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Bioeconomic model to assess the impact of the Landing Obligation

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1. Introduction

The purpose of this report is to document the final methodology used in simulating the impact of different Total Allowable Catch (TAC) scenarios on Irish fleets under the landing obligation. The report summarises the general modelling approach, final data inputs and the methods for simulating the biological, fleet, and economic components. In addition, it details how to run the model through the dedicated R package 'BioEcon' and visualise the results in the 'Shiny App' developed for the project and how the model could be updated in future years. Some suggestions for future development or improvements to the model are made.

As the report builds on the previous reports covering data (Moore, 2020), model methodology (Dolder, 2020) and economic methodology (Muench, 2021) these topics are only summarised briefly in relation to any changes made, with the focus of the report on using and updating the model.

The project was structured around four work packages dealing with biological and fleet data, model development, economic model development and dissemination (Figure 1).

Figure 1: Project work package structure and outputs.

WP1: DATA	WP2: MODEL	WP3: ECONOMICS	WP4: DISSEMINATION
ICES assessment input and output data	FLBEIA model areas 6 and 7	Cost function	ShinyApp
Logbook data (landings and effort)	TAC advice, fleet catch patterns, population models	Coastal impacts: - County - Port - Fleet employment	Full visualisation of outputs
AER data (cost)	Quota allocations (landings, RS, post BX)		Downloadable results
Price data	Tools for sim setup: - TACs - LO - Selectivity - Fleet behaviour		
CLEANED QC/QA DATASET INPUT	CONDITIONED SIM MODEL AND FUNCTIONS	SCENARIO RESULTS INDICATORS	SCENARIO DISSEMINATION
BIOECON R PACKAGE			

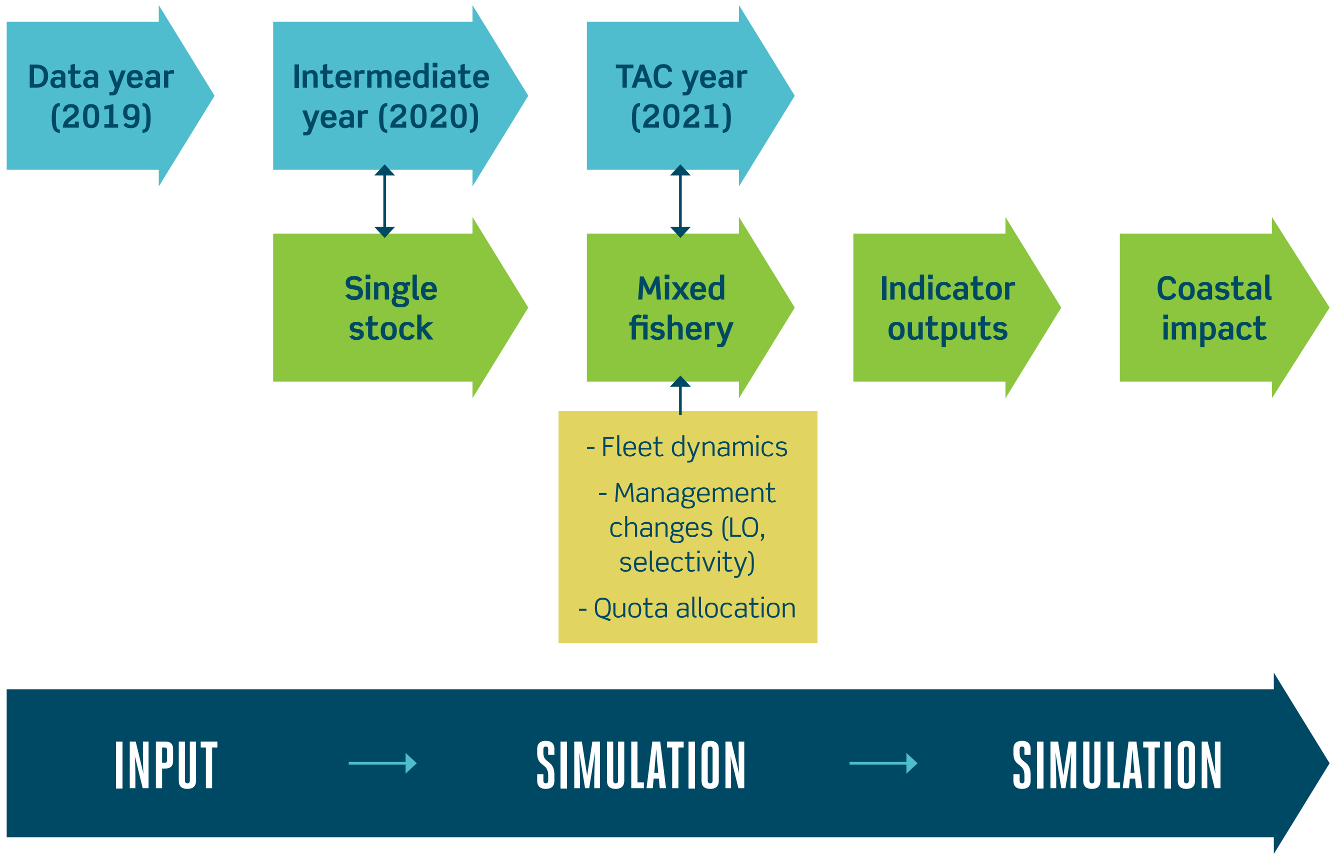
The final model provides a platform to setup and run alternate short-term forecast scenarios of TACs, selectivity and fleet rules to compare the bioeconomic impact on different fleets and stocks exploited by those fleets. Results can be displayed and downloaded from a dedicated Shiny App built for the project.

2. General modelling approach

The model has been developed under the FLBEIA (Fisheries Library Bioeconomic Impact Assessment; Garcia et al., 2017) framework. FLBEIA provides for the implementation of biological and mixed fishery fleet operating models, and an economic impact assessment approach to assess different TAC scenarios and their effect on fleets, métiers and stocks. A downstream economic impact assessment model was implemented using the county and port multiplier approach detailed in Curtin et al. (2018), to assess the impact of TAC changes on different sectors and components of Irish fleets and regions.

The model uses historic data on activity of Irish fleets across different métiers to characterise the fleets' exploitation patterns for different demersal TAC stocks caught in International Council for the Exploration of the Sea (ICES) divisions 6 and 7. This information is used to condition future scenarios that simulate the impact of different assumptions around TAC changes, gear selectivity, landing obligation rules and fleet dynamics. The biological operating model projects forward the dynamics of fish populations in response to the levels of exploitation by the fleets, and the fleet operating model determines catches based on available quotas for the different fleets and mixed fishery interactions (Figure 2). In addition, assumptions were made about the revenue generated from non-quota stocks, pelagic stocks, and non-fishing income so that the full revenue and costs could be considered.

Figure 2: Process map detailing the simulation framework.



New scenarios can be implemented through a series of functions developed in the project that allow interaction with the model using an excel input structure, which then runs userdefined scenarios, summarises the outputs and combines these with previously run scenarios to allow visualisation of the results in a browser-based tool (the Shiny App). Outputs are summarised in terms of changing catches, revenues and downstream impacts on fleet, port and country level profit, employment and gross value added.

3. Data – fleets and stocks

The model was conditioned on historic data covering Irish fleet activity from 2017 – 2019, and the ICES assessments undertaken in 2020, which detail the latest known status on the dynamics of the fish stocks.

Data sources included Irish logbook data on fleet activity (landings and effort), Irish métierlevel sampled catch submitted to ICES InterCatch for the purposes of stock assessments (catch-at-age data and discard information), ICES assessment outputs and assessment forecast inputs (see Moore 2020 for detail).

The final model included data on 10 Irish fleets (Table 1) with the activity of each fleet characterised into métiers by the gear type used (e.g., OTB = otter trawls), mesh-size range (e.g., 70-99mm), target species (e.g., DEF = demersal fish or CRU = crustaceans) and location fishing (e.g., 7a = ICES subdivision 7a, Irish Sea).

Table 1: Final fleet definitions used in the model. *The potting fleet was not included as they do not land any of the quota stocks.

Fleet	Fishing technique	Vessel Length (m)	Description	Fleet name in model
1	TBB	18-40	Beam Trawls	"Beam_trawlers_18<40m"
2	DTS	18-23	Demersal Trawlers	"Otter_trawlers_18<24m"
3	DTS	24-40	Demersal Trawlers	"Otter_trawlers_24<40m"
4	DTS- Freezer	18-23	Freezer Trawlers	"Otter_trawlers_Freezer_18<24m"
5	DTS- Freezer	24-40	Freezer Trawlers	"Otter_trawlers_Freezer_24<40m"
6*	FPO	>12	Polyvalent Potting:	"Pots_>12m"
7	DRB	>12	Specific Scallop Fishery	"Scallopers_>10m"
8	DTS	18-40	Seiners	"Seines_18<40m"
9	TM	All	Pelagic Trawls	"Pelagic_polyvalent_all"
10	PTM	All	Pelagic Trawls	"Pelagic_RSW_all"
None	Undefined	All	All other vessels	None

The model included 47 TAC and Quota stocks (Table 2), in addition to accounting for the revenue of pelagic and non-quota stocks. The stocks that were not explicitly modelled were handled in the following way:

REVENUE PELAGIC STOCKS:	Revenue Pelagic stocks (2019) x Change in TACs (2021:2020) weighted by stock contribution to revenue
REVENUE CRAB, LOBSTER, AND SCALLOP:	Revenue per vessel (average 2017 – 2019) x number of vessels
REVENUE ALL OTHER NON-QUOTA STOCKS (VALUABLE BYCATCH):	Revenue per unit effort (average 2017 – 2019) x scenario effort.

Table 2: Stocks included in the final model.

Stock	Description
Full analytically assessed stocks (14)	
cod.27.6a	West of Scotland cod
cod.27.7e-k	Celtic Sea cod
had.27.7a	Irish Sea haddock
had.27.6b	Rockall haddock
had.27.7b-k	Celtic Sea haddock
hke.27.3a46-8abd	Northern hake
meg.27.7b-k8abd	Celtic Sea and Bay of Biscay megrim
mon.27.78abd	Celtic Sea and Bay of Biscay anglerfish
ple.27.7a	Irish Sea plaice
pok.27.3a46	Northern saithe
sol.27.7a	Irish Sea sole
sol.27.7fg	Celtic Sea sole
whg.27.7a	Irish Sea whiting
whg.27.7b-ce-k	Celtic Sea whiting
Catch only stocks (16)	
Nephrops 6OTH	Nephrops outside of functional units in division 6
Nephrops 7OTH	Nephrops outside of functional units in division 7
Nephrops FU12	Nephrops in Functional Unit 12
Nephrops FU13	Nephrops in Functional Unit 13
Nephrops FU14	Nephrops in Functional Unit 14

Stock	Description
Nephrops FU15	Nephrops in Functional Unit 15
Nephrops FU16	Nephrops in Functional Unit 16
Nephrops FU17	Nephrops in Functional Unit 17
Nephrops FU19	Nephrops in Functional Unit 19
Nephrops FU2021	Nephrops in Functional Unit 20-21
Nephrops FU22	Nephrops in Functional Unit 22
ple.27.7e	Western Channel plaice
ple.27.7fg	Celtic Sea plaice
ple.27.7h-k	Southwest of Ireland Plaice
whg.27.6a	West of Scotland whiting
lez.27.4a6a	Northern megrim
Landings only stocks (17)	
aru.27.5b6a	Faroese and West of Scotland greater silver smelt
aru.27.6b7-1012	Southern greater silver smelt
anf.27.3a46	Northern anglerfish
cod.27.6b	Rockall cod
cod.27.7a	Irish sea cod
gfb.27.nea	Northeast Atlantic greater forkbeard
ghl.27.561214	Northeast Atlantic Greenland halibut
lez.27.6b	Rockall megrim
lin.27.3a4a6-91214	Northeast Atlantic ling
ple.27.7bc	West of Ireland plaice
pol.27.67	Celtic Seas pollack
srx.67	Celtic Seas skates and rays (complex)
sol.27.7bc	West of Ireland sole
sol.27.7h-k	Southwest of Ireland sole
usk.27.3a45b6a7-912b	Northeast Atlantic tusk
usk.27.6b	Rockall tusk
whg.27.6b	Rockall whiting

4. Conditioning – biological, advice and fleet models

The model was conditioned on historic data as described in Dolder (2020). The main assumptions in the modelling condition are set out in this section, and options available in running scenarios are described, where applicable.

4.1 Biological models: population growth

The biological models reflect the complexity of the assessment models available (Table 2). In general, population growth models are only available for those stocks with a full analytical assessment, and the other stocks included are assumed to have a constant biomass from the data years (average 2017-2019) to the simulation year (2021). This results in an assumption that catch rates for those stocks are the same as in recently observed historic data for each fleet and métier. Fully analytical stocks are projected forwards based on an age-structure population growth model. Within this model, the following conditioning assumptions are made, which are similar to those made for producing annual catch advice (Table 3).

Table 3: Biological model conditioning for analytical stocks.

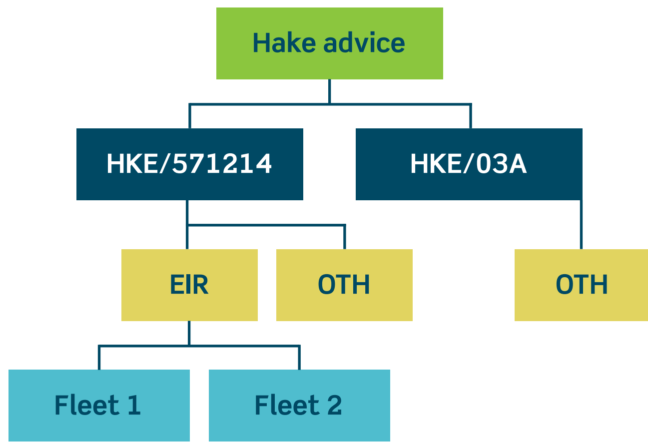
BIOLOGICAL PARAMETERS: NATURAL MORTALITY, STOCK WEIGHTS, MATURITY.	AVERAGE 2017 – 2019 (HISTORICAL DATA).
Recruitment	Value used in ICES short-term forecast.
Intermediate year assumption	Catch value used in ICES short-term forecast.

4.2 Advice model: TACs and Quotas

The TACs are an input to the model scenario, with default values provided based on ICES advice for 2021. It is set so that advice relates to the total catch of the stock, not just the landed component. These values are expected to be changed to run and compare alternative scenarios and detailed on how to do this for simulations are provided in Section 6.

Quotas are determined through a two-step process (Figure 3); first split to Irish fleets according to the relative stability share (Figure 4; which itself takes account of the split between the UK and EU in 2021, where applicable) and secondly, among Irish fleets according to recent landings.

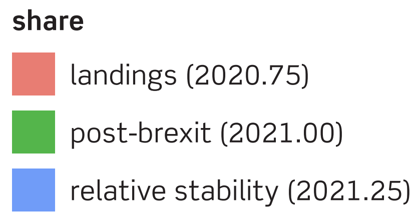
Figure 3: Diagrammatic representation of allocation of the TAC through a 2 stage process.

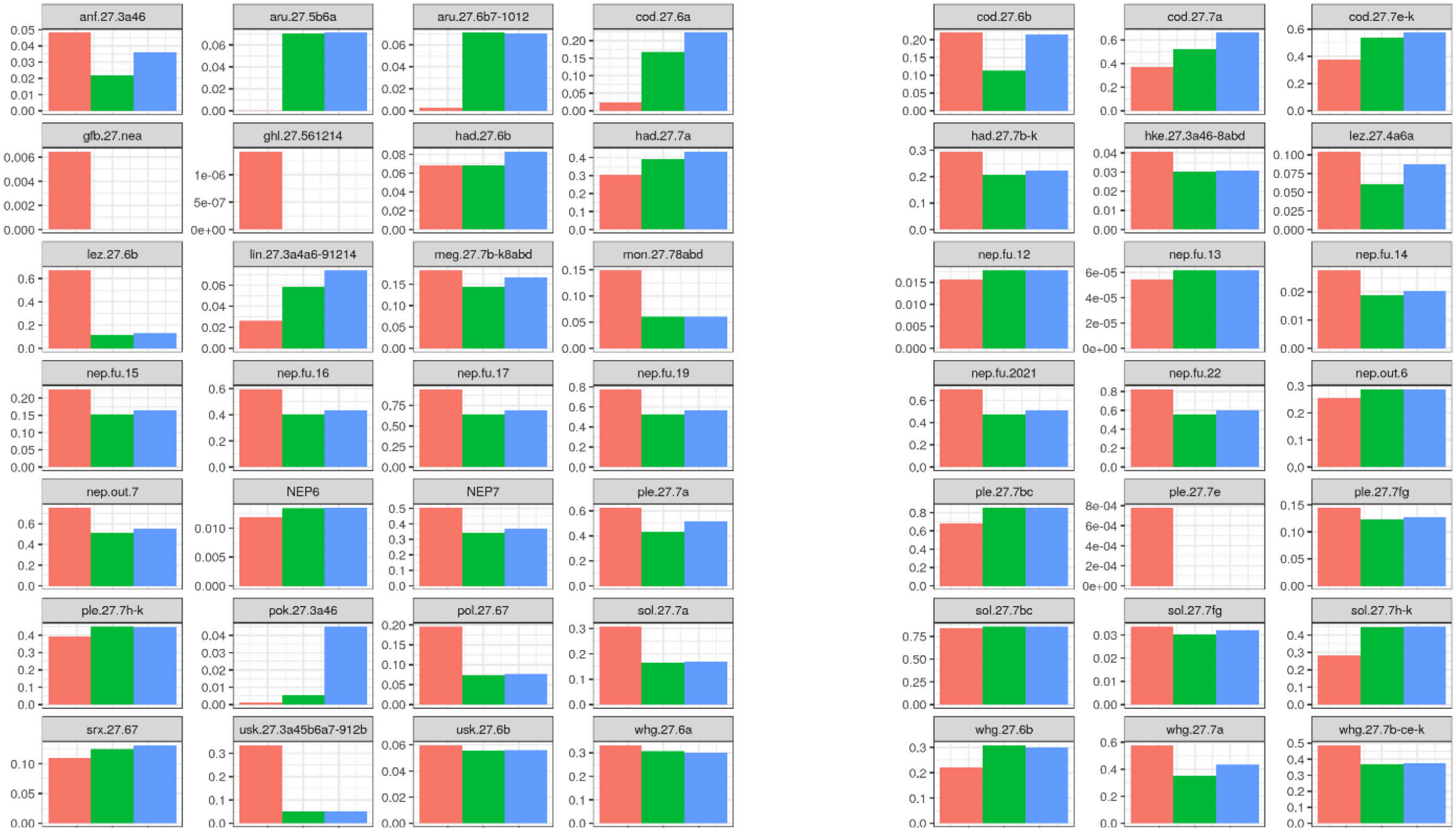


In some cases, there can be significant differences between the initial allocation of quota to Ireland and the final quota due to international swaps. To account for this, the model has been setup to allow the user to specify an additional fraction of the TAC that is assigned to Irish fleets (Section 6).

Figure 4: Share of quotas for Ireland based on landings (red), relative stability in 2020 (RS, blue) and in 2021 (green, post-brexit).

Comparison Quota Share for Irish Fleets





4.3 Fleet models

There are several choices that relate to how to simulate the fleet and métier-based activity. These are subjective choices, and standard practice has been followed for implementation of the model (Table 4).

Table 4: Fleet conditioning assumptions in the model.

ISSUE	ASSUMPTION
Catchability: Catch rate per unit of effort.	Average 2017 - 2019. Fleet, métier, stock and, where applicable, age- specific.
Discard fraction: Proportion of stock discarded.	Average 2017 - 2019. Fleet, métier, stock and, where applicable, age- specific.
Métier effort share: For a given fleet, proportion of time fishing in each métier.	Average 2017 - 2019, unless under 'MaxProfit' scenario where dynamically calculated.
Catch restriction: For a given fleet, what determines the total amount of fishing effort.	Scenario dependent. In a 'min' scenario the first quota reached determines the overall effort, in the 'max' scenario the last quota reached (or capacity limit) determines the overall effort. In each case, restriction is based on the landed component of the catch.

4.4 Landing obligation rules

The model has been conditioned with exemptions for certain fleet and stock combinations based on the delegated act for landing obligation exemptions in place for the Celtic Sea from 2021-2023. In some cases, the exemption criteria are very specific (Table 5) and so an approximation has been implemented based on the fleet definition. In all cases it is possible to change the assumption using the 'LandObl_minimis_p' setting in the scenario setup file (section 6), to specify the proportion of each stock for each fleet that can be exempt from the landings quota restriction.

Table 5: Summary of the landing obligation rules for de minimis and high survivability in place in the Celtic Seas for 2021--2023 (from COMMISSION DELEGATED REGULATION (EU) 2020/2015).

Species	Gears	Areas	Type	Percentage limit	Implementable?
Nephrops	Pots	6 and 7	Survivability	100	Yes
Nephrops	trawl gears > 100mm	6 and 7	Survivability	100	Yes
Nephrops	trawl gears 70-99mm with selectivity measure	6 and 7	Survivability	100	No
Nephrops	trawl gears 80 - 110mm within 12 miles of coast	6a	Survivability	100	No
Skates and Rays (Rajiformes)	any gears	6 and 7	Survivability	100	Yes
Plaice	trammel nets	7d-g	Survivability	100	Yes
Plaice	Otter trawls	7d-g	Survivability	100	Yes
Plaice	Beam trawls < 221kw with flip-up rope	7a-g	Survivability	100	No
Plaice	Beam trawls < 221kw, < 24m, within 12nm of the coast and tow duration of < 90min	7a-g	Survivability	100	No
Plaice	Danish seine	7d	Survivability	100	Yes
all species	pots, traps and creels	5, 6 and 7	Survivability	100	Yes
mackerel	purse seine	6	Survivability	100	Yes
herring	purse seine with specific conditions	6	Survivability	100	No
whiting	bottom trawls and seines, pelagic trawls, beam trawls 80-120mm	7b-k	de minimis	5	Yes
Sole	trammel and gill nets	7d-g	de minimis	3	Yes
Sole	beam trawls with flemish panel	7d-g	de minimis	3	No
haddock	otter trawls and seines > 100mm and no more than 30% Nephrops	7bc,e-k	de minimis	5	Possibly
haddock	all gears > 80mm and >30% Nephrops	7bc,e-k	de minimis	5	Possibly
haddock	beam trawls >80mm with flemish panel	7bc,e-k	de minimis	5	No
all species	demersal fishery targeting brown shrimp with beam trawls >31mm	7a	de minimis	0.15	No
boarfish	bottom trawls	7bc, f-k	de minimis	0.5	Yes

Species	Gears	Areas	Type	Percentage limit	Implementable?
megrim <MCRS	beam trawls 80-119, bottom trawls in specific areas and catch comp rules	7	de minimis	4	No
Sole	beam trawls 80-119 with flemish panel	7a	de minimis	3	No
greater silver smelt	bottom trawls >100mm	5b, 6	de minimis	0.6	Yes
horse mackerel	bottom trawls, seines and beam trawls	6, 7b-k	de minimis	3	Yes
mackerel	bottom trawls, seines and beam trawls	6, 7b-k	de minimis	3	Yes
haddock < MCRS	bottom trawls <120mm in WoS Nephrops fishery with highly selectivty gear	6a	de minimis	3	No
blue whiting	industrial pealgic trawl fishery	5b,6,7	de minimis	5	No
albacore tuna	midwater trawl	7	de minimis	5	Yes
mackerel	midwater trawl < 25m	7d	de minimis	1	No
horse mackerel	midwater trawl < 25m	7d	de minimis	1	No
herring	midwater trawl < 25m	7d	de minimis	1	No

5. Conditioning – Economic models

The following section describes the changes to conditioning of the economic model indicators since Muench (2021).

5.1 Profit Function

The profit was defined as net profit *π* which is calculated by fleet *f* as:

$$\pi_f = \sum_m \sum_{st} [(L_{f,m,st(i)} \cdot p_{f,m,st(i)} + OSInc_{f,m}) \cdot (1 - CS_{f,m})] - VaC_{f,m} \cdot E_{f,m} + (NFInc_{f,v} - FxC_{f,v}) \cdot nv_f$$

constrained by $E_f \leq K_f$

where $OSInc_{f,m} = (PInc_{f,m,v,st(p)} \cdot (\omega_{f,st(p)} \cdot \Delta TAC_{st(p)}) + CLInc_{f,m,v}) \cdot nv_f + (OthInc_{f,m} \cdot E_{f,m})$

The net profit is estimated as Landings *L* (tonnes) of stocks *i…n* included in the model and other stocks income *OSInc* in euros reduced by crew shares *CS* per unit landings, plus nonfishery income *NFInc* (euros), minus variable costs *VaC* (euros) per unit effort *E* (KWSeadays) and the fixed cost *FxC* (euros) for the number of vessels *nv* in the fleet *f*. The value of landings for stocks in the model was estimated by multiplying landings of stock *st(i)* with price *p(i)* (euro per tonne) and summing across all stocks and métiers. The other stock income *OSInc* is the sum of *PInc* pelagic stock income adjusted for *ΔTAC* change in TAC, weighted *w* by the proportion of income each pelagic stock *st(p)* contributes for the fleet, plus a fixed income *CLInc* crab and lobster income, and a variable income for all *OthInc* other stocks.

To condition the stock price in FLBEIA, the landings (in tonnes) as recorded in the logbook provided by Marine Institute by season (quarter) for the years 2017-2019 were converted to landings values. To this purpose, BIM provided prices as recorded in sales notes by stock, harvest area (i.e., ICES subdivision) and gear group (pelagic, beam, gillnet, seine, trawl, and lines, all) for the years 2017-2019. These sales note prices were linked with the respective logbook data provided by Marine Institute. However, while the landings recorded in the logbooks were by season, sales note prices were constant over the year, hence no seasonal variations in the price data were accounted for in deriving total value. Moreover, as only an average price for each stock and year was provided, quality or size of the catch was not further accounted for. *Nephrops*, irrespective of functional units, were assumed to have generated the same price in the respective year, though these do differ by ICES subdivision which in some cases takes account of different Functional Unit values.

Approximately 43% of the logbook-recorded landings was assigned a price by harvest area and gear. In the case the landings record was not in the list of sales prices, the average price for the stock harvested in the area irrespective of gear was assigned to this record. This still left 17.5% of the landing records without assigned price. For these records, an average price for stock by harvest area and gear was used to derive catch values. Using average sales note prices led unsurprisingly to differences in the landing values compared to the one recorded in the logbooks. For most of the stocks in the model using sales note prices led to higher landing values than recorded in the logbook. Only for some stocks, such as sole in the western English Channel (27.7e) and Irish Sea herring (27.iris), the sales note values were lower than the logbook recorded values. Although sales notes and logbooks provided different values per tonne of catch, for most stocks they provide a similar picture with respect to trends of derived income from harvesting these stocks by the Irish fleet.

BIM provided data on costs for the years 2016-2019 which were used to estimate the variable *VaC* and fixed costs *FxC*. This data provided detailed cost breakdown for vessels which were assigned to fleet segments by the Marine Institute, based on the logbook records of the respective vessel. BIM also provided the annual effort of the vessel (in kWSeaDay). The variable costs were defined as the average annual cost of repair [totRepairs], energy [totEnergyCost] and other variable costs [totVarOtherVariable, totVarProvisions, totVarIce, totVarfilters, totVarBait, totVarDues] for each kWSeaDay of the vessels assigned into the respective fleet. Based on effort share of the fleet in each metier, the variable cost per unit effort was allocated into the respective metiers. While the VaC for all fleets defined in the project were related to the effort, for beam trawlers – as agreed with BIM, the VaC were related to the landing values instead of effort. The crew share CS was estimated as average annual fraction of crew wages [totCrewWage] of total reported landings income [totLandgInc] of the vessels in the fleet. The average crew share of each fleet was assigned by landings share to the respective métiers.

Fixed costs *FxC* were calculated for the fleet as sum of non-variable cost [totNoVarOtherFixed, totNoVarLegalFees, totNoVarAccountancy, totNoVarInsurance], cost of capital [totNoVarLoanInterest] and depreciation costs [totDepCost]. While the total *FxC* were used to estimate the net profit, only the average non-variable cost enters the *FxC* to generate gross profits for each fleet.

To account for non-fisheries related income *NFInc*, the average annual income from other activities [totOtherInc] was added. Thus, it was assumed that there are no substitution effects between the incomes from the different fisheries and non-fisheries related income. As these numbers were based on the average values in the sample, the numbers were raised to fleet level by multiplying the number of vessels in the fleet *nv*.

The cost data were provided by BIM for the years 2016-2019. FLBEIA was conditioned on the years 2017-2019. Missing value for the year 2019 were replaced by values from 2018. It was further assumed that the prices and unit cost are constant over time. As such the difference in net profit between the different future management simulations (Dolder, 2020) are caused only by changes in landings *L* and effort *E* for stocks which were assessed in the fleet model. The effort and landings for non-assessed stock was either limited by the respective total allowable catch for this stock (e.g., pelagic species), kept constant (e.g., shellfish) or variable with effort (all other stocks). Effort of the fleet is assumed further to be restricted by the capacity of the fleet *K* (maximum kwSeaDays of the fleet) which also remains constant in the simulated years (i.e., new entrances are not considered).

5.2 Economic Impact on coastal areas and areas of origin

5.2.1. Employment by fleet

Based on the data provided by BIM, the average number of jobs [Tot.Job] per unit landing value generated by the vessels in the fleet segment, was used to estimate the total number of jobs by fleet. The difference between the total number of jobs by year (STECF 2020) and the number of jobs assigned to the fleet in this project, was assigned to the fleet "others".

5.2.2. Employment and gross value added by port

The total landing value was translated into the number of jobs and the gross value added (GVA) for each port region by employing the number of jobs and GVA generated in 2018 **(The Economic Impact of the Seafood Sector,** Fig 6), in relation to the total value of landings in the port in 2018, as reported in the logbook data provided by MI.

Based on the logbook data provided by MI, the landing share of each stock (modelled and non-modelled) by metier and fleet for each year in each of the 10 port regions of interest was calculated. Under the assumption that this landing share remains constant for the simulated year, the changes in landing values for each port region are estimated for each scenario.

The indirect and induced impact of the changes in landing values by port for each scenario were estimated by using the multiplier as provided by BIM.

The difference to the total number of jobs reported in STECF (2018,2019,2020) and the number of jobs estimated for the 10 port regions of interests, were summarised in the category "others".

5.2.3. Employment and gross value added by region

Based on the logbook data provided by MI, the landing share of each stock (modelled and non-modelled) by metier and fleet for each year in each of the 14 regions of vessel registration of interest was calculated. The number of total employment and GVA as reported in STECF (2018,2019,2020) were split by the estimated landing values by region, based on the assumption of constant landings value share of fleet/metier in the respective counties of vessel registration.

The indirect and induced impact of the changes in landing values by home region of the fleet for each scenario were estimated by using the multiplier as provided by BIM.

The difference to the total number of jobs reported in STECF (2018,2019,2020) and the number of jobs estimated for the 14 regions of interests, were summarised in the category "others".

6. R package 'BioEcon'

The conditioned model (data and code) has been compiled into an R package (BioEcon) for convenience to allow straight forward set up of new scenarios. There are several functions which facilitate this process, which are contained within the package.

A 'vignette' example scenario set up file has been provided within the package (doc >

Setting_up_scenarios.html) and each function has an associated helpful, which can be accessed via the usual R help command, e.g., 'change_q'.

In addition, the helpfile has been compiled as a PDF which has been included within the same folder as the R package.

6.1. Software installation

Instructions for installing the required R packages to run the model are included in the 'R_Package/Install_packages.R' script provided. Once those packages are installed, the BioEcon package itself has been provided as a zip file (R_Package/BioEcon_0.0.0.9000.tar.gz). To install in RStudio you go to the menu system Tools > Install packages > Browse and locate the zip file on your computer. Once selected, it should install and be available to use. The software has been tested and runs on R version >= 4.0.0.

6.2. Running a scenario

The following details the steps required to setup and run a new scenario based on different levels of TAC, different fleet assumptions and changes to catchability for some fleet and métier combinations (simulating a gear-change that effects catch rate of a given stock).

6.2.1. Defining the folder structure

The first step to run a scenario is to define where the files will be stored on your computer. This is done via the following command, for example, to store results in the Documents/results/ folder of your computer:

```
library(BioEcon)

make_dir_structure(wd = "C:/Documents/results/")
```

This creates the following five subdirectories:

scenario_inputs	Where the .xslx files are edited to set up a scenario.
scenario_outputs	Where the FLBEIA objects for the scenarios are stored.
scenario_runs	Where the outputs FLBEIA objects from the scenarios are saved.
scenario_summary	Where the scenario summary files are produced
app_inputs	Where the input files for the Shiny App (section 7) are stored.

Note that this function needs to be run only once, and not each time you set up a scenario. The function also sets your working directory in R to the same location, so it is important to go back to this folder for each scenario you run.

6.2.2. Defining the scenario

For each scenario, the user defines a scenario with a short and long name through the following function.

```
create_scenario_template(name = "shortname", description = "A longer description of the scenario")
```

This function does two things:

i. It copies the base setup for the scenarios and creates a new file in the 'scenario_inputs' folder with the same name.

ii. It creates a file which is read into the app with the shortname and description of the scenario.

It is important therefore that this name and description is informative. Please note that the name cannot have any spaces or special characters, but words could be separated by e.g., underscore.

Alternatively, if you want to set up a scenario based on a previously generated scenario (e.g., where TACs are iterated from a previous version), you can provide an alternative template to the scenario function. For example,

```
create_scenario_template(name = "shortname2", description = "A longer description of this new scenario", template = "shortname")
```

Next you need to go to the folder "scenario_inputs" and edit the correspondingly named xlsx file to the desired set up for the scenario. Instructions for changing the file are contained on the README tab, briefly the tabs and their use are:

Tab	Use
fleets_restriction	This sets for each fleet the fleet effort model used in the simulations.
stock_restr	This sets for each fleet the stocks which can limit / choke the fleet.
TACs	This defines the overall TAC level for the stock, and the proportion of the TAC that is additionally added to the Irish quota to take account of international swaps.
LandObl	This sets for each fleet if the landing obligation applies to the fleet
LandObl_minimis	This sets for each fleet if *de minimis* discarding can occur.
LandObl_minimis_p	This sets for each fleet and stock the level of *de minimis* discarding that can occur.
LandObl_yearTransfer	This sets for each fleet if transfer of quota to one year to the next can occur.
LandObl_yearTransfer_p	This sets for each fleet and stock the level of transfer that can occur.
LandObl_discount_yrtransfer	This sets for each fleet and stock the proportion of deduction from the quota under a transfer (i.e., penalty for transfer).

It is likely that only the first three of these tabs will need to be changed to run a scenario.

One these settings have been changed to set up a scenario, for each scenario wanting to be run, it is simply a case of updating the FLBEIA input objects with the following function:

```
update_scenario(name =
"shortname")
```

This function changes edits all the relevant R objects used to run an FLBEIA scenario and saves them for later use.

6.2.3. Implementing selectivity changes

The final step to set up a scenario is to choose whether to implement a change in selectivity / catchability for one or more fleet and métier combinations. A helper function has been provided for this purpose, which can either take a single fleet, métier and stock combination or wild card match against all métiers with a given criteria.

To run without any selectivity changes requires an empty call to the function:

```
change_q(name =
"shortname")
```

To change the catchability of a given fleet and métier for a stock *relative to the historic values* across all ages for the stock requires the following inputs:

```
change_q(name =
"shortname", fleet = "Otter_
trawlers_18<24m", metier =
"OTB_DEF_100-119_27.7.e-k",
stk = "cod.27.7e-k", ages =
"all", rel_change = 0.5)
```

To change for specific ages, you can pass a vector of ages instead, e.g., 1:2 for ages 1 and 2.

Changing the catchability for all metiers meeting a criterion across fleets can be done with the following inputs:

```
change_q(name = "shortname",
fleet = "all", metier = "OTB_DEF
", stk = "cod.27.7ek",
ages = "all", rel_change = 0.5)
```

6.2.4. Running the scenarios

Once this is done, you can sequentially run all scenarios that have been setup through calling the following function:

```
run_scenarios()
```

This runs any scenarios that have not already been run and does not repeat running of the scenarios that are complete.

6.2.5. Updating the summary files

Similarly, to update the summary output files as csv and inputs for the app requires another empty function call:

```
extract_summary_results()
```

The first time this is run it creates the following nine files in the 'scenario_summary' folder:

00_fleet_summary.csv	Fleet level summary indicators.
01_fleet_stock_summary.csv	Detailed fleet and stock indicators.
02_metier_summary.csv	Métier level summary indicators.
03_metier_stock_summary.csv	Detailed output for each métier and stock.
04_biological_summary.csv	Stock level summary indicators.
05_advice_summary.csv	Summary of advice for each fleet and stock.
06_coastal_impact_county.csv	Summary indicators for coastal impacts at the county level.
07_coastal_impact_port.csv	Summary indicators for coastal impacts at the port level.
08_employment_fleet.csv	Summary fleet level employment indicators.

Successive calls to this function append any new scenario results to the files.

The file "ShinyApp_inputs.xlsx provides a description of the variables output to each of the files.

6.2.6. Launching the app

Finally, to run the visualisation app there are two additional functions, to create the files and launch the app in the browser.

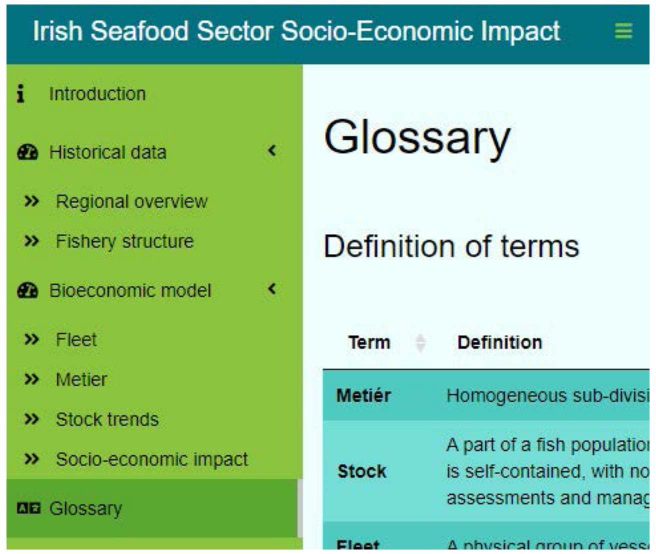
```
create_files_for_app()
run_the_app()
```

7. The visualisation app

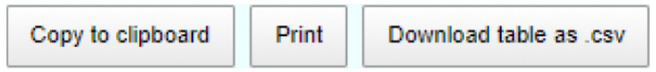
A browser-based application was be developed in RShiny to disseminate the results of this project. This application was designed and built to be accessible by non-experts, but also as an interactive decision tool which enables users to explore the outputs of the simulations and to download and use the final results.

7.1. App set up and functioning

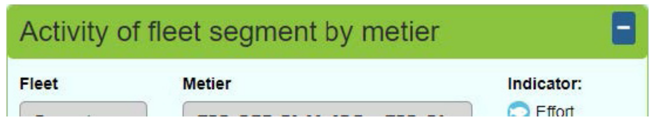
The app itself can be set up and run using two convenience functions build into the project BioEcon package. These functions allow the user to easily merge the required data [BioEcon::create_files_for_app()] and run app [BioEcon::run_the_app()]. Explanations on how to run these functions can be found in the vignette of the package. The layout of the app is broken down into three main sections: introduction, historical data and bioeconomic model results. Below we will discuss each section and its structure. All terminology used in the app is defined in the glossary section of the app.



Throughout the app there is the functionality to filter and download data and tables as CSV files, and to download charts as PNG files. Examples:



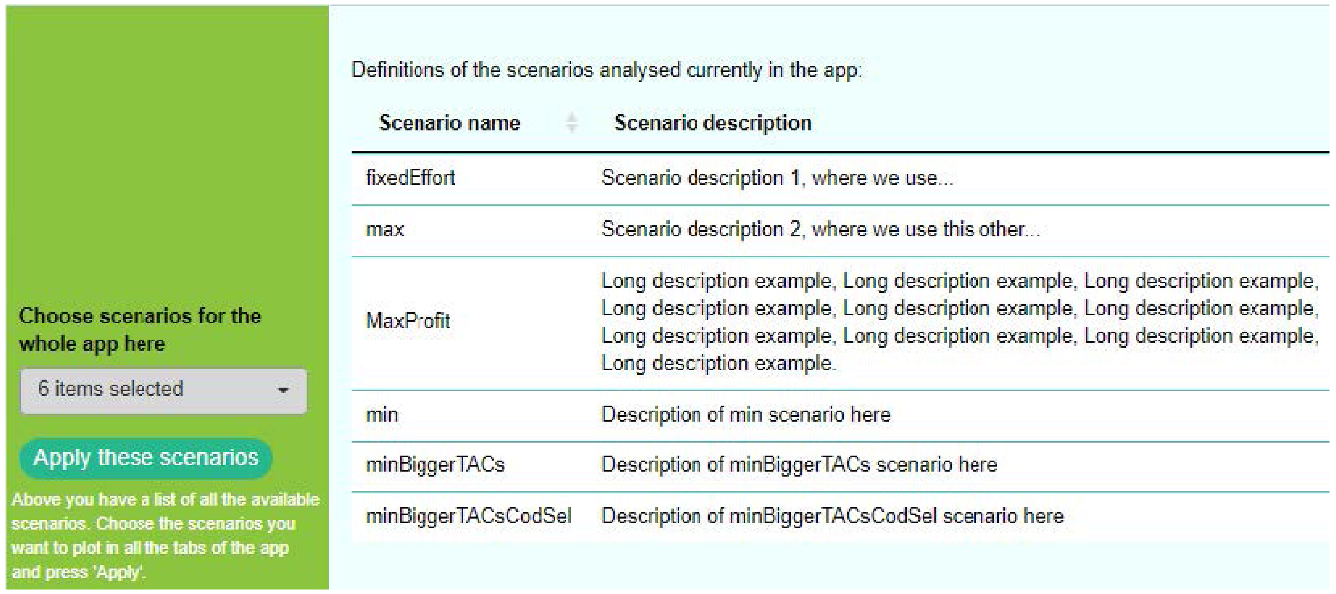
To help on an easier use and visualization of the app, there are multiple collapsible boxes: click on the and to collapse and expand these boxes. Example:



7.2. App Structure

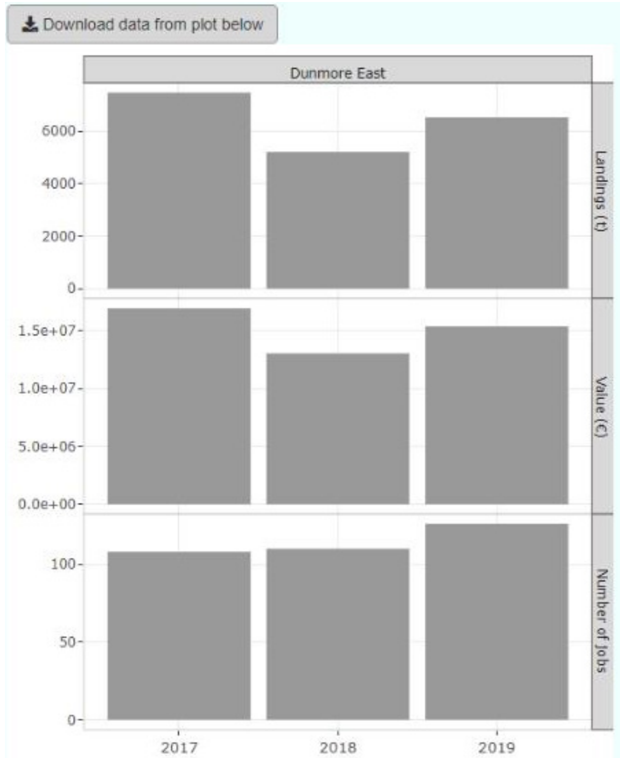
7.2.1. Introduction

The opening page of the app provides an introductory summary of the project and its aims. This page includes a full description of the scenarios presented in the app and allows the user to select which scenarios they would like to view as they explore the outputs of this project.



7.2.2. Historical data

The *'Historical data'* tab provides a summary of trends in the Irish fleet over a recent threeyear period (2017-2019). This data forms the basis of how the model is parameterised but also provides the app user with some context in which to interpret the final results of the simulations. These trends are described in terms of landings (tonnes), value (euros) and employment (numbers of jobs). The 'Regional overview' tab provide this summary in the context of the 10 major Irish ports: Castletownbere, Clogherhead, Dingle, Dunmore East, Greencastle, Howth, Killybegs, Kilmore Quay, Ros a' Mhíl and Union Hall.



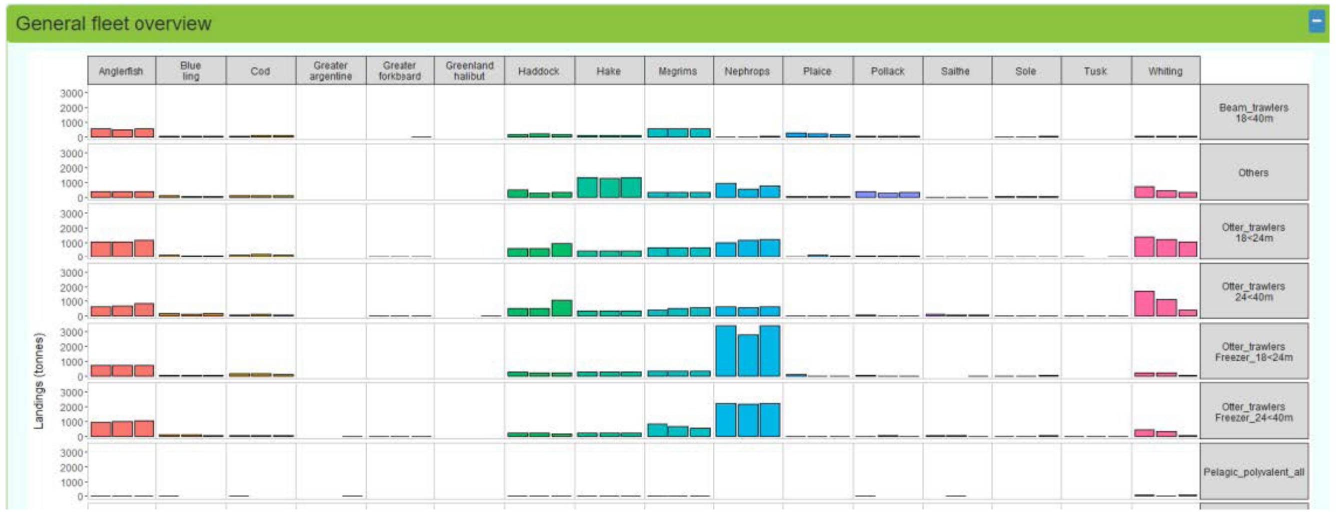
The table below contains data from 2019 for the main Irish ports. Select one row to display detailed plot by year on the right side.

Copy to clipboard | Print | Download table as .csv

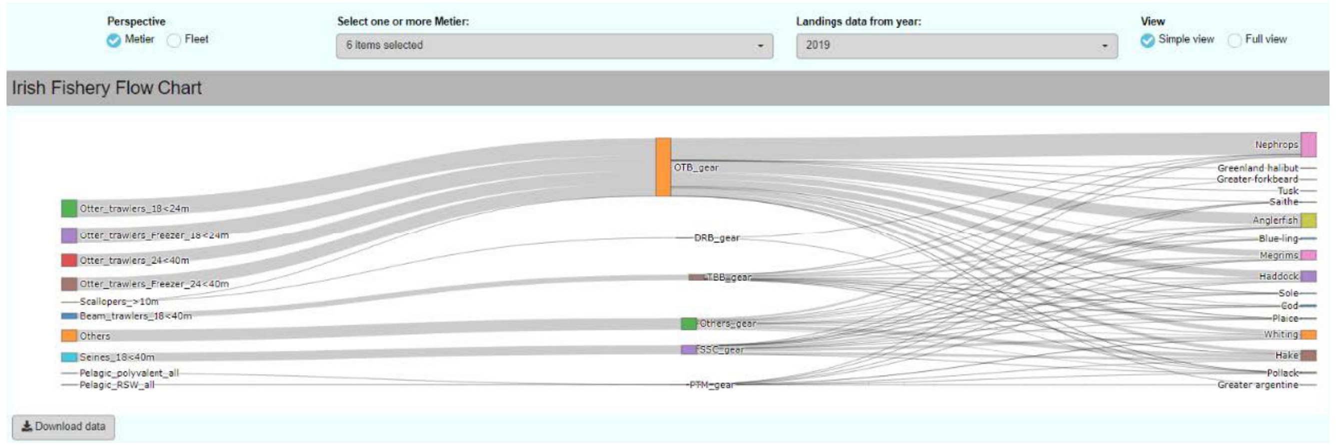
Search:

	Port	Landings (t)	Value (€)	Number of jobs
1	Killybegs	125,243	89,064,318	431
2	Castletownbere	11,716	30,179,303	600
3	Kilmore Quay	3,777	18,863,362	246
4	Dunmore East	6,534	15,385,821	126
5	Union Hall	2,989	11,915,271	160

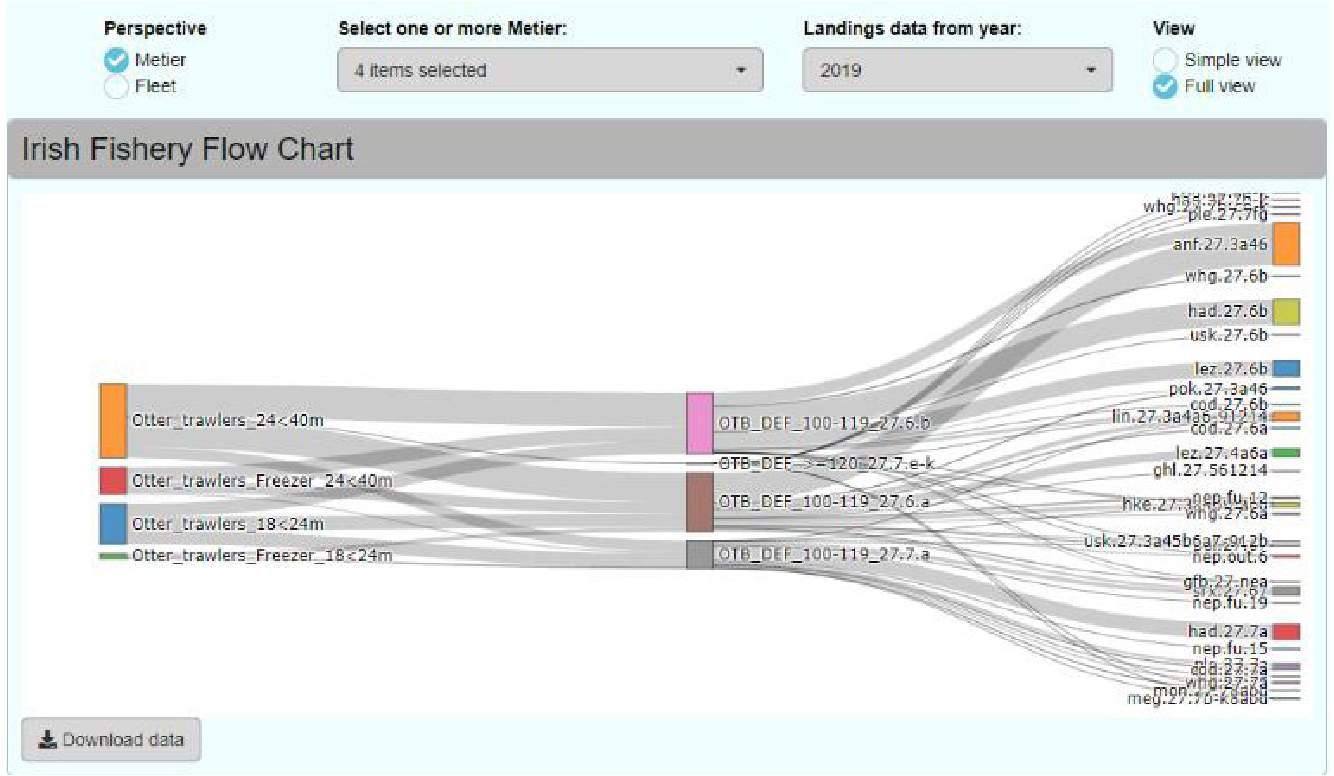
Within the *'Fishery structure'* tab the historical trend in Irish fishery is described at a more disaggregated level, providing important detail on the species, stock and fleet specific information. The 'general fleet overview' presents the main species caught by the fleets identified within this project.



The preceding section labelled *'Flow diagram of fleet segment, fishing metier and fish stock caught'*, gives more detail to these trends in landings, allowing the user to explore the complex mixed fisheries outcomes of the behaviour (métier) executed by fleets. The *'simple view'* selection on the right hand side of this plot provides this landings information in terms of simple gear groupings (e.g. OTB) and species (e.g. *Nephrops*).



However, more detailed information can be visualised by selecting *'Full view'*. This will provide the user with a detailed visual tool to explore the mixed fisheries outcomes of specific fishing behaviours down to the level of gear, target assemblage, mesh size range in project defined groupings of ICES Divisions (e.g. OTB_DEF_100_119_27.7.a) in terms of fish stocks. Métiers and fleets can be added or removed from the plot, and historical year can be selected, in order to enable a user defined experience to explore these historical trends.



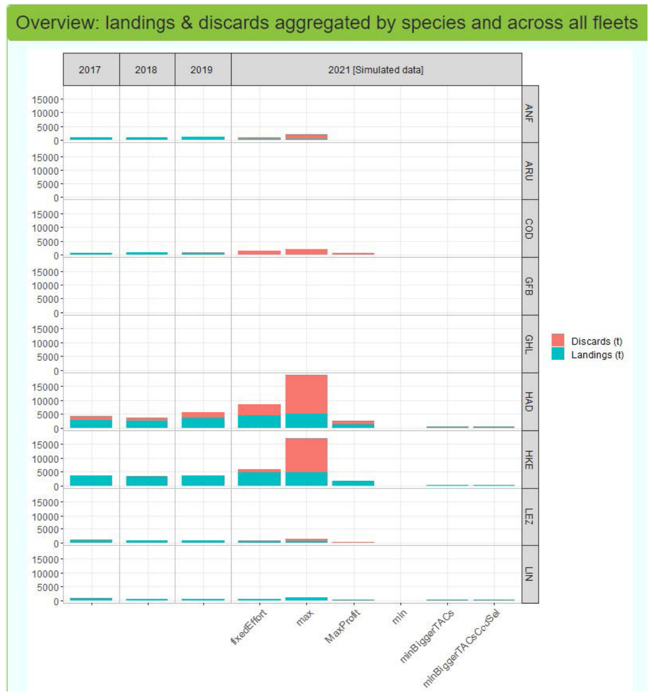
7.2.3. Bioeconomic Model

The results of the scenarios modelled are presented under the *'Bioeconomic model'* section. Given the complexity of these results, these findings have been broken down into four subject areas: fleet, métier, stock trends and socio-economic impact.

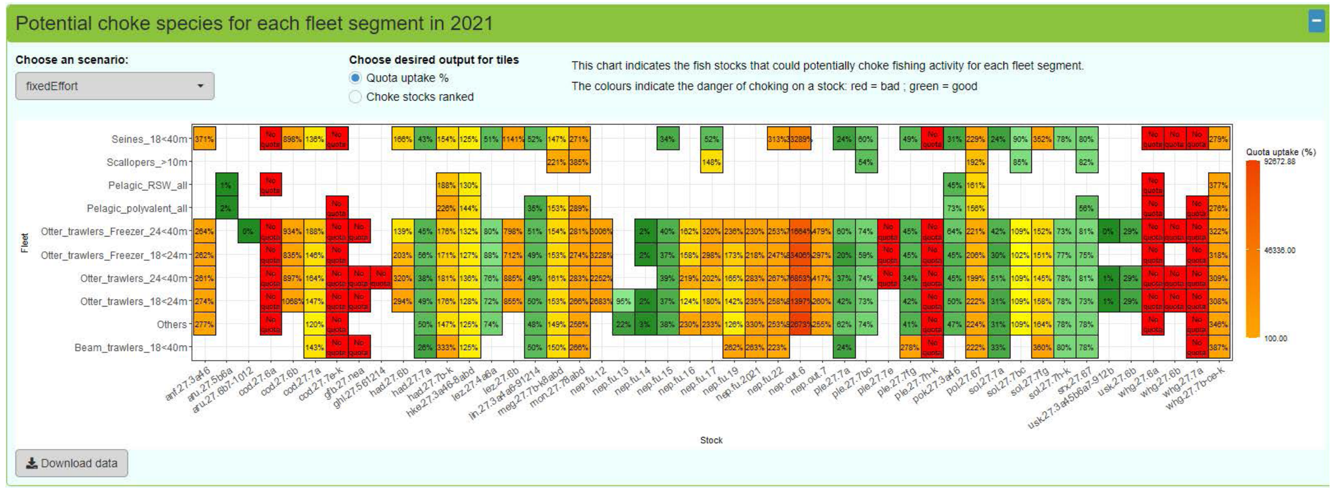
7.2.4. Fleet

The top of the *'Fleet'* tab provides a detailed overview of the species caught by fleets in terms of total landings and discards (tonnes). Historic fishing patterns and the projected catches under each of the scenarios simulated in this model are presented to allow effective comparison.

These results of the projected scenarios can be explored in more detail in the proceeding section *'Landings & discards, catch and effort by fleet and stock'*, where the fleet and stock specific outcomes of each scenario can be explored in terms of landings, discards, catch and effort.



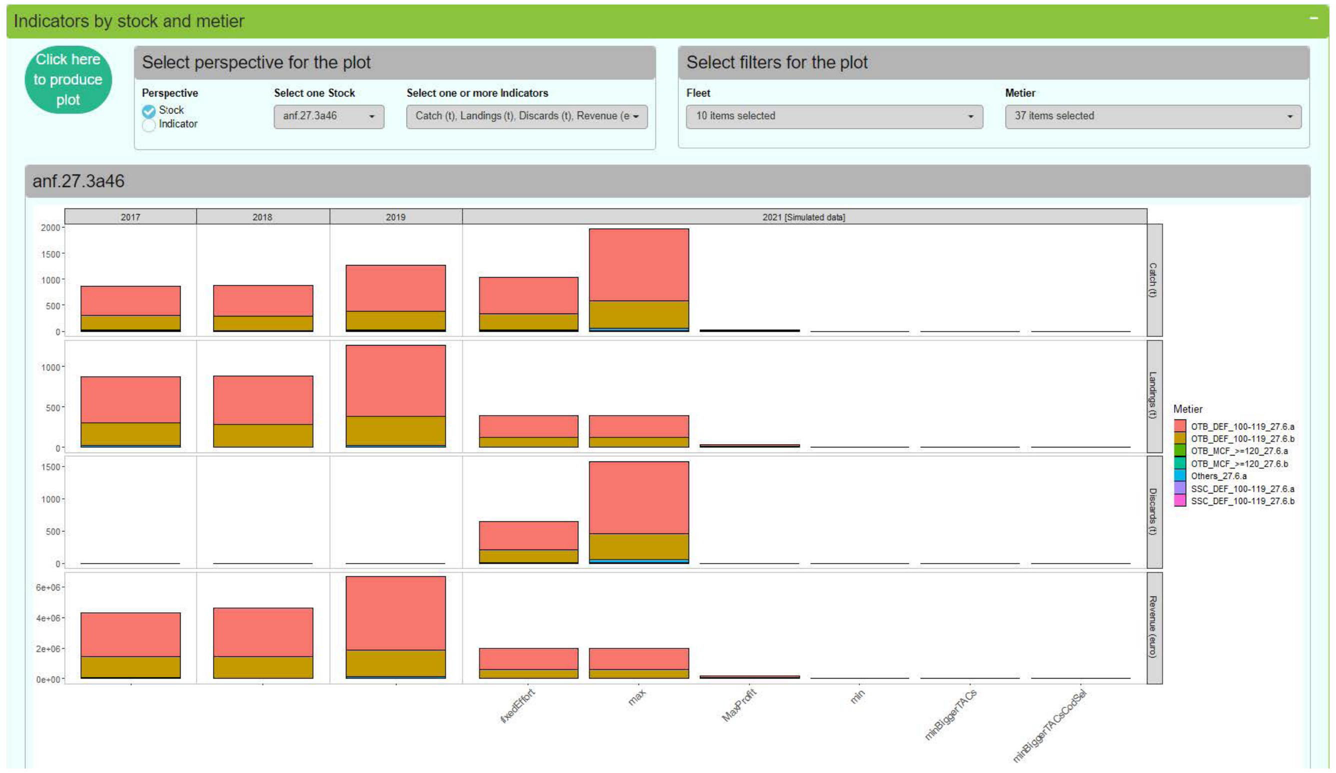
Finally, the implications of changes in effort and TAC set out under each scenario is outlined in the section on *'Potential choke species for each fleet segment in 2021'*. This plot allows the user to identify potential choke stocks for each fleet segment under each scenario projected. The colours indicate the danger of a fleet choking on a stock (red = bad and green = good) and the outcomes are presented in terms of quota uptake or choke species ranking. These plots will provide useful decision tools for managers and users of the advice.



7.2.5. Métier

Métiers describe fisher behaviour in terms of gear and mesh size, and is a measure of fisher intention which is defined in the target assemblage, or dominate species group landed on a trip. Although a vessel can only belong to one fleet, it can display many behaviours within a year, this is particularly true of the Irish fishery which displays high polyvalence throughout the year. Therefore, this *'Metier'* tab provides valuable insight into the complex mixed fisheries outcomes that can result from each behaviour. The *'Metier'* tab begins with a detailed overview of the effort share (kwDays) and gross value (euros) of métiers executed by each fleet.

A more detailed description of the trends by metiers is available in the section marked *'Indicators by stock and métier'*. This section allows the user to select the stock, fleets and metiers of interest. Once selected the user must click the green button on the top left corner of the plot to produce the plots.

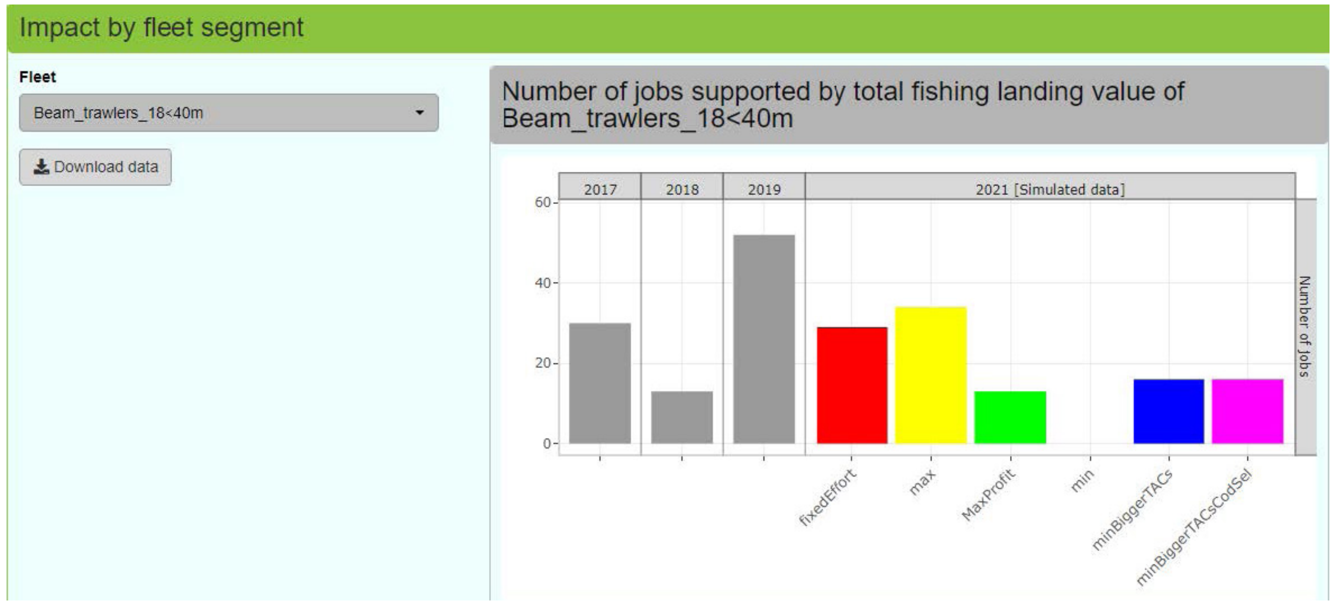


7.2.6. Stock status

The *'Stock status'* tab provides important information on trends in fishing pressure (f), spawning stock biomass (SSB) and recruitment for each stock. For category 1 stocks, where a full analytical assessment is available, the biological reference points in relation to maximum sustainable yield (MSY) is also presented. This enables the user to better understand the implications of scenarios in relation to the current stock status.

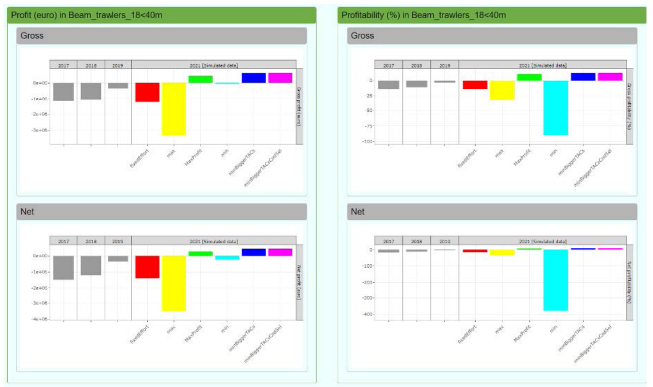
7.2.7. Socio-economic impact

Within the final tab the *'Socio-economic impact'* of the modelled scenarios is compared to the historical data. The top of the tab provides an overview of the number of jobs supported by this fleet segment.



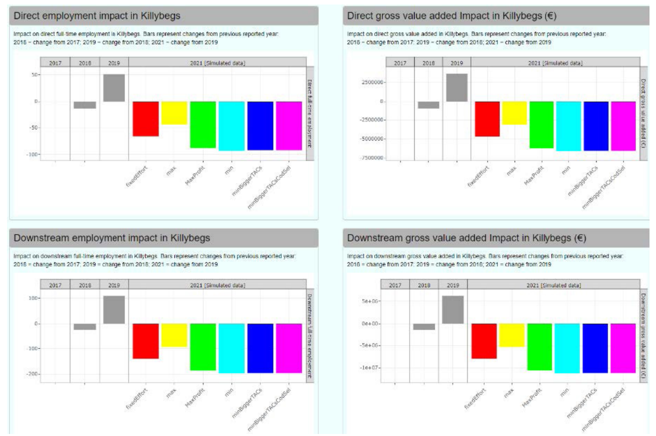
A series of economic variables can also be explored in the proceed plots (by fleet segment, county or port). Showing the impact, losses and gains of the scenarios forecasted.

Example by fleet segment:



Example by county:

Example by port:



8. Updating the model

The following briefly describes the steps required to update the model and incorporate the latest assessment outputs and fleet data. Updating the model is an involved task, but the following structure is intended to make it as straightforward as possible.

All code used in the project has been provided to support future updating.

The following folder structure is used to store the data:

- **data_inputs**

  Folders:
  - stock_data_csv\
  - stock objects\
  - look_ups\
  - logbook_data\
  - econ\
  - age_data_csv\

  Files:
  - tac_advice.xlsx
  - forecast_settings.xslx

8.1. Updating fleet and métier logbook data

A dedicated extraction of logbook data was undertaken by the Marine Institute. These files are contained in the folder logbook_data and include:

- Logbook_Landings for each of the defined fleets, métier and species by year.
- Logbook_Effort for each for the defined fleets and métier by year.
- vessel_numbers for each fleet which contains the number of vessels and average engine power by year.

In addition, in the econ folder there are sales note prices in the file:

- SalesNotesPrices1719_v2 which includes prices per species and gear type supplied by BIM.

Additional data years would need to be extracted and included in these folders to update the values.

Processing of this data is done via the function 'format_logbooks' which combines the logbook data and summarises it as input to the model. Additionally, a fleet_list.csv file is provided which associated the fleet numbers in the data with the names agreed for the project.

8.2. Updating ICES assessment data

Assessment data is contained in the folder 'stock_data_csv' where each stock has an associated xlsx file which contains all the outputs from the stock assessments. This includes all the details required to make FLR Stock objects for each stock, with a high level description which is used to categorise each stock:

	A	B	C	D	E	F	G	H	I
1	stock.name	cod.27.7e-k							
2	stock.desc	Cod (Gadus morhua) in divisions 7.e-k (eastern English Channel and southern Celtic Seas)							
3	first.year	1980							
4	last.year	2019							
5	min.age	1							
6	max.age	7							
7	min.fbar	2							
8	max.fbar	5							
9	plusgroup	7							
10	cat	1							
11									

Once the files are updated with new outputs the updated files can be automatically read in and FLStock objects generated with the 'make_FLStock' function. Each of these stock objects are saved to the 'stock objects' folder for later use.

8.3. Updating Irish ICES intercatch data

Irish data supplied to ICES Intercatch is used to condition the fleet landings and discards at age structure, and these files are stored in the 'age_data_csv' folder. To update these requires the addition of new files for each year of assessment. The files can then be read in and combined using the 'format_intercatch' function.

8.4. Updating ICES assessment forecasts

The model uses the same forecast settings as the ICES assessments, including the recruitment inputs, advised catches and intermediate year assumptions. These are stored and can be updated in the 'forecast_settings.xlsx' file, which is read in to condition the model objects (Section 8.6).

8.5. Updating TAC advice and Quota shares

The ICES advice for 2020 and the quota shares for Irish fleets were compiled in a separate input file 'tac_advice.xlsx' which requires updating. This is automatically used to set the quota shares for Irish fleets in the model, so would need changing in future if these fractions changed.

8.6. Updating Cost data

Cost data was provided by BIM and the file 'Econ_RawDataAnon_Effort_181220.xlsx' used. This file would need appending additional years data to update the model, and the function 'format_cost' used to process this data into average values per vessel or per unit of effort as required as input to the model.

8.7. Conditioning the model objects

Once the data has been updated there are several scripts that construct and condition the input object for FLBEIA. These are as follows:

01_make_FLBiols.R	This code converts the FLStock objects into a list of FLBiols, which contain the biological information on stocks and are an input to FLBEIA. It requires no modification with new data.
02_make_FLFleetExt.R	This code processing all the fleet and intercatch data and generates the individual fleet, métier and stock structures (FLFleets object). This code will require some modification to update the years and deal with any unexpected data problems.
03_stock_conditioning.R	This code sets up the information for the population models, including the forecasts. It reads in the FLBiols and the forecast settings. It will require updating of the year references with new data.
04_fleet_conditioning.R	This code sets up the baseline settings for each of the fleets in the model. It will require updating of the year references with new data.
05_advice_conditioning.R	This code sets up the TAC and quota share settings for the model. It will require updating of the year references with new data, and some adaptations to account for changes to *Nephrops.*
05b_Covars.R	This code sets up the covariates for the model, which includes additional economic data and revenue from non-quota stocks and pelagics. It will require updating of the year references with new data.
06_Model_validation.R	This code checks that the created objects are valid FLBEIA objects.
07_Intermediate_Year.R	This code runs the intermediate year forecasts for each stock. It uses the forecast settings and updates the FLBiol objects. It will require updating of the year references with new data.
10_historic_stock_data.R	This code extracts the stock assessment data from the FLStock objects and saves them as input to the app. It requires little modification.
coastal_impacts_final.R	This code reads in and processes the regional multipliers to inform the coastal impacts. It requires some modifications for updating the model.

Each of these files will require changing directory paths to link with the data sources and file structure on the computer of whoever is running the code.

9. Suggestions for improvements

This section covers some suggestions for improvements to the modelling framework that could be explored in future applications.

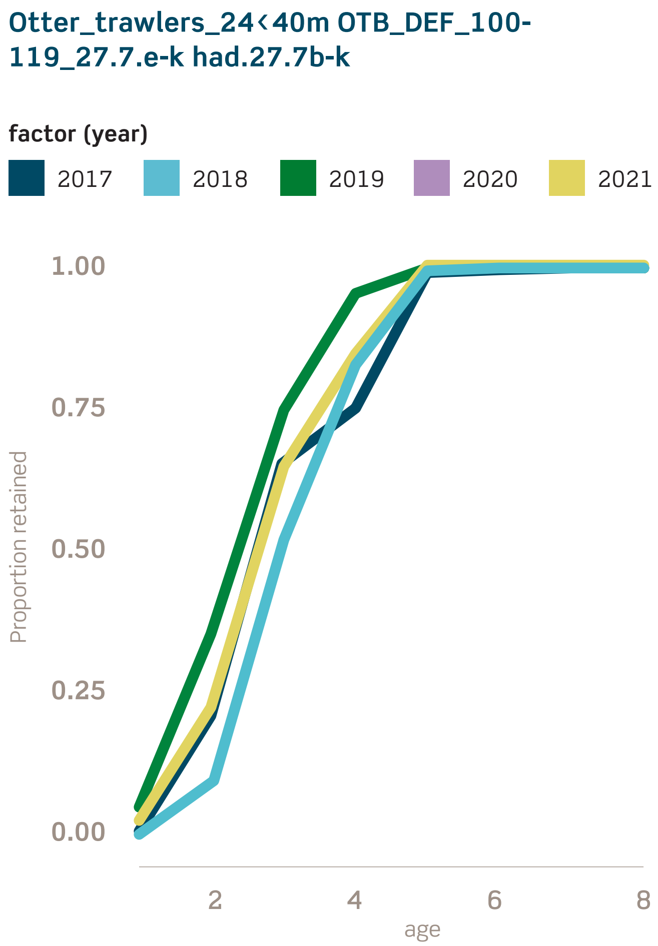
The model is designed to simulate technical interactions in the fisheries; it is not assumed that quotas can be caught independently and fully realised without impacting on other stocks and/or resulting in under or over-quota catches. Therefore, in addition to the TACs that are evaluated the choice of fleet dynamics and future discarding patterns has an impact on the outcomes of the simulations.

On the one-hand, the full implementation of the landing obligation suggests that there will be no discards in the fisheries (except those provided for by the exemptions) and that fleets stop fishing once the first quota is reached. This equates to the 'min' scenario in a mixed-fishery model but has severe consequences in terms of choking of the fisheries that may not be realistic. It also suggests the landing of previous discarded fish that would have a significant impact on price achieved (for example, from smaller fish), but would not be reflected by conditioning the model on past prices. Therefore, assuming that all fish are landed is unlikely to be a true reflection of these changing dynamics and the impact of these changes on prices.

On the other hand, the assumption of 'status quo' fishing effort does not reflect adaptation of fleets to available quotas but may better reflect the level of fishing effort observed in the fisheries. Under this scenario, discarding takes place as two components: i) the previous observed at-age proportions retained (e.g., Figure 5), and ii) any over-quota excess calculated in the model due to too much effort to catch the quotas.

A future implementation could condition future discarding dynamics by partitioning discards into under minimum size (discarded, but no value) and previously over-quota discards (retained and landed). This would require detailed analysis of the fisheries and their proportion retained in relation to the minimum conservation reference size which was outside the scope of this project, but would allow for a clear distinction between what is assumed quota-based discards and size-based discards (not accounting for market-based discards) in simulations.

Figure 5: Example of proportion retained at age, reflecting discard patterns.



10. References

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