North Sea Mixed Fisheries Annex

Mixed Fisheries Annex

Regional specific documentation of standard assessment procedures used by ICES.

Eco-Region: North Sea

Working Group: Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE)

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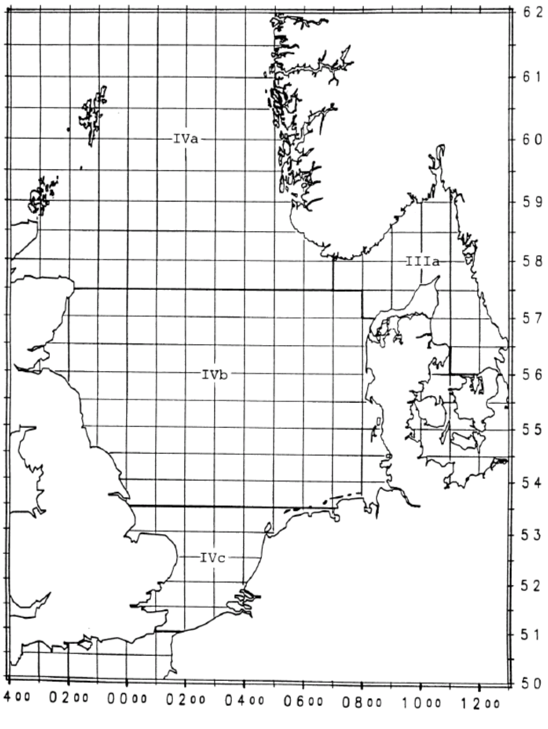
A. General

A.1. Area definition

This mixed fisheries advice will consider finfish species in the ICES area 4, 3.a, 6.a and 7.d (eastern English Channel) (Figure 1) and *Nephrops norvegicus* in functional units FU5, FU6, FU7, FU8, FU9, FU10, FU32, FU33, FU34 and ICES' rectangles outside of these nine functional units – denoted FU_OuTH.

The species considered are part of the demersal mixed fisheries of the North Sea and eastern English Channel, and are cod, haddock, whiting, saithe, plaice, sole, turbot, witch (Table 1) and *Nephrops norvegicus* (Table 2). There are nine *Nephrops* functional units in the North Sea, which are considered as separated stocks. However, only four of these can be assessed through fishery-independent abundance estimates from underwater video surveys, and these were kept as distinct stocks. These cover the stocks along the English and Scottish coast; i.e. FU 6 (Farn Deep), FU 7 (Fladen Ground), FU 8 (Firth of Forth) and FU 9 (Moray Firth). The five other functional units (FU 5, FU 10, FU 32, FU 33 and FU 34) have no independent abundance estimates.



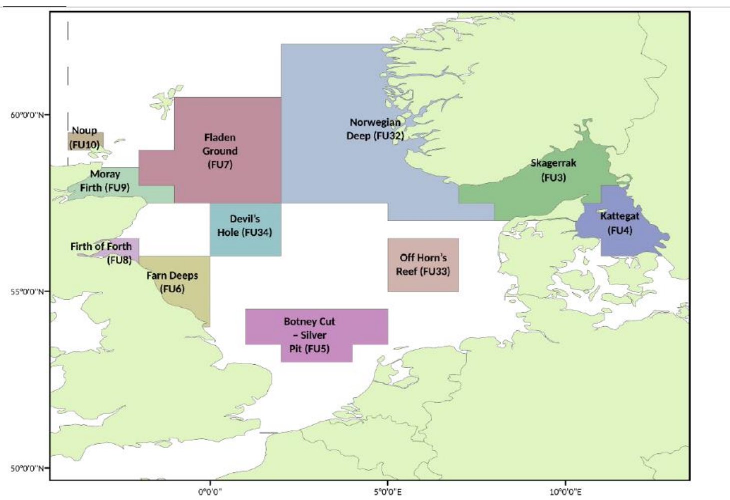


Figure 1. Area description for finfish advice (top) and Nephrops Functional Units (FU) (bottom) in the North Sea and Skagerrak/Kattegat region.

Table 1. Finfish stocks

Species	**ICES single stock advice area**
Cod	Subarea 4, Divison 7.d and Subdivision 3.a.20 (North Sea, eastern English Channel, and Skagerrak)
Haddock	Subarea 4 , Division 6.a and Subdivision 3.a.20 (North Sea, West of Scotland and Skagerrak)
Whiting	Subare 4 and Division 7.d (North Sea and eastern English Channel)
Saithe	Subarea 4, 6 and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)
Plaice	Subarea 4 and Subdivision 3.a.20 (North Sea and Skagerrak)
Sole	Subarea 4(North Sea)
Plaice	Division 7.d (eastern English Channel)
Turbot	Subarea 4(North Sea)
Witch	Subarea 4, Divisions 3.a and 7.d (North Sea, Skagerrak and Kattegat, eastern English Channel)

Table 2. *Nephrops* Functional Units (FU) in the North Sea.

FU no.	Name	ICES area	Statistical rectangles
5	Botney Gut - Silver Pit	4.b, 4.c	36–37 F1–F4; 35F2–F3
6	Farn Deeps	4.b	38–40 E8–E9; 37E9
7	Fladen Ground	4.a	44–49 E9–F1; 45–46E8
8	Firth of Forth	4.b	40–41E7; 41E6
9	Moray Firth	4.a	44–45 E6-E7; 44E8
10	Noup	4.a	47E6
32	Norwegian Deep	4.a	44–52 F2-F6; 43F5–F7
33	Off Horn Reef	4.b	39–41E4; 39–41F5
34	Devil's Hole	4.b	41–43 F0–F1

Herring, mackerel and the industrial fisheries (sandeel, Norway pout and sprat) are not considered in a mixed fisheries advice context given the targeted nature of their fleets.

A.2. Fishery

More information on fisheries in the Greater North Sea can be found in the Greater North Sea Ecoregion – Fisheries overview

Cod in subarea 4, Division 7.d and Subdivision 20

The EU landing obligation was implemented from 1 January 2017 for several gears, including TR1, BT1, and fixed gears for that stock.

Cod are caught by virtually all the demersal gears in Subarea 4 and divisions 20 (Skagerrak) and 7.d, including otter trawls, beam trawls, seine nets, gill nets and lines. Most of these gears take a mixture of species. In some of the fisheries are directed mainly towards cod (for example, some of the fixed gear fisheries), and in others considered to be a by-catch (for example in beam trawls targeting flatfish). An analysis of landings and estimated discards of cod by gear category (excluding Norwegian data) highlighted the following fleets as the most important in terms of cod for 2003–5 (accounting for close to 88% of the EU landings), listed with the main use of each gear (STECF SGRST-07-01):

- Otter trawl, ≥120 mm, a directed roundfish fishery by UK, Danish and German vessels.
- Otter trawl, 70–89 mm, comprising a 70–79 mm French whiting trawl fishery centered in the Eastern Channel, but extending into the North Sea, and an 80–89 mm UK *Nephrops* fishery (with smaller landings of roundfish and angler-fish) occurring entirely in the North Sea.
- Otter trawl, 90–99 mm, a Danish and Swedish mixed demersal fishery centered in the Skagerrak, but extending into the Eastern North Sea.
- Beam trawl, 80–89 mm, a directed Dutch and Belgian flatfish fishery.
- Gillnets, 110–219 mm, a targeted cod and plaice fishery.

For Norway in 2007, trawls (in the saithe fishery) and gillnets account for around 60% (by weight) of cod catches, with the remainder taken by other gears mainly in the fjords and on the coast, whereas in the Skagerrak, trawls and gillnets account for up to 90% of cod catches. The minimum catching size of cod for Norwegian vessels was increased to 40 cm in 2008.

ICES in 2009 (WGFTFB) has noted a change in effort from far sea fishing grounds in mixed fisheries due to increased fuel costs from 2008 to 2009. Probably there is a significant change in fishing pattern from area 4 to Porcupine, Rockall and Celtic Sea.

With regard to trends in effort for these major cod fisheries since 2000, the largest changes in North Sea fisheries have involved an overall reduction in trawl effort and changes in the mesh sizes in use, due to a combination of decommissioning and days-at-sea regulations. For otter trawls, vessels are using either 120 mm+ (in the directed whitefish fishery), 100–119 mm in the Southern North Sea Plaice fishery, or 80–99 mm (primarily in the *Nephrops* fisheries and in a variety of mixed fisheries). The use of other mesh sizes largely occurs in the adjacent areas, with the 70–79 mm gear being used in the Eastern Channel/Southern North Sea Whiting fishery, and the majority of the landings by 90–99 mm trawlers coming from the Skagerrak. Higher discards are associated with these smaller mesh trawl fisheries, but even when these are taken into account, the directed roundfish fishery (trawls with ≥120 mm mesh) still has the largest impact of any single fleet on the cod stock, followed by the mixed demersal fishery (90–99 mm trawls) in the Skagerrak.

Apart from the technical measures set by the Commission, additional unilateral measures are in force in the UK, Denmark and Belgium. The EU minimum landing size (mls) is 35 cm, but Belgium operates a 40 cm mls, while Denmark operate a 35 cm mls in the North Sea and 30 cm in the Skagerrak. Additional measures in the UK relate to the use of square mesh panels and multiple rigs, restrictions on twine size in both whitefish and *Nephrops* gears, limits on extension length for whitefish gear, and a ban on lifting bags. The use of technical meaures in the UK *Nephrops* fishery has particularly increased in 2012 following an agreement at the 2011 December Council fisheries Council on a requirement for UK vessels to use highly selective gear for part of the year. In 2001, vessels fishing in the Norwegian sector of the North Sea had to comply with Norwegian regulations setting the minimum mesh size at 120 mm. Since 2003, the basic minimum mesh size for towed gears targeting cod is 120 mm.

Haddock in Subarea 4, Division 6.a, and Subdivision 20

The EU landing obligation was implemented for TR1, TR2, BT1, BT2, and fixed gears for that stock.

The largest proportion of the haddock stock is taken by the Scottish demersal whitefish fleet. This fleet is not just confined to the North Sea, as vessels will sometimes operate in divisions 6.a (off the west coast of Scotland) and 6.b (Rockall): it is also a multi-species fishery that lands a number of species other than haddock.

Plaice in 4 and subarea 20

Since 2015, plaice in the Skagerrak has been assessed together with the North Sea stock. Since 2016, large mesh trawlers (TR1 and BT1) are under landing obligation in Subarea 4. Plaice is predominantly caught by beam trawlers in the central part of the North Sea and in a mixed fishery with sole in the southern North Sea, though significant quanities are also taken by a directed otter trawl fishery using 100–119 mm in the Southern North Sea. Technical measures applicable to the mixed flatfish beam trawl fishery affect both sole and plaice. The minimum mesh size of 80 mm selects sole at the minimum landing size. However, this mesh size generates high discards of plaice which has a larger minimum landing size than sole. Recent discard estimates indicate fluctuations around 45% discards in catch by weight. Mesh enlargement would reduce the catch of undersized plaice, but would also result in loss of marketable sole. There has been increased use of new gears such as "SumWing" and electric "pulse trawls" which will increasely affect catchability and selectivity of plaice and sole. Most of the beam trawl fleet now use pulse trawl. The overall capacity and effort of North Sea beam trawl vessels has been substantially reduced since 1995, including the decommissioning of 25 vessels in 2008.

Saithe in Subarea 4, Division 6.a, and Subdivision 20

The EU landing obligation was implemented for TR1 targetting Saithe.

Saithe in the North Sea are mainly taken in a direct trawl fishery in deep water along the Northern Shelf edge and the Norwegian Trench. Norwegian, French, and German trawlers take the majority of the catches. In the first quarter of the year the fisheries are directed towards mature fish in spawning aggregations, while concentrations of immature fish (age 3–4) often are targeted during the rest of the year. A small proportion of the total catch is taken in a limited purse seine fishery along the west coast of Norway targeting juveniles (age 2–4). In the Norwegian coastal purse seine fishery inside the 4 nm limit (south of 62°N), the minimum landing size is 32 cm. For other gears in the Norwegian zone (south of 62°N) the current minimum landing size is 40 cm, while in the EU zone it is 35 cm. In 2009 the landings were estimated to be around 105 000 t in Subarea 4 and Division 20, and 7 000 t in Sub-Area 6, which both are well below the TACs for these areas (125 934 and 13 066 t respectively). Significant discards are observed only in Scottish trawlers. However, as Scottish discarding rates are not considered representative of the majority of the saithe fisheries, these have not been used in the assessment.

Sole in Subarea 4

The EU landing obligation was implemented for TR1, TR2, BT1, BT2, gillnets and fixed gears.

Sole are mainly caught in a mixed beam trawl fishery with plaice and other flatfish using 80 mm mesh in the southern North Sea. The minimum mesh size in the mixed beam trawl fishery in the southern North Sea means that large numbers of undersized plaice are discarded.

There is a directed fishery for sole by small inshore vessels using trammel nets and trawls, which fish mainly along the English coasts and possibly exploit different coastal populations. Sole represents the most important species for these vessels in terms of the annual value to the fishery. The fishery for sole by these boats occurs throughout the year with small peaks in landings in spring and autumn. In cold winters, sole are particularly vulnerable to the offshore beamers when they aggregate in localized areas of deeper water.

The minimum landing size for sole is 24 cm. Demersal gears permitted to catch sole are 80 mm for beam trawling and 90 mm for otter trawlers. Fixed nets are required to use 100 mm mesh since 2002 although an exemption to permit 90 mm has been in force since that time. Between 2014 and 2017 the use of pulse trawls in the Dutch fishery operating in the North Sea has increased to 76 vessels (of which 65 > 221 kW) and a handful of vessels operating with traditional beam trawls are now left.

Whiting in Subarea 4 and Division 7.d

The EU landing obligation was implemented for TR1, BT1, gillnets and fixed gears in the North Sea and TR1 and TR2 in the division 7.d

For whiting, there are three distinct areas of major catch: a northern zone, an area off the eastern English coast; and a southern area extending into the English Channel. In the northern area, roundfish are caught in otter trawl and seine fisheries, currently with a 120 mm minimum mesh size. Some vessels operating to the east of this area are using 130 mm mesh. These are mixed demersal fisheries with more specific targeting of individual species in some areas and/or seasons. Cod, haddock and whiting form the predominant roundfish catch in the mixed fisheries, although there can be important bycatches of other species, notably saithe and anglerfish in the northern and eastern North Sea and of *Nephrops* in the more offshore *Nephrops* grounds. Minimum mesh size in *Nephrops* trawls is 80 mm but a range of larger mesh sizes are also used when targeting *Nephrops*. Whiting is becoming a more important species for the Scottish fleet, with many vessels actively targeting whiting and Scottish single seiners have been working closer to shore to target smaller haddock and whiting. The derogation in the EU effort management scheme allowing for extra days fishing by vessels using 90 mm mesh gears with a 120 mm square mesh panel close to the codend (a configuration which releases cod) has so far, been taken up by few vessels. Recent fuel price increases and a lack of quota for deepwater species has resulted in some vessels formerly fishing in deepwater and along the shelf edge to move into the northern North Sea with the shift in fishing grounds likely to result in a change in the species composition of their catches from monkfish to roundfish species including whiting.

Whiting are an important component in the mixed fishery occurring along the English east coast. Industry reports suggest better catch rates here than are implied by the overall North Sea assessment. There has been a displacement of some French vessels steaming from Boulogne-sur-Mer from their traditional grounds in the southern North Sea and English Channel where they have reported very low catch rates during the past two years.

Whiting are a bycatch in some *Nephrops* fisheries that use a smaller mesh size, although landings are restricted through bycatch regulations. They are also caught in flatfish fisheries that use a smaller mesh size. Industrial fishing with small meshed gear is permitted, subject to bycatch limits of protected species including whiting. Regulations also apply to the area of the Norway pout box, preventing industrial fishing with small meshes in an area where the bycatch limits are likely to be exceeded.

WGFTFB (2008) reported use of bigger meshes in the top panel of beam trawler gear by Belgium vessels with an expected reduction in by-catch of roundfish species, especially haddock and whiting. Fluctuations in fuel costs can cause changes in fishing practices. WGFTFB (2008) reported a shift for Scottish vessels from using 100 mm–110 mm for whitefish on the west coast ground (Area 6) to 80 mm prawn codends in the North Sea (area 4), with increased fuel costs considered the major driver.

Nephrops

The EU landing obligation was implemented for TR1, TR2, BT1, BT2, gillnets and fixed gears.

Nephrops is caught in a mixed fishery which takes a catch consisting of haddock, whiting, cod, anglerfish and megrim as well as *Nephrops*. Most of the catch (approx 21 of 25 thousand tonnes) is taken by UK. Days at sea limits apply to *Nephrops* trawlers when using mesh sizes 70–99 mm and in 2009, under the Scottish Conservation Credits Scheme (CCS), the number of days available to Scottish vessels is the same as 2008 and 2007.

A small but increasing proportion of the landings from Subarea 4 are taken from statistical rectangles outside the defined *Nephrops* FUs. An example is the Scottish fishery at the Devil's hole which a few boats normally fishing the Fladen grounds prosecute for a few months at the end of the year.

Plaice in Division 7.d

Plaice is mainly caught in 80 mm beam-trawl (Belgian and English) fisheries for sole or in mixed demersal fisheries using otter trawls (mainly French). There is also a directed fishery during parts of the year by inshore trawlers and netters. Fisheries operating on the spawning aggregation in the beginning of the year catch plaice that originate from the North Sea, divisions 7.d and 7.e components. Since the 80 mm mesh size does not match the minimum landing size for plaice (27 cm), a large number of undersized plaice are discarded.

Sole in Division 7.d

The EU landing obligation was implemented for gillnets.

Sole is mainly caught in 80 mm beam-trawl fisheries with plaice or in mixed demersal fisheries using otter trawls and gill/trammel nets. There is also a directed fishery during parts of the year by inshore trawlers and netters on the English and French coasts.

A.3. Ecosystem aspects

The North Sea is part of what is called the Greater North Sea, together with the English Channel, Skagerrak, and Kattegat. The Northern North Sea is strongly influenced by oceanic inflow and usually stratified in summer, with fishing and oil and gas production as main human activities. The Southern North Sea is characterized by large river inputs and strongly mixed water, and support more diverse human activities (fishing, shipping, ports, gas production, wind farms, and sand extraction. Heterogeneity in the environmental conditions (oceanography, bathymetry, sea floor structure, etc.) strongly affects the distribution of species and length/age structure of populations and their fisheries (Heessen *et al.*, 2015). Despite the fact that the mixed fishery model (Fcube) does not model explicitly the spatial distribution of stocks and fisheries, the metiers structure implemented (species-gear-period-area-exploitation pattern groups) does implicitly consider spatial interactions between the fleet and the stocks through age-specifiy catchabilities.

Episodic changes in the productivity have historically occurred in the North Sea, like the gadoid 'outburst' in the 1970s, and a reduced productivity of herring *Clupea harengus* since 2002. The changes have been described as regime shifts, and the temperature trends of the North Sea seem to be linked to these ecosystem changes. Production in he North Sea food web is dominated by autotrophic organisms which are in turn consumed by zooplankton and benthos, followed by fish, seabirds, and mammals. In the past, large and long-lived fish, elasmobranchs and whales were major predators in the ecosystem. The North Sea food web can now be considered as perturbed as many of these groups are either absent or present only in reduced numbers. Fishing effort has been reduced more than 50% in the North Sea since the implementation of 2002 CFP reforms. This decline in effort has resulted in a decline in the fishing mortality rate of commercial fish stocks. The recovery of larger-sized, more predatory fish populations will likely have consequences for the large forage fish populations in the North Sea (herring, sprat, sandeel, and Norway pout). Multispecies assessment methods can account for some of the species interactions and the impact that the changes in fishing effort in one stock could produce in other species. These models show that natural mortality is now the main source of mortality for many commercial species due to a successful reduction in fishing mortality in recent years.

The Stochastic Multispecies Model (SMS) is the model that have passed the standards defined by the ICES WG on multispecies assessment methods (WGSAM) and it is used to model the trophic interactions between the most important marine species in the North Sea. Estimates of natural mortality (M), derived from this SMS model, are updated by the WGSAM every three years in the so called "key runs" to account for improved knowledge of predation on the main commercial stocks by other species (mainly seals, harbour porpoises and gurnards) and cannibalism; the last update occurred in 2017 with the new key run (ICES WGSAM, 2018). The estimates of M at age by stock provided by WGSAM are then used in the assessment of the historical period for several stocks in the North Sea (WGNSSK, 2019), but also to condition the model for the short term forecast to produce the catch advice. The same information is also used in Fcube.

A more in detail description of the ecosystem aspects of the North Sea can be found in the North Sea ecosystem overview in the ICES advisory report.

B. Data

The mixed fisheries assessment is based on catch and effort data that were compiled mostly on the basis of the data collected in annual ICES data calls (InterCatch database: discards and landings by age and metier, consistent with the DCF definition of métiers), and data collected by STECF for the evaluation of the effort regime (so called accessions data, that contains information on landings and fishing effort by age and metier).

The assessment data for the different stocks is taken from the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). For whiting, the industrial bycatch component is included in the landings, whereas it is dealt with separately in the single-stock forecast. The same applied for haddock, for which the industrial bycatch is now extremely low. The single species haddock forecast also includes some non-standard procedures for projecting mean weight and mean selectivity, and this was accounted for as far as possible in the current mixed-fisheries forecast.

The information of the actual final quota taken by fleet and/or country (final after swaps) was obtained from the FIDES database, and was used to assess the model sensitivity and potential impact of using the actual quota by fleet/country when computing partial F (see Equation 1). Using observed landings as currently done might greatly differ to quotas availability and give another perception of the limiting species. However, these data need further testing to be incorporated in the modelling framework and are not currently used in the advice.

Despite the data collation process is becoming smoother, it remains a very tedious and time-demanding work. It is then necessary to understand the reason for the data mismatches which had not been detected in previous years. For that reason a data quality control process has been initiate by WGMIXFISH in 2020, which, in collaboration with the designated experts in the different countries, will help to improve the standardization in the format that data are presented.

All the data structured by fleets and métiers were used as inputs, together with WGNSSK single stock data and advice, in the integrated FLFBEIA framework.

C. Assessment methodology

Definitions

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

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

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

The procedure for establishing fleets and métiers has been the same since 2012. Nevertheless, as the procedure is applied to the last data year, the number of fleets and métiers can vary from one WGMIXFISH year report to the next. The main steps in the procedure are:

- Matching DCF métiers with definitions used in the cod long-term management plan.
- Establishing fleets by country, gear type and, when deemed necessary, vessel length group.
- Matching consistency between effort and catch data files. Métiers without catch of any of the modelled stocks in the last data year are not retained.
- Aggregating "small" métiers to reduce the number of units in the modelling. A métier failing to catch at least 1.0% of at least one of the stocks considered in the most recent data year is classified as small. Within each fleet, all these small métiers are then aggregated by fleet in one "Other" métier (OTH). Further, all small fleets (i.e. containing only the "OTH" métier), are aggregated into one single "OTH" fleet.

Model used:

FLBEIA

Unlike the previous North Sea FCube model, the North Sea FLBEIA model is conditioned using age-disaggregated catch information at the fleet and métier level, which allows differences in selectivity among fleets/métiers.

The FLBEIA simulation model is presented and described in García *et al*. (2017). The aim of this flexible and generic simulation model is to allow conducting Bio-Economic Impact Assessments of harvest control rule based on management strategies under a Management Strategy Evaluation (MSE) framework. The model provides functions that describe the different components of the system (i.e. stocks, fleets and management procedure). Given fishing opportunities available for each fleet (e.g. TACs by stock or effort allocation by fleet), the model estimates the potential future levels of effort for each fleet, based on fleet effort distribution and catchability by métier. Based on this effort level, landings and discards (i.e. catches) by fleet are estimated using standard forecasting procedures.

The selected function to simulate the behaviour of the fleet is the Simple Mixed Fisheries Behaviour model (SMFB), which is a simplified version of the behaviour of fleets that work in a mixed fisheries framework. The function is seasonal and assumes that effort share among metiers is given as input parameter. Catchability ($q_{f,mt,st}$) by fleet (*f*), métier (*mt*) and stock (*st*) can be estimated as a mean over the recent observed landings and discards. But the user can also select a specific value of q, in case of evidence of changes are expected to occur (e.g. significant technical creep, a change in selectivity due to a change in mesh size…).

For each season (s), fleet effort ($E_{f,s}$) is restricted by the seasonal landing or catch quotas of the stocks captured by the fleet and the landing obligation (LO) can also be included. The effort is calculated following the subsequent steps:

1. Compare the overall seasonal quotas ($\sum_f Q_{f,s,st} \cdot TAC$), with the abundances of the stocks. If the ratio between the overall quota and the abundance ($B_{s,st}$) exceeds the seasonal catch threshold ($\gamma_{s,st}$), then the quota share is reduced in the same degree. That is,

$$\boldsymbol{Q'}_{f,s,st} = \begin{cases} \boldsymbol{Q}_{fl,s,st} & , \ \boldsymbol{if} \ \dfrac{\sum_f \boldsymbol{Q}_{f,s,st} \cdot \boldsymbol{TAC}}{\boldsymbol{B}_{s,st}} \leq \boldsymbol{\gamma}_{s,st} \\ \boldsymbol{Q}_{fls,st} \cdot \dfrac{\boldsymbol{B}_{s,st} \cdot \boldsymbol{\gamma}_{s,st}}{\sum_f \boldsymbol{Q}_{f,s,st} \cdot \boldsymbol{TAC}} & , \ \boldsymbol{if} \ \dfrac{\sum_f \boldsymbol{Q}_{f,s,st} \cdot \boldsymbol{TAC}}{\boldsymbol{B}_{s,st}} > \boldsymbol{\gamma}_{s,st} \end{cases} \quad \textbf{(1)}$$

2. According to the catch production function, Cobb-Douglas in this case, the efforts corresponding to the landing or catch quotas ($\boldsymbol{Q'}_{f,s,st} \cdot TAC$) for individual stocks are calculated, $\{E_{f,s,st_1}, \ldots, E_{f,s,st_n}\}$.
3. Based on the efforts calculated in the previous step, a unique effort ($\hat{E}_{f,s}$) is calculated. However, rather than assume a single set of fleet efforts, the approach used in practice with FLBEIA has been to investigate a number of different scenarios about fleet effort during the forecast period. The user can thus explore the outcomes of a number of options or rules about fleet behaviour (e.g. continue fishing after some quotas are exhausted) or management scenarios (e.g. all fisheries are stopped when the quota of a particular stock is reached).
   - "max" scenario: if one assumes that fishermen continue fishing until the last quota is exhausted, effort by fleet will be set at the maximum across stock-dependent effort by fleet. Over quota catches of species which quota were exhausted before this last one, are assumed to be discarded:

$$\hat{E}_{f,s} = max_{j=1,\ldots,n}\left(E_{f,s,st_j}\right)$$

   - "min" scenario: as a contrast, a more conservative option would be to assume that the fleets would stop fishing when the first quota is exhausted, and thus would set their effort at the minimum across stocks:

$$\hat{E}_{f,s} = min_{j=1,\ldots,n}\left(E_{f,s,st_j}\right)$$

   - "St_E" scenario: Or when the effort selected is the effort most similar to previous year effort in that season

$$\hat{E}_{f,s} = \left\{E_{f,s,st}: \left|1 - \frac{E_{f,s,st}}{E_{f,y-1,s}}\right| = \min_{j=1,\ldots,n}\left|1 - \frac{E_{f,s,st_j}}{E_{f,y-1,s}}\right|\right\}$$

   - "cod-ns" scenario: alternatively, FLBEIA allow exploring management plans for a particular stock, with the fleets setting their effort at the level for this stock. In the North Sea case study, this option is applied for cod.

$$\hat{E}_{f,s} = E_{f,s,stk.nam}$$

   - "value" scenario: incorporates elements of the economic importance of each stock for each fleet. The effort by fleet is equal to the average of the efforts required to catch the quota of each of the stocks, weighted by the catch value of that stock during the intermediate year. This option causes overfishing of some stocks and underutilisation of others
   - "range" scenario: This scenario searches for the minimum sum of differences between potential catches by stock under the "min" and the "max" scenarios within the F_{MSY} ranges.

If there is LO, instead of using the option chosen by the user, the option to calculate the simulated fleet effort will be the minimum among possible efforts.

4. When LO is applied, the new effort is calculated using exemptions and flexibilities (*de minimis*, year transfer and quota swap).
   - *de minimis*: The fleet is allowed to discard a percentage of the quota to increase the effort in order to catch other stocks.
   - *year transfer*: The fleet can borrow next year's quota to catch it in the current year.
   - *quota swap*: A percentage of the quota of one stock can be transferred to the effort limiting stock, if the two stocks are in the same group. Where these groups are specified by the user.
5. The selected effort ($\hat{E}_{f,s}$) is compared with the capacitiy of the fleet ($K_{f,s}$), so that if the capacity is exceeded, the final effort ($E_{f,s}$) should be reduced.

$$\boldsymbol{E_{f,s}} = \begin{cases} \boldsymbol{K_{f,s}} & , \ \boldsymbol{if\ K_{f,s} < \hat{E}_{f,s}} \\ \boldsymbol{\hat{E}_{f,s}} & , \ \boldsymbol{if\ K_{f,s} \geq \hat{E}_{f,s}} \end{cases} \quad \textbf{(2)}$$

6. Finally, the catch corresponding to effort selected is calculated for each stock and compared with the corresponding quota. If the catch is not equal to the quota and the season is not the last one (ns), the seasonal quota shares of the rest of the seasons are reduced or increased proportionally to the weight in the total share. The shares are changed in such a way that the resultant annual quota share is equal to the original one. In case that the difference between actual catch and that corresponding to the quota exceeds the quota left over in the rest of the seasons, the quota in the rest of the seasons is cancelled (i.e. set to 0). Mathematically, for season i where $s \leq i \leq ns$:

$$\boldsymbol{Q''_{f,i,st}} = \mathbf{max}\left(\mathbf{0}, \boldsymbol{Q'_{f,i,st}} + \left(\boldsymbol{Q'_{f,s,st}} - \boldsymbol{Q''_{f,s,st}}\right) \cdot \frac{\boldsymbol{Q'_{f,i,st}}}{\sum_{j<s} \boldsymbol{Q'_{f,j,st}}}\right) \quad (2)$$

   where $\boldsymbol{Q'}$ denotes the quota share obtained in the first step and $\boldsymbol{Q''}$ the new quota share.

Software used:

The FLBEIA model has been coded as a method in R (R Development Core Team, 2020), as part of the FLR framework (Kell *et al.*, 2007; www.flr-project.org). Input data are in the form of FLFleetsExt and FLBiols objects inherited from the FLCore 2.6.16 package objects, and two forecast methods were used, stf() from the FLAssess (version 2.6.3) and fwd() from the Flash (version 2.5.11) packages. Both input parameterisation as well as the stock projections are made using FLBEIA functions and methods (version 1.15.6.8), that are flexible enough to allow covering different alternatives. Full transparency is assured as all the FLBEIA source code is available at GitHub (https://github.com/flr/FLBEIA). The code, software and versions are part of the ICES Transparent Assessment Framework (TAF) and can be fully reproduced from this repository (see https://github.com/ices-taf/2021_NrS_MixedFisheriesAdvice).

D. Short-Term Projection methodology

Baseline runs:

The basis of the FLBEIA model is to estimate the potential future levels of effort by a fleet corresponding to the fishing opportunities (advised catch by stock and/or effort allocations by fleet) available to that fleet, based on fleet effort distribution, and catchability by métier. This level of effort was used to estimate the catches by fleet and stock, using standard forecasting procedures.

In first place a baseline run is performed, with the objective of reproducing as closely as possible the single-species advice produced by ACOM, and act as the reference scenario for subsequent mixed fisheries analyses. These runs also have the incidental benefit of acting as a quality control check on the WGNSSK projections themselves.

The various single-stock forecasts presented by WGNSSK are performed using different software and setups (see table below). However, for the purpose of the mixed fisheries analyses, it is necessary to gather all forecasts into a single unified framework, which builds on the 'fwd()' method in FLR (FLash R add-on package). The same forecast settings as in WGNSSK are used for each stock regarding weight-at-age, selectivity and recruitment, as well as assumptions on the F in the intermediate year and basis for advice (EU Multiannual Plan or MSY approach).

Some stock assessments (e.g. cod 4,7d and 20; haddock 4, 6a and 20; whiting 4 and 7d) use data from the current year (intermediate year) and therefore produce stock abundance estimates for this year, which are used as the starting numbers for the short term forecasts. The FLash fwd() function is not designed to use stock abundances provided in the first year of the projections and overwrites any existing values with the outcome of the survival equation, using numbers and mortality rates from the previous year. Therefore the FLash fwd() function was modified so that, if stock abundances-at-age are provided for the first year in the short term forecast, they are effectively used as starting values and not replaced.

Model used: Overview of software used by WGNSSK.

Species	Assessment	Forecast
COD 4, 3.a and 7.d	SAM	SAM
HADDOCK 4, 3.a and 7.d	TSA	MFDP
PLAICE 4	AAP	FLR 2.3, FLSTF
SAITHE 4, 3.a and 6	SAM	SAM
SOLE 4	AAP	FLR 2.3, FLSTF
WHITING 4 and 7.d	SAM	MFDP
PLAICE 7.d	AAP	FLR 2.x, FLSTF
SOLE 7.d*	SAM	SAM
TURBOT 4	SAM	FLR (fwd-routines)
WITCH 4, 3.a and 7.d	SAM	SAM

Some differences can occur in the forecast calculations, sometimes because of the diversity of single-stock assessment methods used, and the WG always investigates in depth the reasons for potential discrepancies. Adjustments to the FLR forecasts are made if necessary to minimise discrepancies to the largest extent possible. In the case of stocks assessed by WGNSSK with SAM, the catch in numbers at age in the intermediate year is a stochastic value used to the process error in the predicted fleet selectivity, fish survival and recruitment. In contrast FLR estimates in the intermediate year are deterministic forward projections of the assessment year values and average fishing selectivity in the past 3 years, or any other specifications provided by the single stock advice. To minimize this difference between FLR and SAM estimations in the intermediate year, the fwd() function, was modified to overwrite stock numbers in the intermediate year in cases where these are produced by the assessment model (e.g. SAM). This helps to minimize differences between FLR and SAM projections, but this functionality is not currently available for mixed fishery projections in FLBEIA.

As a further check, the single species advice projections are also now reproduced using the conditioned mixed fishery model. Short-term forecasts are conducted for each of stocks with dynamics (i.e. not including the fixed dynamics, Norway lobster stocks), whereby catch constraints corresponding with the single stock advice for the intermediate and advice year are used to limit the fishing effort of the fleets. Contrary to the FLR projections, a single assumption of future selectivity patterns are used, whichis that future catchabilities are equal to the most recent historical data year.

Mixed fisheries runs:

For the intermediate year the projection is based on the s*tatus quo* effort. For the catch advice year FLBEIA is used to run the different scenarios indicated in section C (min, max, Sq_E, Species specific scenarios, Range and value). In the mixed-fisheries runs, all forecasts were done with the same FLR forecasts method.

For every scenario, the following output is generated per stock:

	Description	**Landings**	**F mult**	**SSB**
Baseline forecast for current year	Applying single species forecast assumptions to last year's data (current year – 1)*	Current yr	Current yr	1st Jan TAC yr
Baseline forecast for TAC year	Applying single species HCRs** to current year results*	TAC yr	TAC yr	1st Jan TAC yr + 1
Current year FLBEIA results	Applying FLBEIA to last year's data	Current yr	Current yr	1st Jan TAC yr
FLBEIA estimate of catches in TAC year	Applying FLBEIA on current year FLBEIA results	TAC yr	TAC yr	1st Jan TAC yr + 1
TAC advice results (incl mgt plans)	Applying single species HCRs** to current year FLBEIA results	TAC yr	TAC yr	1st Jan TAC yr + 1

*** For the Baseline runs, a forecast was run for each stock separately following the same settings as in the ICES single species forecast.**

**** Harvest Control Rules – either from single species management plans or with reference to the F_{MSY} transition approach. Where HCRs according to these approaches were not available values according to the precautionary approach were used.**

G. Biological Reference Points

The biological reference points that are used are the same values as referred to in the single stock advisory reports.

H. Other Issues

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