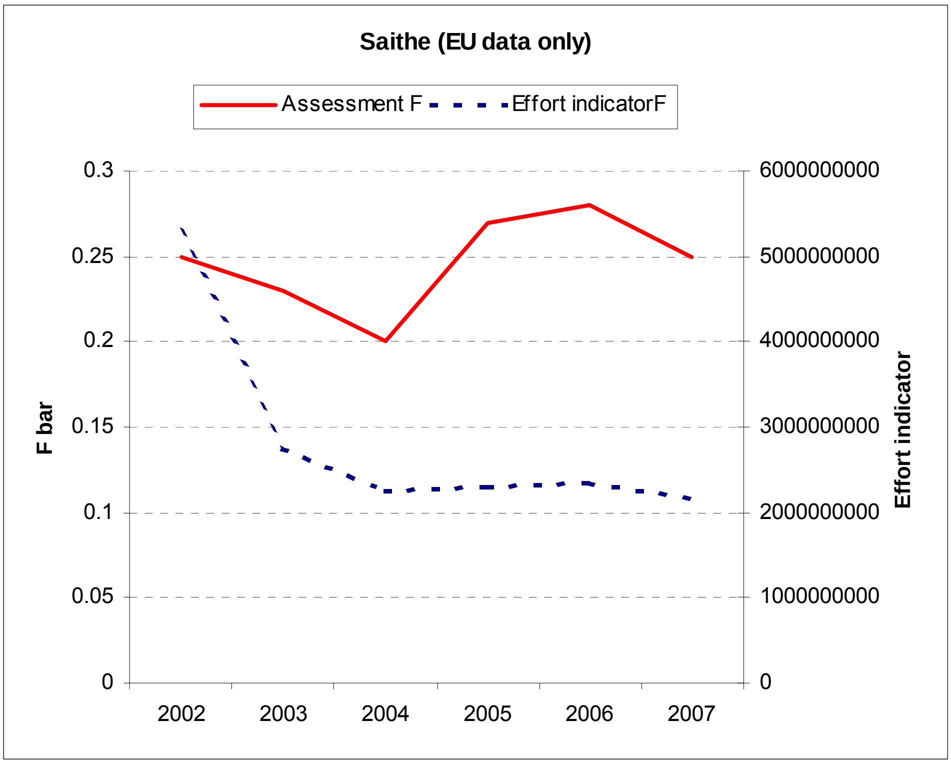


Figure 5.5; Comparison between fishing mortality and a composite effort indicator for North Sea whiting



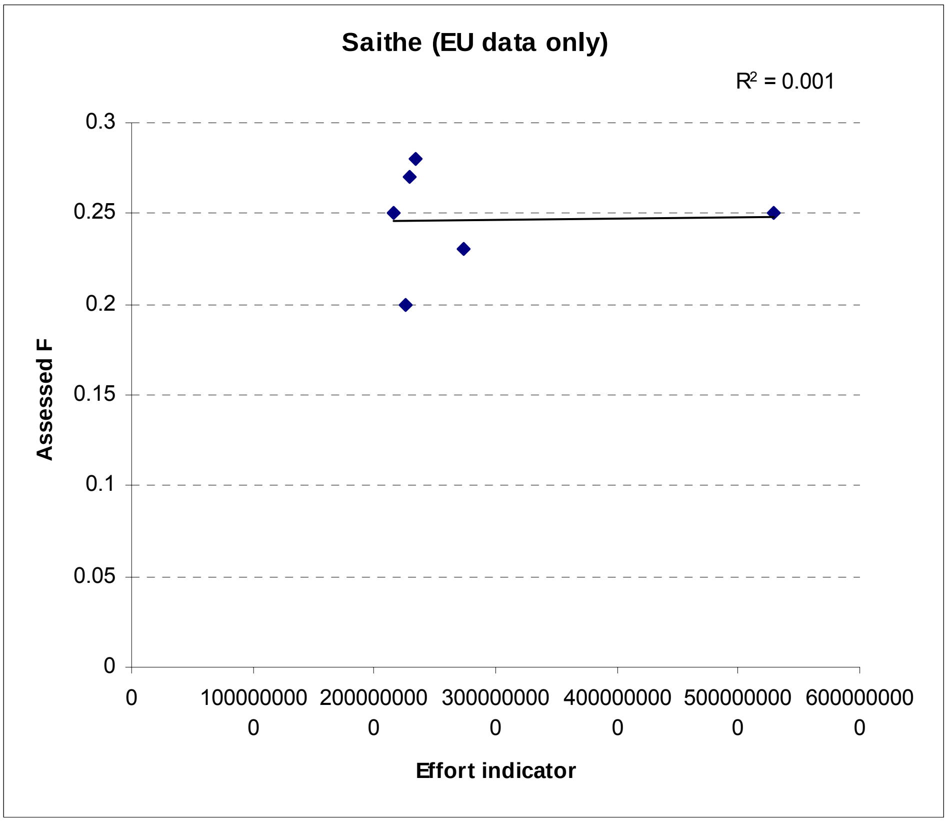
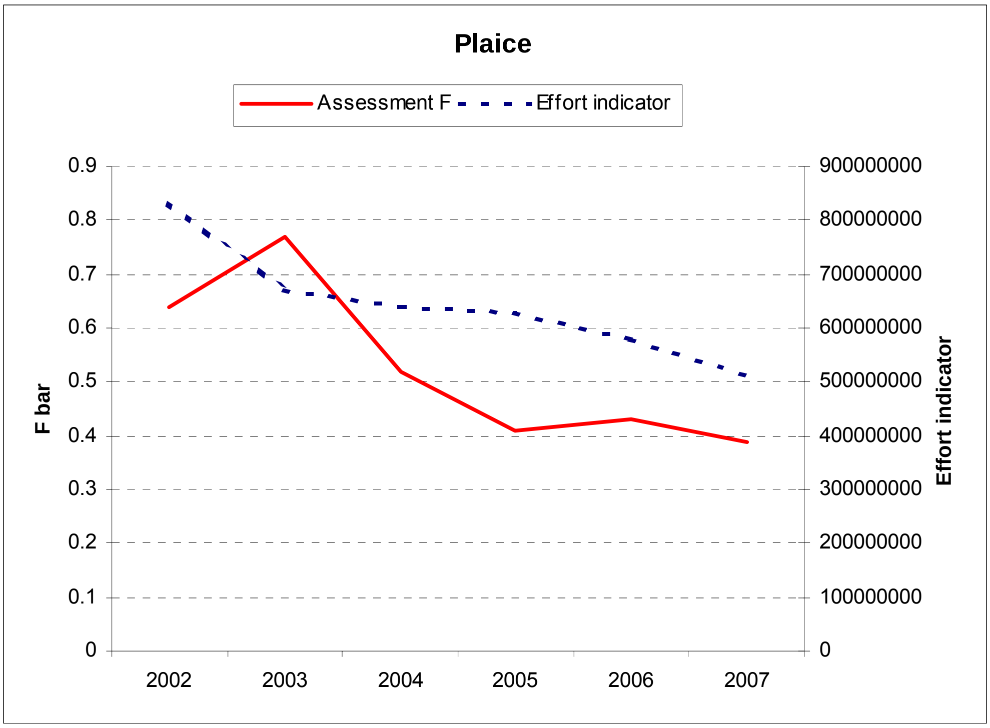


Figure 5.6; Comparison between fishing mortality and a composite effort indicator for North Sea saithe



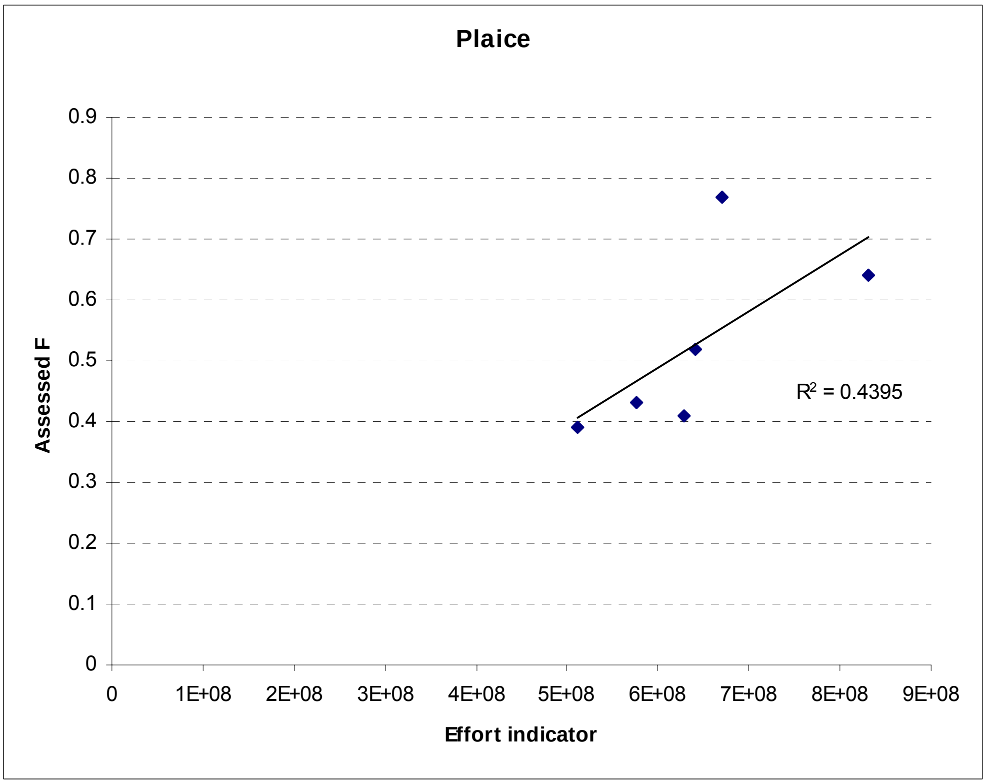
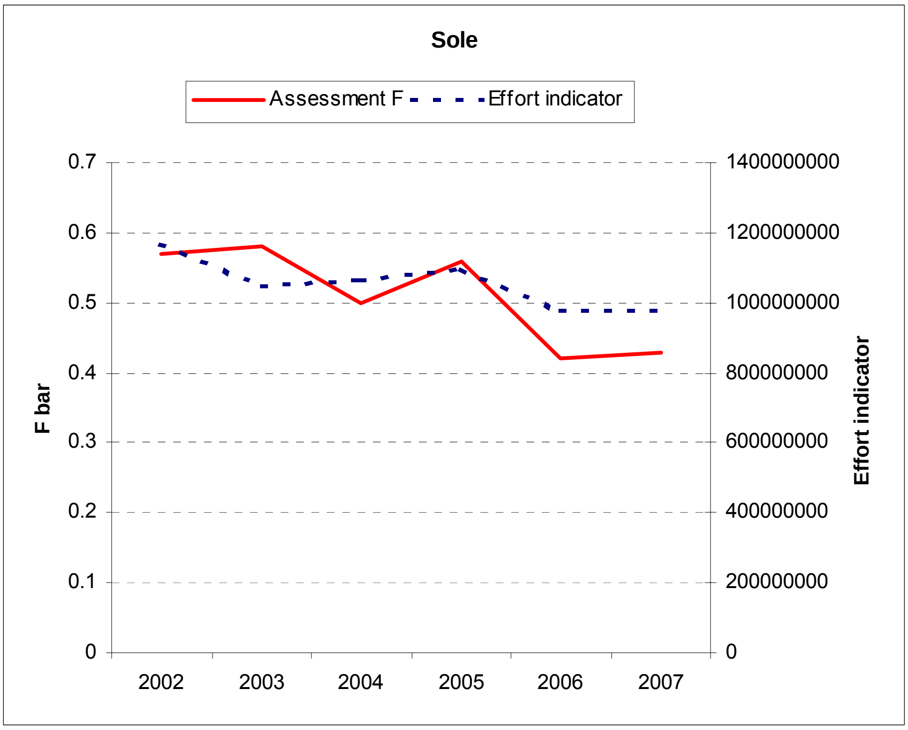


Figure 5.7; Comparison between fishing mortality and a composite effort indicator for North Sea plaic



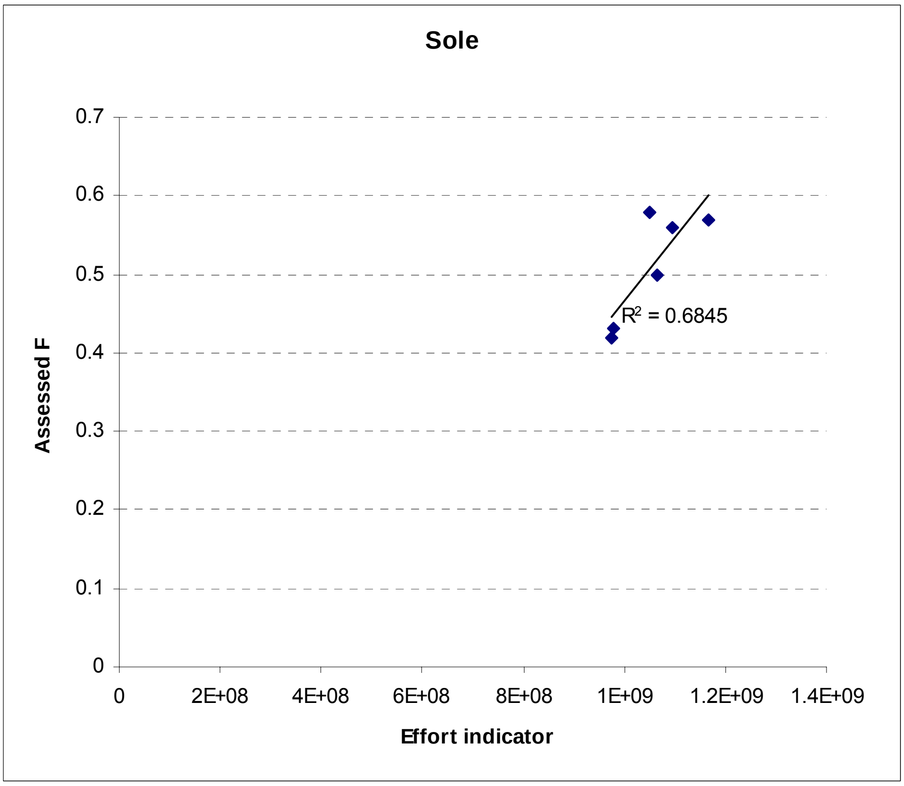


Figure 5.8; Comparison between fishing mortality and a composite effort indicator for North Sea sole

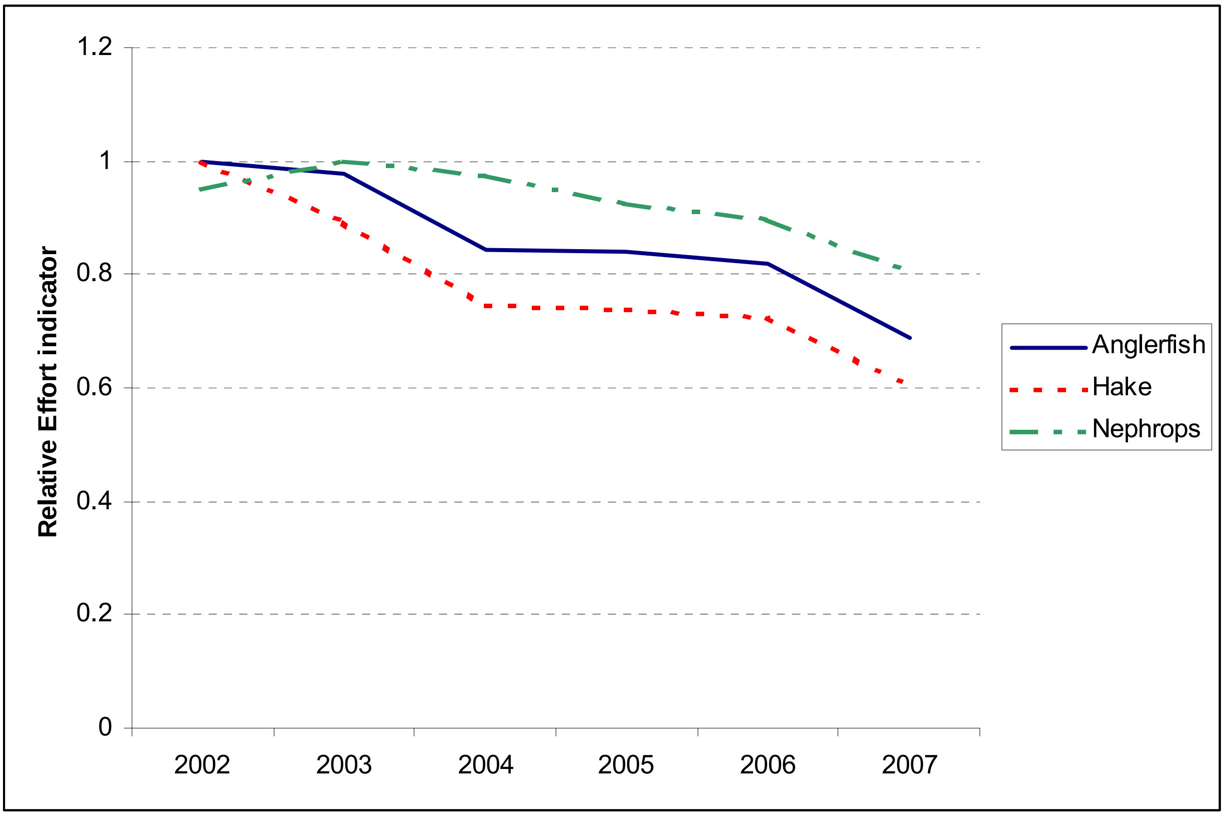


Figure 5.9; Composite effort indicator for North Sea anglerfish, hake and *Nephrops norvegicus*.

6. North Sea fleet definitions and stakeholder perceptions (IFM)

This chapter seeks to compare the fleet definitions applied in the AFRAME Fcube models with the North Sea stakeholder's perceptions of group of boats. It argues that the stakeholders way of thinking about groups do in fact confirm many of the Fcube assumptions about gear, size and species as relevant criteria. But the chapter also argues that stakeholders may have some very specific ideas as to why these criteria are relevant which are grounded not only in considerations of 'type of fish being caught' but also in broader considerations of existing management categories and occupational specialization. Last but not least, the chapter sums up a range of alternative criteria that fishermen also used in addition to gear, species and size when grouping the boats. They relate to both work organization, quota management systems, fishing area, time at sea, processing possibilities, marketing and management impact in terms of the upcoming of new types of fisheries.

6.1. North Sea fleet and métiers definitions

With the Fcube model combines two ways of thinking groups of boats within the scientific community: *fleets* as boat characteristics used for sampling economic data and *métier* as a fishery characteristic used for sampling biological data. The Fcube operates with fleet categories in terms of gear and size as well as fishery activities in terms of species and mesh sizes.

The model does not claim to include all the different fleets and métiers that may exist in the North Sea. Nor are all fleets of the model necessarily represented in the interviewed ports. The following discussion will therefore first and foremost make a general comparison of the basic assumptions and concerns of the scientists' definitions with those of the stakeholders. However, Each Fcube category will be checked with stakeholder categorizations in the end.

6.1.1. Fleet definition 1: Fishing technique

Interview with stakeholders clearly confirm the basic assumption of scientists that gear/fishing technique is a very relevant criteria to start from: All groups made by stakeholders were if not completely then at least partly characterized by their common gear type. In Peterhead stakeholders made distinctions between trawls, purse seiners and Danish seines. In North Shields there was a big difference between trawlers and the boats using static gear. In Texel most boats were beamers so there was never really a reason to voice this level of disaggregation except in relation to an inshore boat using static gear and seine net. In Hanstholm there was no contestation either, that the different gear categories - in this case gill nets, trawls and seine nets should be separated from each other. The stakeholders' perspectives therefore confirm the relevance of gear categories.

The stakeholders may even have gone into more depth than the Fcube model because they also distinguished between twinrig and single rigs; this was seen in Peterhead, North Shields and Hanstholm. Texel stakeholders also showed a particular preoccupation with the experimentations with new gear which were taking place there. They would even make a separate category of these experimenting boats even though, say, their catch species and size remained similar to the group it had originally belonged to before it started experimenting. As the Texel chapter shows, this concern with gear experiments had to do with the very survival of the Texel fleet in the face of the oil crisis. It is therefore a socially and economically relevant criterion to the stakeholders.

6.1.2. Fleet definition 2: Size

The 24 meter size category is used in the Fcube model fleet definitions for Dutch and Danish trawlers. To the stakeholders in the North Sea too, size categories were sometimes used as relevant criteria to break up the larger gear categories. But they only applied size categories up to 18 meters. That they didn't use the larger segments may just be a reflection of the very composition of the local fleet, still it is worth noticing that the stakeholders tend to make categories that are much smaller than the Fcube model due to the impacts that such size categories are having on their fisheries.

In North Shields the 10 meter distinctions appeared to be very relevant in terms of quota allocation in both the prawn and whitefish fishery. And the different categories of 10 and 12 meters was also said to coincide with different levels of catching power.

Boat size as a criteria was also relevant in terms of the rule set you get to work under as a fisherman (e.g. monitoring). The management categories can be considered as something a North Sea fishermen actively relates to when he plans and performs his business; eg. when building a new boat he will take these size segments into consideration and make sure to fit into the segment that most advantageous to him (See North Shields chapter). In Texel the miniature beamtrawler called the 'eurocutter' was also made exactly to be allowed to fish within the 12 mile zone.

Size categories not only describe practice; as a part of the existing management system, it sets the agenda which fishermen must then act around. Fishermen will have to steer into one of the available 'boxes'. As the interviews with fishermen so clearly demonstrate, management fleet categorization can be quite bureaucratic and difficult to deal with, so even though stakeholders and biologists agree on size as a relevant criterion, it doesn't mean that fishermen appreciate this management practice as it implies a certain stiffness and loss of flexibility (See individual chapters).

There are other reasons however, to think of size as a relevant criterion in terms of fishery. The size of a boat sometimes overlap with how far away it will go and big boats and small boats will therefore sometimes fish in different areas as is the case with Texel prawn boats. It might be a question of historical specialization, but again, you might have built your boat to match the area you have a license for due to your traditional rights as is the case for the flat-bottomed Waddenzee shrimp trawlers. The Texel eurocutter is another example of size-and-area matching; it does the same as the larger beamers but fishes within the 12 mile zone.

6.1.3. Metier definition 1: Species caught

Species is an important sorting criterion for the fishermen too insofar as it actually tend to follow the gear groups they are making. A primary gear category was rarely constructed without some indication of its main target specie(s). In fact, gear and species were often used side by side to identify a given category. The importance of 'species' mostly manifest itself through descriptions of the quotas of a boat meaning that fishermen would focus on the rights of different boats to fish a certain species.

However, the fishermen generally did not go into such depth as the biologist with regard to defining the individual species they might catch. They tended to use general categories instead. It's not because the fishermen didn't recognize that different boats had different quotas for different species; when for example the Hanstholm fishermen went through the consume trawlers one by one they would go into details explaining the fish catch compositions of the different boats in terms of the quota they own. But when having to group the boats in categories, they would lump these different fish species together and simply call them 'fish'. A boat would then be a 'consume trawler fishing only fish' if it does not fish prawns. And it will be a 'consume trawler with combined fishery' if it fishes both prawns and fish. This is also exactly the kind of combination that would make a Texel 'flexible' or Peterhead boat 'float' between categories; switching between 'nephrops' and 'fish'. There is therefore reason to conclude, that throughout ports of the North Sea, grouping boats according to species caught is most important in terms of the prawn/whole categories of fish division.

The tendency to group species according to quota and then according to a whitefish/fish and prawn division should probably be understood in the context of the management regime in the North Sea. For example fishermen of North Shields and Peterhead explained how the fishery has become very polarized due to the quota system. One should also consider the methodology of the research though: categorization is exactly a simplifying endeavor and maybe the different catch compositions are really too complicated a phenomenon to be classified into anything else than large boxes.

Besides from the big boxes of prawns and fish you would also find that stakeholders operate with other categories of species. In North Shields and Peterhead you would also have the inshore 'lobster and crab' fishery. In Texel there was a boat with a special license for Mullet that got much attention from almost every fisherman; they classified it as a very specialized fishery with exclusive fishing rights. So sometimes there was room for 'small boxes' too, so to speak. But when big boats go out, their fishery often got simplified all together and put into the same big box.

A distinction which relates to the species caught but which is not included in the Fcube or ICES species classification is the distinction between 'industry fish' and 'consume fish' trawlers. In the meantime, this was one of the most consensual distinctions made by the Hanstholm fishermen. But at the same time, it must be remembered that this distinction is in itself a polarizing result of a management classification; earlier on a boat would be able to combine these two fisheries.

6.1.4. Metier definition 2: Mesh size

No fisherman chose to make categorizations based on mesh size. But just as with the species caught, which is sometimes just implicit in a gear categorization, you actually don't know how much the fishermen take for granted when they make their other categorizations. One time a North Shields skipper who had chosen to group according to catching power and size was asked if net size follows too. He confirmed that everything went together. Mesh size was mentioned in one interview only. It got described as a regulation that varies according to fishing zone and whether you are twin-rigging or single-rigging. So mesh size regulation is part of fishermens' experience and considerations thereof may be implicit in the net related categorizations. But mesh size was never a direct criteria for grouping boats in terms of fish caught or vessel characteristics.

But all in all, one has to conclude that fishermen did not choose to describe their categories in terms of mesh size.

6.2. Common criteria - common concerns?

The sorts made by stakeholders did seem to confirm the Fcube models assumption that gear, size and species matters. These are indeed very central components in the ways fishermen themselves would think group of boats. But the categories they made in each port are sometimes quite different from the national Fcube fleets. Mesh size for example was not voiced as a relevant criterion at any time. At the same time stakeholders would often emphasize the number of nets (twinrig, single rig, pair trawl) and they would apply other size categories than the Fcube due to management impact.

The Fcube assumption that a given fleet in terms of size and gear may catch a certain range of species is also confirmed. Actually the fishermen too seem to keep this as an implicit assumption. They will name a category 'combined trawl' or 'large beamer' and they will say, that the boats within this category target the same species. But the knowledge may not be articulated unless you ask directly. The very composition of the catches is not basis for further categorization either; They make broad categorizations in terms of the fish they catch (e.g. whitefish, prawns, combined, 'place and sole' etc.) When it comes to specialized fisheries, they will often be sure to make a category for exactly this type of fishery. In this respect they are more sensitive to particular species than the Fcube model making 'fleet segment' of very specialized fisheries.

There is reason to be aware however, that while biologists are interested in the 'species caught' criteria from a stock perspective, this may or may not be case for fishermen. Some fishermen consider the amount of fish caught when they group according to catching power or when they for example comment on a specific group, that 'these are the big ones catching the most fish and burning the most oil'. Other fishermen may evaluate the attitudes of a given group or individual fishermen in terms of whether they are in it for the money and catch a lot of fish or whether they are in it just for the life style, and catch only a little. So fishermen may think group of boats in terms of how much they take out of the sea.

Still, there may be other reasons too, why fishermen think that gear, size and species are important criteria. Besides from catching a particular stock using a specific gear, the gear-fish-size nexus can also be a question of completely different occupations, attitudes in terms of profit making, levels of professionalism, ways of selling fish, work practices, income categories, working conditions, survival prospects etc. (see individual port chapters). Besides from this reservation in terms of the possible existence of 'shared concerns' behind the shared categorizations, the stakeholder sorts and interviews also show, that fishermen apply additional grouping criteria which are based in a range of different concerns. They are elaborated upon in the different port chapters, but they can be summed up like this:

Other stakeholder categories	Relevance and/or concerns	Port
One-man net boats	Local fleet development. Quota cut back and lack of crew. Risk to fisherman security	Hanstholm
Processing on board (Boiling of shrimps, filleting of fish, packing shrimps and fish)	New development. New economic potential. 'Factory at sea'.	Hanstholm
Freezing prawns at sea	Adaption from whitefish to prawn fishery. Allows flexibility in terms of shifting fishery.	Peterhead
MAF (Less Active Vessels)	A Danish management category. MAF - Less Active Vessels - get quota allocated from a common Danish pool of quota whereas FKA (vessel quota shares) vessels have a private quota	Hanstholm
One man day trawler	Development in fleet from small net boat to small trawl. Easier work to drag a trawl.	Hanstholm
Part time job, retired fishermen, taxi drivers	An informal - sometimes normative - evaluation of a less active fishery.	NorthShields Texel Peterhead
Fishery as side-line job	A management category	Hanstholm
Day boats	Boats that are only away for the day do not go as far	Hanstholm North Shields
Away for days	Boats that are away for many days go further away	Hanstholm
Tripping/non stop fleet	Two different kinds of fleets in terms of time spent at sea vs. time spend on land and in terms of crew	Peterhead

	organization.	
Inshore boats	Within a specific fishing area. Smaller than other boats. Sometimes evaluated as something less than the 'real fishery' by big boat skippers.	Peterhead North Shields
Fishing area in terms of different seas	Often a secondary grouping criterion. Reflects license distribution.	Texel
Membership of different producers organizations	These organizations are getting more and more important	Peterhead

6.3. *The relevance of the Fcube final fleets definitions*

The Fcube operates with 19 fleets engaging into one to six métiers. This study concludes that compared to the stakeholders, the Fcube model tend operate with broader fleet categories in terms of gear type and size and smaller metier categories in terms of fish species and mesh size.

When you compare the exact fleets with the stakeholder groups you often find that it is possible to confirm the relevance of the fleets in terms of fishing technique and size, but the groups themselves may be too broad. It is difficult to conclude on the species caught as the stakeholders might give some examples, but they will not make a big effort to identify the different species caught. In terms of mesh size however one has to conclude that such categorization was never relevant to the stakeholders' groupings. That mesh size is not relevant to the stakeholder's groupings however, does not automatically mean that they are not aware of different rules in that regard.

As illustrated in the table on 'other stakeholder categories' above, the Fcube model also lacks the kind of stakeholder categories that do not evolve around gear, size and species but which have to do with fishing area, time and distance from shore, processing possibilities and different fishing intensity

It is important to remember however, that only four ports were visited in the North Sea and some fleets and fisheries defined by the Fcube are likely not to be represented in these port. Some Fcube fleets can therefore not be confirmed by stakeholder categories even at the fishing technique level. One should also remember, that the stakeholder's themselves were never presented with these categories and so they were never given a chance to discuss them. Hypothetically it is possible that stakeholders would be able to see their relevance though they did not choose to group the boats like that as their first priority. It is therefore with some methodological reservation that the table below concludes on the relevance of the exact Fcube fleets according to stakeholder perceptions:

Fcube fleet and metiers	+/÷ Match with stakeholder sorting criteria
Fleet: BEL_BEAM **Metier:** [1] "OTH" "TBB_120+" "TBB_80-89" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEPoth"	No conclusion/no Belgian stakeholder interview
Fleet: BEL_OTTER **Metier:** [1] "OTTER_" **Species:** [1] "COD" "HAD" "POK" "WHG" "NEPoth"	No conclusion/no Belgian stakeholder interview
Fleet: DEN_BEAM **Metier:** [1] "OTH" "TBB_120+"	+ 'Bundtrawler' (though not working in Hanstholm) ÷ Mesh size

Species: [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP7" "NEPoth"	÷ Species categories but common species examples: One 'bundtrawler' was bought up by a 'trawler' for the sake of the fish that came with it: plaice, cod, turbot, sole.
Fleet: DEN_DEM_SEINE **Metier**: [1] "DSB_100-119" "DSB_120+" "OTH" **Species:**[1] "COD" "HAD" "PLE" "POK" "SOL" "WHG"	+ Seine net ÷ Mesh size ÷ Species categories but common species examples: cod, plaice (hake, anglerfish, lemon sole and shell fish too by a boat that uses trawl in winter too)
Fleet:DEN_DEM_TRAWL_<24` **Metier:** [1] "OTB_070-099" "OTB_100-119" "OTB_120+" "OTH" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP7" "NEPoth"	+ 'Trawl' ÷ boat size ÷ Mesh size / + number of nets + Subgroups according to road categories of species industry, consumption, combined, deep sea, lobster, shrimp. ÷ Species categories but common species examples: anglerfish, which flounder, plaice, saithe and cod + other subdivisions
Fleet:DEN_DEM_TRAWL24_40 **Metier:** [1] "DSB_120+" "OTB_070-099" "OTB_100-119" "OTB_120+" "OTH" **Species:[**1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP7" "NEPoth"	As above
Fleet: DEN_GILLNET **Metier:[**1] "GNS_070-099" "GNS_100-119" "GNS_120+" "OTB_120+" "OTH" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP7" "NEPoth"	+ 'Garn' ÷ Mesh size ÷ Species categories but common species examples: plaice, sole, cod, hake and flounder + other subdivisions
Fleet: ENG_BEAM **Metier**:[1]"OTH""TBB_DEM_100-119" "TBB_DEM_120+" "TBB_DEM_80-99" **Speices**:[1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP6" "NEPoth"	No conclusion/no beamers among the sampled boats
Fleet:ENG_DEM_TRAWL **Metier:** [1] "OTB_CRU_80-99" "OTB_DEM_100-119" "OTB_DEM_120+" "OTB_DEM_80-99" "OTB_MIX_120+" "OTB_MIX_80-99" [7] "OTH" "PTB_DEM_120+" **Species**: [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP6" "NEPoth"	+ trawlers (implicit) +broad categories of species compositions: 'prawns' and 'whitefish' ÷ Mesh size/ + net type ÷ Species categories + other subdivisions
Fleet: ENG_STATIC **Metier:** [1] "GNS_DEM_120+" "OTH" ENG_STATICspp [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP6" "NEPoth"	+ static nets ÷ mesh size + other gear categorizations: traps + lobster and crab as species ensemble
**Fleet: NLD_BEAM_>=24`** $`NLD_BEAM_>=24`$met [1] "OTH" "TBB_DEM_100+" "TBB_DEM_80-99" $`NLD_BEAM_>=24`$spp [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEPoth"	+ Beamers + boat size distinctions, but different + shrimp as a category + fish as a category + mixed shrimp and fish as a category +additional boat types outside the beamer category
Fleet: NOR_BEAM **Metier:** [1] "OTH" "TBB_DEF_080" "TBB_DEF_120" **Species:** [1] "COD" "HAD" "PLE" "SOL" "WHG" "NEPoth" "POK"	No conclusion/no Norwegian stakeholder interview

$NOR_ROUNDFISH **Metier:**[1] "OTB_DEF_100" "OTB_DEF_120" "OTB_DEF_130" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEPoth"	No conclusion/no Norwegian stakeholder interview
Fleet: SCO_BEAM **Metier:**[1] "TBB_100-119" "TBB_120+" "TBB_80-89" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP6" "NEP7" "NEP8" "NEP9" "NEPoth"	÷ such categorization/possibly no beamer among the sampled boats
Fleet: SCO_DEM_SEINE **Metier:** [1] "DSB_100-119" "DSB_120+" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP6" "NEP7" "NEP8" "NEP9" "NEPoth"	÷ such category + other seines: Danish seine net and purse seine
Fleet: SCO_DEM_TRAWL_<24` **Metier**:[1] "OTB_100-119" "OTB_120+" "OTB_70-89" "OTB_90-99" "OTH" **Species**: [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP6" "NEP7" "NEP8" "NEP9" "NEPoth"	+ trawlers ÷ boat size ÷ mesh size/+ numbers of nets ÷ single species categories, only broad categories of species compositions: ‘prawns’ and ‘whitefish’ + Other subdivisions
$`SCO_DEM_TRAWL_>=24` **Metier**: [1] "OTB_100-119" "OTB_120+" "OTB_70-89" "OTH" **Species:** [1] "COD" "HAD" "PLE" "POK" "SOL" "WHG" "NEP7"	As above
$OTH_OTH OTH_OTHmet [1] "OTH" OTH_OTHspp [1] "COD" "HAD" "WHG" "POK" "SOL" "PLE" "NEP7" "NEPoth"	No such category

7. Fleet and Fishery structure of one Scottish mixed demersal North Sea fishery (FRS)

7.1. Study area and fleets

The area identified in the North Sea for the case study were 24 statistical squares east of the Shetland Islands and north east of Fraserburgh on the Scottish mainland (Figure 7.1) covering 21600nmile^2. This area covers a number of traditional Scottish demersal fishing grounds such as the Fladens, Bressey, Bergen Bank and NE Holes. The fleet targeting this area comprises two distinct sub-groups one targeting whitefish species such as cod, haddock, angler and flatfish the other targeting Nephrops but with a whitefish by-catch. The fishing gears used by these two sub-groups range from whitefish single, twin rig and pair trawl/seine but only single or twin rig is employed by the Nephrops fleet. Another point to note, since 1992 the legal codend mesh sizes employed by the whitefish fleet have been larger than for vessels targeting Nephrops. The time period selected for the study was 2003 to 2006 which covers two notable management events firstly the last Scottish decommissioning scheme and secondly introduction of the EU cod recovery plan and days at sea in 2003. The main target species to be considered for this study were cod, haddock, whiting, anglerfish and Nephrops.

7.2. Categorising fleets within the North Sea case study area

The main data source for the fleets operating in the study area was the Fisheries Information Network (FIN) database introduced in 1995. This database is managed by the Scottish Ministry of Fisheries and contains the information recorded by all skippers in the Scottish fishing fleets on the official EU Logbook. The database contains information on vessel specification, voyage information, main fishing method, codend mesh size used, effort data (fishing time per 24 hour period), days absent and the quantity and value of all species landed during each voyage. However, during previous investigations to define fleets it was discovered that though the recording of catch landings data by skippers was mandatory the gear information and effort data was not. Furthermore it was also discovered that when FIN was introduced the number of main method codes increased to 72, but the codes listed in guidance note at the front of the EU log-book had not been updated and only listed 19 main methods. Though the new codes better described main methods being employed by the Scottish fleet, skippers were only aware of the old codes and continued to use them. A description for the FIN main method codes used in the survey area during the period of this study are given in Table 7.1. Therefore defining the gear used by each vessel in the Scottish demersal fleet from FIN using the main fishing method coding was found to be flawed. For this project an alternative approach has been adopted which attempts to develop a metier utilising other FIN data fields such as mesh size and landings data to enable fleets to be categorised correctly without being totally dependent on using the main method code. An example of this process was to assess the landings allocated to each mesh size in FIN, with the assumption being made that sizes less than 100mm could be considered to be associated with Nephrops gears.

7.3. Data extraction and correction classification of fleets

The initial data extraction for each vessel during every quarter between 2003 and 2006 targeting the study area consisted of the following data fields; name, official number, port registration number, main method code, codend mesh size, weight of landings for each target species and day absent. Supplementary data on vessel engine power and length was also extracted but purely used to establish the correct identification of vessels with the same name, port registration or official numbers.

The next step was to validate what FIN listed as main fishing method code for each vessel against data collected through the FRS observer programme, expert knowledge within the Laboratory and the information recorded on mesh sizes and catch landed for each fishing voyage. For convenience during the checking phase the validated main method code allocated to pair trawl/seine vessels was PAIR. The rationale for this was due to the potential for these vessels to employ both methods during a particular fishing voyage depending on the seabed substrate being targeted. Once each vessel had been correctly categorised the number of vessels and the weight of fish recorded as being caught within the survey area during each quarter by year were then collated and tabulated, this allowed comparisons to be made between original data recorded on FIN and a validated data set.

During the validation phase it was noted that the corrected FIN main method code and codend mesh sizes used during each voyage recorded on FIN could provided a possible solution in determining a vessels main fishing method and hence allocating landings data more accurately.

7.4. Results

Throughout the study period (2003-2006) FIN listed many vessels as employing more than one main fishing method within the study area which was incorrect for nearly all these vessels. This inconsistency was possibly due to either skipper's entering the wrong gear code onto the EU log sheet or incorrect entry of the data onto the FIN database during the collation process. Also during this period the FIN data suggests that it was predominant whitefish gears such as single trawl, twin trawl, seine net and pair trawl/seine and not Nephrops gears being employed in the study area (Tables 2.1 to 2.4). However, after validation the picture was completely different with the main whitefish gear being pair trawl/seine (PTM/SPR) and single seine (SSC) with a slightly reduced number of twin-trawl vessels (OTT), but significant less single trawlers (OTB). Furthermore, the main gear actually being employed in the study area was in fact twin Nephrops trawl (TBNT) using codend mesh sizes below 100mm (Tables 7.5.1-7.5.4). Also identified by the study were Nephrops vessels using two mesh sizes during the year, one Nephrops (<100mm) and the other whitefish (>120mm). This was allowed under legislation during the period of this study and is classified as a two net-rule and allows vessels some flexibility in their fishing practices. However, during this study it became apparent that most if not all these vessels were actually abusing this rule and allocated their landings to whitefish mesh sizes when in fact smaller Nephrops mesh sizes were being used. The main reason for this abuse was due to the weight of Nephrops being less than 35% of the total catch weight. Therefore, Nephrops vessels carrying out this practice have been denoted in all validated main fishing method data with the code TBNT/OTT. Also noted in Table 7.2.2, 7.2.3 and 7.2.4 were 6 vessels being incorrectly coded as using pelagic gears or scallop dredge when in fact these vessels were employing trawl gears.

The weight of landings for each main fishing method as recorded on FIN is given in tables 7.4.1-7.4.4 with the weights against validated main fishing method given in tables 7.5.1-7.5.4. From the FIN data (Tables 7.4.1-7.4.4) OTB and PTB each consistently made up 30% to 40% of total cod landings per year. The majority of Haddock and whiting landings were also attributed to these gears with SSC also making a significant contribution. However, the majority of anglerfish and Nephrops were mostly attributed to OTB with the remainder allocated equally to the multi-trawl codes OTT and TBNT. After validating main fishing method as previously mention it was found that the majority of Nephrops vessels, using codend mesh sizes below 100mm, were incorrectly coded as OTB. This is supported by the landings data for these vessels (Tables 7.5.1-7.5.4) which clearly shows that over 97% of Nephrops were actually landed by TBNT and TBNT/OTT gears every quarter. Another point to note after validation was the increase in quarterly landings of cod attributed to these gears which increased from 1% to between 10%-26% per quarter. Another significant shift was the amount of Anglerfish recorded against OTB, which suggested this gear was landing between 60-70% per quarter. This however was also incorrect as 60-75% of Anglerfish were in reality being landed by whitefish and Nephrops twin trawl gears (OTT, TBNT & TBNT/OTT). During the study it was found that for the most part pair trawl and seine vessels were correctly coded and combining these gears proved the correct assumption. However, it was found that some pair seine vessels had been incorrectly coded as single seine vessels (SSC). Therefore, there were some adjustments in the landings recorded between these gears for haddock, cod and whiting.

From the validated data in tables 7.3.1-7.3.4 it appears that the introduction of days at sea at the start of 2003 had little impact on activity within the study area as vessel numbers remained similar for the first 3 quarters of the year. The decommissioning scheme did appear to affect vessel numbers at the end of 2003, with a sharp drop in the number of vessel noted between Quarters 3 and 4.

7.5. Conclusions

During this study it has been demonstrate that the recording of main fishing method on FIN is flawed and should not be the primary variable used to describe fishing vessel activity within fleets. However, it was found that using a combination of expert knowledge and utilising other FIN data fields it has been possible to validate the actual main method being used by vessels within this study area. As described previously an objective of this study was to develop a metier utilising other FIN data fields to enable Nephrops and whitefish fleets to be categorised correctly without using main fishing method codes. For this study the two key FIN fields used to assist in main method validation were codend mesh size and the species landed by individual vessels. Unfortunately it was found that without expert knowledge of the vessels being studied and an understanding of the regulatory processes (i.e. by-catch limits) used to manager their fishery, developing a metier using FIN data alone would be problematic. An obvious solution to this fundamental flaw would be to ensure vessel main method is being correctly coded. However, with expert knowledge it may be possible to use codend mesh size and a combination of catch composition and the percentage each species contributes to total weight of landings to predict main fishing method.

FIGURE 7.1 – Area used for North Sea case study.

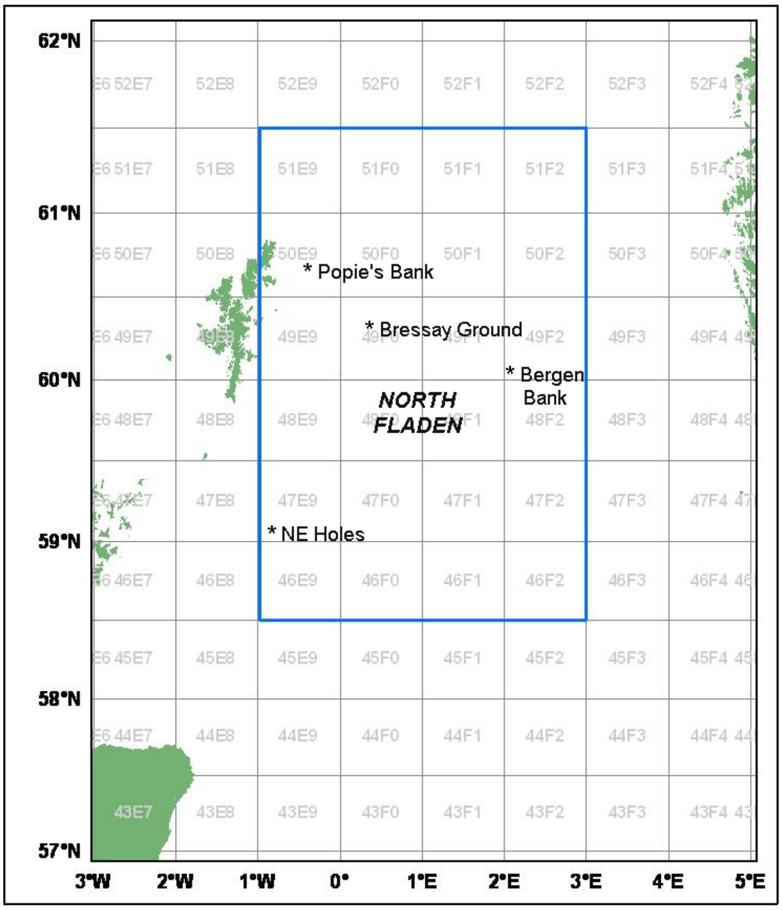


TABLE 7.1 – FIN Main method codes used by vessels targeting the North Sea survey area during the study period 2003 to 2006.

Main method code	Gear description
OTB	Bottom trawls otter
OTT	Twin trawls otter twin multi trawls
PTB	Bottom trawls pair trawls (two vessels)
SPR	Boat/vessel pair seines
SSC	Boat/vessel seines-Scottish seines
SX	Seine net (not specified)
TBB	Bottom trawls beam trawls
TBN	Bottom trawls Nephrops trawls
TBNT	Twin trawls Nephrops twin multi trawls
TX	Other trawls (not specified)
PS1	Purse seine operated by one vessel
PS2	Purse seine operated by two vessels

TABLE 7.2.1 – Actual FIN data number of vessels by main fishing method in survey area during 2003.

2003	(OTB)	(OTT)	(OTM)	(PTB)	(SPR)	(SSC)	(SX)	(TBB)	(TBN)	(TBNT)	(TX)	Total
Q1	143	36	0	49	6	26	1	1	1	19	3	285
Q2	140	29	3	50	6	20	0	0	2	26	0	276
Q3	142	33	1	49	8	15	2	0	0	4	0	254
Q4	116	25	0	32	4	18	0	0	1	17	3	216
Total	**541**	**123**	**4**	**180**	**24**	**79**	**3**	**1**	**4**	**66**	**6**	**1031**

TABLE 7.2.2 – Actual FIN data number of vessels by main fishing method in survey area during 2004.

2004	(OTB)	(OTT)	(OTM)	(PTB)	(SPR)	(SSC)	(SX)	(TBB)	(TBN)	(TBNT)	(TX)	Total
Q1	103	22	0	28	5	18	0	1	0	4	1	182
Q2	126	28	0	30	4	16	0	0	1	12	3	220
Q3	122	25	0	32	7	14	0	0	0	9	0	209
Q4	117	28	1	27	8	19	0	1	1	11	0	213
Total	**468**	**103**	**1**	**117**	**24**	**67**	**0**	**2**	**2**	**36**	**4**	**824**

TABLE 7.2.3 – Actual FIN data number of vessels by main fishing method in survey area during 2005.

2005	(OTB)	(OTT)	(PS1)	(OTM)	(PS2)	(PTB)	(SPR)	(SSC)	(SX)	(TBB)	(TBN)	(TBNT)	(TX)	Total
Q1	112	28	0	0	0	31	5	19	1	0	0	10	1	207
Q2	126	32	0	2	0	37	4	18	0	1	1	20	2	243
Q3	242	68	1	1	1	75	8	33	0	0	0	22	3	454
Q4	102	30	0	1	0	36	1	19	2	1	0	1	1	194
Total	**582**	**158**	**1**	**4**	**1**	**179**	**18**	**89**	**3**	**2**	**1**	**53**	**7**	**1098**

TABLE 7.2.4 – Actual data number of vessels by main fishing method in survey area during 2006.

2006	(DRB)	(OTB)	(OTT)	(PS1)	(PTB)	(SSC)	(SX)	(TBN)	(TBNT)	(TX)	Total
Q1	2	123	43	0	38	22	3	0	0	1	232
Q2	0	137	53	0	33	13	2	0	0	1	239
Q3	0	115	48	0	37	21	0	0	0	5	226
Q4	1	91	36	1	38	23	0	0	0	4	194
Total	**3**	**466**	**180**	**1**	**146**	**79**	**5**	**0**	**0**	**11**	**891**

TABLE 7.3.1 – Validated FIN data of vessels by actual main fishing method in survey area during 2003.

2003	OTB	OTT	PAIR	PAIR/TBNT	SSC	TBN	TBNT	TBNT/OTT	Total
Q1	29	26	45	1	14	1	59	40	215
Q2	21	26	49	1	10	1	77	28	213
Q3	24	25	47	0	9	1	75	28	209
Q4	19	22	34	0	10	1	67	18	171
TOTAL	**93**	**99**	**175**	**2**	**43**	**4**	**278**	**114**	**808**

TABLE 7.3.2 – Validated FIN data of vessels by actual main fishing method in survey area during 2004.

2004	OTB	OTT	PAIR	PAIR/TBNT	SSC	TBN	TBNT	TBNT/OTT	Total
Q1	18	23	35	0	12	1	57	14	160
Q2	17	21	35	0	11	0	77	20	181
Q3	20	29	32	1	8	0	65	14	169
Q4	18	25	33	0	14	0	61	18	169
TOTAL	**73**	**98**	**135**	**1**	**45**	**1**	**260**	**66**	**679**

TABLE 7.3.3 – Validated FIN data of vessels by actual main fishing method in survey area during 2005.

2005	OTB	OTT	OTT/OTB	PAIR	PAIR/OTT	PAIR/TBN	PAIR/TBNT	SSC	TBB	TBN	TBNT	TBNT/OTT
Q1	20	22	0	37	0	0	12	0	0	66	15	13
Q2	20	18	0	37	0	0	0	13	1	1	86	14
Q3	19	25	1	40	1	0	0	10	0	1	77	10
Q4	13	21	0	39	0	1	0	14	0	1	55	14
TOTAL	**72**	**86**	**1**	**153**	**1**	**1**	**12**	**37**	**1**	**69**	**233**	**38**

TABLE 7.3.4 – Validated FIN data of vessels by actual main fishing method in survey area during 2006.

2006	OTB	OTT	OTT/OTB	PAIR	SSC	TBB	TBN	TBNT	TBNT/OTT	TBNT/OTB	Total
Q1	18	19	0	39	15	0	0	74	17	0	182
Q2	13	23	0	39	13	0	1	88	14	0	191
Q3	17	24	0	37	14	0	1	73	15	0	181
Q4	17	24	0	39	13	0	0	60	9	1	162
TOTAL	**65**	**90**	**0**	**154**	**55**	**0**	**2**	**295**	**55**	**1**	**716**

TABLE 7.4.1 – Actual FIN data weight of landings (Metric tons) v main fishing method during 2003.

Species	2003	(OTB)	(OTT)	(OTM)	(PTB)	(SPR)	(SSC)	(SX)	(TBB)	(TBN)	(TBNT)	(TX)
Cod	Q1	387	57	0	274	30	0	0	0	1	17	10
Cod	Q2	457	51	3	534	40	200	0	0	0	32	0
Cod	Q3	389	61	0	454	24	87	6	0	0	1	0
Cod	Q4	250	32	0	222	12	79	0	0	0	8	0
Total		**1484**	**201**	**3**	**1485**	**106**	**367**	**6**	**0**	**1**	**58**	**10**
Haddock	Q1	1267	150	0	1039	110	904	0	4	1	28	9
Haddock	Q2	713	58	3	838	74	279	0	0	0	29	0
Haddock	Q3	1467	159	1	1364	104	493	43	0	0	9	0
Haddock	Q4	805	98	0	972	51	506	0	0	0	23	0
Total		**4252**	**465**	**5**	**4214**	**339**	**2182**	**43**	**4**	**1**	**88**	**9**
Anglerfish	Q1	452	69	0	59	3	37	0	0	2	28	0
Anglerfish	Q2	411	54	2	127	8	48	0	0	0	49	0
Anglerfish	Q3	309	44	1	69	4	29	1	0	0	1	0
Anglerfish	Q4	281	33	0	34	1	19	0	0	3	10	15
Total		**1452**	**200**	**3**	**290**	**16**	**133**	**1**	**0**	**5**	**88**	**16**
Nephrops	Q1	668	85	0	44	0	0	0	0	2	83	0
Nephrops	Q2	511	48	1	5	0	0	0	0	1	128	0
Nephrops	Q3	464	86	0	12	0	0	0	0	0	10	0
Nephrops	Q4	585	58	0	28		1	0	0	1	72	0
Total		**2227**	**276**	**1**	**89**	**0**	**1**	**0**	**0**	**4**	**292**	**0**
Whiting	Q1	423	52	0	469	65	326	0	5	0	14	0
Whiting	Q2	346	33	7	366	21	123	0	0	1	38	0
Whiting	Q3	238	38	0	146	11	76	0	0	0	1	0
Whiting	Q4	253	37	0	152	9	81	0	0	1	12	0
Total		**1261**	**160**	**7**	**1134**	**106**	**606**	**0**	**5**	**3**	**64**	**0**

TABLE 7.4.2 – Actual FIN data weight of landings (Metric tons) v main fishing method during 2004.

Species	**2004**	**(OTB)**	**(OTT)**	**(OTM)**	**(PTB)**	**(SPR)**	**(SSC)**	**(TBB)**	**(TBN)**	**(TBNT)**	**(TX)**
Cod	Q1	212	18	0	284	18	111	0	0	2	4
Cod	Q2	384	31	0	565	46	185	0	0	6	5
Cod	Q3	438	49	0	348	30	101	0	0	3	0
Cod	Q4	317	88	0	187	24	78	1	0	4	0
Total		**1351**	**186**	**0**	**1384**	**118**	**474**	**1**	**0**	**15**	**9**
Haddock	Q1	1256	80	0	1036	101	949	5	0	4	0
Haddock	Q2	1031	69	0	757	59	241	0	0	32	0
Haddock	Q3	1458	172	0	1036	100	750	0	0	15	0
Haddock	Q4	1443	236	4	1564	215	1211	1	4	33	0
Total		**5188**	**557**	**4**	**4393**	**476**	**3151**	**6**	**5**	**84**	**0**
Anglerfish	Q1	354	33	0	40	2	31	0	0	4	0
Anglerfish	Q2	627	89	0	104	9	34	0	1	22	3
Anglerfish	Q3	368	45	0	70	3	22	0	0	2	0
Anglerfish	Q4	353	86	0	28	1	27	5	1	5	0
Total		**1701**	**254**	**0**	**241**	**16**	**114**	**6**	**2**	**33**	**3**
Nephrops	Q1	365	60	0	3	0	0	0	0	18	0
Nephrops	Q2	1413	187	0	7	0	0	0	3	111	0
Nephrops	Q3	488	74	0	0	0	0	0	0	37	0
Nephrops	Q4	799	88	4	2	0	0	0	5	48	0
Total		**3066**	**409**	**4**	**12**	**0**	**0**	**0**	**7**	**214**	**0**
Whiting	Q1	370	41	0	314	48	196	0	0	7	0
Whiting	Q2	427	33	0	232	18	93	0	0	11	0
Whiting	Q3	199	31	0	89	5	56	0	0	5	0
Whiting	Q4	342	42	0	183	18	103	0	1	12	0
Total		**1339**	**147**	**0**	**818**	**89**	**449**	**0**	**1**	**34**	**0**

TABLE 7.4.3 – Actual FIN data weight of landings (Metric tons) v main fishing method during 2005.

Species	**2005**	**(OTB)**	**(OTT)**	**single (P1)**	**(OTM)**	**Pair (P2)**	**(PTB)**	**(SPR)**	**(SSC)**	**(SX)**	**(TBB)**	**(TBN)**	**(TBNT)**	**(TX)**
Cod	Q1	236	30	0	0	0	278	8	120	1	0	0	3	0
Cod	Q2	338	49	0	0	0	477	12	115	0	0	0	12	2
Cod	Q3	480	118	4	0	4	426	28	110	0	0	0	5	3
Cod	Q4	290	63	0	2	0	214	1	99	5	1	0	0	2
Total		**1344**	**259**	**4**	**2**	**4**	**1395**	**48**	**444**	**6**	**1**	**0**	**20**	**6**
Haddock	Q1	1943	98	0	0	0	2304	217	1211	3	0	0	9	0
Haddock	Q2	730	116	0	0	0	837	38	297	0	0	1	52	0
Haddock	Q3	1929	317	8	12	4	1798	155	1041	0	0	0	38	0
Haddock	Q4	1840	218	0	0	0	3757	23	1382	47	10	0	2	1
Total		**6442**	**748**	**8**	**13**	**4**	**8696**	**433**	**3930**	**50**	**10**	**1**	**101**	**1**
Anglerfish	Q1	393	57	0	0	0	44	2	30	0	0	0	11	0
Anglerfish	Q2	623	111	0	1	0	91	3	29	0	2	0	32	4
Anglerfish	Q3	548	150	0	0	1	51	2	19	0	0	0	7	1
Anglerfish	Q4	373	91	0	1	0	32	0	26	2	1	0	0	2
Total		**1938**	**409**	**0**	**2**	**1**	**219**	**7**	**104**	**2**	**2**	**0**	**51**	**7**
Nephrops	Q1	584	155	0	0	0	8	0	0	0	0	0	55	2
Nephrops	Q2	1047	237	0	4	0	9	0	0	0	0	1	148	2
Nephrops	Q3	1015	281	0	0	0	0	0	0	0	0	0	97	0
Nephrops	Q4	602	221	0	0	0	0	0	0	0	7	0	6	0
Total		**3248**	**893**	**0**	**4**	**0**	**17**	**0**	**0**	**0**	**7**	**1**	**305**	**3**
Whiting	Q1	369	44	0	0	0	264	24	187	0	0	0	9	0
Whiting	Q2	247	39	0	0	0	152	8	79	0	0	0	13	0
Whiting	Q3	273	59	1	2	2	121	7	88	0	0	0	9	0
Whiting	Q4	325	76	0	1	0	392	1	137	5	4	0	1	2
Total		**1214**	**218**	**1**	**3**	**2**	**930**	**40**	**491**	**6**	**4**	**0**	**33**	**2**

TABLE 7.4.4 – Actual FIN data weight of landings (Metric tons) v main fishing method during 2006.

Species	**2006**	**(DRB)**	**(OTB)**	**(OTT)**	**single (P1)**	**(PTB)**	**(SSC)**	(SX)	**(TBN)**	**(TBNT)**	**(TX)**
Cod	Q1	1	253	69	0	230	161	0	0	0	0
Cod	Q2	0	490	141	0	410	123	4	0	0	0
Cod	Q3	0	451	111	0	391	136	0	0	0	3
Cod	Q4	0	250	59	1	263	78	0	0	0	0
Total		**1**	**1445**	**381**	**1**	**1293**	**499**	**4**	**0**	**0**	**3**
Haddock	Q1	23	2220	259	0	2690	700	30	0	0	0
Haddock	Q2	0	1092	209	0	1242	382	3	0	0	0
Haddock	Q3	0	1614	470	0	2407	1069	0	0	0	0
Haddock	Q4	0	1053	0	0	0	0	0	0	0	0
Total		**23**	**5978**	**938**	**0**	**6339**	**2151**	**32**	**0**	**0**	**0**
Anglerfish	Q1	0	442	113	0	28	31	0	0	0	0
Anglerfish	Q2	0	714	217	0	99	0	1	0	0	11
Anglerfish	Q3	0	480	140	0	52	35	0	0	0	9
Anglerfish	Q4	0	266	87	0	37	18	0	0	0	16
Total		**0**	**1903**	**557**	**0**	**216**	**84**	**2**	**0**	**0**	**36**
Nephrops	Q1	0	770	194	0	0	1	0	0	0	0
Nephrops	Q2	0	1231	469	0	0	0	0	0	0	0
Nephrops	Q3	0	927	398	0	0	0	0	0	0	0
Nephrops	Q4	0	473	351	0	0	0	0	0	0	0
Total		**0**	**3402**	**1411**	**0**	**0**	**1**	**0**	**0**	**0**	**0**
Whiting	Q1	1	611	103	0	412	186	6	0	0	0
Whiting	Q2	0	560	93	0	417	184	1	0	0	0
Whiting	Q3	0	328	91	0	356	231	0	0	0	0
Whiting	Q4	0	379	191	2	594	192	0	0	0	0
Total		**1**	**1878**	**478**	**2**	**1779**	**792**	**7**	**0**	**0**	**0**

TABLE 7.5.1 – Weight of landings (Metric tons) v Validated main fishing method during 2003.

Species	**2003**	**OTB**	**OTT**	**PAIR**	**PAIR/TBNT**	**SSC**	**TBB**	**TBN**	**TBNT**	**TBNT/OTT**
Cod	Q1	124	119	377	12	48	0	2	83	151
Cod	Q2	140	152	683	13	80	0	1	135	114
Cod	Q3	156	128	533	0	55	0	0	50	100
Cod	Q4	108	67	281	0	50	0	0	44	54
Total		**528**	**465**	**1874**	**25**	**233**	**0**	**3**	**312**	**419**
Haddock	Q1	580	215	1564	20	478	0	1	205	448
Haddock	Q2	342	168	1119	18	114	0	0	122	112
Haddock	Q3	603	247	1729	0	317	0	3	322	421
Haddock	Q4	406	177	1255	0	320	0	0	167	129
Total		**1931**	**807**	**5667**	**38**	**1229**	**0**	**4**	**815**	**1111**
Anglerfish	Q1	106	121	59	1	15	0	1	140	207
Anglerfish	Q2	84	121	154	5	21	0	1	171	142
Anglerfish	Q3	113	89	108	0	9	0	0	50	89
Anglerfish	Q4	82	92	51	0	10	0	0	83	64
Total		**384**	**422**	**374**	**5**	**55**	**0**	**2**	**444**	**502**
Nephrops	Q1	0	12	0	2	0	0	4	445	419
Nephrops	Q2	1	4	0	11	0	0	3	503	172
Nephrops	Q3	0	0	0	0	0	0	2	396	172
Nephrops	Q4	5	15	0	0	0	0	0	537	185
Total		**6**	**31**	**1**	**13**	**0**	**0**	**9**	**1881**	**949**
Whiting	Q1	141	87	628	5	203	0	1	78	212
Whiting	Q2	102	71	427	1	88	0	0	133	113
Whiting	Q3	66	34	162	0	54	0	1	73	121
Whiting	Q4	87	52	180	0	67	0		95	64
Total		**395**	**243**	**1398**	**6**	**413**	**0**	**2**	**378**	**510**

TABLE 7.5.2 – Weight of landings (Metric tons) v Validated main fishing method during 2004.

Species	**2004**	**OTB**	**OTT**	**PAIR**	**PAIR/TBNT**	**SSC**	**TBNT**	**TBNT/OTT**
Cod	Q1	93	78	369	0	1	43	34
Cod	Q2	126	147	736	0	61	88	64
Cod	Q3	152	237	447	1	43	35	53
Cod	Q4	89	181	251	0	41	72	65
Total		**460**	**643**	**1803**	**1**	**146**	**239**	**215**
Haddock	Q1	791	225	1614	0	586	73	142
Haddock	Q2	566	129	964	0	90	312	129
Haddock	Q3	693	524	1475	6	452	231	149
Haddock	Q4	529	544	2180	0	867	338	252
Total		**2580**	**1422**	**6233**	**6**	**1996**	**954**	**672**
Anglerfish	Q1	99	112	60	0	16	109	68
Anglerfish	Q2	114	172	140	0	18	304	140
Anglerfish	Q3	120	191	85	2	9	34	69
Anglerfish	Q4	123	245	44	0	13	32	49
Total		**457**	**719**	**329**	**2**	**56**	**479**	**326**
Nephrops	Q1	1	20	1	0	0	288	135
Nephrops	Q2	1	18	0	0	0	1369	333
Nephrops	Q3	6	4	0	4	0	446	139
Nephrops	Q4	1	6	0	0	0	668	271
Total		**9**	**48**	**1**	**4**	**0**	**2771**	**878**
Whiting	Q1	139	102	450	0	155	55	74
Whiting	Q2	243	58	257	0	73	122	51
Whiting	Q3	76	60	101	1	51	59	36
Whiting	Q4	62	57	209	0	3255	176	101
Total		**522**	**277**	**1017**	**1**	**3535**	**413**	**263**

TABLE 7.5.3 – Weight of landings (Metric tons) v Validated main fishing method during 2005.

Species	**2005**	**OTB**	**OTT**	**OTT/OTB**	**PAIR**	**PAIR/OTT**	**PAIR/TBN**	**SSC**	**TBB**	**TBN**	**TBNT**	**TBNT/OTT**
Cod	Q1	101	95	0	366	0	0	38	0	0	36	39
Cod	Q2	91	125	0	560	0	0	49	0	0	93	84
Cod	Q3	129	308	3	512	12	0	55	0	0	127	33
Cod	Q4	84	124	0	286	0	8	48	0	1	78	47
Total		**406**	**651**	**3**	**1726**	**12**	**8**	**190**	**0**	**2**	**335**	**203**
Haddock	Q1	1069	486	0	3173	0	0	661	0	0	187	207
Haddock	Q2	279	123	0	1046	0	0	162	0	0	354	105
Haddock	Q3	842	667	17	2268	35	0	684	0	5	713	70
Haddock	Q4	644	612	0	4378	0	81	1023	0	3	383	158
Total		**2835**	**1887**	**17**	**10865**	**35**	**81**	**2531**	**0**	**8**	**1637**	**540**
Anglerfish	Q1	90	156	0	57	0	0	15	0	0	123	96
Anglerfish	Q2	112	189	0	124	0	0	14	2	0	269	184
Anglerfish	Q3	123	360	0	68	7	0	7	0	0	148	66
Anglerfish	Q4	76	184	0	51	0	0	11	0	1	114	92
Total		**401**	**889**	**0**	**300**	**7**	**0**	**47**	**2**	**2**	**653**	**437**
Nephrops	Q1	1	10	0	0	0	0	0	0	0	603	188
Nephrops	Q2	1	15	0	42	0	0	0	0	1	1217	171
Nephrops	Q3	7	17	0	0	0	0	0	0	7	1253	109
Nephrops	Q4	1	14	0	0	0	0	0	0	10	593	218
Total		**10**	**56**	**0**	**43**	**0**	**0**	**0**	**0**	**17**	**3666**	**686**
Whiting	Q1	134	77	0	337	0	0	141	0	0	127	82
Whiting	Q2	81	46	0	183	0	0	62	0	0	120	48
Whiting	Q3	81	71	0	139	2	0	82	0	1	167	19
Whiting	Q4	80	82	0	425	0	12	131	0	1	152	61
Total		**375**	**275**	**0**	**1083**	**2**	**12**	**416**	**0**	**2**	**565**	**211**

TABLE 7.5.4 – Weight of landings (Metric tons) v Validated main fishing method during 2006.

Species	2006	OTB	OTT	PAIR	SSC	TBN	TBNT	TBNT/OTB	TBNT/OTT
Cod	Q1	103	98	328	76	0	103	0	6
Cod	Q2	176	238	501	62	0	116	0	76
Cod	Q3	171	268	440	82	0	72	0	59
Cod	Q4	125	127	294	42	0	51	0	13
Total		**574**	**730**	**1563**	**262**	**0**	**342**	**0**	**154**
Haddock	Q1	1153	593	3077	616	0	284	0	200
Haddock	Q2	597	265	1453	251	0	275	0	87
Haddock	Q3	628	616	2699	863	0	561	0	191
Haddock	Q4	658	305	2140	362	0	198	0	57
Total		**3036**	**1779**	**9369**	**2092**	**0**	**1317**	**0**	**535**
Anglerfish	Q1	73	164	41	17	0	185	0	135
Anglerfish	Q2	130	353	132	18	0	292	0	146
Anglerfish	Q3	84	290	66	21	0	124	0	123
Anglerfish	Q4	74	149	40	15	0	96	1	34
Total		**361**	**956**	**279**	**70**	**0**	**697**	**1**	**438**
Nephrops	Q1	3	18	0	0	0	795	0	149
Nephrops	Q2	0	23	0	0	1	1451	0	226
Nephrops	Q3	0	16	0	0	1	1131	0	176
Nephrops	Q4	0	26	0	0	0	645	1	153
Total		**3**	**83**	**1**	**0**	**1**	**4022**	**1**	**704**
Whiting	Q1	198	140	479	182	0	192	0	128
Whiting	Q2	263	134	467	166	0	168	0	57
Whiting	Q3	89	63	390	219	0	203	0	41
Whiting	Q4	119	89	645	154	0	297	0	55
Total		**669**	**426**	**1981**	**9217**	**0**	**860**	**0**	**280**