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SEAFISH BIOECONOMIC MODELLING

Methodology Report

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Authors

Simon Mardle, Fishor Consulting

Jennifer Russell, Anderson Solutions (Consulting) Ltd

Arina Motova, Senior Economist, Seafish

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Sea Fish Industry Authority
18 Logie Mill
Logie Green Road
Edinburgh, EH7 4HS

Front cover photograph courtesy of Ian Reid, fisherman

Contents

1 Introduction

The methodology report is intended to be a supplementary report to reports on findings from the Seafish bioeconomic model. The main purpose of the methodology report is to provide:

- more detail on the operation of the three modules that together form the Seafish bioeconomic model. The three modules are the data input framework, the simulation engine and the results output framework; and
- more detail on the design and operation of the individual simulations developed for the model.

The separately published report on findings does include a description of the model and its operation, which may be sufficient for most readers. The methodology report contains more technical detail.

1.1 Background

The landing obligation is a requirement to land all catches of quota species, from 2019 onwards for demersal fleets, and the regulation incorporates provisions that are designed to support the effective implementation of the landing obligation which include: (i) quota uplift (quota adjustment/quota top-up) to reflect that TACs represent total catch instead of landings; and (ii) exemptions and derogations from the landing obligation.

Seafish undertook a Landing Obligation Economic Impact Assessment, published in February 2016, to investigate potential impacts from the introduction of the landing obligation. In 2015/16, little was known about how the demersal landing obligation would be implemented from 1st January 2016. The project developed a new approach to identifying choke stocks in an economic impact assessment framework. This work was supported by stakeholders including government and industry. The aim was to indicate some of the challenges ahead and mitigations, as defined in Article 15 of the CFP (EU REGULATION No 1380/2013 on the Common Fisheries Policy), that may be used to alleviate the impact of the landing obligation to demersal fleets. The last complete year of logbook and economic data available for this analysis was 2013. One of the most valuable tools developed during this project was a bioeconomic model.

The model developed for the first analysis included 51 demersal quota stocks (19 ICES-assessed) and 50 UK fleet segments (described by Producer Organisation and main fishery/gear, e.g. SFPO Whitefish trawl) fishing in three sea areas (North Sea, West of Scotland and Other North Western Waters).

1.2 Updating the Model

Since the first economic impact assessment of the landing obligation, the landing obligation has been implemented for demersal fleets. There is now much more clarity on how the different aspects of the landing obligation are being implemented. To better reflect the reality of the landing obligation, the bioeconomic model has been amended and updated. The report describes the specification of the new model and its three constituent modules.

The update of the model incorporates the latest logbook and economic data available (2015, allowing for update to 2016 when available), and to re-structure the model to include metier level analysis which enables a finer level of detail to be investigated. Furthermore, the improvement in quality of data inputs (e.g. discard rates and quota uplifts from STECF working groups) is also taken into account. The new model also includes more detailed fleet segmentation and includes more stocks (assessed and non-assessed, and TAC and non-TAC).

1.3 Value of a Bioeconomic Model

Bioeconomic modelling provides a framework for analysis that is consistent with the activities of fleets and the interactions between those activities and stocks. Modelling enables analyses to be conducted that inform the likely outcomes of policy interventions in fisheries. Policy interventions such as the landing obligation are a step-change in policy for which there is no known impact historically on fleets. With best available data, bioeconomic modelling allows simulations to be undertaken that evaluate the potential impacts of policy under different assumptions thus providing an indication of outcomes on fleets in future years.

The bioeconomic analysis tests the consequences of the landing obligation for the UK fleet under a number of simulations using different assumptions. The simulations vary from fleets receiving no quota uplift and no re-allocation of quota across fleets to an allocated quota uplift and some re-allocation of quota. The model is based on the FISHRENT structure, and uses informed assumptions to undertake the analysis.

1.4 Structure of methodology report

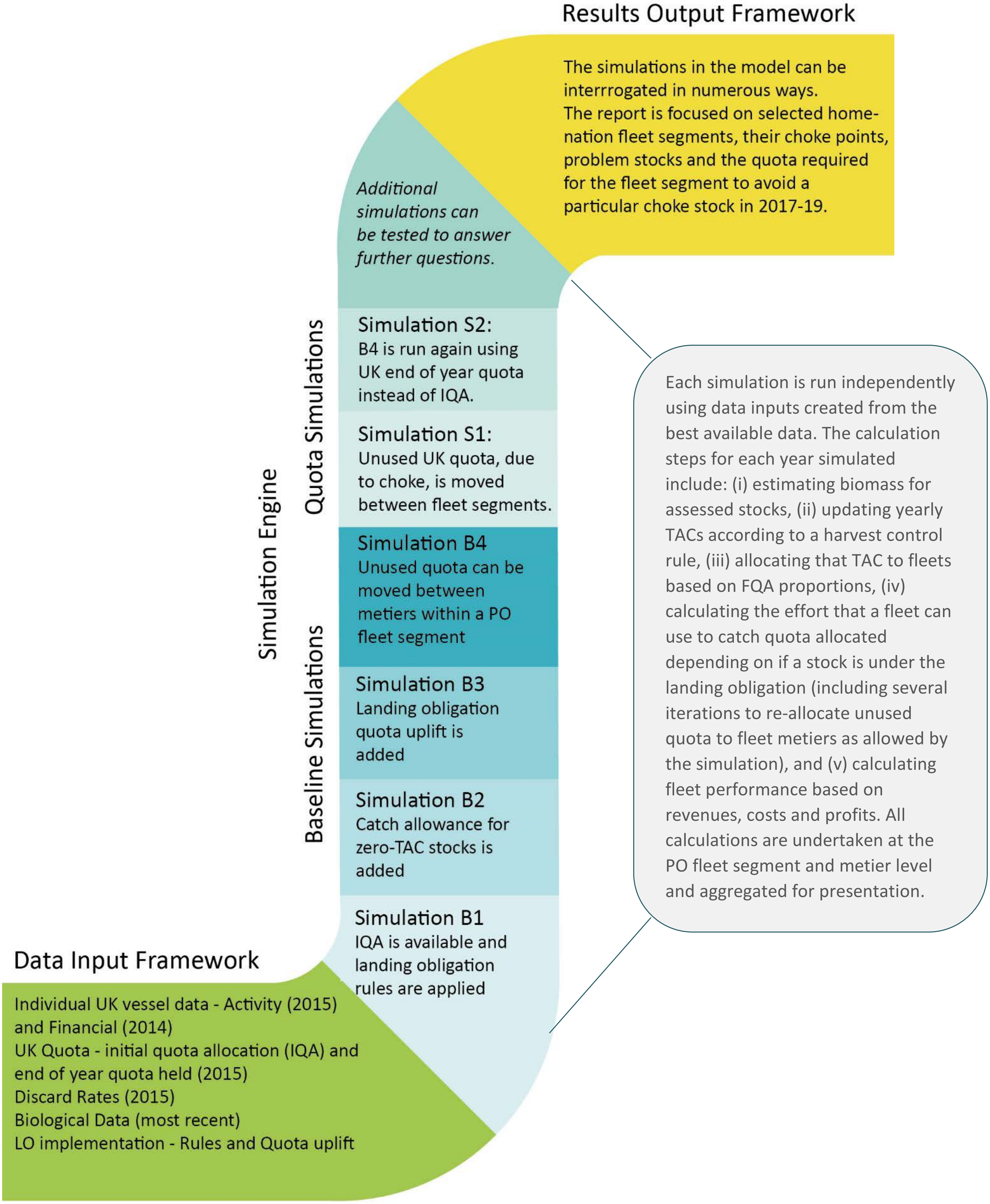
The structure of the methodology report is as follows:

- Chapter 2 presents an overview of the model, this overview is also included in the findings report;
- Chapter 3 provides a detailed description of the data input framework;
- Chapter 4 provides descriptions of how simulations are undertaken within the model and descriptions of the simulations currently developed;
- Chapter 5 presents a description of the results output framework, which is largely replicated in the findings report.
- Appendix A provides details on the fleet segments included in the model;
- Appendix B provides details on the metiers included in the model;
- Appendix C provides a list of all stocks included in the model;
- Appendix D presents the average discard rates used; and
- Appendix E details how the landing obligation has been phased in the model in 2016-2018.

2 Overview of Seafish Bioeconomic Model

As shown in Figure 2-1, three modules were created to produce the bioeconomic analysis: the data input framework, the simulation engine and the results output framework.

Figure 2-1: Overview of the bioeconomic modelling process



3 Data Input Framework (DIF)

The purpose of the DIF is to prepare data from different data sources and in different formats for input to the simulation engine. An approach using standard procedures for data processing has been developed for use with the bioeconomic model.

The main data sources include UK landings logbook data (MMO), UK fleet register (MMO), Seafish fleet economic performance data (Seafish), STECF discard data (STECF), transition period 2016-18 rules (Advisory Councils), TACs and adjustments (FIDES, STECF), and stock assessment data (ICES).

The data is processed in the R statistical package and prepared for the model. All data processing, starting with attribution of the vessel to a specific PO fleet segment through to preparation of data by fleet/metier/stock, is undertaken through R scripts. These scripts are grouped by purpose to the following modules:

1. Fleet data – preparation of fleet segmentation and metiers based on individual vessel information, and preparation of fleet related data including weight and value of landings, number of vessels and days at sea;
2. TAC and quotas – preparation of all information, related to quota distribution between fleets as well as processing overall TACs from FIDES format to SEAFISH model format, including quota uplift;
3. Discards – preparation and processing of discards data by home-nation and metier;
4. Biomass – preparation and processing of biological information from ICES stock assessment;
5. Economics – preparation of economic variables for model including variable, fixed and capital costs;
6. Landing Obligation (LO) implementation – preparation of variables, defining LO implementation process during transitional period.

The processes involved in producing the above groups are described in the following sub-sections.

3.1 Fleet data

The fleet data module is the main module of the DIF, allocating all individual vessels to fleets. This allocates each vessel to a PO fleet segment that is described by home-nation, PO and main fishery (e.g. GBS_SFPO_Nephrops). In evaluating the catch and effort data, a list of metiers for each PO fleet segment are defined. The metiers are described by ICES sub-area and gear (e.g. 4b_TR2). The activity information is obtained from administrative sources (e.g. logbooks, sales notes and the fleet register).

3.1.1 PO fleet segments and metiers definition

In summary, the information is taken from the Seafish economic data set, UK fleet register, sales notes and logbooks to create the list of fleets. These fleet segments are populated with the data in the other modules.

The routine starts with the allocation of vessels to home-nation (using fleet register), to PO and to Seafish fleet segment. Data confidentiality is a key consideration in developing fleets so that individual vessels cannot be identified from the aggregated data. Therefore, in cases where there are less than five vessels in a PO fleet segment then those vessels are allocated to a “Remaining PO” group. If there are enough vessels (i.e. >5) to include a home-nation and fishery tag then this is maintained. All active UK vessels (fishing at least 1 day during the year) are allocated to a PO fleet segment.

In addition, trawlers mostly landing demersal whitefish are distinguished from other demersal trawlers principally using TR1 gear. This is measured using a 50% proportion of revenue threshold for whitefish species (e.g. cod, haddock, saithe, whiting etc), therefore where whitefish catches contribute more than 50% to the vessels annual revenue the boat is assigned to whitefish subgroup of demersal trawlers (i.e. DEM_white).

In cases where individual vessels within a PO are doing unique activities and cannot be allocated to the PO fleet segment, or where vessels were inactive during the year then those boats are allocated to the "Other" fleet, maintaining the home-nation and PO tags (e.g. GBS_SFPO_Other). Please see Appendix A for information on the fleet segments.

After allocating all vessels to the fleet segments and ensuring that all fleets contain more than five vessels, the list of metiers for each of the fleet is created. A similar rule on confidentiality for fishing in a metier is used as with PO fleet segments. Therefore, if there are less than five vessels within the PO fleet segment fishing in a metier then the activity is allocated to the undefined metier (i.e. "Other") within the same PO fleet segment. In the version of the model reported here, this results in a final list of 96 PO fleet segments and 412 PO fleet segments with their defined metiers (i.e. approximately four metiers per PO fleet segment on average). Please see Appendix B for information on the metiers included in the model.

The approach developed for allocation of vessels to fleets and metiers enables an automated fleet definition with several cross-checks during the operation to ensure consistency. The confidentiality criterion is a necessary one and does reduce the list of PO fleet segments and metiers significantly. It can be argued that there is some interesting information missing for some unique vessels, however the purpose of the analysis to provide a UK analysis for the main fleet segments and their activities.

3.1.2 Fleet activity data

Once all vessels have been assigned to PO fleet segments and their activities have metier identifiers the following data variables can be created by PO fleet segment, metier and stock as required:

- number of vessels by PO fleet segment;
- number of vessels by PO fleet segment and metier;
- total number of days at sea by PO fleet segment and metier;
- maximum number of days at sea per vessel by PO fleet segment;
- weight of landings in tonnes by PO fleet segment, metier and stock;
- value of landings in GBP by PO fleet segment, metier and stock; and
- average price in GBP per kg by PO fleet segment and stock.

3.2 UK Quota: Initial quota allocation and quota uplift

3.2.1 Initial quota allocation

The quota available to the UK at the beginning of the year is the starting point for allocation of quota to the PO fleet segments in the model. The allocation is estimated from the initial quota allocation to the UK from the FIDES database and the individual FQAs by license from the MMO database.

Understanding who has access to the UK's quota allocation is not as straightforward as might initially be presumed. At the beginning of the year, the UK's quota is allocated to licenses based on FQA holdings. This initial quota allocation is provided to:

- active vessel licenses; and
- dummy PO licenses.

Quota allocated to active vessel licenses is straightforward to handle. An active vessel is allocated an amount of quota which the vessel then fishes against. Therefore, in the model this quota is allocated to the PO fleet segment that the vessel is allocated to.

If the PO has more than one PO fleet segment defined, the quota held on dummy licenses is more challenging to accurately allocate to fleet segments. The approach adopted is to allocate the quota held on dummy licenses to PO fleet segments proportionally, based on the landings of each stock in the reference year. For example, if a PO fleet segment landed 60% of the haddock landings in the PO, then this PO fleet segment would be allocated 60% of the haddock quota held on dummy licenses. A weakness of this approach could occur where POs hold quota on a dummy license which is not fished by members of the PO.

The allocation of quota is input to the model at a PO fleet segment level (e.g. GBS_SFO_Dem-White). The quota allocated to a PO fleet segment is then allocated to metiers to support metier level analysis in the model. The approach used is one where the PO fleet segment's quota is in the first instance allocated to metiers based on proportion of landings from each metier in the reference year. Different simulations build on this basic allocation and may be able to reallocate quota across metiers. It should be noted that in each PO fleet segment metier, all vessels are presumed to have average activity, i.e. they have the same catch rates, same effort, equal quota share etc.

The model is informed by initial quota allocation which means that the baseline simulations do not take into account the effect of international quota swaps, i.e. including the quota that might be available at the end of the year. However, simulations can be developed to test the impact of quota held at the end of the year (i.e. incorporating national and international swaps).

3.2.2 Quota uplift (also known as quota adjustment and quota top-up)

Under the landing obligation, TACs are adjusted to represent catch quotas rather than the landing quotas used prior to the landing obligation. By definition catch quotas take account of a landings element and an element that previously would have been discarded. Quota uplift is aimed to mitigate against the impact of choke stocks to fleets and vessels to some degree. In the simplest case, if all discards are accounted for in a quota uplift then fishing would be able to continue at similar levels with all catch accounted for. However, due primarily to allocation of TACs to EU Member States based on relative stability and then national allocation of that quota to POs or vessels, the quota available to PO fleets/vessels does not reflect recent discard rates.

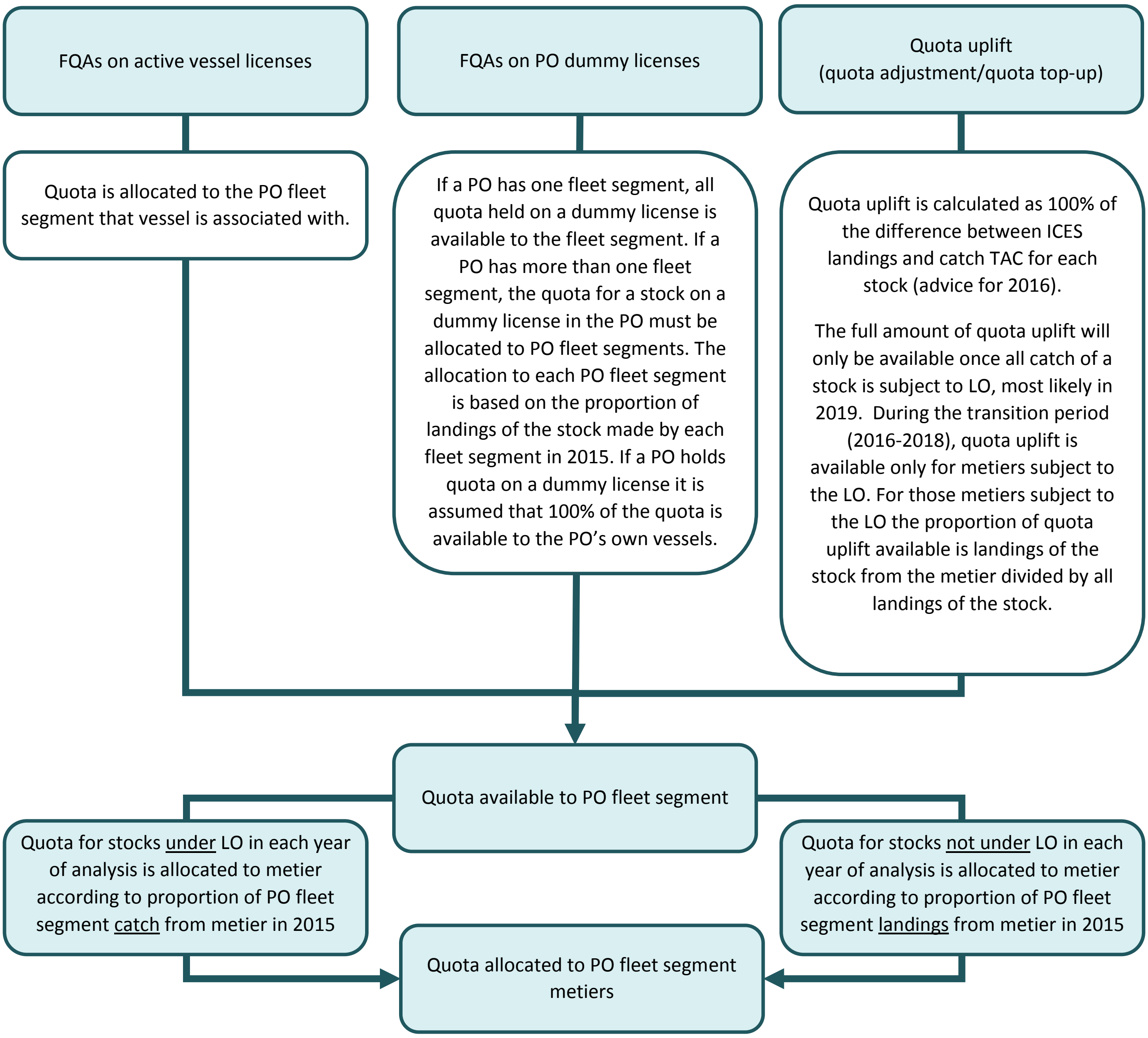
The adjustments to TAC are calculated at an EU level based on discard rates observed in Member States fleets (defined by fleet and metier as above), and collected in the FIDES database. The aim is to account for and indeed transfer ICES discard estimates into the calculation of available TAC. The amount of adjustment for each stock varies, not only by observed discard rates but also by status of the stock. For stocks that are fished at sustainable levels, the quota uplift is expected to equal the difference between ICES advice on landings TAC and catch TAC. The quota uplifts available in 2016 are incorporated into the model. It is understood that the total EU adjustment amount is distributed to Member States based on Relative Stability.

In the transitional period for demersal fleets (i.e. 2016-18), the calculation and distribution of quota uplift is more complex than it will be once the landing obligation is fully implemented as not all vessels/fleets are subject to the landing obligation for certain stocks. The amount of quota uplift to be applied during the transitional period is to be agreed by the EU following advice from STECF. The STECF methodology requires calculation of the proportion of the fishery that will be subject to the landing obligation in a given year. The amount of quota uplift at an EU level will then be calculated according to the estimated discards for that proportion of the fishery only.

The amount of quota uplift for 2016 is known and is incorporated in the model. For 2017 and 2018, the estimation of quota uplifts in the model follows STECF methodology and uses a combination of ICES information (i.e. the difference between landings TAC and catch TAC) and historic landings data (i.e. proportion of landings under the landing obligation), as STECF advice is not yet available. Where no uplift is allocated in the model this is because ICES has not yet provided information. The inclusion of quota uplift in the model then follows the introduction of stocks by metier in the North Sea and North West Waters discard management plans. The estimated amount of quota uplift is made available only to metiers under the landing obligation. When STECF advice does become available it can replace the calculations of quota uplift made in the model.

Figure 3-1 presents a visual demonstration of the approach to initial quota allocation to PO fleet segment metiers and quota uplift in the model.

Figure 3-1: Allocation of UK quota to PO fleet segment metiers, including quota uplift



The quota information is provided to the model by PO fleet segment, metier and stock as required:

- EU TAC in tonnes by stock;
- UK initial quota in tonnes by stock;
- UK adjusted quota in tonnes at end of year by stock;
- TAC percentage multiplier (quota uplift) by stock; and
- UK percentage quota share by fleet.

3.3 Discard Rates

The discard rates used for this analysis are calculated from landings and discards data available in the FDI (Fisheries Dependent Information) database of STECF. For this project, additional rules and procedures were defined to take into account the home-nation, the area where the fish was caught and the gear used. However, as information is aggregated, the same discard rates for an area are applied to different PO fleet segments with the same metiers. In the FDI, the North Sea is represented as one region, whilst we distinguish between sub-area 4a, 4b and 4c in the model. Accordingly, we use North Sea discard rates for sub-areas 4a and 4b, but for sub-area 4c we assume the same discard rates as in Eastern English Channel (sub-area 7d).

The processing of 2015 data showed stocks with very high discard rates, some equal to 100%. If a fleet makes landings of such a stock then this is not possible. So, in this case we limit the maximum discard rate to 99.5%.

The discard rates are input to the model by PO fleet segment, metier and stock. The average discard rates used can be found in Appendix D.

3.4 Biological Data

ICES information on assessed stocks is used to develop the mass balance representation of stocks in the model. The precise definition of the functions used in the model regarding this functionality are detailed in section 4.2.1.

The biological data is input to the model for assessed stocks only:

- biomass level at most recent year;
- natural mortality;
- Fmsy level;
- stock status related to the level of biomass; and
- stock status related to Fmsy.

Note that additional data to inform the stock biomass growth model are pre-calculated, using ICES time--series data (biomass and landings) for assessed stocks.

3.5 Economic Data

Seafish estimates of fleet performance at a vessel level are aggregated to a PO fleet segment level to provide cost and other income data. The economic data is input to the model by PO fleet segment only and include:

- capital costs in GBP per vessel by PO fleet segment;

- crew share as a percentage of landings value by PO fleet segment;
- fixed costs in GBP per vessel by PO fleet segment;
- fuel costs in GBP per day at sea by PO fleet segment;
- other fixed costs in GBP per vessel by PO fleet segment;
- other income in GBP by PO fleet segment; and
- variable costs in GBP per day at sea by PO fleet segment.

An additional correction variable for income is also provided in order to calibrate the fleet economics in the model to the fleet performance outcomes reported annually by Seafish.

3.6 Landing obligation implementation

In 2019 all quota stocks will be subject to the landing obligation for demersal fleets. However, during the transition period (2016-2018) PO fleet segments will be subject to the landing obligation for different stocks depending on how and where they fish. Accordingly, the LO implementation data contains a table of metiers and stocks by year that are subject to the landing obligation. This table is defined by the user. At the time of model development, the North Sea Advisory Council had specified transition rules for North Sea stocks between 2016-18. In the case of the North-Western Waters Advisory Council only 2016 and 2017 were available. No additional assumptions have been made for 2018 in the model for stocks under NWWAC jurisdiction.

The landing obligation implementation data is input to the model by metier and stock:

- LO implementation true or false by metier, stock and year (see Appendix E).

In addition, the user can specify the minimum catch of a stock that is allowed before it becomes subject to the landing obligation. For example, zero-TAC stocks under the cod recovery plan were accounted for under the plan by allowing catch of those stocks up to 1.5% of total catch. Also, it may be considered that a PO fleet segment that catches a low amount of a particular stock may be able to have that covered by known available quota outside its allocation. If a minimum catch is specified in the model, then stocks caught in particularly low volumes would not be identified as choke stocks. The minimum catch share (as a percentage of total catch weight) would be input to the model by stock and applicable to all PO fleet segment metiers. The only current use of such a measure in the model is a catch allowance for zero-TAC stocks.

Two further variables concerning fish caught below minimum conservation reference size (MCRS) are accounted for, however data is not readily available for either currently so they are not populated. For completeness they take the following form:

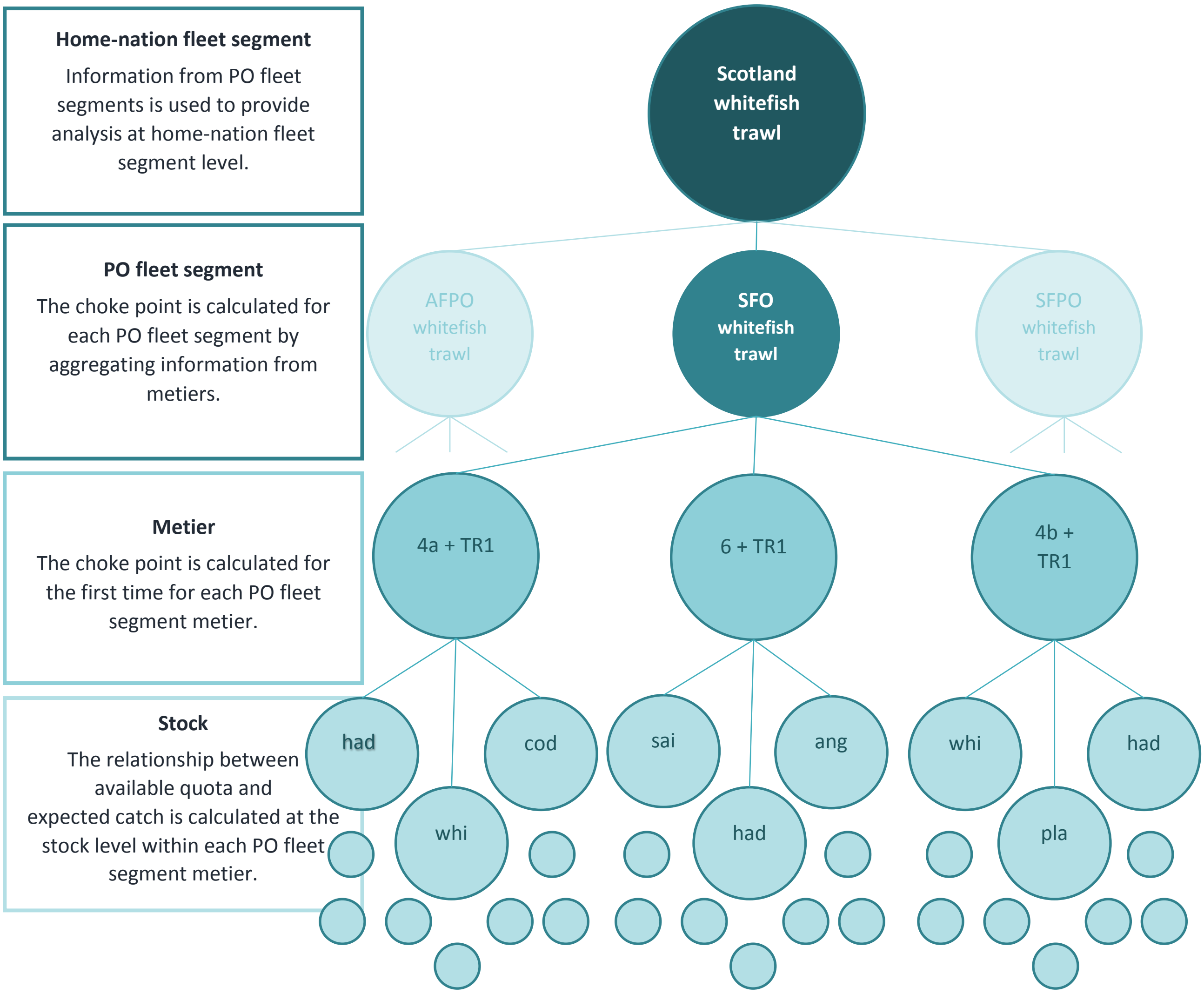
- price for the fish bellow MCRS (no data yet) in GBP per kg by stock; and
- share of landings below MCRS (no data yet) as a percentage of catch by PO fleet segment metier and stock.

4 Simulation Engine

4.1 Components of the Model

As shown in Figure 4-1, the main components of the model are home-nation, PO fleet segment (plus non-sector segments), metier and stock. The other main component is year, denoted by subscript y (not shown in Figure 4-1).

Figure 4-1: Main components of the model (excluding year)Figure 5-1: Aggregating the findings from the simulations to a home-nation fleet segment



4.1.1 Home-nation and PO fleet segment

Home-nation and PO fleet segment combine to describe a fleet (i.e. GBS_SFO_Nephrops) and in the model are denoted by the subscript f. There are some PO fleet segments with sufficient English and Scottish vessels to form separate fleets, for example GBE_ASFPO_Nephrops and GBS_ASFPO_Nephrops. There are 96 PO fleet segments in the model (see appendix A).

4.1.2 Metiers

Metiers in which a fleet fishes are identified and denoted by the subscript m. Metiers describe an ICES sub-area and gear used (see Appendix B). There are 69 different metiers in the model covering the ICES sub-areas around the UK and main fishing activities of the UK fleets, of which 24 are specifically related to regulated demersal gear (see Table 4-1). Other gears included in the model are dredge, pots, lines, hooks and otter trawl. When the different metiers are combined with the PO fleet segment component, this creates 412 metier nodes in the model.

Table 4-1. List of regulated demersal gear defined in metiers by sea area

North Sea and West of Scotland metiers	Other North Western Waters metiers
North Sea:	VIIa_BT
II-V_TR1	VIIa_TR1
IVa_TR1	VIIa_TR2
IVa_TR2	VIId_TR1
IVb_BT	VIId_TR2
IVb_TR1	VIIe_BT
IVb_TR2	VIIe_TR1
IVc_BT	VIIe_TR2
IVc_TR1	VIIfg_BT
IVc_TR2	VIIfg_TR1
West of Scotland:	VIIfg_TR2
VI_TR1	VIIhjk_BT
VI_TR2	VIIhjk_TR1

BT1 and BT2 were combined to BT.

4.1.3 Stocks

There are 72 stocks included in the model, including those that are assessed (e.g. North Sea cod, Irish Sea Cod) and non-assessed (e.g. anglerfish in Area VII), and quota (e.g. North Sea ling) and non-quota (e.g. scallops, cuttlefish) (see appendix C). An assessed stock is included as such in the model if it has a suitable time-series of biomass and landings data as reported by ICES. There are 27 assessed stocks in the model. Note that hake is represented as two management units in the model as separate quotas are allocated (e.g. North Sea hake and Western Waters hake) even though one stock (Northern hake) is assessed. Stocks are caught in multiple metiers by different PO fleet segments. When stock is combined with the PO fleet segment and metier components, this creates 5,017 stock nodes in the model.

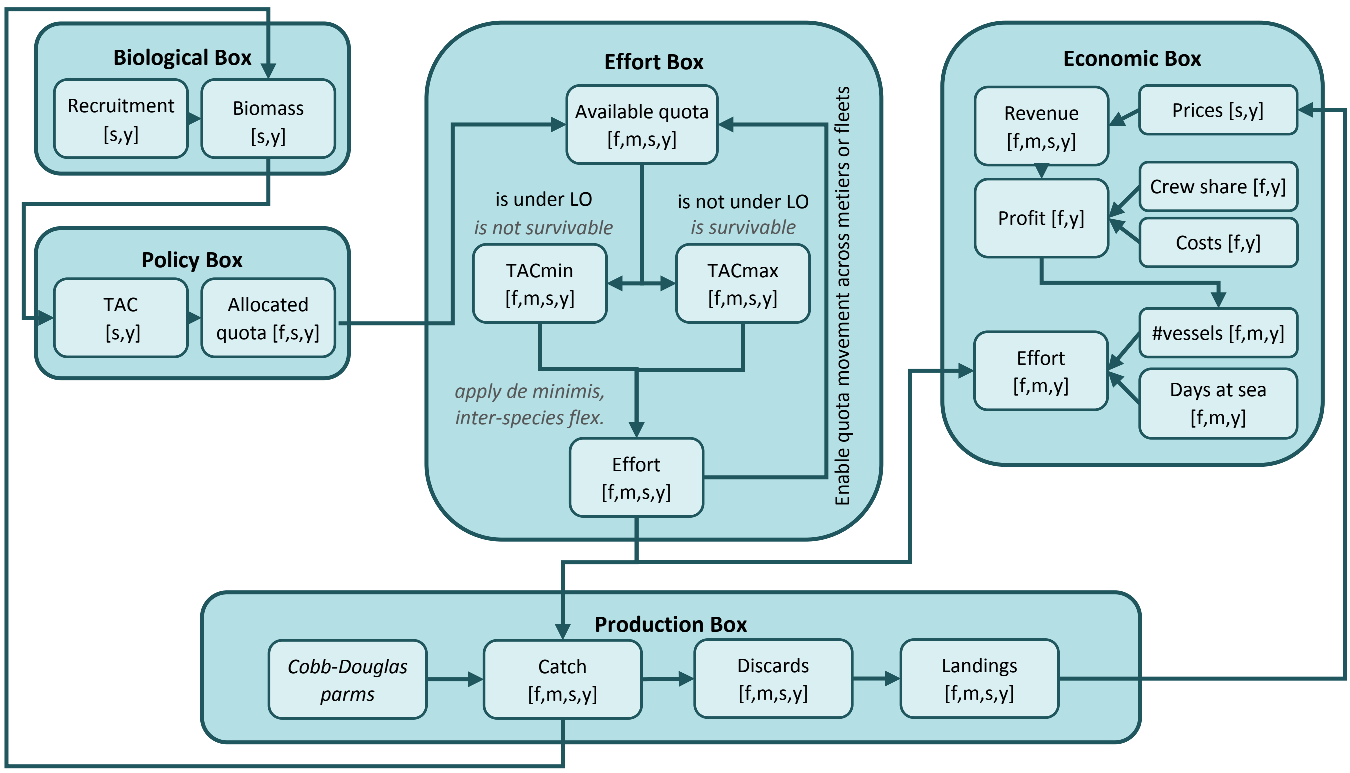
4.1.4 Year

The baseline year is defined as the starting point for the simulation, at this time 2015, where the last full set of logbook and fleet economic data is available. A simulation is undertaken at an annual level and runs for 10 years beyond the baseline, denoted by subscript y. Key years in the simulation runs remain 2016 through 2019, which is the first year the landings obligation comes into force for key TAC-controlled demersal species, through a transition period to 2019, which is the year that remaining TAC-controlled demersal species become subject to the landings obligation.

4.2 Bioeconomic simulation specification

Five modules link together to provide a yearly analysis, these are indicated in Figure 4-2 including the dimensions of PO fleet segment (f), metier (m), stock (s) and year (y) as applied in the model.

Figure 4-2: Bioeconomic simulation structure



The five modules (boxes) and their components are described in more detail below.

4.2.1 Biological Box

The biological box contains two important calculations (i.e. biomass and growth) and an output (estimate of total fishing mortality). The biology implements a mass balance equation, where the biomass of a stock in the current year equals the biomass plus growth minus catch of that stock in the previous year. Logistic growth is parameterised to a quadratic equation (as below) but in effect any relevant growth equation can be parameterised to historic data and implemented.

$$\text{Biomass}_{[\text{stock,year}]} = \text{Biomass}_{[\text{stock,year-1}]} + \text{Growth}_{[\text{stock,year-1}]} - \text{totalCatch}_{[\text{stock,year-1}]}$$

$$\text{Growth}_{[\text{stock,year}]} = \gamma 1_{[\text{stock}]} + \gamma 2_{[\text{stock}]} * \text{Biomass}_{[\text{stock,year}]} + \gamma 3_{[\text{stock}]} * \text{Biomass}_{[\text{stock,year}]}^{2}$$

$$\text{fishingMortality}_{[\text{stock,year}]} = \text{totalCatch}_{[\text{stock,year}]} / \text{Biomass}_{[\text{stock,year}]}$$

where γ (1 to 3) are pre-determined parameters based on regression analysis of historic data. Note that in the current version of the model $\gamma 3 = 0$ as it was not found to generally make any significant difference to the function tested.

4.2.2 Policy Box

The policy box controls the identification of total allowable catches (TACs). The target TAC for each stock in a given year is first identified based on a calculation using the standard Baranov equation as used in stock assessments taking account of target fishing mortality (e.g. F_{MSY}) and natural mortality (i.e. M) of a stock. A limit is imposed in the model that a TAC cannot change by more than a given percentage (in FISHRENT 15% typically) year on year, although this percentage can be set as required. Each TAC by stock and year is then allocated across fleets modelled based on historic TAC share (i.e. TACsh) towards relative stability.

$targetTAC_{[stock,year]} = Biomass_{[stock,year]}*(1–exp(-targetF_{[stock]}-M_{[stock]}))*(targetF_{[stock]}/(targetF_{[stock]}+M_{[stock]}))$

TAClimit: $95\% * targetTAC_{[stock,year-1]} <= TAC_{[stock,year]} <= 105\% * targetTAC_{[stock,year-1]}$

$TAC_{[fleet,stock,year]} = TAC_{[stock,year]} * TACsh_{[fleet,stock]}$

The equations above simulate a harvest control rule that takes account of dynamic changes to stock biomass (e.g. through stock growth minus catches taken, ref section 4.2.1), where such stock data is available, to update quota available year on year (+/- 5%). By 2019, in reported simulations, this could see a quota increase/decrease by +/- 22% versus the base year level, 2015. In a ten year period this could see a quota increase or decrease by a maximum of +/- 55% from base year levels. So, in each simulation the biomass and TAC of a stock responds to the fishing mortality associated with that simulation.

4.2.3 Effort Box

With the TAC estimated, the level of effort required to catch that amount of stock (i.e. target effort) can be calculated using a re-arranged version of the Cobb-Douglas catch equation above. There are two basic situations that the quota can be managed:

TACmin: the most restrictive TAC is used to determine the level of effort that a fleet can exert; and

TACmax: the least restrictive TAC is used to determine the level of effort that a fleet can exert.

As a result, if a stock is under the landing obligation then it follows TACmin, if not then it follows TACmax. With the level of target effort calculated, a fleet's estimated effort can be identified. A constraint is added to the effort variable to ensure that it does not exceed the maximum effort of a fleet, calculated from average fishing days per vessel and number of vessels.

For each stock in each PO fleet segment metier, the quota available in each year is combined with the calculated catch rate for the metier, to calculate the number of days at sea required to catch the available quota. If the number of days at sea required to catch the quota is estimated to be lower than the days the PO fleet segment fished in the metier in 2015, then the stock is considered to be a potential choke stock and the choke point for the stock is the days at sea prior to choke. The primary choke stock is the stock with the earliest choke point in the metier in each simulation, i.e. fewest days at sea.

$targetEffort_{[fleet,stock,year]} = [TAC_{[fleet,stock,year]} / (q_{[fleet,stock]}*Biomass_{[stock,year]}^{\beta})]^{(1/\alpha)}$

TACmin: $Effort_{[fleet,year]} = min[targetEffort_{[fleet,stock,year]}]$

TACmax: $Effort_{[fleet,year]} = max[targetEffort_{[fleet,stock,year]}]$

$maxEffort_{[fleet,year]} = seaDays_{[fleet,year]} * nbrVessels_{[fleet,year]}$

$propMEffort_{[fleet,metier,year]} = sum_{(stock)}(Catch_{[fleet,metier,stock,year-1]} / totalFleetCatch_{[fleet,stock,year-1]})$ OR

$= (seaDays_{[fleet,metier,year]} * nbrVessels_{[fleet,year]}) / maxEffort_{[fleet,year]}$

$Effort_{[fleet,metier,year]} <= propMEffort_{[fleet,metier,year]} * maxEffort_{[fleet,year]}$

It is at this point that policy levers such as survivability, interspecies flexibility, de minimis and movement of quota can be included. For the most part, from a technical point of view, these involve a different TAC being evaluated in targetEffort (e.g. movement of quota, interspecies flexibility or de minimis) or an assumption of TACmax rather than TACmin (e.g. a "survivable" stock being exempt from the LO).

In the current version of the model, de minimis, interspecies flexibility and survivability are not tested under simulations. Note that in the first version of the model they were tested and that functionality remains. For completeness it is summarised below:

De minimis – is an exemption that allows for a percentage of catch (e.g. 5%) to be discarded under conditions detailed in Article 15. The previous model included three different versions of de minimis:

- De Minimis Lax simulated an allowed level of discards of 5% of the total catch of demersal quota stocks by a PO fleet segment. It is not stock specific and is calculated on the total catch of the PO fleet segment, not the quota or catch of a specific stock.
- De Minimis Mid simulated an allowed level of discards of 5% of a stock as long as total discards of that stock in the UK do not exceed 5% of the EU TAC for the stock.
- De Minimis Strict simulated an allowed level of discards of 5% of a stock can be discarded as long as total discards in the UK do not exceed 5% of the UK TAC for the stock.

Interspecies flexibility – is a derogation that allows for up to 9% of quota for one stock to be moved to another stock so long as that stock is considered to be within safe biological limits

Survivability – is an exemption that allows for stocks that are considered to have a good chance of survival can be discarded.

Note that quota allocation in the model is demonstrated in Figure 3-1.

4.2.4 Production Box

The production box simulates the harvest attained from a given year's fishing effort and stock biomass with a parameterised catchability (q) by fleet, metier and stock. Catch takes a Cobb-Douglas specification with alpha and beta taking values of 1 making this a Schaefer catch equation.

Total catch of a stock, including that from unassessed fleets, can be calculated (i.e. including TACsh). Furthermore, if estimates of the stock caught below minimum landing size (i.e. d%MCRS) exist then this can also be included in total catch. Overquota discards are estimated simply by taking the difference between the catch and TAC for a given year, where it is assumed that all over quota discards cannot be landed for human consumption. Further, it is assumed that Overquota discards are distributed over metiers according to weighted catch in each metier. Estimated landings then follow.

$$\text{Catch}_{[fleet,metier,stock,year]} = q_{[fleet,metier,stock]} * \text{Effort}_{[fleet,metier,year]}^{\alpha} * \text{Biomass}_{[stock,year]}^{\beta}$$

$$\text{totalFleetCatch}_{[fleet,stock,year]} = \text{sum}_{[metier]}(\text{Catch}_{[fleet,metier,stock,year]})$$

$$\text{totalCatch}_{[stock,year]} = \text{sum}_{[fleet]}(\text{totalFleetCatch}_{[fleet,stock,year]} / \text{TACsh}_{[fleet,stock]})$$

$$\text{Catch<mrs}_{[fleet,metier,stock,year]} = \text{d\%MCRS}_{[fleet,metier,stock]} * \text{Catch}_{[fleet,metier,stock,year]}$$

$$\text{Catch>tac}_{[fleet,stock,year]} = \max(0, \text{sum}_{[metier]}(\text{Catch}_{[fleet,metier,stock,year]} - \text{Catch<mrs}_{[fleet,metier,stock,year]}) - \text{TAC}_{[fleet,stock,year]})$$

$$\text{m\%TAC}_{[fleet,metier,stock,year]} = \text{Catch}_{[fleet,metier,stock,year]} / \text{totalFleetCatch}_{[fleet,stock,year]}$$

$$\text{unwantedCatch}_{[fleet,metier,stock,year]} = \text{Catch<mcrs}_{[fleet,metier,stock,year]} + (\text{m\%TAC}_{[fleet,metier,stock,year]} * \text{Catch>tac}_{fleet,stock,year]})$$

$$\text{Landings}_{[fleet,metier,stock,year]} = \text{Catch}_{[fleet,metier,stock,year]} - \text{unwantedCatch}_{[fleet,metier,stock,year]}$$

Note that for any stock where sufficient recruitment and biomass data is not available then biomass for that stock in any year will be assumed equal to one. This approach models catch using estimated catch per unit effort but enables catchability to be incorporated.

4.2.5 Economic Box

With landings and prices, as well as additional revenue from other species, the revenue of fleets can be calculated. Crew costs are based on a proportion of revenue, variable costs of the number of days fished (i.e. Effort) and fixed and capital costs on the number of vessels in a fleet. Gross cash flow (or operating profit) and net profit can then be calculated directly.

$$\text{fishPrice}_{[\text{stock,year}]} = \textit{constantPrice} \text{ OR } \textit{flexPrice} \text{ OR } \textit{projectedPrice} \text{ OR } \textit{responsePrice}$$

$$\text{Revenue}_{[\text{fleet,year}]} = \text{sum}_{[\text{metier,stock}]}(\text{Landings}_{[\text{fleet,metier,stock,year}]} * \text{fishPrice}_{[\text{stock,year}]}) + \text{otherStockRevenue}_{[\text{fleet,year}]}$$

$$\text{Revenue<mcrs}_{[\text{fleet,year}]} = \text{sum}_{[\text{metier,stock}]}(\text{Catch<mcrs}_{[\text{fleet,metier,stock,year}]} * \text{fishPrice<mcrs}_{[\text{stock}]})$$

$$\text{crewCosts}_{[\text{fleet,year}]} = \text{crewShare}_{[\text{fleet}]} * \text{Revenue}_{[\text{fleet,year}]}$$

$$\text{variableCosts}_{[\text{fleet,year}]} = \text{sum}_{(\text{metier})}(\text{Effort}_{[\text{fleet,metier,year}]}) * (\text{variableCostPerDay}_{[\text{fleet,year}]} + \text{fuelCosts}_{[\text{fleet,year}]})$$

$$\text{fixedCosts}_{[\text{fleet,year}]} = \text{numberVessels}_{[\text{fleet,year}]} * \text{fixedCostPerVessel}_{[\text{fleet,year}]}$$

$$\text{capitalCosts}_{[\text{fleet,year}]} = \text{numberVessels}_{[\text{fleet,year}]} * \text{capitalCostPerVessel}_{[\text{fleet,year}]}$$

$$\text{grossCashflow}_{[\text{fleet,year}]} = \text{Revenue}_{[\text{fleet,year}]} - \text{crewCosts}_{[\text{fleet,year}]} - \text{variableCosts}_{[\text{fleet,year}]} - \text{fixedCosts}_{[\text{fleet,year}]}$$

$$\text{netProfit}_{[\text{fleet,year}]} = \text{grossCashflow}_{[\text{fleet,year}]} - \text{capitalCosts}_{[\text{fleet,year}]}$$

4.3 Simulations

The simulations are the purpose of the model and where the challenges of understanding how a highly diverse industry might be affected by different policy options action are addressed. The principle question being asked is "how will fleets be affected under various assumptions of implementing the new landing obligations". The model is designed to be able to consider "what-if" analyses to inform how key levers available to policy makers could impact on the fleets and fisheries under the landing obligation.

Levers, or a combination of levers, essentially define a simulation to be investigated. Changing availability of quota is important and includes likely quota uplift levels by stocks, the ability to swap quota (e.g. across species and fleets) and of potential exemptions (e.g. de minimis). Furthermore, key data such as discard rates can be investigated for sensitivity on results.

The policy levers modelled and the simulations that have been run at the time of writing are presented in Table 4-2. There are four baselines developed, each of which builds on the previous baseline, to enable investigation of the effect of each "fundamental" lever in turn starting with B1 with no levers; B2 with zero-TAC stocks accounted for; B3 with quota uplift introduced; and B4 with a PO fleet segment's quota enabled to move across it's metiers, if required, to alleviate a choke. B4 is therefore the baseline presented for comparison to other simulations. There are two quota simulation developed building on B4: namely S1 which enables UK quota trade and S2 which uses end of year UK quota that incorporates international swaps.

Table 4-2. Specification of simulations

Simulation	Zero-TAC stocks	Quota uplift	Metier quota reallocation	UK quota trade	Eno of year quota (after international swaps	De-minimis	Inter-species Flexibility	Survivability
B1 Baseline without uplift	×	×	×	×	×	×	×	×
B2 Baseline without uplift excl zeroTAC	✓	×	×	×	×	×	×	×
B3 Baseline with uplift excl zeroTAC	✓	✓	×	×	×	×	×	×
B4 Baseline, B3+Metier quota re-allocation	✓	✓	✓	×	×	×	×	×
S1, B4+UK quota trade	✓	✓	✓	✓	×	×	×	×
S2, B4 + Adj Quota 2015	✓	✓	✓	×	✓	×	×	×

The first version of the model also included policy levers such as de-minimis, inter-species flexibility and survivability for investigation. At this point in the landing obligation implementation it is not clear how these would be implemented so for the current findings report these were not developed further. However, exemptions could be tested when it is more clear how they are going to be implemented.

Quota uplifts used in the model, using the approach described previously, are presented in Table 4-3.

Table 4-3. Quota uplift in 2016 and 2019 by stock code

Stock	2016	2019		Stock	2016	2019		Stock	2016	2019
ANGNS	-	+4%		HAKWS	+12%	+11%		PLANS	+25%	+30%
ANGWS	-	+4%		LEMWITNS	-	+35%		SAINS	+6%	+5%
BSFWS	-	+4%		MEG7	-	+17%		SAIWS	-	+5%
COD5B6A	-	+382%		MEGNS	-	+14%		SOL7A	-	+8%
COD7D	-	+26%		MEGWS	-	+14%		SOL7D	+9%	+10%
CODNS	-	+26%		NEP7	+11%	+18%		SOL7E	-	+2%
DABFLENS	-	+675%		NEPNS	+3%	+10%		SOL7FG	+1%	+3%
HAD5B6A	+11%	+21%		NEPWS	+2%	+7%		SOLNS	+1%	+7%
HAD7A	+27%	+89%		PLA7A	-	+242%		TURBNS	-	+4%
HAD7BK	-	+61%		PLA7DE	-	+73%		WHI7BK	+26%	+27%
HADNS	+17%	+21%		PLA7FG	-	+270%		WHINS	-	+86%
HADWS	-	+14%		PLA7HJK	-	+57%		WHIWS	-	+177%
HAKNS	+11%	+11%								

Stocks with no quota uplift are: ANG7, Bass, COD6B, COD7A, COD7BKXD, Cuttlefish, HER4C7D, HER7A, HER7EF, HERNS, HERWS, LIN4, LINWS, MACBOX, MACNS, MACWS, Pilchards, PLAWS, POL7, POLWS, Queen Scallops, SAI7, Scallops, SKA67XD, SKA7D, SKANS, SOL7BC, SOL7HJK, SOLWS, SPR7DE, SPRNS, Squid, USK4, USK567, WHI7A

The following two sub-sections detail the baseline simulations B1-B4 and the quota simulations S1-S2.

4.3.1 Baseline simulations

There are four baseline simulations (B1-B4) in the model with each baseline simulation building on the previous one.

4.3.1.1 Baseline simulation B1: LO is implemented

Baseline simulation B1 assumes that each PO fleet segment only has its initial quota allocation available for its vessels and, by 2019, UK vessels cannot discard any demersal quota stocks. In the simulation there are no mitigation measures from industry or government that could reduce negative impacts arising from the landing obligation. The year in which stocks become subject to the landing obligation in different fleet segments and metiers prior to 2019 is informed by existing and proposed management rules put forward by the North Sea and North Western Waters Regional Groups. The approach taken in the model is shown in Appendix E.

4.3.1.2 Baseline simulation B2: Mitigation for zero-TAC stocks

Baseline simulation B2 adds a catch allowance for zero-TAC stocks to simulation B1. The simulation provides a catch allowance of 1.5% of a fleet segment's total catch (all quota stocks, all sea areas) for zero-TAC stocks. The simulation does not exempt these stocks from the landing obligation but does significantly reduce the likelihood that these stocks will create a choke point in the model. Without a catch allowance for zero-TAC stocks, PO fleet segments operating in metiers where a zero-TAC stock is caught could immediately face a choke point and be unable to fish.

The simulation effectively avoids a zero-TAC stock creating a choke point in the model.

4.3.1.3 Baseline simulation B3: TAC uplift is applied

Baseline simulation B3 adds a positive adjustment (known as quota adjustment, quota uplift or quota top-up) to the quota available to a PO fleet segment when a stock becomes subject to the landing obligation for the fleet segment. This takes account of the move from landings-based TACs to catch-based TACs, thereby allowing for a level of discarded fish. Note that if a stock is not within sustainable limits then its TAC may still be seen to decrease even under catch-based TACs.

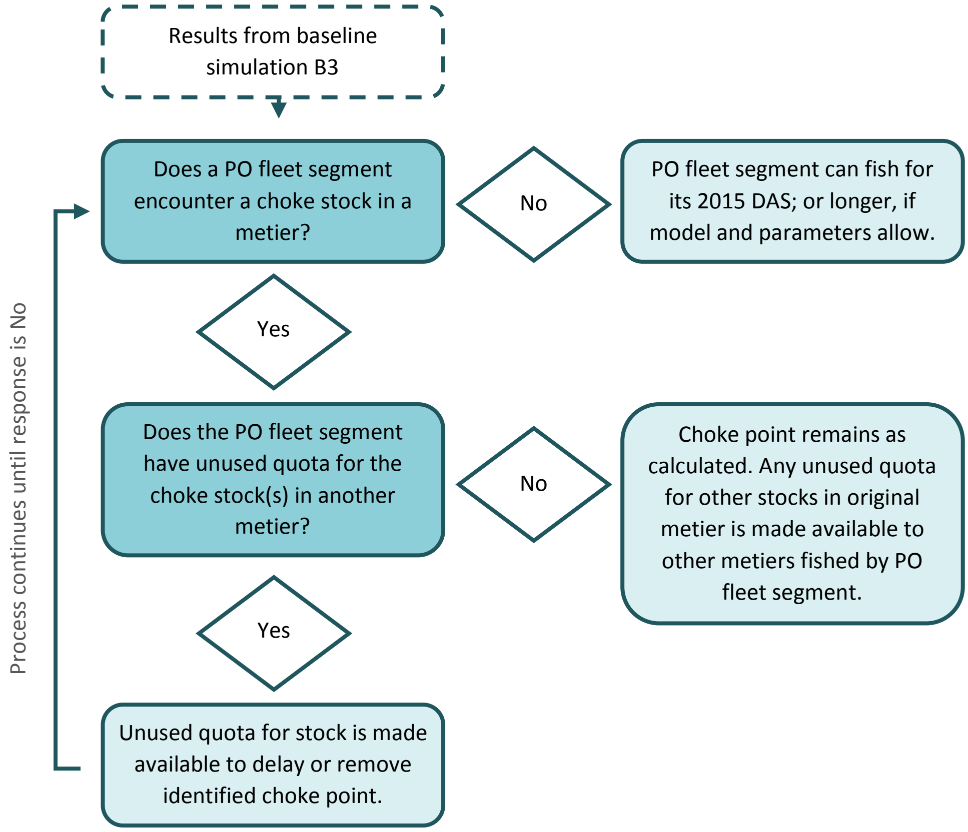
The quota uplift is indicated at the TAC level by the percentage increase that is required to move from landings-based TACs to catch-based TACs. This is taken from 2016 ICES catch advice and would be reflective of the quota uplift advised if all fleets were subject to the landing obligation for stocks, namely the situation in 2019. The quota uplift available to each fleet is then identified as the same proportion that they receive of UK quota. During the transition period (2016-18), only those fleets subject to the landing obligation are modelled to receive their share of the corresponding quota uplift.

4.3.1.4 Baseline simulation B4: Quota movement between metiers

In addition to the mitigation included in baseline simulation B3, baseline simulation B4 enables the movement of effort between metiers within a PO fleet segment. To recall, the model allocates quota to a PO fleet segment based on FQAs (see section 3.2.1). The PO fleet segment quota is then allocated to metiers based on the proportion of landings in each metier versus the fleet's total. This baseline simulation uses as much of the quota in each metier as allocated at this stage. Then any unused quota is made available to the PO fleet segment's other metiers to make as much use of it as possible before choking or reaching its target of days fished in 2015. This follows the idea of optimising quota across metiers but guided by previous levels of fishing activity in those metiers. To summarise, this actively extends fishing opportunity within a PO fleet segment by reallocating unused effort in a PO fleet segment metier (created by a choke point) to another metier to delay a choke point.

Baseline simulation B4 is a more complex simulation than the earlier baseline simulations. Figure 4-3 provides a visual demonstration of the process for simulation B4.

Figure 4-3: Process for baseline simulation B4



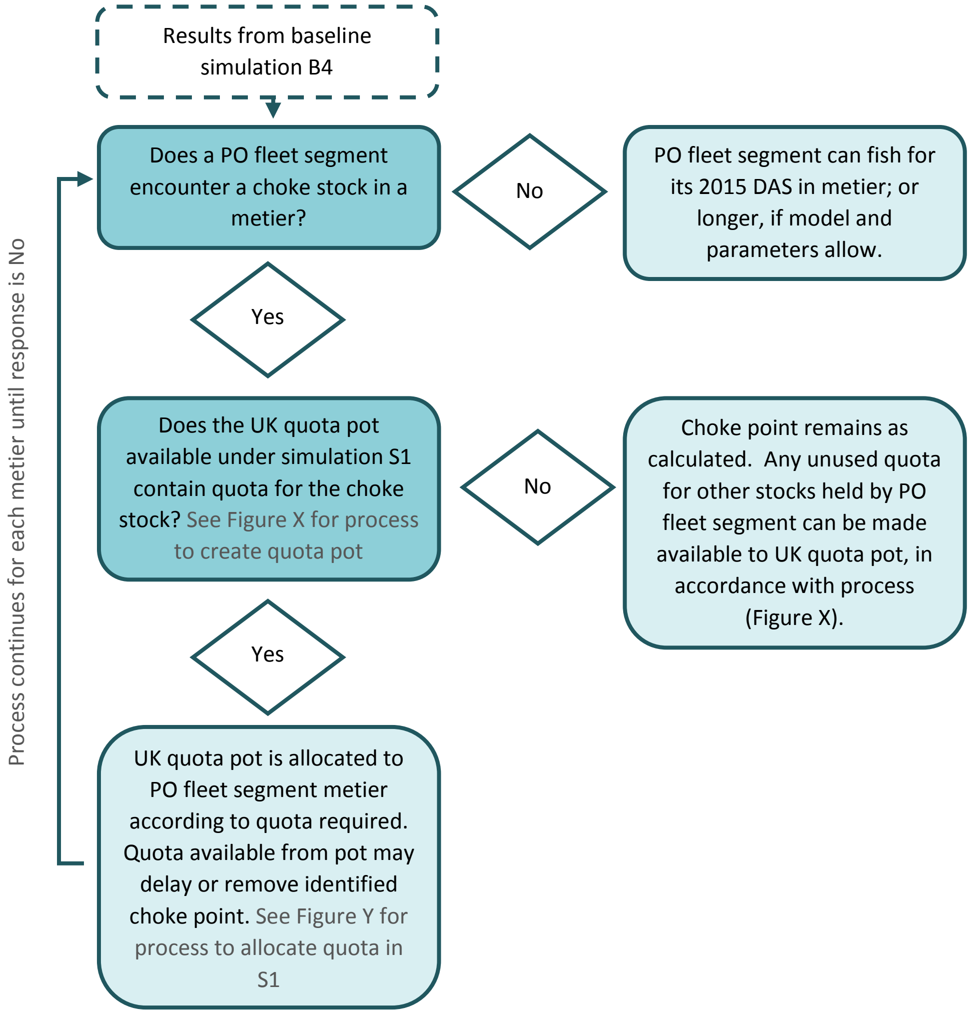
It is assumed that baseline simulation B4 provides a good foundation for adding further simulations and a benchmark for understanding the value of further simulations. Therefore, B4 is presented in the results as the preferred baseline for comparison.

4.3.2 Quota simulations

4.3.2.1 Quota simulation S1: Quota is moved between PO fleet segments

Simulation S1 builds on baseline B4 to enable any unused quota not used by PO fleet segments (either through choking or reaching the 2015 effort target) to be made available to other PO fleet segments to alleviate to some degree their choke situations. The approach used aims to be fair, and as far as possible aims to allocate unused quota to the proportion that it's required by PO fleet segments. For example, if two fleets each require an additional 50 tonnes to remove the potential choke of a stock then each will be allocated 50% of the unused quota. However, it's not quite that simple as even though it has a new amount of quota of its choke stock available, it may then choke on another stock that would prevent the use of that additional quota made available, which could otherwise be used by other PO fleet segments. Furthermore, if a PO fleet segment's unused quota was made available to others before it could make use of any unused quota after the alleviation of a choke point from another stock then it'd be left at that first found choke point! So, this simulation takes into account the dynamics of the situation regarding the need for quota and aims to make any unused quota available to those fleets that need it on an iterative basis. This enables a fleet to make as much use of quota allocated to itself but also take advantage of quota released by other fleet segments. Therefore, this approach simulates an optimisation of unused quota across fleets in an iterative process. That process is presented in Figure 4-44.

Figure 4-4: Process for quota simulation S1: the movement of quota between PO fleet segments



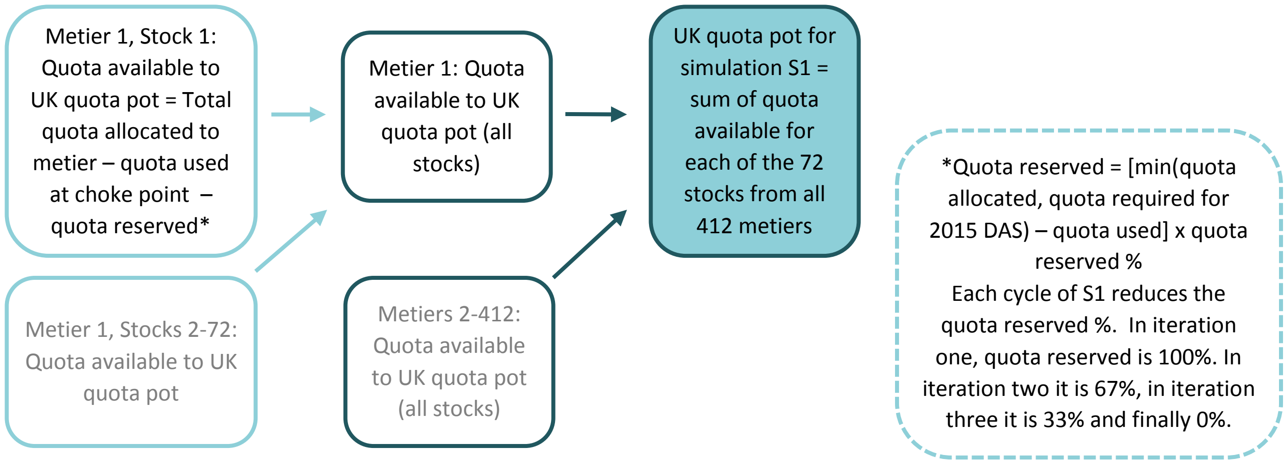
Simulation S1 is the most complex of the simulations tested. There are two separate calculations required to inform the process described above:

The UK quota pot created for simulation S1 consists of quota in excess of what each metier requires to reach 2015 DAS plus quota that exceeds metier requirements under each iteration of the process.

Figure 4-5 presents the calculations required to quantify the quota pot.

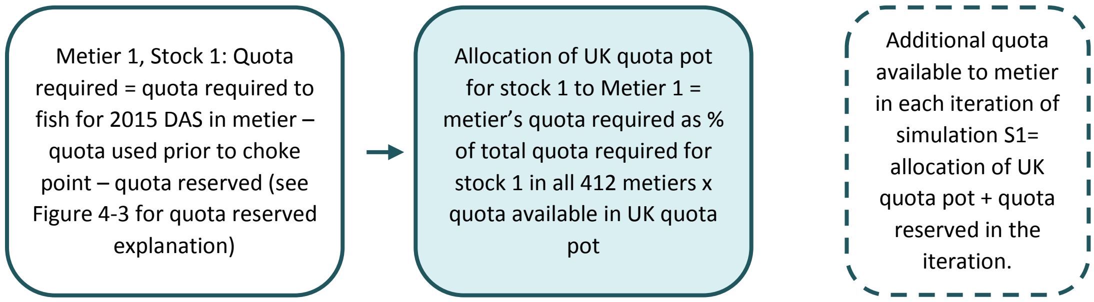
- The allocation of the UK quota pot is based on need at a metier level. Figure 4-6 presents the calculations used to quantify need and allocate from the UK quota pot.

Figure 4-5: Process for calculating UK quota pot in simulation S1



The idea of reserved quota is to avoid removing quota from a PO fleet segment metier that could have been used if the simulation succeeds in delaying the choke point. For example, if the primary choke stock in a metier is saithe and an iteration of simulation S1 succeeds in transferring sufficient quota to the metier to delay the choke point, the fleet segment may be able to continue fishing in the metier until a secondary choke stock, for example cod, is encountered. Without a process for reserving quota, cod quota could have been removed by the simulation before the benefit of receiving the saithe quota could be realised. This process mimics a vessel owner holding onto quota while they try to find a solution for their choke stock. In the simulation, if quota cannot be found to remove a choke point, in the fourth iteration of the S1 process all unused quota is moved to the UK quota pot where it may be reallocated to other PO fleet segment metiers.

Figure 4-6: Process for allocating quota pot in simulation S1



4.3.2.2 Quota simulation S2: End of year quota is starting point

Simulation S2 repeats the process for baseline simulation B4. The only difference is the input data used for quota available to the UK PO fleet segments. Quota simulation S2 is informed by the quota held by the UK at the end of the year (i.e. the most recent year that information is available for). The end of year quota available presents the situation of quota available to the UK after swaps with other EU member states. For example, the difference between initial quota allocation in the beginning of the year and end of year situation for North Sea Hake quota and North Sea saithe quota is +544% and +171% respectively. Other stocks may see reductions in quota available through swapping (e.g. Sole in VIIfg of 50%). In simulation S2, the end of year quota is used instead of the initial quota allocation (IQA), which is used for the baseline simulations.

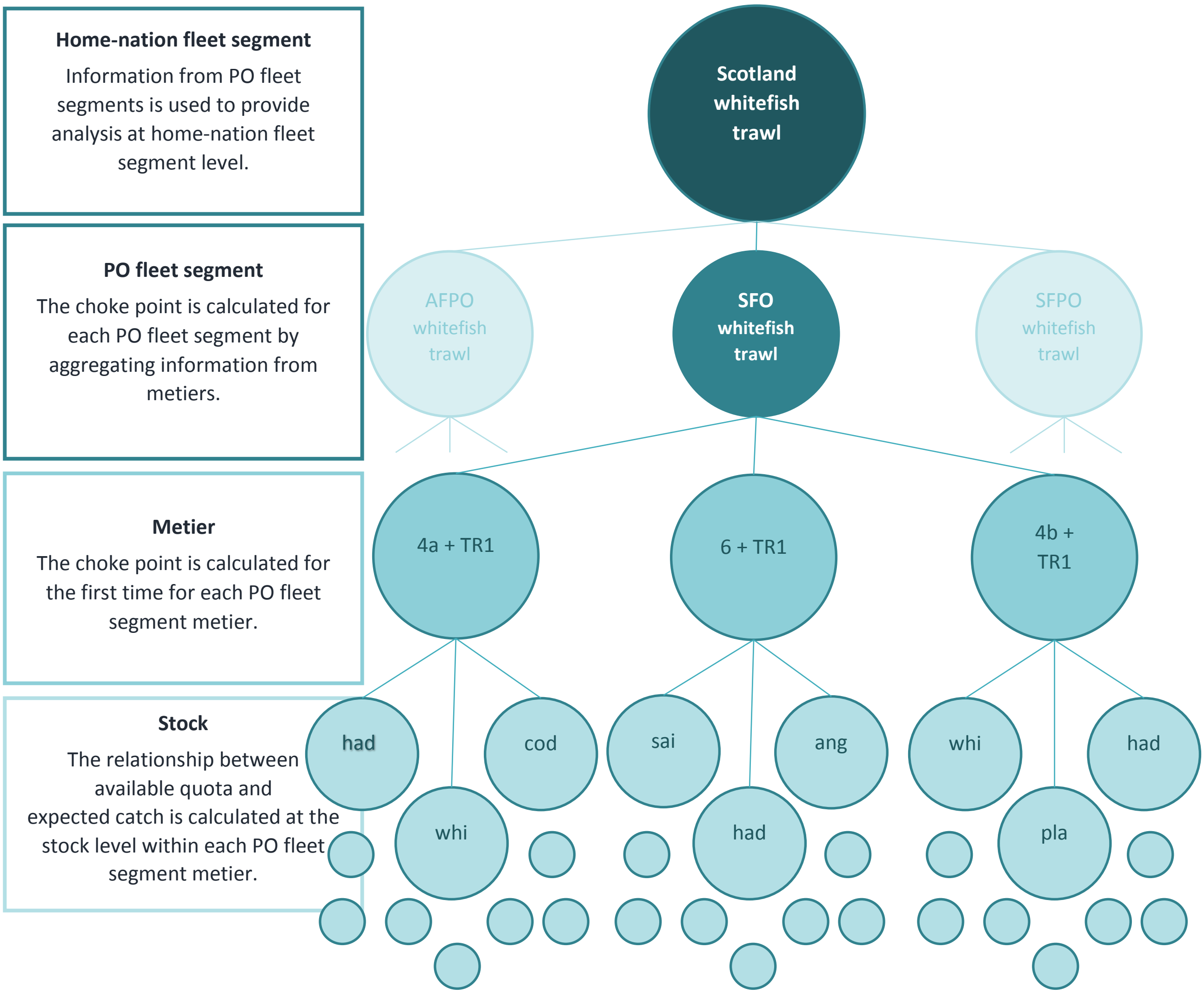
Note that given a lack of available data of how the end of year quota is allocated to PO fleet segments, the same approach is taken as with initial quota allocation, i.e. quota is allocated in line with FQAs held. If the information for quota held by vessels at year end was available then a simple process of updating the PO fleet segment quota shares could be undertaken and provided as an input to the model.

5 Results Output Framework

5.1 Aggregation

The main purpose of the results output framework is to take the results created at the PO fleet segment, metier and stock level (by year), and aggregate them to present at the national fleet segment level (e.g. Scotland whitefish trawl fleet). This is due to the need to present the effect of the landing obligation at a national level but also due to confidentiality as it is agreed that PO specific information from the analysis will not be made publicly available. The aggregation levels that build information from the metier and stock level to the home-nation fleet segment are shown in Figure 5-1.

Figure 5-1: Aggregating the findings from the simulations to a home-nation fleet segment



There are two main challenges in presenting the results at the home-nation fleet segment level: firstly the impact of the landing obligation on the fleet segments needs to be calculated; and secondly the stocks that are most challenging regarding availability of quota need to be identified. The following two sub-sections describe these two outputs: choke point analysis and most challenging stocks. An example is provided in the third sub-section.

5.1.1 Choke point analysis

The choke point analysis is straightforward in that a choke point (or maximum level of fishing effort) is identified for each PO fleet segment in each metier (by year) to catch the allocated quotas by stock. This approach to the analysis is focused on the point at which a fleet segment could run out of quota for any of the stocks that it catches. In most cases, for a metier under the landing obligation that point will result in a stock (the primary choke stock) that limits a fleet's activity to below that achieved in 2015. As the choke point is output as a level of effort (in days) achieved by each PO fleet segment in each metier, the choke point of the national fleet segment is simply an aggregation of the days at the choke point for each PO fleet segment in each metier. This can then be compared to the target effort (2015 days at sea in this case) to provide the choke point of the national fleet and presented as a percentage of the days at sea in 2015.

To reiterate, when findings from each simulation are aggregated to PO fleet segment or home-nation level, the choke point analysis sums the days at sea for each primary choke stock in each of the included metiers. The aggregation means that the choke point for a PO or home-nation fleet segment, can be caused by a combination of different primary choke stocks in different metiers. Therefore, the choke point analysis uses the minimum choke points which are determined by the characteristics of individual PO fleet segments (quota holdings, catch rates etc.).

5.1.2 Most challenging stocks

It is clear that PO fleet segments have different amounts of quota available for each stock. Given a difference in the quota allocations to PO fleet segments and with different catch rates in specific metiers, there may be different stocks choking the PO fleet segments across metiers in a national fleet segment. Also, the differences in activity by PO fleet segments under a national fleet segment can be significant. For example, the GBS_Nephrops fleet in 2015 on average fished 54% of days in West of Scotland and 23% of days in North Sea using TR2 gear. However, vessels in three of the PO fleet segments only fish in the North Sea and the other four fish predominantly in West of Scotland. There is also varying levels of TR1 activity across the PO fleet segments.

Therefore, to understand the choke characteristics of individual stocks, the most challenging stocks analysis is designed to aggregate the results for each stock across multiple metiers. One complication is that some stocks may be caught in some metiers but not in others, which means that a simple aggregation process across metiers and stocks is not possible. To overcome this, unused effort per stock is calculated across all PO fleet segment metiers in the home-nation fleet segment and aggregated to indicate the scale of the challenge caused by each stock. Unused effort is the difference between 2015 days at sea in each metier and the days at sea estimated to catch the quota allocated to each metier. The stock with the largest unused effort is the stock identified as the most challenging stock. In this way, differences in catch composition across metiers can be considered. So, the stock identified as most challenging may not always be the primary choke stock for different POs but, out of all the stocks caught, it is the stock that could cause the greatest choke challenge across the home-nation fleet segment given the quota held by PO fleet segments. This approach can also be used to provide a UK view of challenging stocks.

5.1.3 Example

The following example is a simplified one used to demonstrate the choke point analysis and the most challenging stock analysis. It presents a hypothetical home-nation fleet segment which contains **three PO fleet segments**. Each PO fleet segment has only **two potential choke stocks** (even though there are three stocks in the analysis). Prior to the landing obligation, each PO fleet segment fished for 2,000 days per annum, therefore, total days at sea for the home-nation fleet segment was 6,000 days. The data used to calculate the choke point and the most challenging stock for the home-nation fleet segment is provided in Table 5-1.

Table 5-1. Example data for calculating choke points and most challenging stocks

PO fleet segment	Primary choke			Secondary choke		
	Primary choke stock	Choke Point	Unused days (2,000 days minus choke point days)	Secondary choke stock	Choke point	Unused days (2,000 days minus choke point days)
A	Saithe	1,200	800	Hake	1,300	700
B	Hake	900	1,100	Saithe	1,500	500
C	Cod	1,600	400	Hake	1,650	350

Choke Point Analysis: The home-nation choke point analysis sums the primary choke point for each PO fleet segment (1,200 + 900 + 1,600) to calculate the choke point of 3,700 days or 62% (3,700 as % of 6,000 days).

Notes – this represents the days at sea possible before each PO fleet segment encounters its own primary choke stock. The analysis is not stock specific. The most challenging stock analysis is stock specific.

Most Challenging Stocks Analysis: To identify the potential challenge caused by each stock the model calculates the number of unused days. In the example hake is the most challenging stock because it means that 2,150 potential days at sea are unused (700 + 1,100 + 350). Saithe is only a potential choke stock for two POs and means 1,300 days at sea could be unused. Cod is only a potential choke stock for one PO and means only 400 days at sea could be unused. For each most challenging stock, the amount of quota required is directly proportional to the amount of effort indicated to be needed to avoid choke. Therefore, the results output framework indicates the amount of quota for the most challenging stock that could be required to keep the home-nation fleet fishing for 6,000 days, assuming no other choke stock is encountered. So, in this example the most challenging stocks are: hake requiring 56% more quota, saithe requiring 28% more quota and cod requiring 7% more quota to avoid chokes and reach 2015 fishing effort. As an alternative measure, the results output framework also quantifies the improvement in selectivity that could be required to stop the stock from creating a choke.

If you have information that could be used by Seafish to improve the model, or you would like to ask questions about the operation of the model, please contact the Seafish Economics Team.

Appendix A: Fleet Segmentation

Table A-1: Combination of Seafish fleet segments and model fleet definitions

	Seafish fleet segment	LO Fishery	LO Fishery code
1	Area VIIA demersal trawl	Demersal trawl / seine	DEM
2	Area VIIBCDEFGHK 24-40m	Demersal trawl / seine	DEM
3	Area VIIBCDEFGHK trawlers 10-24m	Demersal trawl / seine	DEM
4	NSWOS demersal over 24m	Demersal trawl / seine	DEM
5	NSWOS demersal pair trawl seine	Demersal trawl / seine	DEM
6	NSWOS demersal seiners	Demersal trawl / seine	DEM
7	NSWOS demersal under 24m over 300kW	Demersal trawl / seine	DEM
8	NSWOS demersal under 24m under 300kW	Demersal trawl / seine	DEM
9	Area VIIA nephrops over 250kW	Nephrops trawl	NEP
10	North Sea nephrops over 300kW	Nephrops trawl	NEP
11	North Sea nephrops under 300kW	Nephrops trawl	NEP
12	Area VIIA nephrops under 250kW	Nephrops trawl	NEP
13	WOS nephrops over 250kW	Nephrops trawl	NEP
14	WOS nephrops under 250kW	Nephrops trawl	NEP
15	North Sea beam trawl over 300kW	Beam trawl	BM
16	North Sea beam trawl under 300kW	Beam trawl	BM
17	South West beamers over 250kW	Beam trawl	BM
18	South West beamers under 250kW	Beam trawl	BM
19	UK scallop dredge over 15m	UK scallop dredge	DRG
20	UK scallop dredge under 15m	UK scallop dredge	DRG
21	Pots and traps 10-12m	Pots and traps	FPO
22	Pots and traps over 12m	Pots and traps	FPO
23	Gill netters	Gill netters	DFN
24	Pelagic over 40m	Pelagic trawlers	TM
25	Under 10m demersal trawl/seine	Demersal trawl / seine <10m	10DEM
26	Under 10m drift and/or fixed nets	Drift and/or fixed nets < 10m	10DFN
27	Under 10m pots and traps	Pots and traps < 10m	10FPO
28	Under 10m using hooks	Hooks < 10m	10HOK
29	Longliners	Other	OTH
30	Low activity over 10m	Other	OTH
31	Low activity under 10m	Other	OTH
32	Miscellaneous	Other	OTH
33	Inactive	Other	OTH

Table A-2: List of PO/non-sector fleet segments combined with fishery

ID.	PO/non-sector fleet	No. of home-nations	No. of vessels	ID.	PO/non-sector fleet	No. of home-nations	No. of vessels
1	AFPO_DEM-white	1	9	**41**	Non-sect-u10m_OTH	4	2814
2	AFPO_OTH	1	7	**42**	NPO_NEP	1	10
3	ANIFPO_DRG	1	6	**43**	NPO_OTH	1	21
4	ANIFPO_NEP	1	20	**44**	NSFO_BM	1	5
5	ANIFPO_OTH	1	16	**45**	NSFO_DRG	1	13
6	ASFPO_DEM	1	7	**46**	NSFO_OTH	1	7
7	ASFPO_NEP	2	24	**47**	OFPO_NEP	1	5
8	ASFPO_OTH	1	10	**48**	OFPO_OTH	1	6
9	CFPO_BM	1	18	**49**	REM_10FPO	1	16
10	CFPO_DEM	1	34	**50**	REM_OTH	4	325
11	CFPO_DFN	1	19	**51**	REM-PO_OTH	2	31
12	CFPO_DRG	1	11	**52**	SFO_DEM	1	33
13	CFPO_FPO	1	12	**53**	SFO_DEM-white	1	14
14	CFPO_OTH	1	7	**54**	SFO_DRG	1	12
15	EEFPO_DEM-white	1	16	**55**	SFO_NEP	1	105
16	EEFPO_FPO	1	7	**56**	SFO_OTH	1	18
17	EEFPO_OTH	1	15	**57**	SFO_TM	1	7
18	FFPO_DEM	1	6	**58**	SFPO_DEM-white	1	24
19	FFPO_DFN	1	5	**59**	SFPO_DRG	1	5
20	FFPO_OTH	1	16	**60**	SFPO_OTH	1	2
21	LFPO_BM	1	6	**61**	SFPO_TM	1	7
22	NESFO_DEM-white	1	19	**62**	SWFPO_BM	1	19
23	NESFO_OTH	1	5	**63**	SWFPO_DEM	1	27
24	NIFPO_10DEM	1	7	**64**	SWFPO_DRG	2	25
25	NIFPO_DEM	1	13	**65**	SWFPO_OTH	1	8
26	NIFPO_DRG	1	15	**66**	TFFPO_DEM	1	6
27	NIFPO_NEP	1	78	**67**	TFFPO_NEP	1	12
28	NIFPO_OTH	1	19	**68**	TFFPO_OTH	1	10
29	Non-sect-o10m_BM	1	7	**69**	WoSFPO_FPO	1	6
30	Non-sect-o10m_DEM	1	13	**70**	WoSFPO_NEP	1	20
31	Non-sect-o10m_DRG	3	98	**71**	WoSFPO_OTH	1	6
32	Non-sect-o10m_FPO	3	200	**72**	WWCFPO_DEM	1	6
33	Non-sect-o10m_NEP	1	20		**Grand Total**	**96**	**6058**
34	Non-sect-o10m_OTH	4	125				
35	Non-sect-u10m_10DEM	2	156				
36	Non-sect-u10m_10DFN	2	224				
37	Non-sect-u10m_10FPO	4	963				
38	Non-sect-u10m_10HOK	3	127				
39	Non-sect-u10m_DRG	3	83				
40	Non-sect-u10m_FPO	1	6				

Appendix B: Metier information

Table B-1: Main gears separated for modelling of fleet activities within the model

Gear	Share of DAS in 2015	Share of value in 2015	Share of weight landed in 2015
BT	2.2%	4.2%	2.2%
DRG	6.9%	7.4%	5.7%
Hooks	4.5%	0.5%	0.2%
LL1	0.6%	1.8%	0.7%
Nets	6.7%	2.3%	1.1%
Otter	0.4%	17.7%	35.9%
Pots	45.4%	12.7%	7.2%
TR1	6.0%	16.5%	11.1%
TR2	14.4%	9.0%	4.3%
Oth*	13.0%	27.9%	31.6%
Grand Total	**100%**	**100%**	**100%**

** could be another gear not listed, or one of the gears listed, but there was not enough of vessels (<5) in the fleet segment using the gear to form separate metier.*

Table B-2 lists the fishing areas included in the model. Information on the days at sea and proportionate share of value and weight landed by each gear type is also included in the table. In the previous version of the model, the area based analysis was structured around the ICES areas of 4, 6 and 7.

Table B-2: ICES fishing areas included in the model

Area	Share of DAS in 2015	Share of value in 2015	Share of weight landed in 2015
II&V	0.0%	0.3%	0.2%
IVa	15.4%	25.4%	30.6%
IVb	17.1%	7.7%	3.9%
IVc	3.4%	1.5%	2.1%
VI	21.1%	17.3%	18.0%
VIIa	8.2%	5.3%	4.3%
VIId	6.6%	2.3%	1.4%
VIIe	10.8%	7.5%	4.1%
VIIfg	4.5%	2.2%	1.4%
VIIhjk	1.0%	2.1%	0.9%
Oth*	11.8%	28.5%	33.2%
Grand Total	**100%**	**100%**	**100%**

** could be another Area not listed, or one of the areas listed, but there was not enough of vessels (<5) of particular fleet operating in the area to form separate metier.*

Appendix C: List of stocks included in the model

	Stock/species	Share of value landed in 2015	Share of weight landed in 2015		Stock/species	Share of value landed in 2015	Share of weight landed in 2015
1	ANG7	2.40%	0.95%	41	PLAWS	0.00%	0.01%
2	ANGNS	2.54%	1.15%	42	POL7	0.32%	0.17%
3	ANGWS	0.86%	0.38%	43	POLWS	0.01%	0.00%
4	BSFWS	0.02%	0.02%	44	SAI7	0.01%	0.01%
5	COD5B6A	0.04%	0.02%	45	SAINS	1.07%	1.27%
6	COD6B	0.00%	0.00%	46	SAIWS	0.35%	0.47%
7	COD7A	0.01%	0.01%	47	SKA67XD	0.35%	0.27%
8	COD7BKXD	0.12%	0.06%	48	SKA7D	0.03%	0.02%
9	COD7D	0.04%	0.02%	49	SKANS	0.09%	0.09%
10	CODNS	3.69%	2.10%	50	SOL7A	0.01%	0.00%
11	DABFLENS	0.03%	0.05%	51	SOL7BC	0.00%	0.00%
12	HAD5B6A	0.56%	0.43%	52	SOL7D	0.38%	0.06%
13	HAD7A	0.09%	0.09%	53	SOL7E	0.63%	0.07%
14	HAD7BK	0.15%	0.11%	54	SOL7FG	0.10%	0.01%
15	HADNS	4.56%	3.66%	55	SOL7HJK	0.07%	0.01%
16	HADWS	0.34%	0.29%	56	SOLNS	0.75%	0.11%
17	HAKNS	0.84%	0.42%	57	SOLWS	0.00%	0.00%
18	HAKWS	2.56%	1.04%	58	SPR7DE	0.06%	0.38%
19	HER4C7D	0.14%	0.45%	59	SPRNS	0.00%	0.00%
20	HER7A	0.20%	0.69%	60	TURBNS	0.38%	0.07%
21	HER7EF	0.01%	0.05%	61	USK4	0.00%	0.01%
22	HERNS	3.25%	9.92%	62	USK567	0.01%	0.01%
23	HERWS	0.69%	2.17%	63	WHI7A	0.00%	0.00%
24	LEMWITNS	0.51%	0.22%	64	WHI7BK	0.13%	0.17%
25	LIN4	0.32%	0.28%	65	WHINS	1.35%	1.42%
26	LINWS	0.42%	0.33%	66	WHIWS	0.02%	0.02%
27	MACBOX	10.41%	18.23%	67	Bass	0.74%	0.10%
28	MACNS	0.15%	0.23%	68	Cuttlefish	1.39%	0.86%
29	MACWS	9.76%	16.05%	69	Pilchards	0.21%	0.61%
30	MEG7	1.13%	0.42%	70	Queen Scallops	0.94%	1.79%
31	MEGNS	0.38%	0.17%	71	Scallops	7.40%	4.00%
32	MEGWS	0.18%	0.09%	72	Squid	1.09%	0.33%
33	NEP7	2.06%	1.01%	73	OTH*	22.08%	21.22%
34	NEPNS	3.16%	0.99%		**Grand Total**	**100%**	**100%**
35	NEPWS	5.51%	1.67%				
36	PLA7A	0.01%	0.01%				
37	PLA7DE	0.24%	0.18%				
38	PLA7FG	0.00%	0.00%				
39	PLA7HJK	0.00%	0.00%				
40	PLANS	2.65%	2.46%				

** All species and the rest of stocks not included in the list of 72 stocks/species above.*

Appendix D: Discard rates by gear, home-nation and stock

	TR1 (whitefish and demersal trawl)			TR2 (nephrops trawl)			BT (beam trawl)
	England	Scotland	Northern Ireland	England	Scotland	Northern Ireland	England
Anglers 7	1.3%	2.7%	0.0%	0.0%	0.0%	8.9%	3.3%
Anglers 4	0.6%	0.8%		4.6%	22.0%	21.6%	0.5%
Anglers 6		0.3%			52.7%	0.3%	
Boarfish 6		0.4%					
Cod 5b6a		83.0%			97.5%	0.0%	
Cod 6b		0.0%					
Cod 7a			32.4%		73.3%	67.0%	
Cod 7b-k(ex.d)	3.4%	8.7%		0.0%			7.7%
Cod 4	4.9%	27.9%		42.8%	98.3%	95.5%	3.8%
Dabs 4	61.6%	92.3%		94.0%	99.6%		91.5%
Haddock 5b6a		6.0%			95.6%	85.6%	
Haddock 7a			3.4%		80.0%	73.0%	
Haddock 7b-k	13.1%	20.8%		0.0%			21.6%
Haddock 4	2.9%	8.3%		88.4%	86.3%	86.8%	0.0%
Haddock 6b		6.0%					
Hake 4	6.7%	55.7%		81.8%	95.9%	93.8%	0.0%
Hake 6-7	4.4%	22.3%	0.0%	0.0%	47.3%	27.3%	13.8%
Lemon sole 4	90.6%	8.3%		78.7%	64.9%	68.4%	39.2%
Ling 4	2.3%	1.5%		65.6%	75.5%	75.0%	14.3%
Ling 6-7	2.9%	6.9%	0.0%	0.0%	64.6%	0.8%	10.6%
Megrim 7	3.5%	7.7%		0.0%	100.0%	50.0%	1.9%
Megrim 4	7.9%	3.3%			86.1%	85.7%	
Megrim 6		8.7%			67.7%	0.0%	
Nephrops 7	3.6%	3.3%			18.0%	16.9%	0.0%
Nephrops 4	3.6%	1.1%		1.4%	23.3%	17.5%	32.7%
Nephrops 6		7.1%			6.3%	0.0%	
Plaice 7a			12.6%		88.1%	91.9%	
Plaice 7de	0.0%			0.0%			44.4%
Plaice 7fg		0.0%		0.0%			0.0%
Plaice 7hjk		62.6%					45.9%
Plaice 4	10.3%	14.3%		54.5%	88.8%	88.5%	50.1%
Plaice 6		46.8%			98.6%	87.7%	
Pollack 7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Pollack 6		0.0%			0.0%	0.0%	
Saithe 7	0.0%		0.0%	0.0%		0.0%	0.0%
Saithe 4	1.7%	41.3%		0.0%	73.3%	73.3%	0.0%
Saithe 6		7.7%			91.2%	0.0%	
Skate 6-7 (ex.d)	2.4%	0.0%	0.0%	0.0%	0.5%	0.0%	32.5%
Skate 4	76.0%	0.0%		42.4%	21.6%	33.3%	17.9%
Sole 7a					0.0%	9.5%	
Sole 7e	0.0%			0.0%			0.5%
Sole 7fg		0.0%		0.0%			0.0%
Sole 7hjk		5.9%					2.0%
Sole 4	0.0%	1.1%		15.4%	67.6%	50.0%	13.3%
Sole 6		27.0%			91.0%	0.0%	
Sprat 7de				0.0%			
Sprat 4		0.0%					
Turbot 4	0.0%	2.7%		0.6%	15.3%	0.0%	5.9%
Tusk 4		0.0%			0.0%		
Tusk 5,6,7		13.7%					
Whiting 7a			38.9%		99.3%	99.4%	
Whiting 7b-k	4.8%	20.2%		0.0%			13.6%
Whiting 4	72.8%	18.4%		92.9%	82.7%	83.0%	95.3%
Whiting 6		45.7%			99.7%	99.1%	

Appendix E: Phasing of landing obligation 2016-18, as implemented in the model

Table E-1: North Sea phasing, 2016-2018

	IVa_TR1			IVa_TR2			IVb_BT			IVb_TR1			IVb_TR2			IVc_BT			IVc_TR1			IVc_TR2		
Stock	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Sole		1	1	1	1	1	1	1	1		1	1	1	1	1					1	1	1	1	1
Plaice	1	1	1			1			1	1	1	1			1				1	1	1			1
Haddock	1	1	1		1	1		1	1	1	1	1		1	1								1	1
Cod		1	1			1			1		1	1			1					1	1			1
Nephrops		1	1	1	1	1		1	1		1	1	1	1	1									
Whiting		1	1			1			1		1	1			1					1	1			1
Saithe			1			1			1			1			1									

Table E-2: West of Scotland phasing, 2016-2018

	VI_TR1			VI_TR2		
Stock	2016	2017	2018	2016	2017	2018
Haddock 5B6A	1	1	1		1	1
Nephrops				1	1	1
Plaice		1	1			
Sole		1	1			
Megrim		1	1			

Table E-3: Other North-Western Waters phasing, 2016-2018

	VIIa_TR1			VIIa_TR2			VIId_TR1			VIId_TR2			VIIe_BT			VIIfg_BT			VIIfg_TR1		
Stock	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Sole 7D							1	1	1	1	1	1									
Nephrops				1	1	1													1	1	1
Haddock 7A	1	1	1																		
Sole 7FG																1	1	1			
Sole 7E													1	1	1						
Hake		1	1																		

Acronyms

DAS – Days at Sea

FDI – Fisheries Dependent Information

FPO – Fish Producers Organisation

FQA – Fixed Quota Allocation

ICES – International Council for the Exploration of the Sea

IQA – Initial Quota Allocation

PO – Producers Organisation

STECF – Scientific, Technical and Economic Committee for Fisheries

TAC – Total Allowable Catch

DIF – Data Input Framework

MMO – Marine Management Organisation

MCRS – Minimum Conservation Reference Size

FIDES – Fishery Data Exhange System

List of PO abbreviations

AFPO	Aberdeen FPO Ltd
ANIFPO	Anglo-North Irish FPO Ltd
ASFPO	Anglo-Scottish FPO Ltd
CFPO	Cornish FPO Ltd
EEFPO	Eastern England Fish Producers Organisation Ltd
FFPO	Fleetwood FPO Ltd
LFPO	Lowestoft FPO Ltd
NAFPO	North Atlantic Fish Producers Organisation Ltd
NESFO	North East of Scotland Fishermen's Organisation
NSFO	North Sea Fishermen's Organisation Ltd
NIFPO	Northern Ireland FPO Ltd
NPO	Northern Producers Organisation Ltd
OFPO	Orkney FPO Ltd
SFO	Scottish Fishermen's Organisation
SFPO	Shetland FPO Ltd
SWFPO	South Western FPO Ltd
TFFPO	The Fife FPO Ltd
TFPO	The FPO Ltd
WWCFPO	Wales and West Coast FPO Ltd
WoSFPO	West of Scotland FPO Ltd

List of stocks and species

	Stock code	Species name and area		Stock code	Species name and area
1	ANG7	Anglers 7	37	PLA7DE	Plaice 7de
2	ANGNS	Anglers 4	38	PLA7FG	Plaice 7fg
3	ANGWS	Anglers 6	39	PLA7HJK	Plaice 7hjk
4	BSFWS	Boarfish 6	40	PLANS	Plaice 4
5	COD5B6A	Cod 5b6a	41	PLAWS	Plaice 6
6	COD6B	Cod 6b	42	POL7	Pollack 7
7	COD7A	Cod 7a	43	POLWS	Pollack 6
8	COD7BKXD	Cod 7b-k(ex.d)	44	SAI7	Saithe 7
9	COD7D	Cod 7d	45	SAINS	Saithe 4
10	CODNS	Cod 4	46	SAIWS	Saithe 6
11	DABFLENS	Dabs 4	47	SKA67XD	Skate 6-7 (ex.d)
12	HAD5B6A	Haddock 5b6a	48	SKA7D	Skate 7d
13	HAD7A	Haddock 7a	49	SKANS	Skate 4
14	HAD7BK	Haddock 7b-k	50	SOL7A	Sole 7a
15	HADNS	Haddock 4	51	SOL7BC	Sole 7bc
16	HADWS	Haddock 6b	52	SOL7D	Sole 7d
17	HAKNS	Hake 4	53	SOL7E	Sole 7e
18	HAKWS	Hake 6-7	54	SOL7FG	Sole 7fg
19	HER4C7D	Herring 7d	55	SOL7HJK	Sole 7hjk
20	HER7A	Herring 7a	56	SOLNS	Sole 4
21	HER7EF	Herring 7ef	57	SOLWS	Sole 6
22	HERNS	Herring 4	58	SPR7DE	Sprat 7de
23	HERWS	Herring 6	59	SPRNS	Sprat 4
24	LEMWITNS	Lemon sole 4	60	TURBNS	Turbot 4
25	LIN4	Ling 4	61	USK4	Tusk 4
26	LINWS	Ling 6-7	62	USK567	Tusk 5,6,7
27	MACBOX	Mackerel 7	63	WHI7A	Whiting 7a
28	MACNS	Mackerel 4	64	WHI7BK	Whiting 7b-k
29	MACWS	Mackerel 6	65	WHINS	Whiting 4
30	MEG7	Megrim 7	66	WHIWS	Whiting 6
31	MEGNS	Megrim 4	67	Bass	Sea Bass
32	MEGWS	Megrim 6	68	Cuttlefish	Cuttlefish
33	NEP7	Nephrops 7	69	Pilchards	Pilchards
34	NEPNS	Nephrops 4	70	Queen Scallops	Queen Scallops
35	NEPWS	Nephrops 6	71	Scallops	Scallops
36	PLA7A	Plaice 7a	72	Squid	Squid