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# Scientific, Technical and Economic Committee for Fisheries (STECF) - Review of the Technical Measures Regulation (STECF-22-19)

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Joint Research Centre

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**EWG-22-19 report:**

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## Abstract

Commission Decision of 25 February 2016 setting up a Scientific, Technical and Economic Committee for Fisheries, C(2016) 1084, OJ C 74, 26.2.2016, p. 4–10. The Commission may consult the group on any matter relating to marine and fisheries biology, fishing gear technology, fisheries economics, fisheries governance, ecosystem effects of fisheries, aquaculture or similar disciplines. This report presents the findings of the STECF Expert Working Group 22-19: Review of the Technical Measures Regulation, from the meeting held from 23rd to 27th January 2023 at JRC Ispra. The 33 stocks analysed in this report with regards to their selectivity correspond to those that were identified to have age-structured information available, in accordance with Annex XIV of Regulation (EU) No 2019/1241: Species for selectivity performance indicators. Eleven stocks were examined in more detail in specific cases studies. The report of the EWG-2219 was reviewed by the STECF during its March 2023 Plenary Meeting and subsequently released.

**SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) - Review of the Technical Measures Regulation (STECF-22-19)**

**Request to the STECF**

STECF is requested to review the report of the STECF Expert Working Group meeting, evaluate the findings and make any appropriate comments and recommendations.

**STECF comments**

EWG 22-19 was held at the JRC in Ispra, Italy, 23-27 January 2023. The meeting was attended by 18 experts in total, including 5 STECF members and 2 JRC experts. STECF considers that the EWG adequately addressed the TORs and has the following specific comments on the ToRs addressed by EWG 22-19.

**ToR 1 - Identify the ages and sizes at which fish (as per Annex XIV of the Technical Measures Regulation 2019/1241) would need to be caught to optimise yield and reduce the catches of juveniles as far as possible, building upon the relevant work of STECF-21-07. Prioritise stocks where the highest gains can be achieved.**

STECF notes that the analysis carried out by EWG 22-19 has identified the potential gains that can be made in terms of single stock catches (yield) and spawning stock biomass (SSB) by increasing gear selectivity, both under current and varying fishing mortality (F). These gains are typically accompanied with improvements in the protection of juveniles, except for early maturing species.

STECF notes that the work conducted by this EWG covered 33 stocks relevant to Annex XIV of the TMR and observes that stocks which show the highest potential gains in terms of yield and/or SSB through improving selectivity, are mainly long-lived, late maturing roundfish stocks, and also currently fished above FMSY. As such, STECF notes that EWG 22-19 identified 11 'priority stocks' for such highest gains: cod.27.22-24, cod.27.47d20, cod.27.6a, cod.27.7e-k, whg.27.7a, pok.27.3a4 (in the NorthEast Atlantic) and, HKE.01-05-06-07, HKE.08-09-10-11, HKE.17-18, HKE.19, HKE.20 (in the Mediterranean Sea)

STECF observes that a large increase in L50 (length corresponding to 50% probability that a fish from the population is captured) of priority stocks would be required to reach the identified optimal yields under current F patterns. Therefore, to achieve optimal yield, stocks fished far above FMSY would require a combination of improved selectivity with a decrease in F.

STECF notes that optimal L50 estimates, both under current F and variable F, are uncertain, as they are based on the current population characteristics and biological parameters of the stocks, which are expected to change if stock sizes increase substantially.

**ToR 2 - Identify the fishing gears corresponding to the optimum age and size of each of the stocks in (1).**

STECF observes that for priority stocks there is limited availability of gear selectivity studies for static gears compared to the availability of gear selectivity studies for active gears. This hindered a thorough evaluation of the potential impact of static gears. However, based on the limited information available, combined with the partial selectivity of fleet segments inferred from the stock assessments (where available), static gears (GNS, GTR, LLS) generally seem to capture fish closer to their optimal size than active gears (OTB, TBB). The analysis by the EWG demonstrates also that there are cases where modifications of active gears may result in large gains in yield.

STECF notes that the observed selectivity of the OTB fleet segment was worse (i.e., shifted to smaller fish) than expected from baseline codends in all cases expect for cod.27.6.a, where observed selectivity was fractionally better (~2cm) then the available gear studies. STECF notes that the observed selectivity of two stocks - cod.27.47d20 and pok.27.3a46 - was found to be the same as the baseline codend. Therefore, STECF observes that gear selectivity is not always a reliable predictor of population selectivity.

**ToR 3 - If feasible, identify possible operational changes needed to realise the transition to higher yields. Identify the technical support required to assess at the regional level, the potential socio-economic implications of fisheries-based transition plans for improving yields.**

STECF observes that any transition in gear selectivity comes with implementation challenges and short term economic losses, which are greater in the case of gear change (e.g., from active to static gears) than in the case of gear modification (e.g., codend mesh increase in trawlers). By contrast, based on the available information, the potential gains in yield and protection of juveniles seem to be typically greater for gear changes than for gear modifications.

STECF observes that technological change is complex and challenging to achieve due to the inherent uncertainty and the underlying perception of the fishing industry that such changes will lead to significant capital outlay and economic loss.

STECF observes that analyses of socio-economic implications of fisheries-based transitions depend on the availability of data and bio-economic models for specific fisheries. To ensure meaningful results these models would need to account for: short term (1-2 years) losses and longer term (5-10 years) benefits; incorporate target, bycatch and PET species; and include relevant fleets (to be able to investigate the socio-economic consequences) and metiers (with explicit selectivity).

Several models have been developed to analyse socio-economic impacts of management measures (STECF 2018, Nielsen et al. 2017), including (but not limited too) FLBEIA (Celtic Sea, Bay of Biscay and North Sea (under development)), SIMFISH (Flatfish fishery North Sea), FishRent (demersal and pelagic versions for North Sea), BEMTOOL and IAM (Western Med). STECF notes that these models would need effort to update to make them fit for purpose.

STECF observes the current gap in quantitative analysis on the socio-economic impact of technical measures. For such an impact assessment to be conducted this year, STECF plenary proposes the following four-step process which may provide some insights in the socio-economic implications of fisheries-based transitions:

1- **Define questions & scenarios (responsibility of DGMARE)** – For this process to succeed, there would need to be a clearly defined list of questions and scenarios provided to STECF (preferably by end of April) specifying a shortlist of priorities for the EWG to explore as test cases. These questions would outline the combination of stocks, gears, technical measures, and areas to explore.

2- **Scoping exercise (responsibility of STECF)** – A dedicated subgroup could be formed during PLEN 23-02, focusing on defining the test cases for socio-economic assessments which would then be conducted during the follow-up EWG planned for later in 2023 (EWG 23-15). This sub-group would identify data needs, available models, skills and people required at the EWG meeting.

3- **Synthesis of current knowledge (conducted by ad hoc contract)** – An ad hoc contract in advance of EWG 23-15 could be used to conduct a literature review on the current knowledge of the socio-economic implications of changes in technical measures (e.g., Simons et al. 2015). This review would provide context and support for the analysis to ensure meaningful conclusions can be drawn from the findings of the model applications in EWG 23-15. It is also a fallback option in case a limited number of test cases can be analysed in the EWG.

4- **Implementation of test case (responsibility of EWG 23-15)** - The experts attending the EWG 23-15 (economists, mixed fisheries stock assessors, and modellers) will use the data and apply models identified by the scoping exercise, to provide test case(s) of fisheries-based transition plans to inform future research goals and advice needs. The literature review will also allow putting the model results in a broader context of implementation of technical measures.

## STECF conclusions

STECF concludes that improved selectivity is more likely to lead to higher gains in yield and/or SSB for stocks which are long lived, late maturing, and currently fished far above FMSY, such as Northeast Atlantic cod stocks and Mediterranean hake stocks.

STECF concludes that improved gear selectivity is only one aspect of optimising yield and reducing juveniles catches. As a result, the gear studies considered by the EWG would be more likely to provide higher gains in terms of yield and SSB, if priority stocks were fished at or below FMSY.

STECF concludes that additional gear selectivity studies are required to provide robust estimates of selectivity for static gears (GNS, GTR, LLS); and additional selectivity options for active gears (OTB) that provide a gear selectivity shifted closer to the optimal fish lengths identified in the analysis.

STECF concludes that differences in gear selectivity coming from gear trials and the realised population selectivity of the OTB fleets are observed in some priority stocks. This could be driven by the operational reality of how gears are used and effected by external forces such as fisher behaviour, season, or be indicative of a higher availability of smaller fish to the commercial trawlers.

STECF concludes that mixed fisheries (target, bycatch and PET species) bio-economic models would provide valuable information on the trade-offs involved for reaching the optimal yield goals. Several models already exist that can account for the population dynamics, fisher behaviour, and seasonality of selectivity patterns of multiple stocks combined.

STECF concludes fisheries-based transition plans for modified or alternative gears require not only technical trials, but to be also supported by assessments of socio-economic impacts. STECF recognises that substantial work will be required to develop such assessments, which would need to be tailored to specific regions and fisheries. To achieve this, STECF proposes a four-step process should be followed to ensure favourable outcomes of the EWG 23-15.

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# REPORT TO THE STECF

# EXPERT WORKING GROUP ON
# Review of the Technical Measures Regulation
# (EWG-22-19)

## JRC Ispra, 23-27 January 2023

# 1 INTRODUCTION

The entry into force of the "Technical Measures Regulation" (TMR)[1], introduced the obligation for the Commission to report to the European Parliament and to the Council on the implementation of the Regulation. This reporting obligation is aimed at assessing the "extent to which technical measures both at regional and Union level have contributed to achieving the objectives set out in Article 3 and reaching the targets set out in Article 4" (Article 31.1). The Regulation does not set legally binding targets; the indicators are monitoring tools which may inform deliberations or decisions at regional level.

Measuring progress in achieving the objectives set out in Article 3 and in reaching the targets set out in Article 4 is vital to check whether technical measures put in place are adequate and fit for purpose, and consequently, to assess where and how changes should be made.

In 2020, a dedicated STECF EWG (EWG 20-02; STECF, 2020a) was tasked to evaluate the performance of technical measures in line with the above. The main requirement needed for structuring the evaluation exercise and the associated EWG was to establish and agree on a methodology and the appropriate indicators that can be used routinely to carry out the evaluation required by the Regulation.

Following EWG 20-02, and given that STECF will be requested to undertake an evaluation of the performance of the technical measures every three years thereby advising the Commission on their triannual reporting obligation, some options on how to proceed in the future were provided and discussed during STECF PLEN 21-01 and EWG 21-02. Taking into consideration that a key objective of the TMR is to optimise exploitation patterns (Article 3(2a) of the TMR), discussions during STECF PLEN 21-01 and EWG 21-02 highlighted the necessity to assess not only whether there are any changes in selectivity but also how far stocks lie from the optimal selectivity that would offer the highest possible yields. For these reasons, a stepwise approach was suggested and followed, with a dedicated STECF EWG (EWG 21-07; STECF, 2021) acting as a first step. Specifically, EWG 21-07 assessed the population selectivity-at-age of species listed in Annex XIV of the TMR and compared it to the optimal one.

Following EWG 21-07, STECF PLEN 22-01 and STECF PLEN 22-03 suggested that the second step of the process, assigned to EWG 22-19, should be the evaluation of the population selectivity-at-length of species listed in Annex XIV of the TMR, in order to be able to link it with actual size-based fishing gear selectivity and offer optimisation solutions. Specifically, the Commission requested STECF to make available information concerning the optimal sizes and ages at which each commercial fish species, taken individually, should be caught if these species were fished in separate, clean fisheries, as well as the types and technical definitions of fishing gear that would be appropriate to catch fish of these sizes. This information will assist Member States in identifying the direction and the potential gains to be achieved concerning each fish stock individually. Recognising that many EU fisheries interact simultaneously with multiple species during their operation, Member States will also need technical support and operational tools to identify the costs, benefits and feasibility of transitioning from current fishing gears to the direction of optimal yields. At this stage, STECF was requested to identify the necessary operational changes and to identify the technical support necessary to inform Member States and other parties of the costs and benefits of various transition options.

The main mechanism for adjusting the permitted structure of fishing gear in order to help optimise exploitation patterns, protect juveniles and help achieve MSY is through amendments of annexes of the TMR, following the regionalisation procedure set out in Article 15 of that Regulation, i.e. based on joint recommendations from Member States in accordance with Article 18 of the CFP (Regulation (EU) No 1380/2013). It is anticipated that at a later stage, further work will be needed to develop advanced technical support tools, most likely tailored to specific regions and fisheries.

[1] Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019 on the conservation of fisheries resources and the protection of marine ecosystems through technical measures.

## 1.1 Terms of Reference for EWG-22-19

Following discussions after EWG 20-02 and EWG 21-07, EWG 22-19 is requested to:

1) Identify the ages and sizes at which fish (as per Annex XIV of the Technical Measures Regulation 2019/1241) would need to be caught to optimise yield and reduce the catches of juveniles as far as possible, building upon the relevant work of STECF-21-07. Prioritise stocks where the highest gains can be achieved.

2) Identify the fishing gears corresponding to the optimum age and size of each of the stocks in (1).

3) If feasible, identify possible operational changes needed to realise the transition to higher yields. Identify the technical support required to assess at the regional level, the potential socio-economic implications of fisheries-based transition plans for improving yields.

# 2 GENERAL APPROACH TO THE TERMS OF REFERENCE

## 2.1 Concepts

Fisheries selectivity describes the ability to target and capture fish by size and species during harvesting operations, allowing bycatch of juvenile fish and non-target species to escape unharmed (Garcia, 2009). Accordingly, fisheries selectivity may either refer to (un)desirable species (species selectivity) or sizes (size selectivity). Species selectivity typically refers to the avoidance of unwanted species (e.g., endangered species, choke species, non-commercial species), while size selectivity refers to the avoidance of specific sizes (e.g., juveniles, individuals below Minimum Conservation Reference Size - MCRS) of a given species. Size selectivity is the focus of this report.

Following Millar & Fryer (1999), three different types of selectivity can be defined in order to describe adequately the population selectivity related to size of a fish *l*. The following definitions and equation are taken from equations (1) & (2) of the aforementioned paper and are an adaptation of them in order to define population selectivity in a compact and hierarchical way:

• $v(l)$: The probability of fish of length *l* is available to the gear (i.e. part of the vulnerable population)

• $c(l)$: The probability of fish of length *l* contacts the gear given that is available to the gear (i.e. probability of non-avoidance)

• $r(l)$: The probability that a fish of length *l* is captured given that it contacted the gear (i.e. gear selectivity).

These three types of selectivity are related to population selectivity $s(l)$ as:

$$s(l) \propto v(l) \times c(l) \times r(l) \quad (1)$$

where $s(l)$ is the population selectivity defined as the probability that a fish of length *l* from the population is captured. In a more schematic form:

(availability probability) → (contact probability) → (retention probability)

where each probability holds if and only if its preceding holds.

Consequently, population selectivity is the result of fish availability, fish avoidance behaviour and gear selectivity. Assuming that the non-avoidance probability is adequately captured by the gear trials and is reflected by gear selectivity, it can be inferred that population selectivity describes the differential vulnerability to fishing of the demographic components of an entire fish population, as a result of both the gear used (e.g., active or passive gear, mesh shape and size) and availability (e.g., due to the choice of time and place to fish) (Millar & Fryer, 1999; Scott & Sampson, 2011).

In age-structured stock assessments, population selectivity is inferred as:

$$s(a) = F(a)/\max(F(a)) \quad (2)$$

where $F(a)$ is the fishing mortality at age *a* and $\max F(a)$ is the maximum fishing mortality observed at any age-classs, which is also known as apical F ($F_{apical}$) (Scott & Sampson 2011).

This report deals both with population selectivity, gear selectivity and availability, as well as with the interplay between them. Within the report, 'selectivity' refers to 'population selectivity', unless otherwise specified (e.g. as 'gear selectivity'). Accordingly, 'A50'/'L50' are used for population age-at-50%-selectivity and population length-at-50%-selectivity, respectively, while '$A_g50$'/'$L_g50$' are used for gear age-at-50%-selectivity and gear length-at-50%-selectivity, respectively.

## 2.2 Approach

For ToR 1, EWG 22-19 revisited the age-based work on selectivity done by EWG 21-07, which had estimated the age-at-50%-selectivity (A50) for the current selectivity and two versions of optimised selectivity ('crank' and 'shift', explained later), obtained by projections to equilibrium under the current fishing mortality (*F*) and different selectivity curves, for a set of stocks corresponding to the Annex XIV of Regulation (EU) No 2019/1241. EWG 22-19 extended that work by calculating the length-at-50%-selectivity (L50) corresponding to the age-based estimations of EWG 21-07, and then identified a set of 11 'priority stocks' based on the highest estimated gains in terms of both yield and protection of juveniles.

In order to transform age-based estimates to length-based ones, EWG 22-19 implemented a deterministic conversion using the stock-specific parameters of the von Bertalanffy growth equation ($L_{inf}$, k and $t_0$). These were taken from the respective STECF stock assessment reports in the case of Mediterranean stocks. For ICES stocks, where von Bertalanffy parameters were not readily available, these were estimated by fitting the von Bertalanffy equation over survey data taken from DATRAS.

EWG 21-07 had also carried out projections for each stock under both varying *F* and selectivity-at-age, to construct three-dimensional graphs ('isopleths') of the equilibrium yield and SSB from different combinations of *F* and selectivity, to identify the combinations that lead to higher yields at lower levels of stock depletion. EWG 22-19 extended that work by exchanging selectivity-at-age with selectivity-at-length and rescaling the isopleths.

For ToR 2, EWG 22-19 reviewed and compiled available gear selectivity parameters from both peer-reviewed and grey literature for as many stocks (by region as listed in Annex XIV of Regulation (EU) No 2019/1241) and gears as possible. Priority was however given to the 11 stocks with the highest expected gains of increased selectivity from ToR 1 (see later). The aim was to identify and list size selectivity information and technical specifications, both for the regional baseline gears, and for other relevant alternative gears by stock and region. Special focus was to find gear trials reporting particularly high size selectivity to match the request of ToR 2 as far as possible.

EWG 22-19 then focused on the 11 priority stocks (six ICES stocks and five Mediterranean ones) with the highest potential gains as separate case studies in order to examine in more detail: (a) how the current selectivity curve (both age-based and length-based) compared with the optimal one, (b) how the selectivity-at-length curves of different fleet segments (where available from the stock assessments) compared between them and with the optimal one and (c) how different gear selectivity curves (typically one curve for the default/baseline gear and 1-3 curves for improved gears) compared both between them, to the selectivity curve of the respective fleet segment and to the optimal selectivity curve. The L50 of different gears ($L_g50$) was also plotted on the stock-specific isopleths of the equilibrium yield and SSB from different combinations of *F* and selectivity to identify if improved selectivity would require smaller changes in *F* to approach the optimal yields, and if improved selectivity would be associated with lower levels of stock depletion.

EWG 22-19 split ToR 3 in two parts. In the first part, EWG 22-19 described the operational changes (i.e. gear modifications or gear shifts) that could be made to transition fisheries to higher yields. The second part considers the technical support, information and data needed to assess the socio-economic implications of making these transitions. Both parts were addressed qualitatively by illustrating challenges and lessons learnt based on relevant case studies in the literature, and also from work by EWG 21-07. The work done is intended as a potential first step to assist DGMARE in discussing and designing transition plans with Member States and other stakeholders going forward.

# 3 MATERIALS AND METHODS

## 3.1 Data

### *3.1.1 Stock dataset*

To maintain consistency, the stocks analysed in this report were the same as the ones analysed by EWG 21-07 (STECF, 2021), and correspond to those that were identified to have age-structured information available, among the stocks listed in Annex XIV of Regulation (EU) No 2019/1241. In total, 20 ICES stocks and 13 Mediterranean ones were considered (Table 3.1.1.1).

**Table 3.1.1.1:** Summary table of stocks by region and area that were considered in this report. The column 'Fleet Data' indicates the availability of partial F-at-age data of different fleet segments. NEA: Northeast Atlantic, MED: Mediterranean Sea; BS: Baltic Sea, NS: North Sea; NWW: Northwestern Waters; SWW: Southwestern Waters; WM: Western Mediterranean; CEM: Central and Eastern Mediterranean.

| Region | Area | Stock | Species | Assessment | Fleet Data |
|---|---|---|---|---|---|
| NEA | BS | cod.27.22-24 | *Gadus morhua* | ICES, SAM, 2021 | Yes |
| NEA | BS | ple.27.21-23 | *Pleuronectes platessa* | ICES, SAM, 2021 | Yes |
| NEA | NS | cod.27.47d20 | *Gadus morhua* | ICES, SAM, 2021 | Yes |
| NEA | NS | had.27.46a20 | *Melanogrammus aeglefinus* | ICES, TSA, 2021 | Yes |
| NEA | NS | ple.27.420 | *Pleuronectes platessa* | ICES, AAP, 2021 | Yes |
| NEA | NS | ple.27.7d | *Pleuronectes platessa* | ICES, AAP, 2021 | Yes |
| NEA | NS | pok.27.3a46 | *Pollachius virens* | ICES, SAM, 2021 | Yes |
| NEA | NS | whg.27.47d | *Merlangius merlangus* | ICES, SAM, 2021 | Yes |
| NEA | NWW | cod.27.6a | *Gadus morhua* | ICES, SAM, 2021 | Yes |
| NEA | NWW | cod.27.7e-k | *Gadus morhua* | ICES, SAM, 2021 | No |
| NEA | NWW | had.27.6b | *Melanogrammus aeglefinus* | ICES, XSA, 2021 | Yes |
| NEA | NWW | had.27.7a | *Melanogrammus aeglefinus* | ICES, ASAP, 2021 | Yes |
| NEA | NWW | had.27.7b-k | *Melanogrammus aeglefinus* | ICES, SAM, 2021 | No |
| NEA | NWW | ple.27.7a | *Pleuronectes platessa* | ICES, SAM, 2021 | Yes |
| NEA | NWW | whg.27.7a | *Merlangius merlangus* | ICES, ASAP, 2021 | No |
| NEA | NWW | whg.27.7b-ce-k | *Merlangius merlangus* | ICES, SAM, 2021 | No |
| NEA | SWW | hke.27.3a46-8abd | *Merluccius merluccius* | ICES, SS3, 2021 | No |
| NEA | SWW | ldb.27.8c9a | *Lepidorhombus boscii* | ICES, XSA, 2021 | No |
| NEA | SWW | meg.27.7b-k8abd | *Lepidorhombus whiffiagonis* | ICES, Bayesian, 2021 | Yes |
| NEA | SWW | meg.27.8c9a | *Lepidorhombus whiffiagonis* | ICES, XSA, 2021 | No |
| MED | WM | HKE.01_05_06_07 | *Merluccius merluccius* | STEFC, a4a, 2020 | Yes |
| MED | WM | HKE.08_09_10_11 | *Merluccius merluccius* | STEFC, a4a, 2020 | Yes |
| MED | WM | MUR.05 | *Mullus surmuletus* | STEFC, a4a, 2020 | Yes |
| MED | WM | MUT.01 | *Mullus barbatus* | STEFC, a4a, 2020 | No |
| MED | WM | MUT.06 | *Mullus barbatus* | STEFC, a4a, 2020 | No |
| MED | WM | MUT.07 | *Mullus barbatus* | STEFC, a4a, 2020 | Yes |
| MED | WM | MUT.09 | *Mullus barbatus* | STEFC, a4a, 2020 | Yes |
| MED | WM | MUT.10 | *Mullus barbatus* | STEFC, a4a, 2020 | Yes |
| MED | CEM | HKE.17_18 | *Merluccius merluccius* | STEFC, SS3, 2020 | No |
| MED | CEM | HKE.19 | *Merluccius merluccius* | STEFC, a4a, 2020 | No |
| MED | CEM | HKE.20 | *Merluccius merluccius* | STEFC, a4a, 2020 | No |
| MED | CEM | MUT.17_18 | *Mullus barbatus* | STEFC, a4a, 2020 | No |
| MED | CEM | MUT.22 | *Mullus barbatus* | STEFC, a4a, 2020 | No |

For all stocks, EWG 22-19 used the same stock assessment outputs that had been used by EWG 21-07 in the form of 'FLStock' objects. For some of the stocks, partial F-at-age by fleet segment in the form of 'FLQuant' objects were also available and analysed. More details on data sources and data preparation can be found in STECF, 2021.

### 3.1.2 DATASET FOR THE VON BERTALANFFY PARAMETER ESTIMATION

For the 20 ICES stocks in Table 3.1.1.1, survey-collected length-at-age data were used to estimate the von Bertalanffy growth curve parameters. This data was extracted from DATRAS (ICES), which is an online database of trawl surveys with access to standard data products, which provide quality assured survey data. DATRAS stores data collected primarily from bottom trawl fish surveys coordinated by ICES expert groups. The surveys used in this analysis are highlight in Table 3.1.2.1, and were based on the available information in advice sheets. All data, before entering the database, have to pass an extensive quality check. This data was extracted using the 'icesDatras' package in R (Millar *et al.*, 2022).

**Table 3.1.2.1** Summary of surveys used by stock, information taken from ICES advice sheets. BS: Baltic Sea, NS: North Sea; NWW: Northwestern Waters; SWW: Southwestern Waters.

| Area | Stock | Species | Surveys used for assessment |
|---|---|---|---|
| BS | cod.27.22-24 | *Gadus morhua* | Baltic International Trawl Survey (BITS)<br>Kattegat Cod Survey (FEJUCS) |
| BS | ple.27.21-23 | *Pleuronectes platessa* | North Sea International Bottom Trawl (NS-IBTS)<br>Baltic International Trawl Survey (BITS) |
| NS | cod.27.47d20 | *Gadus morhua* | North Sea International Bottom Trawl (NS-IBTS) |
| NS | had.27.46a20 | *Melanogrammus aeglefinus* | North Sea International Bottom Trawl (NS-IBTS)<br>Scottish West Coast Bottom Trawl Survey (up to 2010) SWC-IBTS<br>Scottish West Coast Groundfish Survey (ScoGFS-WIBTS)<br>Scottish West Coast Groundfish Survey (UK-SCOWCGFS)<br>North Sea International Bottom Trawl (NS-IBTS)<br>Irish Ground Fish Survey (IGFS-WIBTS) |
| NS | ple.27.420 | *Pleuronectes platessa* | Trident<br>BTS - Isis, Common sole (Isis)<br>Belgica<br>Solea<br>Sole Net Survey (SNS)<br>North Sea International Bottom Trawl (NS-IBTS) |
| NS | ple.27.7d | *Pleuronectes platessa* | Beam Trawl Survey - North Sea, Irish Sea and Western Channel (UK-BTS)<br>French Channel Groundfish Survey (FR-GFS) |
| NS | pok.27.3a46 | *Pollachius virens* | North Sea International Bottom Trawl (NS-IBTS) |
| NS | whg.27.47d | *Merlangius merlangus* | North Sea International Bottom Trawl (NS-IBTS) |
| NWW | cod.27.6a | *Gadus morhua* | Scottish West Coast Groundfish Survey (ScoGFS-WIBTS)<br>Scottish West Coast Groundfish Survey (UK-SCOWCGFS)<br>Irish Ground Fish Survey (IGFS-WIBTS) |

| Area | Stock | Species | Surveys used for assessment |
|---|---|---|---|
| NWW | cod.27.7e-k | *Gadus morhua* | Irish Ground Fish Survey (IGFS-WIBTS)<br>French Southern Atlantic Bottom Trawl Survey (EVHOE-WIBTS) |
| NWW | had.27.6b | *Melanogrammus aeglefinus* | Scottish Rockall Bottom Trawl Survey (Rock-WIBTS) |
| NWW | had.27.7a | *Melanogrammus aeglefinus* | Northern Ireland Ground Fish Survey (NIGFS-WIBTS)<br>The Northern Ireland MIK Survey (NI MIK)<br>UK Fishery Science Partnership (UKFSPW) |
| NWW | had.27.7b-k | *Melanogrammus aeglefinus* | Irish Ground Fish Survey (IGFS-WIBTS)<br>French Southern Atlantic Bottom Trawl Survey (EVHOE-WIBTS) |
| NWW | ple.27.7a | *Pleuronectes platessa* | UK (E&W)-BTS<br>Northern Ireland Ground Fish Survey (NIGFS-WIBTS) |
| NWW | whg.27.7a | *Merlangius merlangus* | Northern Ireland Ground Fish Survey (NIGFS-WIBTS)<br>The Northern Ireland MIK Survey (NI MIK) |
| NWW | whg.27.7b-ce-k | *Merlangius merlangus* | Irish Ground Fish Survey (IGFS-WIBTS)<br>French Southern Atlantic Bottom Trawl Survey (EVHOE-WIBTS) |
| SWW | hke.27.3a46-8abd | *Merluccius merluccius* | Spanish North Coast Bottom Trawl Survey (SP-NSGFS)<br>Irish Ground Fish Survey (IGFS-WIBTS)<br>Irish Anglerfish and Megrim Survey (IE-IAMS)<br>French surveys in the Bay of Biscay (FR-RESSGAC) |
| SWW | ldb.27.8c9a | *Lepidorhombus boscii* | Spanish North Coast Bottom Trawl Survey (SP-NSGFS)<br>Spanish North Coast Bottom Trawl Survey (SP-NSGFS) |
| SWW | meg.27.8c9a | *Lepidorhombus whiffiagonis* | Spanish North Coast Bottom Trawl Survey (SP-NSGFS) |
| SWW | meg.27.7b-k8abd | *Lepidorhombus whiffiagonis* | Spanish Porcupine Bottom Trawl Survey (SP-NSGFS)<br>Irish Ground Fish Survey (IGFS-WIBTS)<br>French Southern Atlantic Bottom Trawl Survey (EVHOE-WIBTS) |

The von Bertalanffy growth curve parameters for the 13 Mediterranean stocks of Table 3.1.1.1 were extracted from the respective STECF stock assessment reports (STECF, 2020b; 2020c).

## 3.2 Methods

### 3.2.1 VON BERTALANFFY PARAMETER ESTIMATION IN ICES STOCKS

The FSA package in R (Ogle *et al.*, 2020) was used to determine the starting values Ford-Walford (vbStarts{FSA}) and a Von Bertalanfy growth function (VBGF) was fit to DATRAS survey data for each stock, by bootstrapping a nonlinear regression (nls{stats}(R Core 2022)). The most common version of the VBGF was used to calculate these values. Within the FSA package this is refered to as the 'typical' version of the VBGF and is represented by:

$$E[L|t] = L_{inf}\,(1 - e^{-k(t-t0)}) \qquad (3)$$

where $E[L|t]$ is the expected or average length at time (or age) t, $L_{inf}$ is the asymptotic average length, k is the body growth rate coefficient (units are $y^{-1}$), and $t_0$ represents the time or age when the average length was zero (Ogle, 2016).

It should be noted that $L_{inf}$ is the asymptote for the model of average length-at-age (Francis, 1988). As with any average, it does not correspond to the maximum length of the animal. Some individuals will be larger than average; thus, some animals will be larger than $L_{inf}$.

### 3.2.2 SELECTIVITY ANALYSIS

For the analysis of the impact of varying age-based selectivity, the R package FLSelex was used, that is available on https://github.com/Henning-Winker/FLSelex. This package is used in FLR (Fisheries Library in R; Kell *et al.*, 2007) and its development was led by the co-chair of EWG 21-07, Henning Winker (JRC). For the analysis of varying length-based selectivity by EWG 22-19, a length-based version of FLSelex, FLSelexLen, was developed by Michael Gras (JRC), with the support of the EWG 22-19 expert Danai Mantopoulou-Palouka (Aristotle University of Thessaloniki). FLSelexLen is available on https://github.com/michaelgras/FLSelexLen.

FLSelex and FLSelexLen include a range of age-based and length-based functions, respectively, that allow fitting selectivity curves, varying selectivity by 'cranking' or 'shifting' the selectivity curve (Fig 3.2.2.1, 3.2.2.2), estimating the equilibrium optimisation of selectivity, as well as forecasting. They also include a range of relevant plotting functions. More details on FLSelex can be found in the 'FLSelex Handbook' available on https://github.com/Henning-Winker/FLSelex and in STECF, 2021.

It should be noted that spawner-recruit relationships (SRRs) were integrated into yield maximisations at equilibrium. These SRRs were the same ones used by EWG 21-07 (STECF, 2021). The SRRs were Beverton-Holt for all stocks except cod.27.6a, where a segmented regression with a breakpoint at $B_{lim}$ was used, and for the Mediterranean hake stocks where the geometric mean of recruitment was used. Therefore, for Mediterranean hake stocks equilibrium yield-per-recruit (YPR) and SSB-per-recruit (SBR) have been estimated rather than equilibrium yield and SSB. More details on the SSR fitting and selection can be found in STECF, 2021.

For practical reasons and simplicity, EWG 22-19 used the age-at-50%-selectivity (A50) and length-at-50%-selectivity (L50) inferred from the ascending part of the selectivity curve as the common 'currency' to quantify selectivity. This approximation works well for logistic selectivity curves, but may be less accurate for selectivity curves of other types (e.g. dome-shaped; saddle-shaped), which are often encountered in fish stocks (Sampson & Scott, 2012).

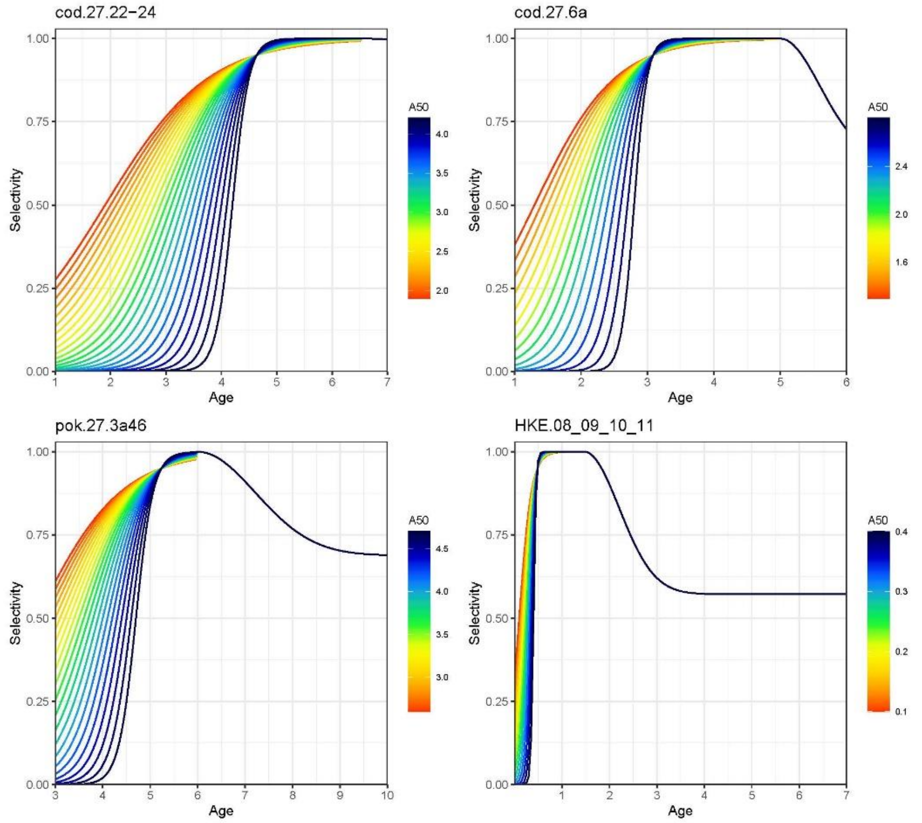


**Figure 3.2.2.1** 'Cranking' the ascending slope of the estimated selectivity curve by varying A50, shown for examples from the Northeast Atlantic (cod.27.22-24, cod.27.6a, pok.27.3a46) and the Mediterranean Sea (HKE.08-09-10-11).

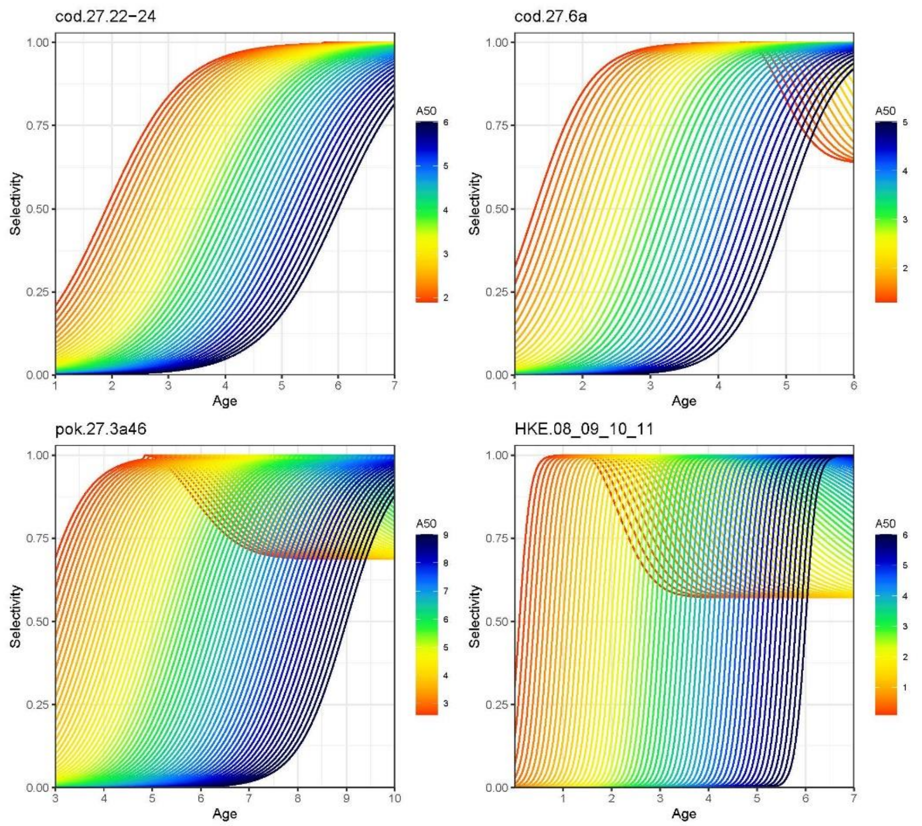


**Figure 3.2.2.2** 'Shifting' the estimated selectivity curve, shown for examples from the Northeast Atlantic (cod.27.22-24, cod.27.6a, pok.27.3a46) and the Mediterranean Sea (HKE.08-09-10-11).

# 4 RESULTS

## 4.1 Von Bertalanffy parameter estimates

### 4.1.1 NE ATLANTIC STOCKS

The VBGF parameter estimates extracted by fitting the VBGF over survey data from DATRAS for the 20 NE Atlantic stocks are presented in Table 4.1.1.1, together with a summary of the data used.

**Table 4.1.1.1** Von Bertalanffy parameter estimates ($L_{inf}$ in cm, k, $t_0$) for each of the 20 ICES stocks analysed here. Par: parameter; Est: estimate; Q: quarter.

| Stock | Par | Est | Std. error | Median | 2.50% | 97.50% | Max age | Max length | Sample size | Q | Sex | Year range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cod.27.22_24 | Linf | 125 | Value not estimated – fixed value | | | | 10 | 125 | 13723 | 1 | M/F/U | 2003 - 2022 |
| | k | 0.148 | 0.0007 | 0.148 | 0.146 | 0.149 | | | | | | |
| | t0 | -0.051 | 0.012 | -0.051 | -0.075 | -0.027 | | | | | | |
| ple.27.21-23 | Linf | 41.7 | 3.25 | 41.7 | 41.1 | 42.4 | 17 | 560 | 18406 | 1 | F | 2003 - 2022 |
| | k | 0.258 | 0.005 | 0.258 | 0.247 | 0.269 | | | | | | |
| | t0 | -0.340 | 0.027 | -0.340 | -0.400 | -0.286 | | | | | | |
| cod.27.47d20 | Linf | 138.1 | 23.0 | 138.1 | 134.0 | 142.6 | 13 | 1260 | 11303 | 1 | M/F/U | - |
| | k | 0.177 | 0.005 | 0.177 | 0.168 | 0.186 | | | | | | |
| | t0 | 0.165 | 0.013 | 0.164 | 0.139 | 0.191 | | | | | | |
| had.27.46a20 | Linf | 45.4 | 0.815 | 45.4 | 45.2 | 45.6 | 17 | 92 | 90393 | 3 | M/F/U | 2010-2022 |
| | k | 0.400 | 0.002 | 0.400 | 0.395 | 0.404 | | | | | | |
| | t0 | -0.693 | 0.006 | -0.693 | -0.703 | -0.681 | | | | | | |
| ple.27.420 | Lin | 40.8 | 0.86 | 40.8 | 40.6 | 40.9 | 32 | 67 | 68283 | 3 | M/F/U | 2010-2022 |
| | k | 0.249 | 0.019 | 0.249 | 0.245 | 0.253 | | | | | | |
| | T0 | -1.117 | 0.0164 | -1.117 | -1.149 | -1.086 | | | | | | |
| ple.27.7d | Linf | 57.1 | 1.18 | 57.1 | 54.9 | 59.5 | 19 | 60 | 7232 | 3 | F | 2010-2021 |
| | k | 0.125 | 0.005 | 0.124 | 0.114 | 0.136 | | | | | | |
| | t0 | -2.218 | 0.078 | -2.216 | -2.374 | -2.061 | | | | | | |
| pok.27.3a46 | Linf | 146.0 | 1.89 | 146.0 | 142.6 | 150.1 | 20 | 115 | 22992 | 3 | M/F/U | 2010-2022 |
| | k | 0.075 | 0.0016 | 0.075 | 0.114 | 0.136 | | | | | | |
| | t0 | -1.446 | 0.032 | -1.446 | -1.512 | -1.386 | | | | | | |
| whg.27.47d | Linf | 48.5 | 0.77 | 48.5 | 47.9 | 49.2 | 11 | 58 | 25095 | 3 | F | 2010-2022 |
| | k | 0.263 | 0.002 | 0.263 | 0.254 | 0.272 | | | | | | |
| | t0 | -1.237 | 0.005 | -1.237 | -1.195 | -1.283 | | | | | | |
| cod.27.6a | Linf | 137.6 | 26.8 | 131.4 | 105.3 | 205.2 | 4 | 79 | 649 | 4 | M/F/U | 2003 - 2012 |
| | k | 0.159 | 0.039 | 0.160 | 0.082 | 0.233 | | | | | | |
| | t0 | -1.179 | 0.157 | -1.166 | -1.521 | -0.907 | | | | | | |
| had.27.7b_k | Linf | 56.3 | 0.3 | 56.3 | 55.7 | 56.8 | 10 | 820 | 27171 | 4 | M/F/U | 2004 - 2021 |
| | k | 0.312 | 0.0046 | 0.312 | 0.303 | 0.320 | | | | | | |
| | t0 | -1.178 | 0.016 | -1.178 | -1.209 | -1.146 | | | | | | |
| cod.27.7e_k | Linf | 128.8 | 3.2 | 128.7 | 123 | 135.4 | 7 | 1100 | 2318 | 4 | M/F/U | 2003 - 2021 |
| | k | 0.287 | 0.014 | 0.287 | 0.261 | 0.314 | | | | | | |
| | t0 | -0.295 | 0.029 | -0.294 | -0.352 | -0.239 | | | | | | |
| had.27.6b | Linf | 53.7 | 0.2 | 53.7 | 53.3 | 54.2 | 13 | 810 | 13024 | 3 | M/F/U | 2013 - 2021 |
| | k | 0.331 | 0.004 | 0.331 | 0.323 | 0.340 | | | | | | |

| Stock | Par | Est | Std. error | Median | 2.50% | 97.50% | Max age | Max length | Sample size | Q | Sex | Year range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | t0 | -0.882 | 0.014 | -0.882 | -0.910 | -0.855 | | | | | | |
| had.27.7a | Linf | 63.1 | 0.8 | 63.1 | 61.5 | 64.8 | 9 | 753 | 12606 | 1 | M/F/U | 2008 - 2021 |
| | k | 0.246 | 0.006 | 0.246 | 0.234 | 0.259 | | | | | | |
| | t0 | -0.326 | 0.019 | -0.326 | -0.363 | -0.289 | | | | | | |
| ple.27.7a | Linf | 43.3 | 1.6 | 43.2 | 40.6 | 46.9 | 18 | 537 | 1916 | 1 | F | 2009 - 2017 |
| | k | 0.147 | 0.014 | 0.147 | 0.120 | 0.175 | | | | | | |
| | t0 | -1.853 | 0.220 | -1.838 | -2.345 | -1.464 | | | | | | |
| whg.27.7a | Linf | 43.6 | 0.5 | 43.6 | 42.7 | 44.6 | 7 | 494 | 17051 | 1 | M/F/U | 2008 - 2021 |
| | k | 0.374 | 0.009 | 0.374 | 0.357 | 0.394 | | | | | | |
| | t0 | -0.247 | 0.017 | -0.247 | -0.280 | -0.214 | | | | | | |
| whg.27.7b_ce_k | Linf | 51.2 | 0.3 | 51.1 | 50.5 | 51.8 | 8 | 650 | 20316 | 4 | M/F/U | 2004 - 2021 |
| | k | 0.334 | 0.006 | 0.334 | 0.323 | 0.345 | | | | | | |
| | t0 | -1.221 | 0.016 | -1.221 | -1.253 | -1.189 | | | | | | |
| hke.27.3a46-8abd | Linf | 108.3 | 2.5 | 108.2 | 103.6 | 113.2 | 11 | 912 | 3203 | 4 | M/F/U | 2003 - 2008 |
| | k | 0.105 | 0.004 | 0.105 | 0.098 | 0.113 | | | | | | |
| | t0 | -1.257 | 0.035 | -1.256 | -1.327 | -1.191 | | | | | | |
| lbd.27.8c9a | Linf | 41.9 | 2.7 | 41.5 | 37.9 | 48.2 | 9 | 400 | 4975 | 4 | F | 2003 – 2020 |
| | k | 0.113 | 0.017 | 0.113 | 0.080 | 0.146 | | | | | | |
| | t0 | -4.332 | 0.446 | -4.309 | -5.258 | -3.551 | | | | | | |
| meg.27.8c9a | Linf | 52.6 | 2.8 | 52.2 | 48.3 | 58.9 | 11 | 540 | 4435 | 4 | F | 2003 - 2020 |
| | k | 0.115 | 0.014 | 0.115 | 0.088 | 0.142 | | | | | | |
| | t0 | -3.795 | 0.311 | -3.769 | -4.427 | -3.253 | | | | | | |
| meg.27.7b-k8abd | Linf | 73.8 | 3.8 | 73.4 | 67.2 | 82.4 | 12 | 590 | 7463 | 4 | F | 2003 - 2021 |
| | k | 0.075 | 0.007 | 0.0752 | 0.062 | 0.088 | | | | | | |
| | t0 | -2.049 | 0.140 | -2.041 | -2.336 | -1.799 | | | | | | |

### 4.1.2 MEDITERRANEAN STOCKS

The VBGF parameter estimates for the 13 Mediterranean stocks were extracted from the Mediterranean stock assessment reports of the STECF EWG 20-09 and EWG 20-15 (STECF, 2020b; 2020c), in order to be in line with the stock objects used in the corresponding analysis. These VBGF parameters are used for age-slicing of the EU DCF length data prior to the stock assessments. In some cases, where sex-specific VBGF estimates were available, STECF EWG 20-09 and EWG 20-15 performed age-slicing by sex during the FLR stock object preparation. Nevertheless, STECF EWG 22-19 opted for using only one set of VBGF parameters for each stock to convert ages into lengths; either a 'sexes combined' one, or the 'female' one (Table 4.1.2.1).

**Table 4.1.2.1** Summary of the VBGF parameters used by STECF EWG 20-09 and EWG 20-15 to age-slice EU DCF length data to prepare the FLR stock objects for stock assessment. The VBGF parameters highlighted in bold are the ones used by STECF EWG 22-19 to derive lengths from ages. WM: Western Mediterranean; CEM: Central and Eastern Mediterranean; C: sexes combined; F: Females; M: Males.

| Area | Stock | Assessment | sex | $L_{inf}$ (cm) | k | $t_0$ | Comments |
|---|---|---|---|---|---|---|---|
| WM | HKE.01_05_06_07 | STEFC, a4a, 2020 | C | **110** | **0.178** | **-0.005** | |
| WM | HKE.08_09_10_11 | STEFC, a4a, 2020 | F | **95** | **0.16** | **-0.06** | |
| | | | M | 60 | 0.265 | -0.06 | |
| WM | MUR.05 | STEFC, a4a, 2020 | C | **33.4** | **0.43** | **-0.1** | |
| WM | MUT.01 | STEFC, a4a, 2020 | C | **34.5** | **0.34** | **-0.14** | |

| Area | Stock | Assessment | sex | $L_{inf}$ (cm) | k | $t_0$ | Comments |
|---|---|---|---|---|---|---|---|
| WM | MUT.06 | STEFC, a4a, 2020 | C | **34.5** | **0.34** | **-0.14** | |
| WM | MUT.07 | STEFC, a4a, 2020 | C | **26.25** | **0.5** | **-0.55** | ALKs used to convert length data into ages for the assessment done by EWG 20-09; fitted VBGF used by EWG 22-19 |
| WM | MUT.09 | STEFC, a4a, 2020 | F | **26.56** | **0.545** | **0.17** | t0 +0.5 correction (original t0 = -0.33) |
| | | | M | 21.55 | 0.56 | 0.17 | t0 +0.5 correction (original t0 = -0.33) |
| WM | MUT.10 | STEFC, a4a, 2020 | F | **30** | **0.243** | **0.62** | |
| | | | M | 26 | 0.237 | 0.9 | |
| CEM | HKE.17_18 | STEFC, a4a, 2020 | F | **111** | **0.1** | **-0.717** | |
| | | | M | 73 | 0.15 | -0.741 | |
| CEM | HKE.19 | STEFC, a4a, 2020 | F | **111** | **0.1** | **-0.6** | |
| | | | M | 73 | 0.15 | -0.73 | |
| CEM | HKE.20 | STEFC, a4a, 2020 | C | **104** | **0.12** | **-0.01** | |
| CEM | MUT.17_18 | STEFC, a4a, 2020 | F | **29.185** | **0.247** | **-0.768** | |
| | | | M | 22.725 | 0.328 | -0.816 | |
| CEM | MUT.22 | STEFC, a4a, 2020 | C | **32.6** | **0.17** | **-1.78** | |

## 4.2 Identify the ages and sizes at which fish would need to be caught to optimise yield and reduce the catches of juveniles (ToR 1)

### 4.2.1 OPTIMISATION UNDER CURRENT FISHING MORTALITY

The optimal age/size that fish of each stock need to be caught, i.e. age-at-50%-selectivity (A50) and length-at-50%-selectivity (L50), for yield to be maximised under current fishing mortality are shown in Tables 4.2.1.1 and 4.2.1.3 for ICES and Mediterranean stocks, respectively. 'Current' F and selectivity refer to the average of the last three years available from the assessments (2018-2020 for ICES stocks, 2017-2019 for Mediterranean stocks).

In the NE Atlantic, the optimal 'shift' type of selectivity change (Fig. 3.2.2.2) generates higher yields than the optimal 'crank' type of selectivity change (Fig. 3.2.2.1) for 12 stocks, and vice versa for 8 stocks (Table 4.2.1.1, Table 4.3.1). Meanwhile, the respective gains in protection of juveniles are higher for the 'shift' than the 'crank' type for 13 of the 20 stocks (Table 4.3.1). Due to unrealistic estimates of length from the age-to-length conversion for cod.27.6a, possibly owing to the low estimated value of $t_0$ (Table 4.1.1.1), VBGF parameters from the neighbouring cod.27.47d20 were used for the age-to-length conversion of cod.27.6a.

In the Mediterranean, the optimal 'shift' type of selectivity change generates higher yields than the optimal 'crank' type of selectivity change for 11 of the 13 stocks (Table 4.2.1.3, Table 4.3.2). Meanwhile, the respective gains in protection of juveniles are higher for the 'shift' than the 'crank' type for 6 stocks, while in the 7 remaining stocks juveniles consist less than 0.3% of the catch for both the 'crank' and the 'shift' type (Table 4.3.2). It should be noted that selectivity typically peaks at earlier ages/sizes in Mediterranean stocks than NE Atlantic ones (Fig. 3.2.2.1), leaving little space for 'crank' to improve selectivity compared to 'shift'.

To visualise which fleet segments are closer and which further from the optimal selectivity, the A50 and L50 inferred from the partial F-at-age curves (partial selectivity) of fleet segments were examined, wherever these were available. Typically, trawlers (OTB, TBB) were found to select younger/smaller fish than passive gears (e.g. GNS, GTR, LLS), both in the NE Atlantic (Table 4.2.1.2) and the Mediterranean (Table 4.2.1.4).

**Table 4.2.1.1** Selectivity estimates for NE Atlantic stocks summarizing the age-at-50%-selectivity (A50) and length-at-50%-selectivity (L50) for the current selectivity ('Current') and the optimised selectivity curves ('Crank', 'Shift'). In addition, the $A_{mat}$/$L_{mat}$ corresponding to age/length-at-50%-maturity ('Maturity'), the $A_{opt}$/ $L_{opt}$ at which the total biomass of an unfished cohort (F = 0) attains a maximum ('Max Biomass'), as well as the $A_{plusgroup}$/$L_{plusgroup}$ of the maximum age/length assumed in the assessment ('Plusgroup') are provided for reference. Ages are as reported by EWG 21-07 and lengths were derived from ages using VBGF parameters estimated on the basis of DATRAS data. All ages are given in y and all lengths in cm. Bold font indicates the A50/L50 producing the highest gains in yield (see also Table 4.3.1).

| | | | **Current** | | **Crank** | | **Shift** | | **Maturity** | | **Max Biomass** | | **Plusgroup** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Region | Area | Stock | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{mat}$ | $L_{mat}$ | $A_{opt}$ | $L_{opt}$ | $A_{plusgroup}$ | $L_{plusgroup}$ |
| NEA | BS | cod.27.22-24 | 2.7 | 40.7 | 4.2 | 59.6 | **6.0** | **80.4** | 1.9 | 30 | 6 | 80.4 | 7 | 91.2 |
| NEA | BS | ple.27.21-23 | 2.3 | 20.6 | 3.6 | 26.6 | **6.0** | **33.6** | 2.0 | 18.9 | 6 | 33.6 | 7 | 35.4 |
| NEA | NS | cod.27.47d20 | 1.9 | 36.5 | 2.8 | 51.5 | **4.4** | **72.9** | 3.0 | 54.5 | 5 | 79.5 | 6 | 89 |
| NEA | NS | had.27.46a20 | 1.9 | 29.3 | **1.3** | **24.9** | 1.3 | 24.9 | 2.6 | 33.2 | 7 | 43.3 | 8 | 44 |
| NEA | NS | ple.27.420 | 1.5 | 19.6 | 2.0 | 22 | **7.2** | **35.7** | 2.5 | 24.2 | 9 | 37.5 | 10 | 38.3 |
| NEA | NS | ple.27.7d | 1.9 | 22.9 | 2.0 | 23.3 | **2.0** | **23.3** | 2.9 | 26.9 | 4 | 30.8 | 7 | 39 |
| NEA | NS | pok.27.3a46 | 3.8 | 47.4 | 4.7 | 53.9 | **8.1** | **74.6** | 4.7 | 53.9 | 9 | 79.2 | 10 | 84 |
| NEA | NS | whg.27.47d | 2.3 | 29.4 | **1.6** | **25.5** | 1.6 | 25.5 | 1.3 | 23.6 | 4 | 36.3 | 8 | 44.3 |
| NEA | NWW | cod.27.6a* | 2.2 | 41.8 | **3.8** | 65.8 | 4.0 | 68.1 | 1.9 | 36.5 | 4 | 68.1 | 7 | 97.0 |
| NEA | NWW | cod.27.7e-k | 1.1 | 42.5 | 1.8 | 58.2 | **4.6** | **97.2** | 2.0 | 62.1 | 5 | 100.6 | 7 | 113 |
| NEA | NWW | had.27.6b | 2.1 | 33.7 | 3.3 | 40.3 | **5.0** | **46.1** | 2.6 | 36.8 | 5 | 46.1 | 7 | 49.8 |
| NEA | NWW | had.27.7a | 0.9 | 16.4 | **0.6** | **12.9** | 0.6 | 12.9 | 1.6 | 23.8 | 4 | 41.4 | 5 | 46.1 |
| NEA | NWW | had.27.7b-k | 3.2 | 41.9 | 2.7 | 39.5 | **2.7** | **39.5** | 1.6 | 32.6 | 7 | 51.9 | 8 | 53 |
| NEA | NWW | ple.27.7a | 1.8 | 18 | 1.3 | 16.1 | **3.8** | **24.5** | 2.9 | 21.8 | 7 | 31.6 | 8 | 33.2 |
| NEA | NWW | whg.27.7a | 0.5 | 10.6 | **1.2** | **18.2** | 1.7 | 22.6 | 1.6 | 21.8 | 4 | 34.7 | 6 | 39.4 |
| NEA | NWW | whg.27.7b-ce-k | 3.0 | 38.7 | **2.1** | **34.3** | 2.1 | 34.3 | 0.9 | 26 | 6 | 46.6 | 7 | 47.9 |
| NEA | SWW | hke.27.3a46-8abd | 1.8 | 29.8 | **3.5** | **42.7** | 3.5 | 42.7 | 2.6 | 36.2 | 5 | 52.3 | 15 | 88.8 |
| NEA | SWW | ldb.27.8c9a | 3.4 | 24.4 | 5.2 | 27.6 | **5.6** | **28.2** | 1.0 | 18.9 | 6 | 28.8 | 7 | 30.2 |
| NEA | SWW | meg.27.7b-k8abd | 3.2 | 24 | **2.7** | **22.1** | 2.8 | 22.5 | 2.8 | 22.5 | 5 | 30.3 | 10 | 43.9 |
| NEA | SWW | meg.27.8c9a | 3.2 | 29 | 5.8 | 35.1 | **6.0** | **35.5** | 1.2 | 22.9 | 6 | 35.5 | 7 | 37.3 |

*length coversions were made using the VBGF parameters of cod.27.47d20

**Table 4.2.1.2** Selectivity estimates for the ICES stocks summarizing the current age-at-50%-selectivity (A50; y) and length-at-50%-selectivity (L50; cm) by fleet segments using different gear types. OTB: bottom otter trawls; DRB: Towed dredges; GNS: Set gillnets; GTR: Trammel nets; LLS: Set longlines; MWT: Midwater Trawl; PAS: Passive gears; SEI: Seine nets; TBB: Beam trawls. Ages are as reported by EWG 21-07 and lengths were derived from ages using VBGF parameters estimated on the basis of DATRAS data.

| | | **OTB** | | **DRB** | | **GNS** | | **GTR** | | **LLS** | | **MWT** | | **PAS** | | **SEI** | | **TBB** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Stock | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ |
| BS | cod.27.22-24 | 2.38 | 36.5 | | | 3.17 | 46.8 | | | | | | | 3.14 | 46.4 | | | | |
| BS | ple.27.21-23 | 2.26 | 20.4 | | | | | | | | | | | 3.25 | 25.2 | | | | |

| | | OTB | | DRB | | GNS | | GTR | | LLS | | MWT | | PAS | | SEI | | TBB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Stock | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ |
| NS | cod.27.47d20 | 1.86 | 35.8 | | | 2.41 | 45.3 | | | 2.29 | 43.3 | | | | | 2.08 | 39.7 | 1.57 | 30.4 |
| NS | had.27.46a20 | 1.97 | 29.7 | | | 5.19 | 41.1 | | | | | | | | | 1.88 | 29.2 | | |
| NS | ple.27.420 | 2.03 | 22.2 | | | | | | | | | | | | | 1.95 | 21.8 | 1.28 | 18.4 |
| NS | ple.27.7d | 1.89 | 22.9 | 2.13 | 23.9 | | | 2.1 | 23.8 | | | | | | | 2.08 | 23.7 | 2.26 | 24.4 |
| NS | pok.27.3a46 | 3.7 | 46.7 | | | 7.4 | 70.7 | | | | | | | | | | | | |
| NS | whg.27.47d | 2.64 | 31 | | | | | | | | | | | | | 3.7 | 35.3 | 1.16 | 22.7 |
| NWW | cod.27.6a* | 2.11 | 40.6 | | | | | | | | | | | | | | | | |
| NWW | had.27.6b | 1.72 | 31 | | | | | | | | | | | | | | | | |
| NWW | had.27.7a | 0.9 | 16.4 | | | | | | | | | 2.86 | 34.3 | | | 2.52 | 31.8 | | |
| NWW | ple.27.7a | 1.73 | 17.8 | | | | | | | | | | | | | | | 1.8 | 18 |
| SWW | meg.27.7b-k8abd | 3.32 | 24.5 | | | | | | | | | | | | | | | 3.25 | 24.2 |

*length coversions were made using the VBGF parameters of cod.27.47d20

**Table 4.2.1.3** Selectivity estimates for Mediterranean stocks summarizing the age-at-50%-selectivity (A50) and length-at-50%-selectivity (L50) for the current selectivity ('Current') and the optimised selectivity curves ('Crank', 'Shift'). In addition, the $A_{mat}$/$L_{mat}$ corresponding to age/length-at-50%-maturity ('Maturity'), the $A_{opt}$/ $L_{opt}$ at which the total biomass of an unfished cohort (F = 0) attains a maximum ('Max Biomass'), as well as the $A_{plusgroup}$/$L_{plusgroup}$ of the maximum age/length assumed in the assessment ('Plusgroup') are provided for reference. Ages are as reported by EWG 21-07 and lengths were derived from ages using VBGF parameters used and reported by EWG 20-09 and EWG 20-15. All ages are given in y and all lengths in cm. Bold font indicates the A50/L50 producing the highest gains in yield (see also Table 4.3.2).

| | | | Current | | Crank | | Shift | | Maturity | | Max Biomass | | Plusgroup | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Region | Area | Stock | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{mat}$ | $L_{mat}$ | $A_{opt}$ | $L_{opt}$ | $A_{plusgroup}$ | $L_{PlusGroup}$ |
| MED | WM | HKE.01_05_06_07 | 0.6 | 11.2 | 1.3 | 22.8 | **4.0** | **56.1** | 1.5 | 25.9 | 4 | 56.1 | 5 | 64.9 |
| MED | WM | HKE.08_09_10_11 | 0.2 | 3.9 | 0.4 | 6.7 | **5.5** | **56** | 1.4 | 19.8 | 6 | 59 | 7 | 64.3 |
| MED | WM | MUR.05 | 1.0 | 12.6 | 0.8 | 10.7 | **0.7** | **9.7** | 0.6 | 8.7 | 4 | 27.7 | 5 | 29.7 |
| MED | WM | MUT.01 | 1.6 | 15.4 | 2.4 | 20 | **3.0** | **22.6** | 0.6 | 7.7 | 3 | 22.6 | 4 | 26.1 |
| MED | WM | MUT.06 | 1.1 | 11.9 | 1.3 | 13.4 | **3.0** | **22.6** | 0.6 | 7.7 | 3 | 22.6 | 4 | 26.1 |
| MED | WM | MUT.07 | 0.8 | 12.9 | **1.3** | **15.8** | 1.8 | 18.1 | 0.6 | 11.5 | 3 | 21.8 | 4 | 23.6 |
| MED | WM | MUT.09 | 1.0 | 9.7 | **1.4** | **13** | 1.7 | 15 | 0.6 | 5.5 | 3 | 20.9 | 4 | 23.3 |
| MED | WM | MUT.10 | 1.1 | 3.3 | 1.5 | 5.8 | **3.0** | **13.2** | 0.6 | NA | 3 | 13.2 | 4 | 16.8 |
| MED | CEM | HKE.17_18 | 1.2 | 19.4 | 2.4 | 29.7 | **7.0** | **59.7** | 3.1 | 35.2 | 19 | 95.5 | 20 | 97 |
| MED | CEM | HKE.19 | 0.2 | 8.5 | 1.7 | 22.8 | **5.6** | **51.3** | 1.7 | 22.8 | 6 | 53.6 | 7 | 59.1 |
| MED | CEM | HKE.20 | 0.9 | 10.8 | 1.6 | 18.3 | **2.8** | **29.8** | 1.4 | 16.2 | 3 | 31.5 | 4 | 39.7 |
| MED | CEM | MUT.17_18 | 1.1 | 10.8 | 1.5 | 12.5 | **2.5** | **16.2** | 0.6 | 8.4 | 3 | 17.7 | 4 | 20.2 |
| MED | CEM | MUT.22 | 0.5 | 10.5 | 0.4 | 10.1 | **1.1** | **12.6** | 0.3 | 9.7 | 2 | 15.5 | 5 | 22.3 |

**Table 4.2.1.4** Selectivity estimates for Mediterranean stocks summarizing the current age-at-50%-selectivity (A50; y) and length-at-50%-selectivity (L50; cm) by fleet segments using different gear types. GNS: Set gillnets; GTR: Trammel nets; LLS: Set longlines; OTB: bottom otter trawls. Ages are as reported by EWG 21-07 (except for LLS of HKE which was calculated for EWG 22-19) and lengths were derived from ages using VBGF parameters used and reported by EWG 20-09.

| | | **GNS** | | **GTR** | | **LLS** | | **OTB** | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Stock | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ | $A_{50}$ | $L_{50}$ |
| WM | HKE.01_05_06_07 | 1.14 | 20.3 | | | 2.9 | 44.4 | 0.39 | 7.5 |
| WM | HKE.08_09_10_11 | 2.1 | 27.8 | 0.97 | 14.4 | 3.97 | 45.2 | 0.15 | 3.1 |
| WM | MUT.01 | | | 1.94 | 17.5 | | | 1.48 | 14.6 |
| WM | MUT.07 | | | | | | | 0.77 | 12.7 |
| WM | MUT.09 | | | 3.24 | 21.6 | | | 1.01 | 9.8 |
| WM | MUT.10 | 3.01 | 13.2 | 1.2 | 3.9 | | | 1.19 | 3.9 |

### 4.2.2 OPTIMISATION UNDER VARYING FISHING MORTALITY

The constructed isopleths (Fig. 4.2.2.1 - 4.2.2.6) illustrate the trade-offs between selectivity and F with respect to relative yield and SSB. They also allow to infer the optimal selectivity for different levels of F. The isopleths suggest that heavily overfished stocks (e.g. cod.27.22-24; cod.27.7e-k; HKE.01-05-06-07) would require a greater change in selectivity (increase in A50/L50) to approach the area of optimal yields, compared to those exploited closer to $F_{MSY}$. For almost all stocks, except for some of the ones currently exploited below $F_{MSY}$ (e.g. whg.27.47d, had.27.7a, MUT.22), any increase in A50/L50 would mean higher equilibrium yields at lower levels of stock depletion.

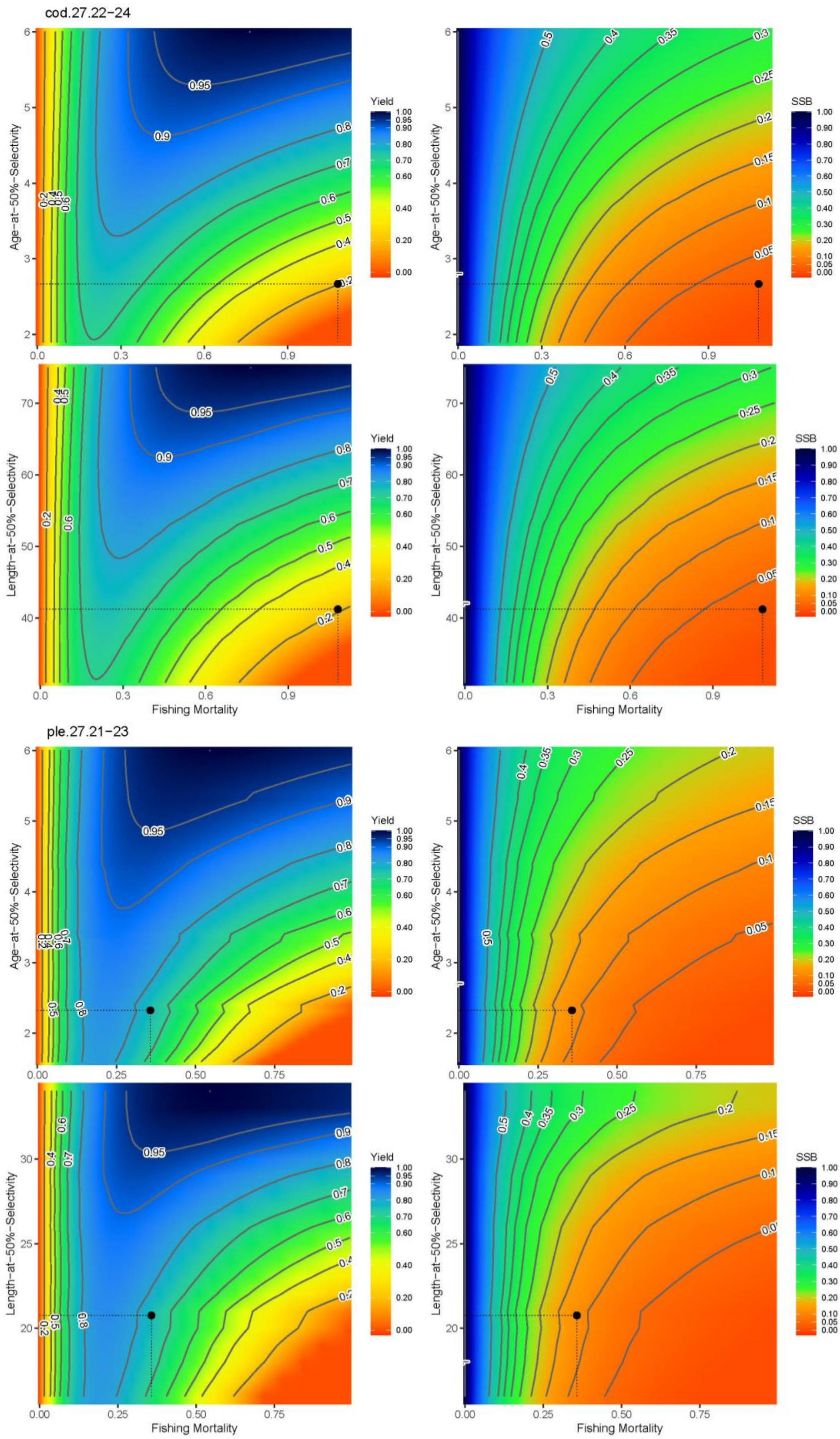


**Figure 4.2.2.1** Isopleths by stock in the Western Baltic Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

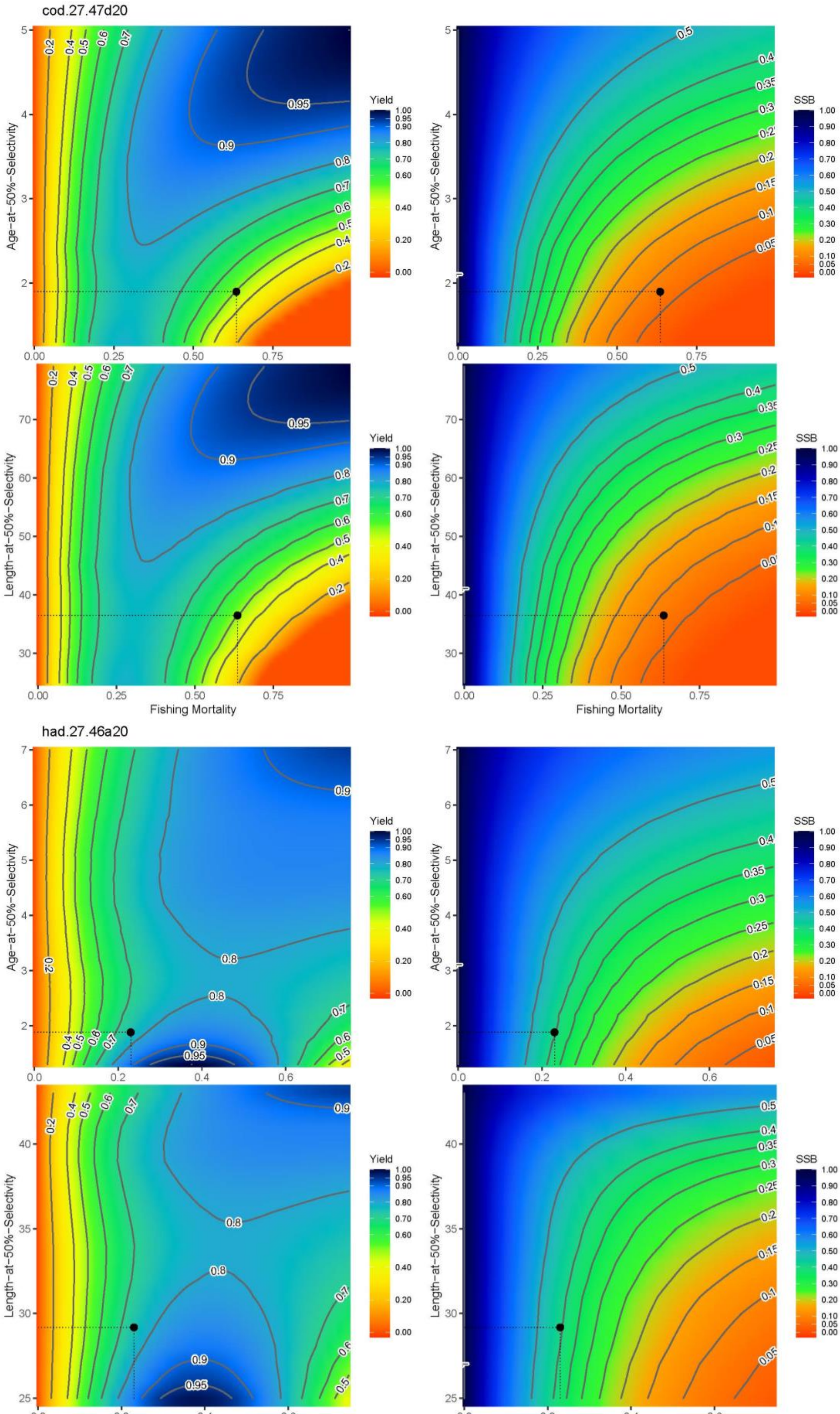


**Figure 4.2.2.2** Isopleths by stock in the Greater North Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

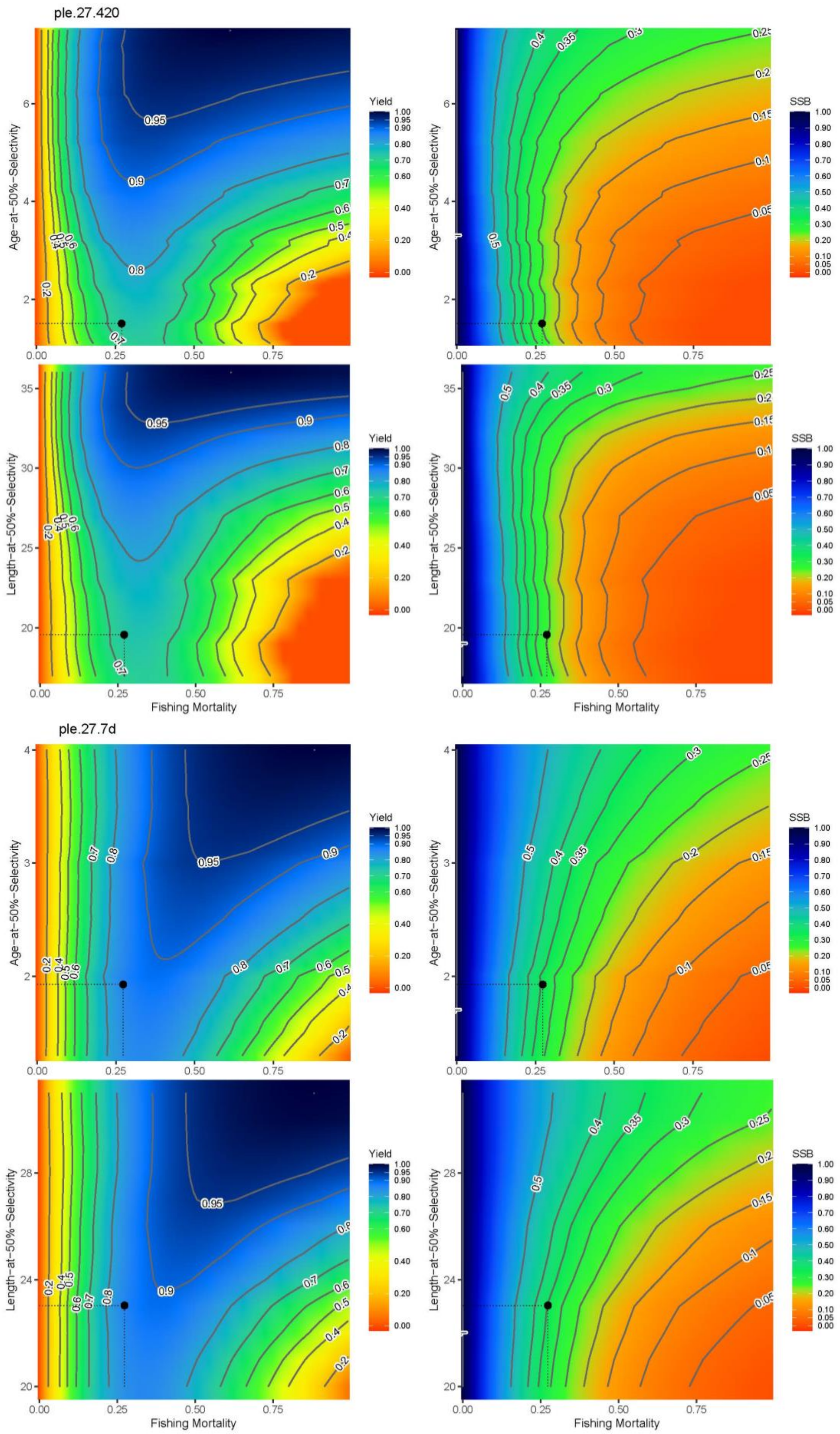


**Figure 4.2.2.2 (cont.)** Isopleths by stock in the Greater North Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

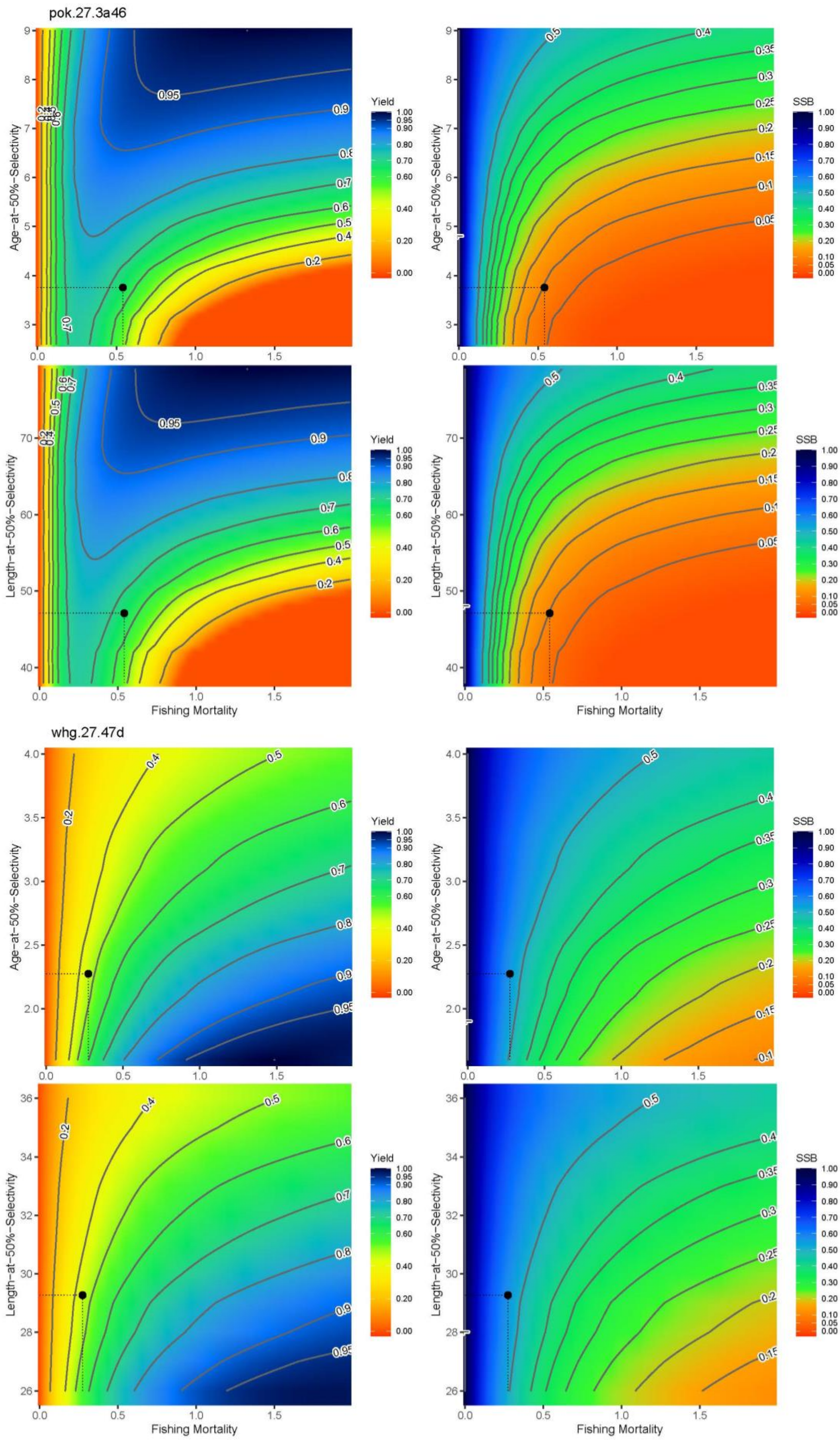


**Figure 4.2.2.2 (cont.)** Isopleths by stock in the Greater North Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

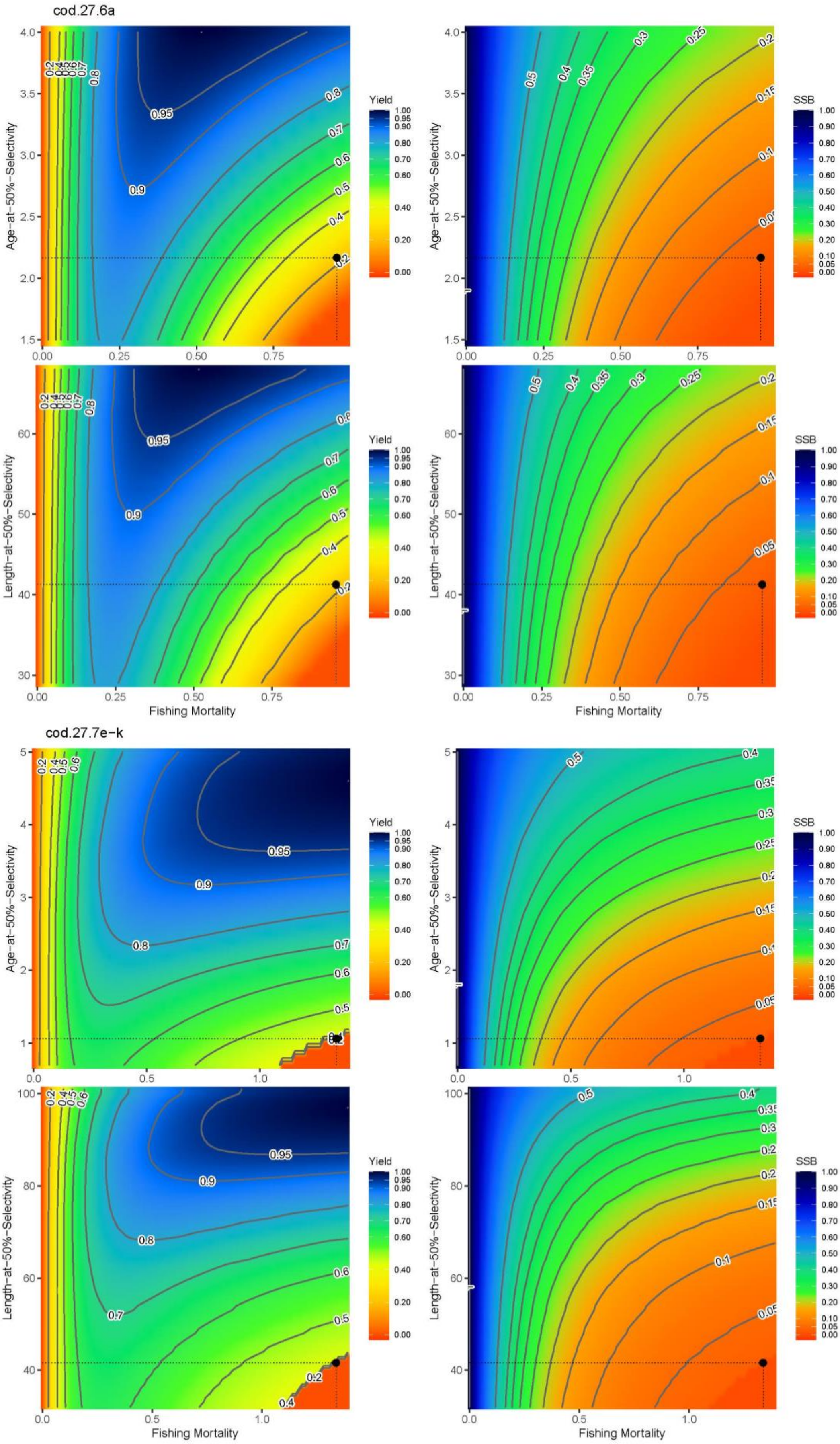


**Figure 4.2.2.3** Isopleths by stock in the North Western Waters. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

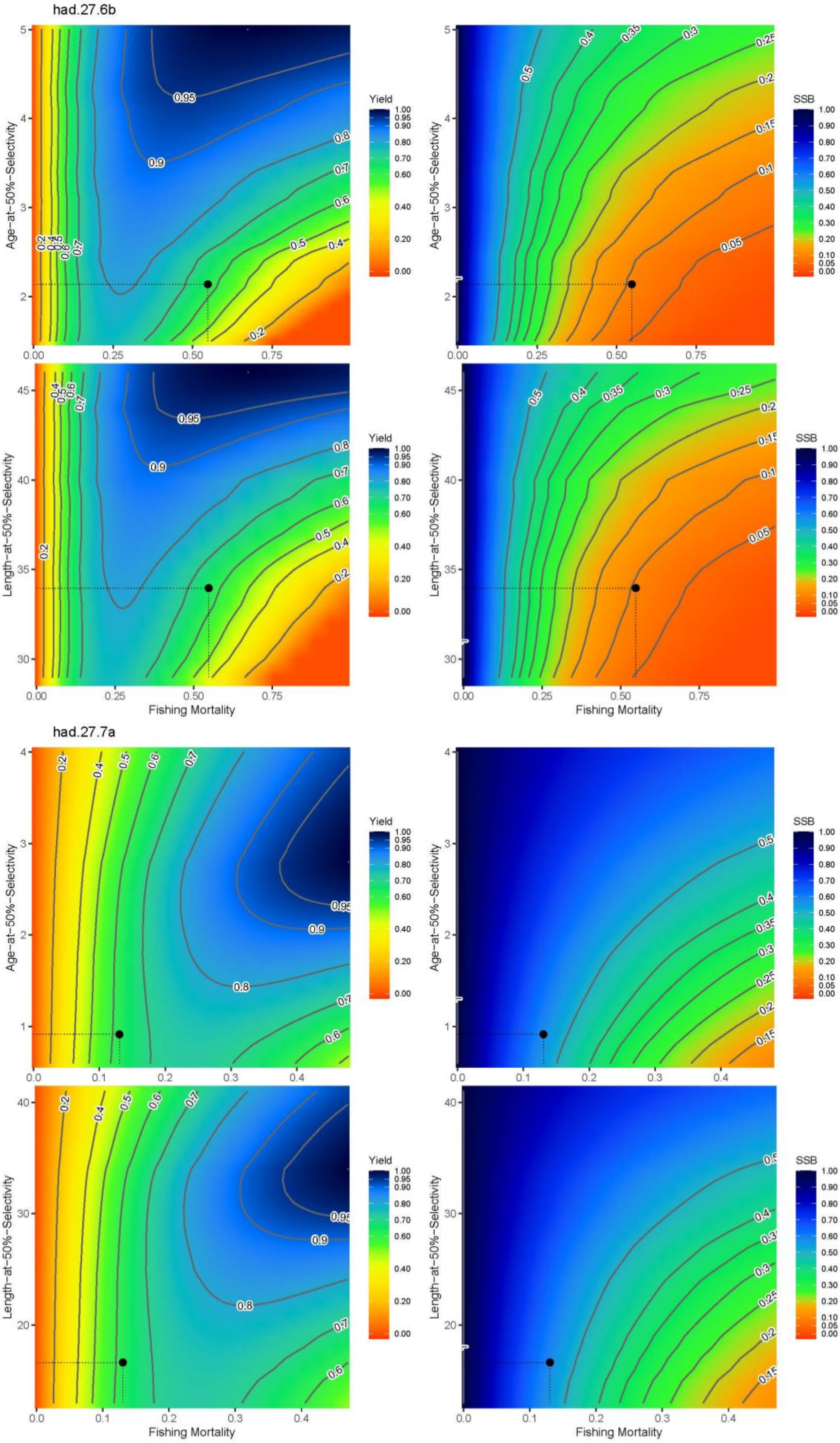


**Figure 4.2.2.3 (cont.)** Isopleths by stock in the North Western Waters. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

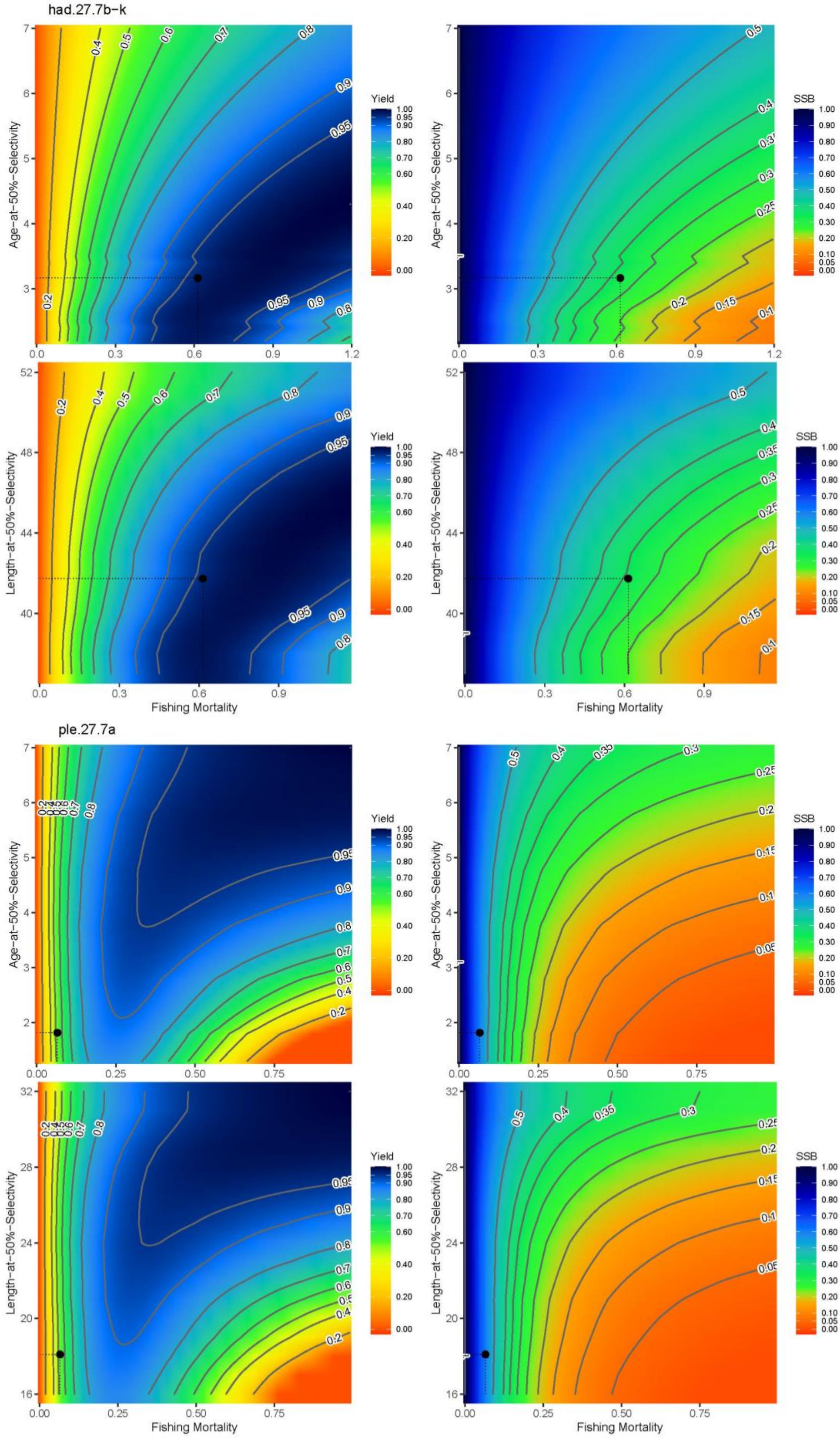


**Figure 4.2.2.3 (cont.)** Isopleths by stock in the North Western Waters. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

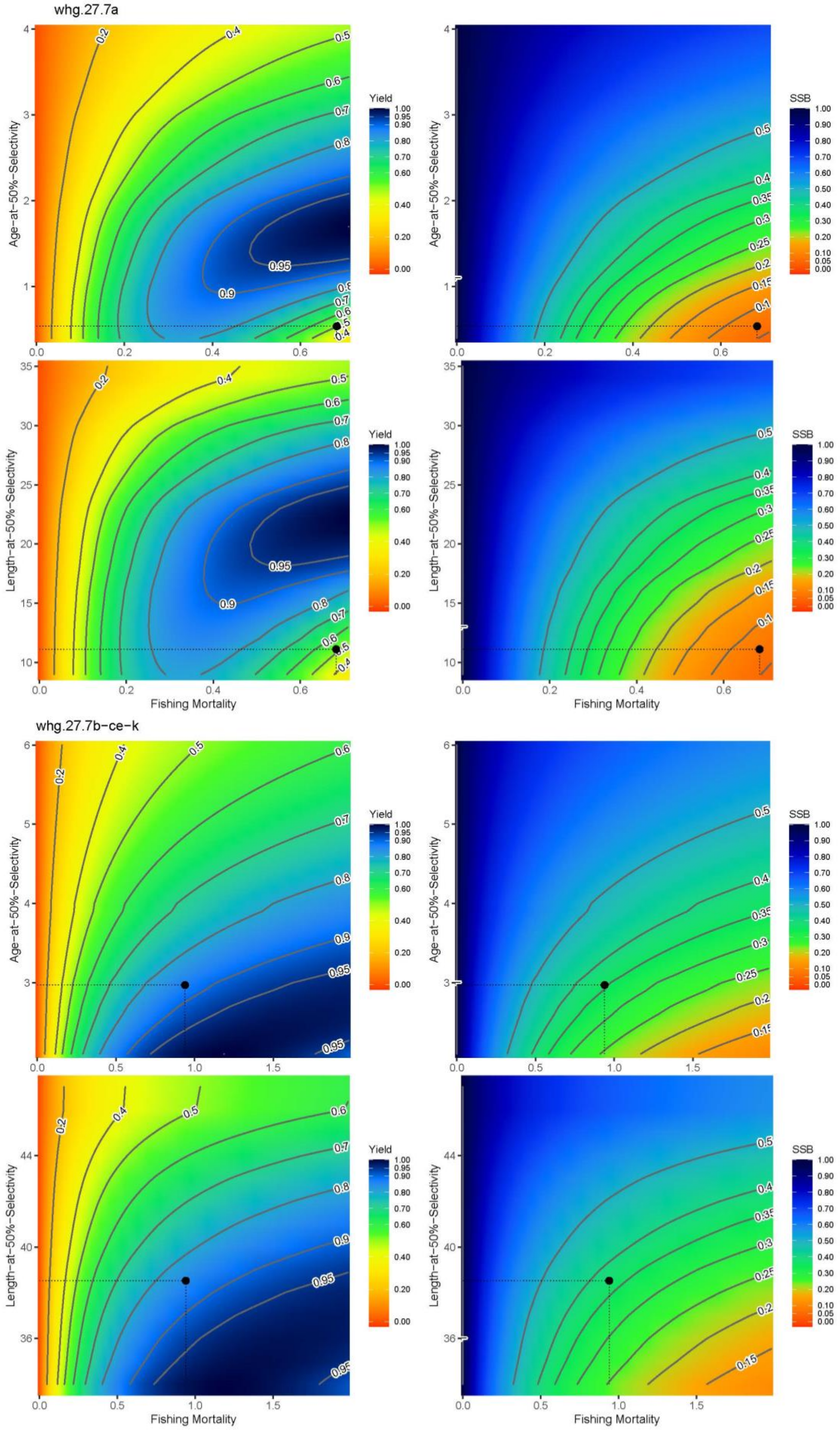


**Figure 4.2.2.3 (cont.)** Isopleths by stock in the North Western Waters. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

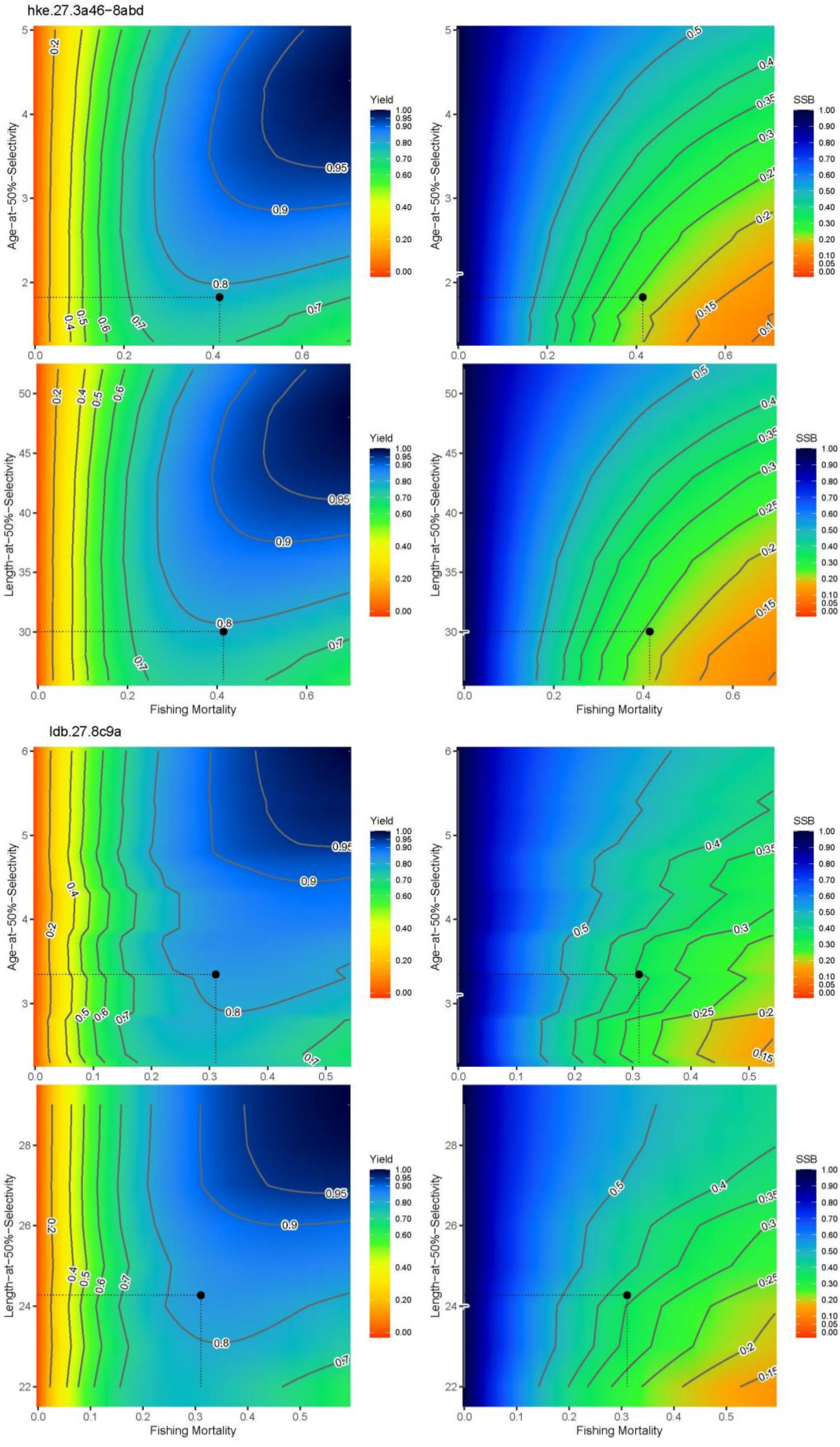


**Figure 4.2.2.4** Isopleths by stock in the South Western Waters. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

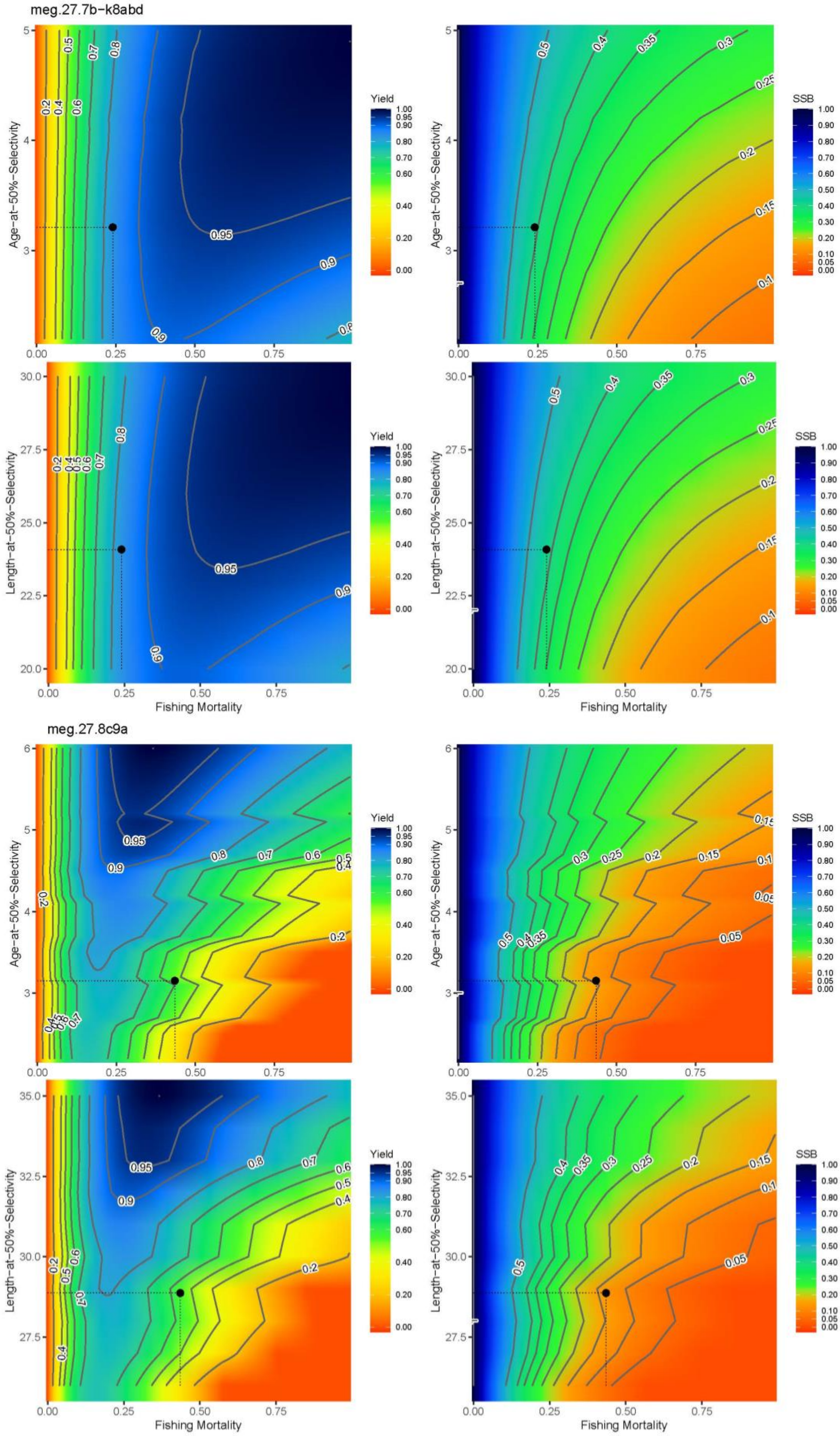


**Figure 4.2.2.4 (cont.)** Isopleths by stock in the South Western Waters. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

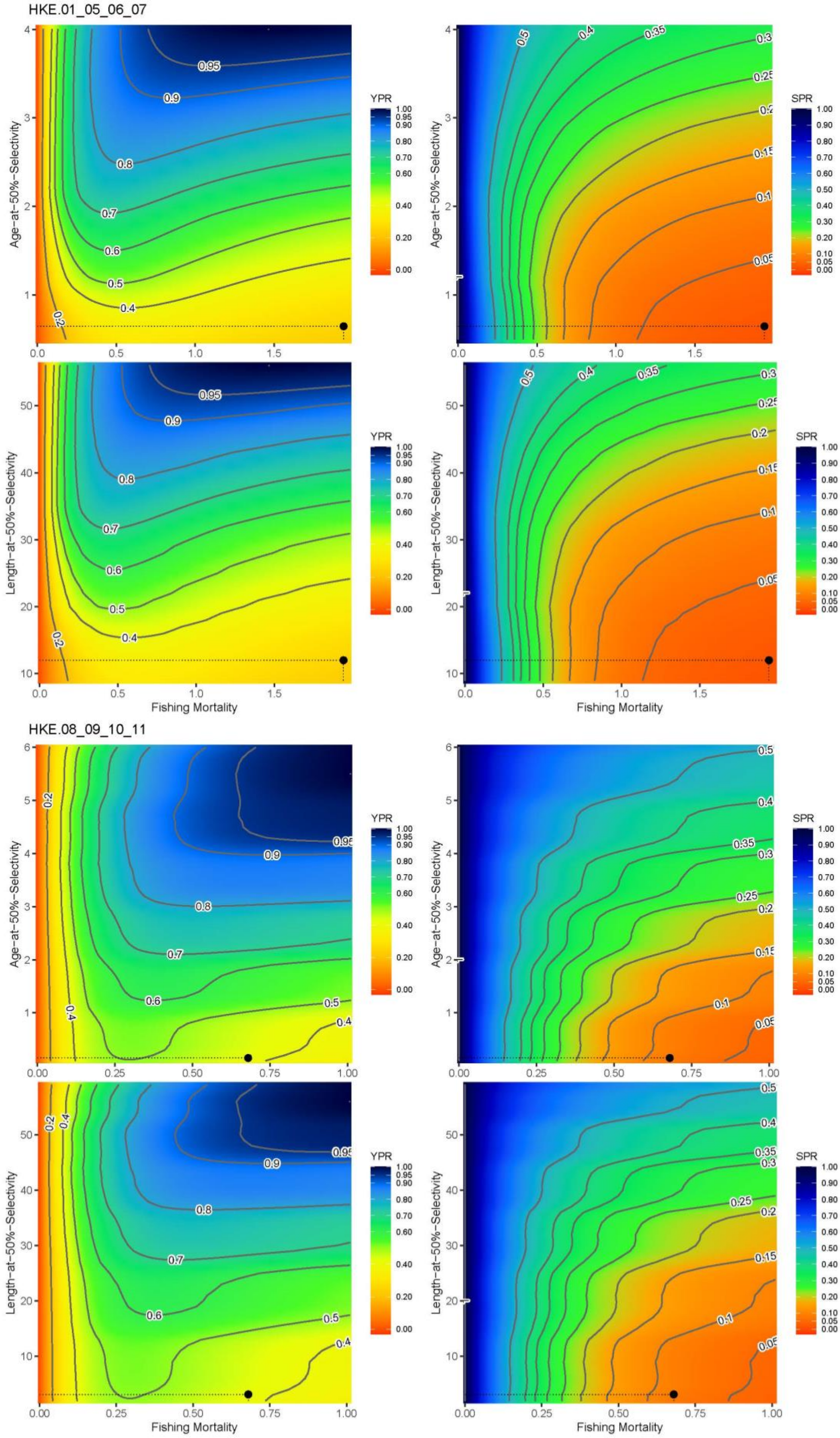


**Figure 4.2.2.5** Isopleths by stock in the Western Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

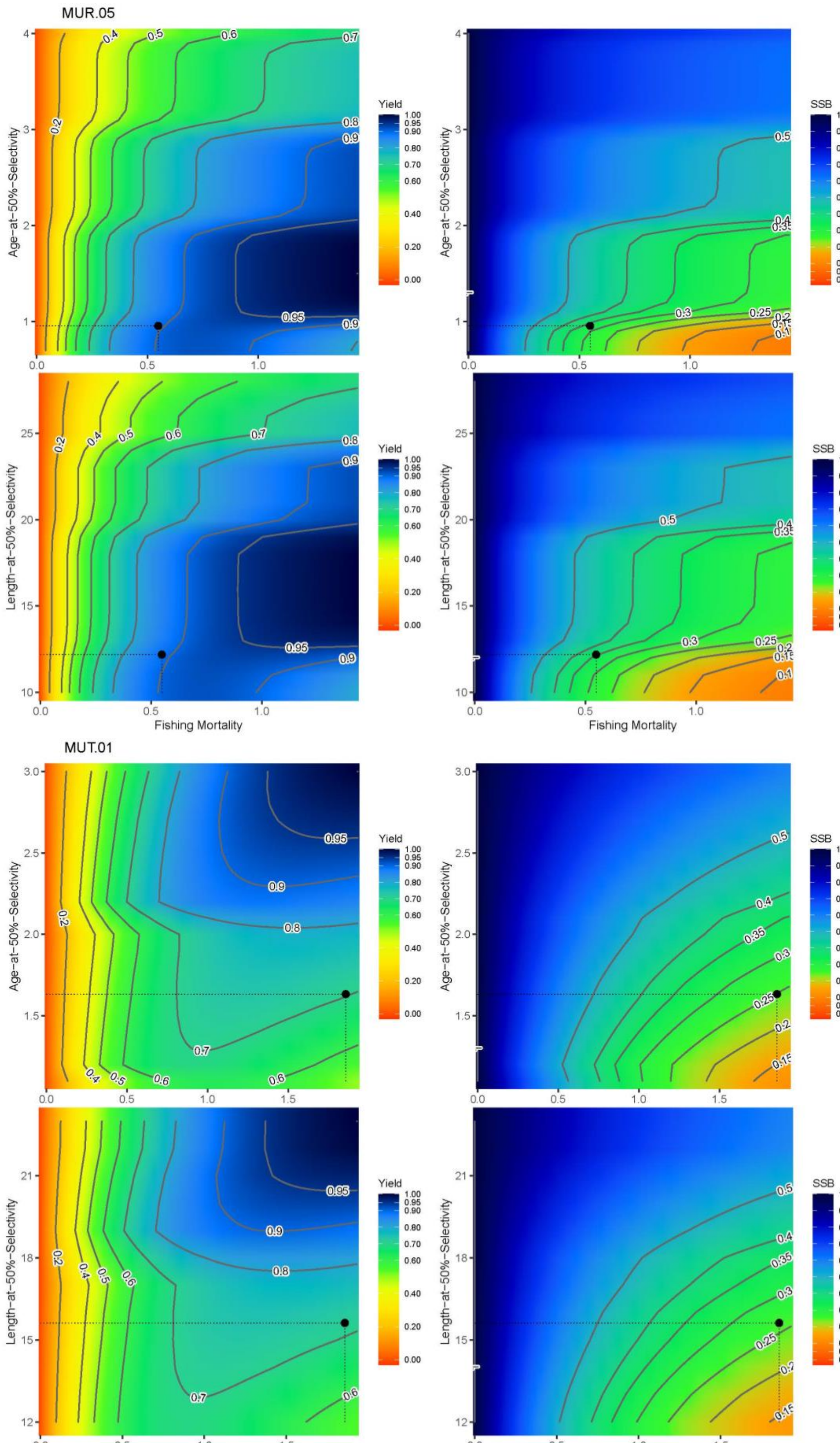


**Figure 4.2.2.5 (cont.)** Isopleths by stock in the Western Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

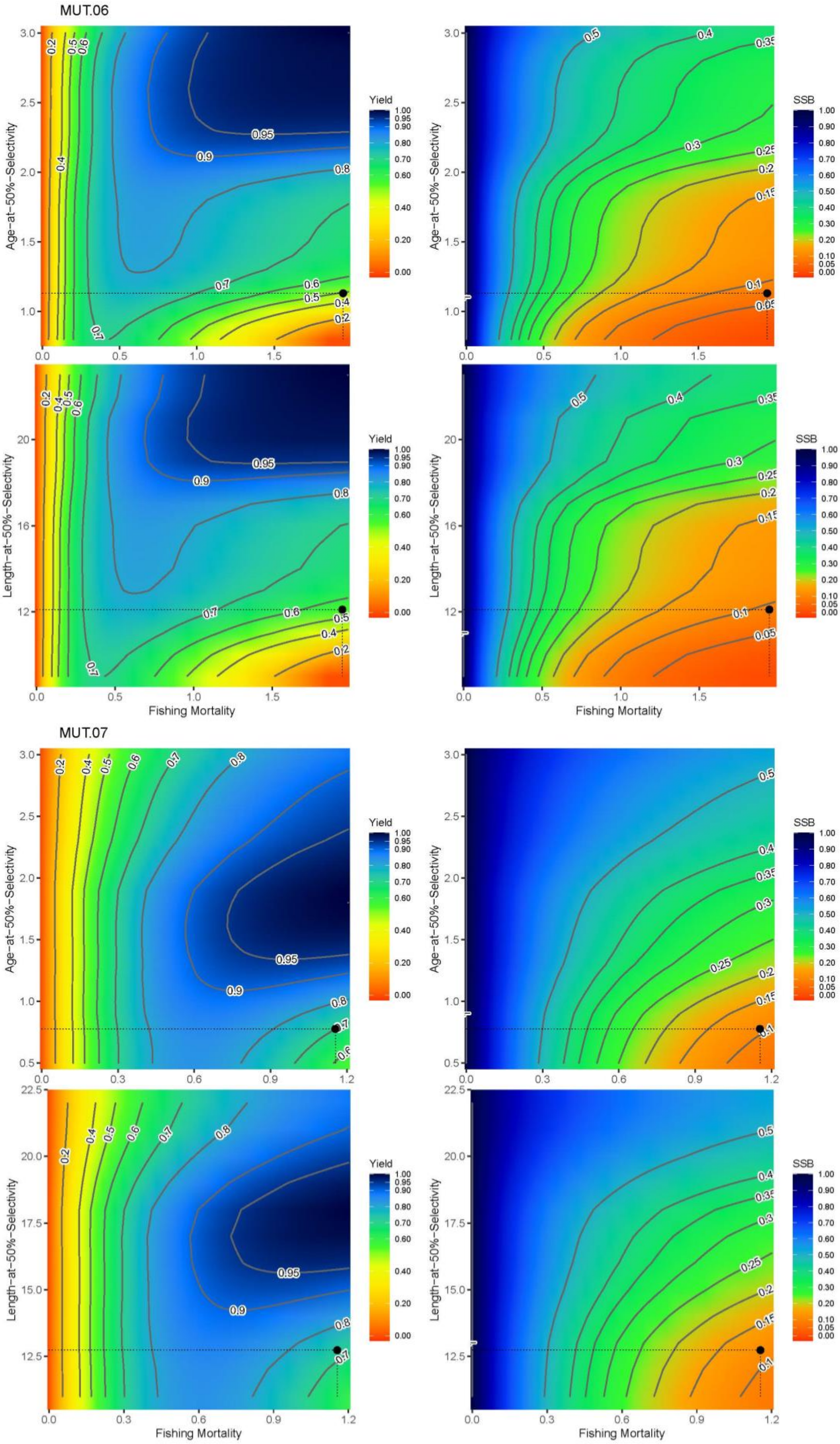


**Figure 4.2.2.5 (cont.)** Isopleths by stock in the Western Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

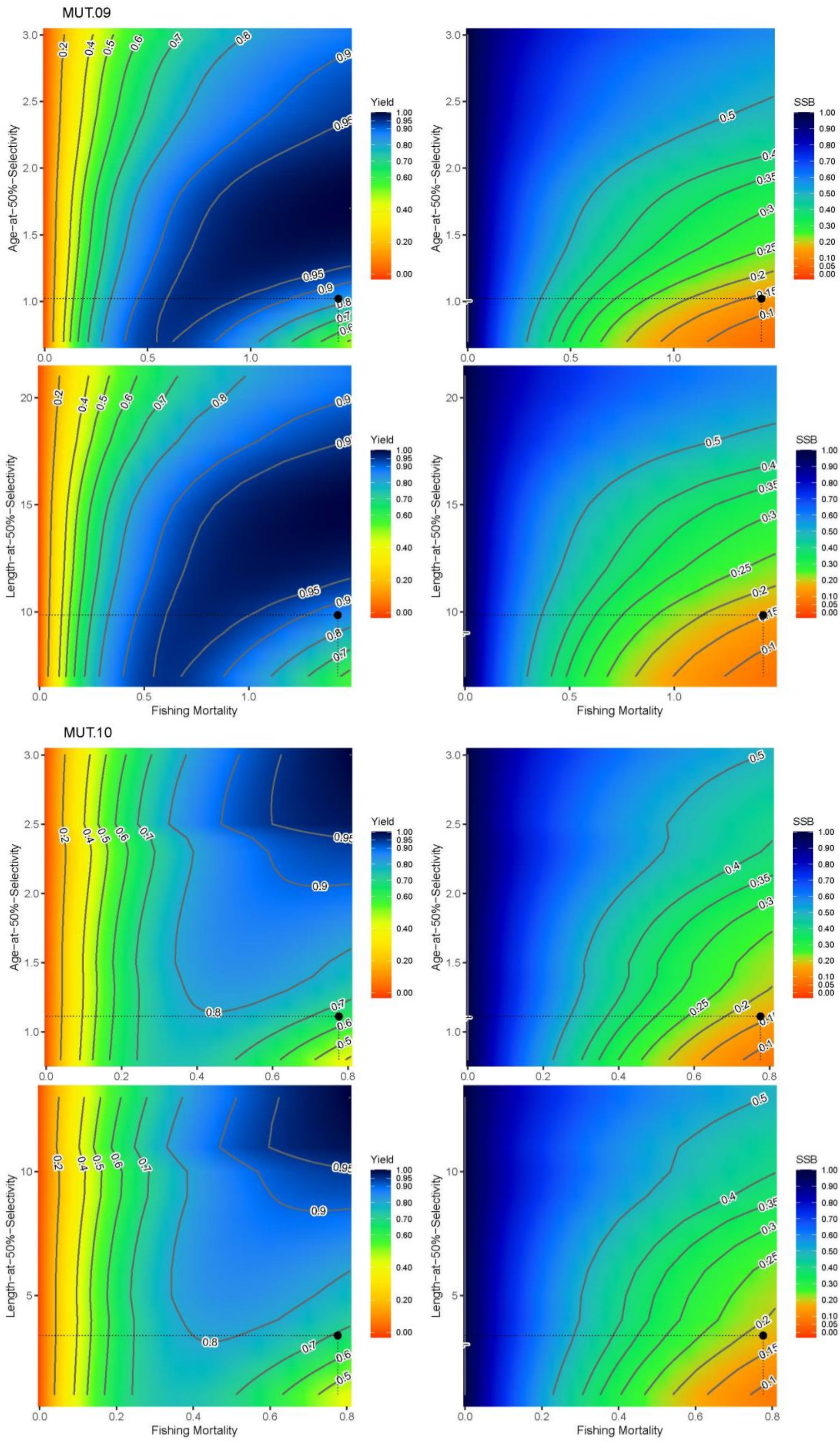


**Figure 4.2.2.5 (cont.)** Isopleths by stock in the Western Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

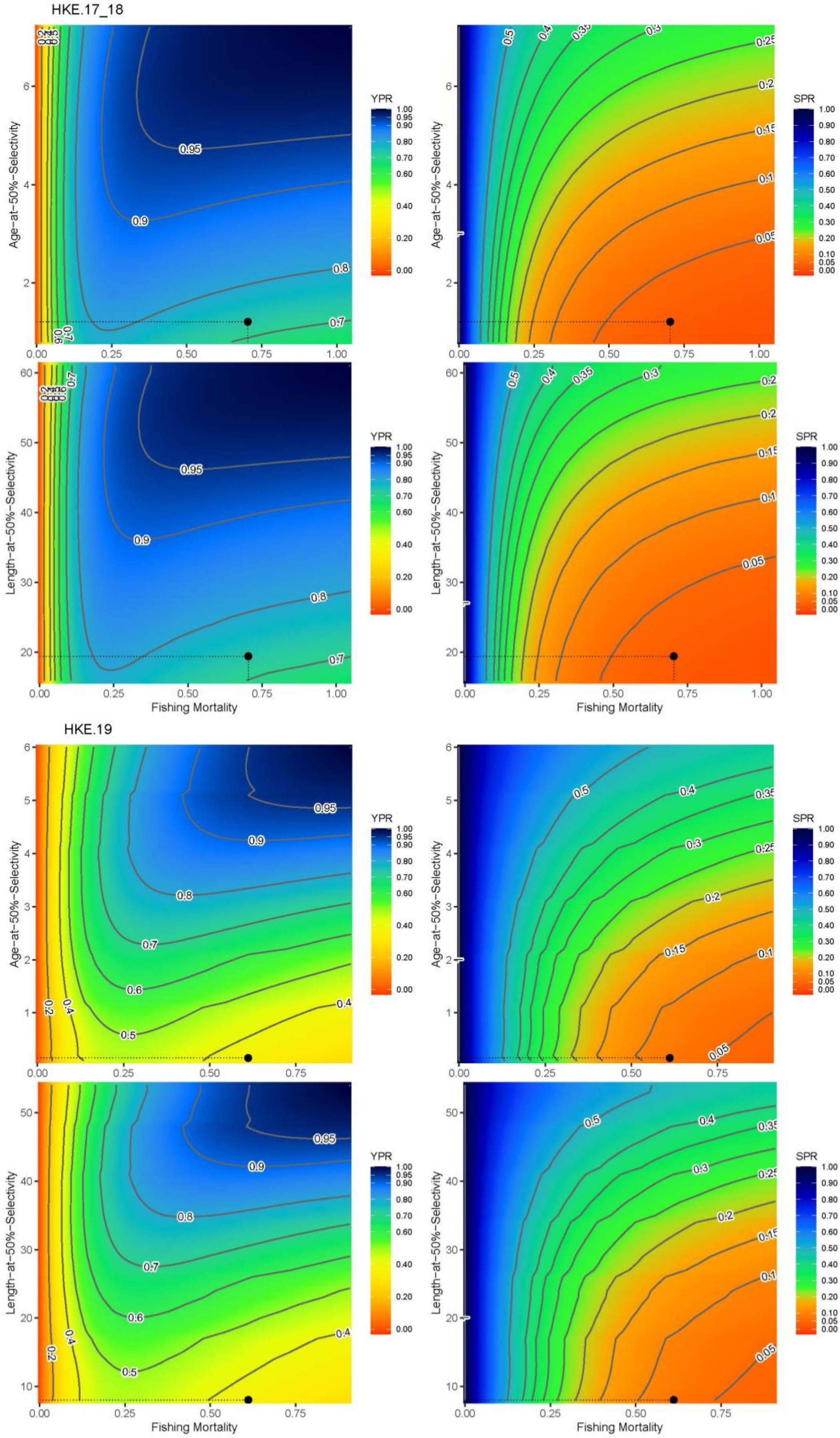


**Figure 4.2.2.6** Isopleths by stock in the Central and Eastern Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

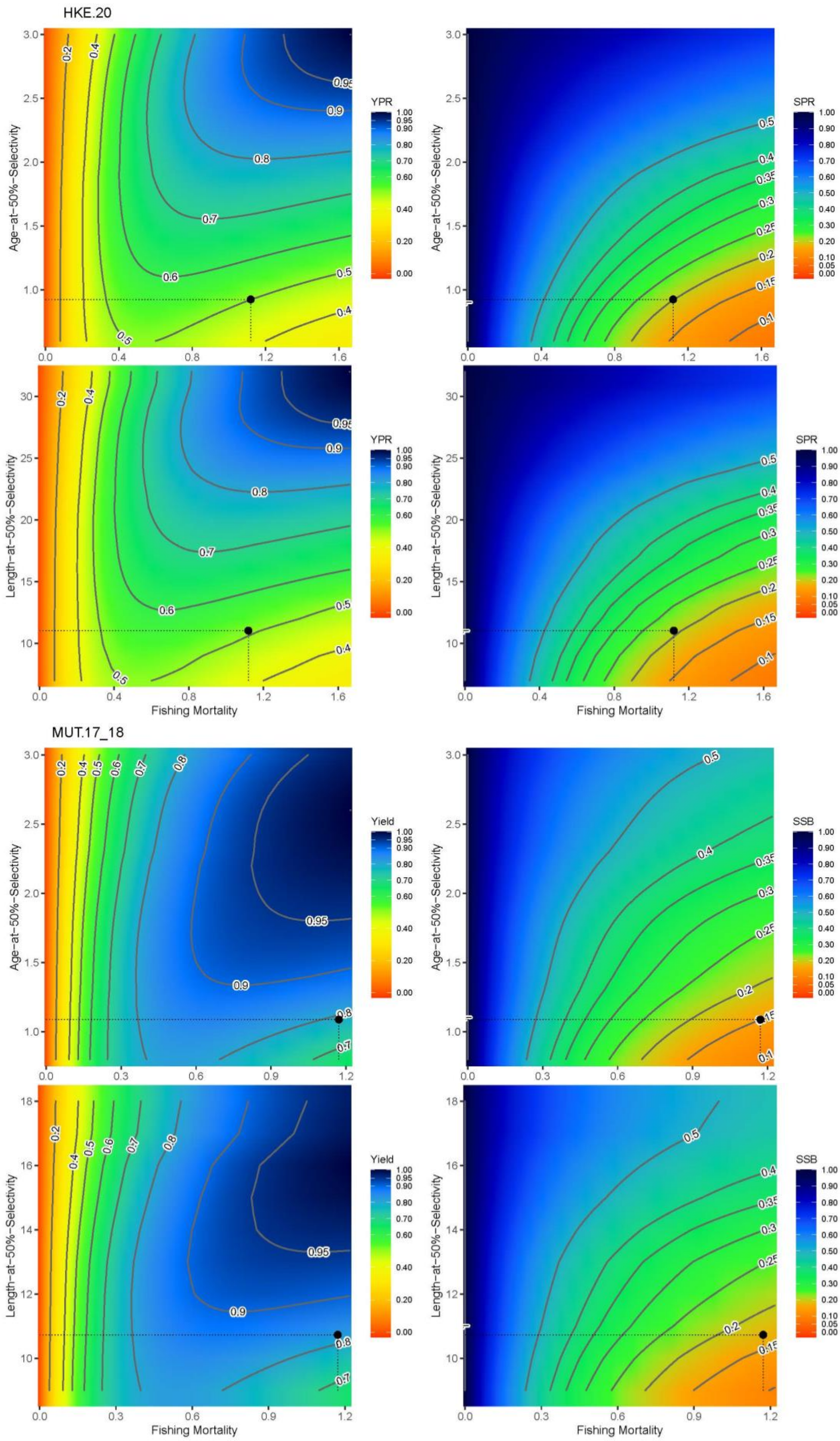


**Figure 4.2.2.6 (cont.)** Isopleths by stock in the Central and Eastern Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

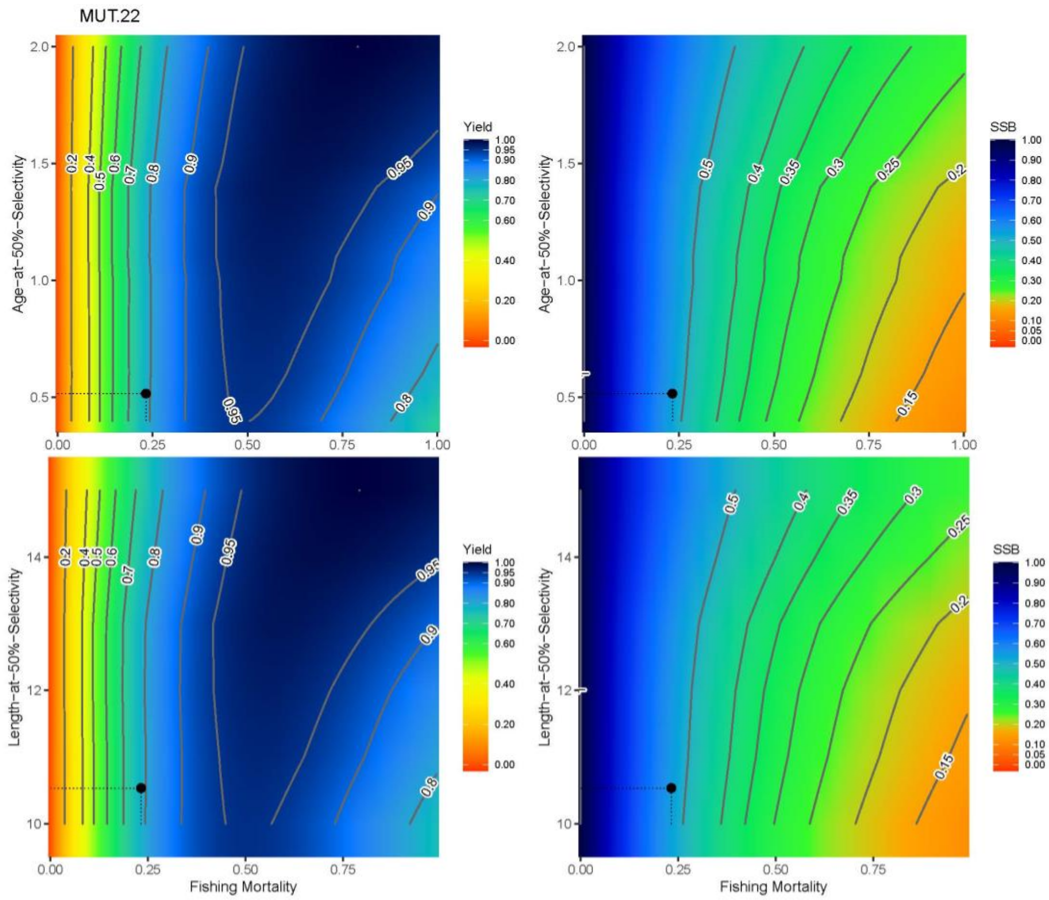


**Figure 4.2.2.6 (cont.)** Isopleths by stock in the Central and Eastern Mediterranean Sea. Equilibrium yield (left) and SSB (right) under varying ('shifting') age-at-50%-selectivity (A50, y; top) or length-at-50%-selectivity (L50, cm; bottom) and fishing mortality ($F_{apical}$). The black dot represents the estimate under current selectivity and $F_{apical}$.

## 4.3 Prioritisation of stocks with the highest potential gains (ToR 1)

To prioritise the stocks with highest potential gains, EWG 22-19 built on the outcomes of EWG 21-07 (STECF, 2021). EWG 21-07 provided for each stock a total of five deterministic projection scenarios over a time horizon of 50 years to attain equilibrium quantities for (a) yield and (b) the proportion of juveniles in the catches under current F. As 'crank' and 'shift' projections (Fig. 3.2.2.1, 3.2.2.2) provided the maximum potential gains in yield (%), EWG 22-19 decided to focus on these two scenarios as basis for prioritisation. Differences between the outcomes of current selectivity and 'crank' or 'shift' projections were calculated to explore the effect on equilibrium yields and the proportion of juveniles in the catches.

Six stocks were shortlisted in the NE Atlantic using this rationale: four on the basis of the highest predicted yield change (cod.27.22-24; cod.27.7e-k, cod.27.6a, cod.27.47d20) and another two based on the reduction in juveniles in the catch of more than 50% (whg.27.7a, pok.27.3a46) (Table 4.3.1).

Five stocks were shortlisted in the Mediterranean: four on the basis of the highest predicted yield change (HKE.01-05-06-07; HKE.08_09_10_11, HKE.19, HKE.20) and another one based on the highest reduction in juveniles in the catch (HKE.17_18) (Table 4.3.2).

These six NE Atlantic and five Mediterranean stocks were more closely examined in dedicated case studies chapters (Chapters 4.5-4.6) with regards to their selectivity and options to improve it.

**Table 4.3.1** Prediction for NE Atlantic stocks summarizing the yield change (%) relative to the current selectivity under current F and the associated change in the percentage of juvenile fish in the catch, for the scenarios of fishing at the optimised 'crank' and 'shift' selectivity. The stocks with highest predicted gains in yield are marked in green and the stocks with higher reductions in juveniles in the catch of the remaining stocks are marked in blue.

| Area | Stock | Yield change (%) | | Change in % juveniles in catch | |
|---|---|---|---|---|---|
| | | Crank | Shift | Crank | Shift |
| BS | cod.27.22-24 | 322.9 | 402.1 | -26.3 | -29.1 |
| BS | ple.27.21-23 | 14.9 | 28.3 | -13.1 | -20.2 |
| NS | cod.27.47d20 | 44.5 | 92.4 | -35.3 | -58.3 |
| NS | had.27.46a20 | 22 | 17.3 | 28.8 | 23.6 |
| NS | ple.27.420 | 1.3 | 29.8 | -9.1 | -37.9 |
| NS | ple.27.7d | 0 | 0.8 | -1.8 | -1.4 |
| NS | pok.27.3a46 | 17.6 | 43.5 | -30 | -51.8 |
| NS | whg.27.47d | 43.9 | 28.9 | 35.1 | 19.5 |
| NWW | cod.27.6a | 362.1 | 315.2 | -36.1 | -26.5 |
| NWW | cod.27.7e-k | 160.9 | 375.3 | -36.2 | -73.5 |
| NWW | had.27.6b | 33 | 44.2 | -36.2 | -35.7 |
| NWW | had.27.7a | 2.4 | 0.9 | 18.9 | 14.3 |
| NWW | had.27.7b-k | 1.1 | 2 | 6.7 | 5.1 |
| NWW | ple.27.7a | 0.6 | 7.6 | 6.4 | -18.8 |
| NWW | whg.27.7a | 106.5 | 98.1 | -76.7 | -64 |
| NWW | whg.27.7b-ce-k | 20.1 | 14.1 | 24.4 | 14.3 |
| SWW | hke.27.3a46-8abd | 22.8 | 16.9 | -54.4 | -29.8 |
| SWW | ldb.27.8c9a | 4.4 | 11.1 | -5.4 | -4.7 |
| SWW | meg.27.7b-k8abd | 0.5 | -0.1 | 10.4 | 5.9 |
| SWW | meg.27.8c9a | 62.8 | 64 | -8.9 | -7.1 |

**Table 4.3.2** Prediction for Mediterranean stocks summarizing the yield change (%) relative to the current selectivity under current F and the associated change in the percentage of juvenile fish in the catch, for the scenarios of fishing at the optimised 'crank' and 'shift' selectivity. The stocks with highest predicted gains in yield are marked in green and the stock with higher reductions in juveniles in the catch is marked in blue.

| Area | Stock | Yield change (%) | | Change in % juveniles in catch | |
|---|---|---|---|---|---|
| | | Crank | Shift | Crank | Shift |
| WM | HKE.01_05_06_07 | 88.3 | 294 | -67.8 | -86.1 |
| WM | HKE.08_09_10_11 | 6.1 | 129.7 | -19.9 | -78.6 |
| WM | MUR.05 | 0.6 | 1 | 0.2 | 0 |
| WM | MUT.01 | 35.3 | 43.9 | 0 | 0 |
| WM | MUT.06 | 24.8 | 67.8 | 0 | 0 |
| WM | MUT.07 | 28.8 | 27.3 | -13.2 | -13 |
| WM | MUT.09 | 6.2 | 5 | -2.9 | -2.8 |

| Area | Stock | Yield change (%) | | Change in % juveniles in catch | |
|---|---|---|---|---|---|
| | | Crank | Shift | Crank | Shift |
| WM | MUT.10 | 25.1 | 47.5 | -1.3 | -1.3 |
| CEM | HKE.17_18 | 16.7 | 34.9 | -49.6 | -89.6 |
| CEM | HKE.19 | 17.9 | 166.6 | -23.5 | -77.6 |
| CEM | HKE.20 | 49.4 | 99.3 | -52.3 | -61.1 |
| CEM | MUT.17_18 | 17.3 | 21.6 | -2.3 | -2.3 |
| CEM | MUT.22 | 0.4 | 0.6 | 0.2 | -1.9 |

## 4.4 Identify the fishing gears corresponding to the optimum ages and sizes (ToR 2)

Based on the stocks listed in annex XIV of the TMR, i.e. 'species for selectivity performance indicators', a sub-group of experts at EWG 22-19 were assigned to review and compile information on gear selectivity by size (hereby referred to as 'gear selectivity') per stock and region. To prioritize the available time and resources, main focus was to collect and compile gear selectivity data for the stocks where the highest gains can be achieved (Table 4.3.1 & 4.3.2). This means that the number of listed gear options is not equally complete for all stocks. A multi-directional approach of searches was implemented in scientific data bases, personal expertise, and direct contacts with other experts to find information in both peer-reviewed and grey literature. The aim was to identify and list gear selectivity information and technical specifications, both for the regional baseline gears (gears for which no catch composition rules apply in the TCM regional annexes) and for other relevant alternative gears in each region. The compilation of gear selectivity information per stock and region is presented in the Annex (Annex 1).

Special interest was given to identify gear trials which reported particularly high size selectivity to better match the request of ToR 2. However this proved to be challenging as for most stocks/regions the range of mesh sizes/size selectivity parameters in published studies is rather narrow and centred around current and historical, often smaller, mesh sizes and/or mesh configurations. This means that it is difficult to find documented examples of gears with a selectivity high enough to correspond to some of the suggested optimal sizes (Tables 4.2.1.1, 4.2.1.3), at least under current fishing mortalities. In some cases, EWG 22-19 therefore choose to list and use examples of gears with higher size selectivity for a species from an adjacent area (with similar fisheries). Characteristic examples are two studies with large-meshed codends for cod and saithe from the Barents Sea (Sistiaga *et al.*, 2009; Brinkhof *et al.*, 2022), which were used as examples of more optimal gears in terms of size selectivity for cod and saithe in the North Sea and West of Scotland (see Annex 1). Listing these higher selectivity gear options from adjacent areas as options for these stocks does not mean that they are necessarily directly applicable in similar EU fisheries, but merely meant as examples of what can possibly be achieved in terms of gear selectivity.

Another observation from the literature review exercise is that most research on absolute gear selectivity has been done on demersal bottom trawls and seines (more correctly on cod-ends). By contrast, gear selectivity data for gillnets, longlines and other passive fishing gears are much scarcer, often lacking entirely for many species/stocks in most regions. More specifically, although some studies on passive gears report other kind of gear selectivity/catch information (for example mean/modal size of catch plus some measure of variability), this information was seldom presented in a way that could be directly used by EWG 22-19 (i.e. the function that describes the gear selectivity by length was not reported or it was not easy to be calculated from the reported information). There were also examples of trawl trials with similar issues of applicability for EWG 22-19, i.e. in cases where the gear selectivity function (and parameters) were not clearly reported. All in all, this means that the compilation of gear selectivity by stock and region presented in Annex 1 is far from complete but shall be seen as an initial shortlist of gear options for optimizing gear selectivity. More effort is needed if a more comprehensive list of gear alternatives by stock and region is requested.

### 4.4.1 NORTH SEA (ANNEX V OF TMR)

The North Sea region comprises Union waters in ICES divisions 2a and 3a and ICES sub-area 4. Annex V of the TMR stipulates that the North Sea baseline mesh size in towed gear is 120mm, except for division 3a (Skagerrak and Kattegat) where 90mm (with a 270mm diamond mesh panel) is allowed. Baseline mesh size for nets is 120mm. Smaller mesh sizes can be used in certain directed fisheries but only if by-catches of cod, haddock and saithe do not exceed 20% of the total catch weight. Examples of major demersal trawl fisheries that uses mesh sizes smaller than the baseline are fisheries for flatfishes like plaice (100mm), sole (80mm), Nephrops and whiting (80mm) and Pandalus (35mm). Many of these smaller mesh gears must be fitted with a square mesh panel or a grid.

Additional technical measures are in place as part of remedial measures for cod in the North Sea (Art 16 of Council Regulation (EU) 2022/109). These include the following gear measures in the northern part of the region (the Northern North Sea and the Skagerrak):

For TR1 trawls and seines >100mm:

- i) belly trawls with a minimum belly mesh size of 600mm
- ii) raised fishing line (0.6 m)
- iii) horizontal separating panel with large mesh escape panel

For TR2 trawls and seines 70-100mm:

- (i) horizontal sorting grid with maximum 50mm bar spacing separating flatfish and roundfish, with an unblocked fish outlet for roundfish
- (ii) SELTRA panel with 300mm square-mesh size
- (iii) sorting grid with maximum 35mm bar spacing, with an unblocked fish outlet;

These gear options stem from an EU/Norway meeting in 2020 where many potential alternatives to reduce cod bycatches in trawl fisheries were presented and discussed (Graham & Olsen, 2020). As most of these gears were studied using catch comparison trials, i.e. trials comparing catches between a new/alternative gear and a baseline gear to estimate catch equivalence, EWG 22-19 understands that information about absolute selectivity parameters ($L_g50$ and $SR_g$) are lacking for some of the listed gears. The remedial measures gears with reported selectivity estimates were included in the Annex (Annex 1).

Notably, exemptions from the remedial gear measures listed above are possible if one fishes under a so called national cod avoidance plan. EWG 22-19 is not aware of any evaluation of the degree of implementation of the North Sea cod remedial gear measures but understands that some fleets continuously use the baseline trawl gears under national plans. Because of the uncertain implementation, EWG 22-19 choose to focus on the selectivity of the TMR baseline gears instead of the remedial measures' gears in ToR 3.

### 4.4.2 NORTH WESTERN WATERS (ANNEX VI OF TMR)

The North Western Waters region comprises Union waters of sub-areas 5,6 and 7. The TMR lays down a baseline mesh size of 100mm in ICES divisions 7b-7k and 120mm in the rest of the region.

Like in the North Sea region, smaller mesh sizes can be used in certain directed fisheries if by-catches of cod, haddock and saithe do not exceed 20% of the total catch weight. For instance, an 80mm codend may be used in directed Nephrops fisheries if combined with either a square mesh panel of at least 120mm or sorting grid with a maximum bar spacing of 35mm.

Additional technical measures are in place for vessels targeting Nephrops using bottom trawls or seines in EU waters of the West of Scotland, Irish Sea and parts of the Celtic Sea. The survival exemption to the landing obligation for Nephrops in sub-area 7 is linked to the use of the Irish Sea and Celtic Sea technical measures which effectively widens their application. Of these measures, a 300mm square mesh panel is most commonly used.

Remedial measures have been implemented in parts of the Celtic Sea to ensure the rapid return of cod and whiting stocks to levels capable of producing MSY. These gears include:

1. 110mm cod-end with 120mm square-mesh panel
2. 100mm T90 cod-end
3. 120mm cod-end
4. 100mm with 160mm square-mesh panel

In addition to the above measures, a raised fishing line (1m spacing between the fishing line and ground gear) has been introduced to reduce catches of cod, and must be used by vessels with catches consisting of at least 20% of haddock.

The majority of the selectivity studies carried out on the above gears have used the catch comparison method as it is an accepted method of demonstrating equivalent selectivity with existing gears, a requirement for the implementation of additional technical measures in the TMR. This method does not provide estimates of $L_g50$ and $SR_g$ for each gear.

STECF PLEN 20-01 provided estimates of the $L_g50$ and $SR_g$ of the above gears using a model of selectivity developed by Madsen & Ferro (2003). The results of the analyses with the raised fishing line are included in Annex 1. When considering these results, EWG 22-19 notes the following caveat from STECF PLEN 20-01: STECF claimed that most of the analyses presented below have been performed during the limited time of the written procedure and with only limited preparatory work, and cannot thus cover all aspects of relevance for the request. STECF underlined that more careful and in-depth analyses would need to be performed in the frame of dedicated research studies.

BIM in Ireland have extensively tested a range of codend and square mesh panel mesh size combinations and the resulting $L_g50$s and $SR_g$s are included in the table.

#### 4.4.2.1 STOCK SPECIFIC SELECTIVITY – COD.27.7E-K

Since 2019 the TAC for this stock has been for bycatches only. The majority of catches are attributed to otter trawl fleets (ICES, 2022a). Under the TMR a wide range of technical measure options are in place for bottom trawlers and depend on catch composition. Otter board fleets in this area typically target either fish or Nephrops with a bycatch of cod.

Under the TMR the baseline mesh size for bottom trawls and seiners in ICES divisions 7b-7k is 100mm but within the Celtic Sea Protection Zone remedial measures have been implemented to protect whiting and cod:

1. 110mm cod-end with 120mm square-mesh panel
2. 100mm T90 cod-end
3. 120mm cod-end
4. 100mm with 160mm square-mesh panel

An additional cod protection measure is in place for bottom trawlers. Vessels with catches consisting of at least 20% haddock are required to use a raised fishing line, consisting of 1m spacing between the fishing line and ground gear of the trawl.

The TMR includes a derogation from the above measures for bottom trawlers and seiners with catches consisting of at least 55 % of either whiting or a combination of hake, monk and megrim:

- 100mm cod-end with a 100mm square mesh panel;
- T90 100mm cod-end and extension.

The codend mesh size and square mesh panel combinations above are highly selective for whiting. The raised fishing line is more selective for larger, faster growing cod.

For vessels targeting Nephrops, with catches consisting of more than 30 %, a derogation to the 100mm baseline is also in place within the Celtic Sea Protection Zone:

- 300mm squared mesh panel; vessels below 12 meters in length over all may use a 200mm square mesh panel;
- SELTRA panel;
- Sorting grid with a 35mm bar or a similar Netgrid selectivity device;
- 100mm cod-end with a 100mm square mesh panel;

- dual cod-end with the uppermost cod-end constructed with T90 mesh of at least 90mm and fitted with a separation panel with a maximum mesh size of 300mm.

Use of the above gears is a condition of the survival exemption for Nephrops in sub-area 7 and their use is widespread across 7b-7k. The most commonly used gear is likely to be an 80mm codend with 300mm square mesh panel as a square mesh panel has been required in the fishery for some time.

Trials conducted by BIM in the Irish Sea during 2017 compared catches from a 300mm square mesh panel with those from a SELTRA 300, fitted with a 300mm square mesh panel closer to the codline, and found that the SELTRA reduced cod catches by 81 % (BIM, 2017). Reductions in cod catches from this study are in line with those of Madsen & Valentinsson (2010) who tested the SELTRA 300 in the Kattegat and Skagerrak using the covered codend method. The sorting grid with 35mm bar spacing reduces catches of cod too large to pass through the bars but losses of commercial catches of Nephrops have been reported, as well as handling difficulties.

#### 4.4.2.2 STOCK SPECIFIC SELECTIVITY – WHG.27.7A

ICES advises that the majority of Irish Sea whiting (98 %) are bycatches in the Nephrops fishery and are below MCRS (27 cm) (ICES, 2021). Under the TMR the baseline mesh size in the Irish Sea is 120mm but vessels with catches comprising > 30 % Nephrops and fishing with more than one trawl must use a codend mesh size of at least 80mm combined with additional technical measures to reduce catches of finfish:

- 300mm square mesh panel; vessels below 12 meters in length over all may use a 200mm squared mesh panel;
- SELTRA panel;
- Sorting grid with 35mm bar spacing;
- CEFAS Netgrid;
- Flip-flap trawl.

The majority of whiting catches in the Irish Sea are below MCRS with a large component of the stock measuring < 20 cm. BIM and the Irish Fishing Industry have tested a range of gear modifications aimed at reducing catches of whiting, a major potential choke species in the Irish Sea Nephrops fishery. Gears such as the 300mm square mesh panel and SELTRA achieve large reductions in catches of whiting and haddock but are ineffective for whiting < 20 cm which can form a major component of the catch (Browne *et al.*, 2018). The Swedish grid can be effective in this regard but is also associated with handling difficulties (Graham & Fryer, 2006) and losses of marketable Nephrops. Increasing codend mesh size from 80 to 90mm is effective at reducing catches of whiting < 20 cm but with losses of marketable Nephrops.

Increasing codend mesh size in the Irish Sea Nephrops fishery may not optimise exploitation patterns, protect juveniles and help achieve MSY for whiting as Sangster *et al.*, (1996) found that most whiting and haddock < 20 cm died following escape through codends with mesh sizes ranging between 70 and 110mm. They found that survival of smaller codend escapees was much worse than for larger whiting (or haddock) and suggest that survival may be a complex function of fish length.

Measures which permit escapement of < 20 cm whiting earlier on in the capture process are likely to improve survival rates. BIM have recently developed and tested modified multi-rig sweep configurations with some success for larger fish and elasmobranchs but not small whiting. Northern Irish work in the same fishery has focused on modifying the forward part of twin-rigged Nephrops trawls by removing the cover which has successfully reduced catches of < 20 cm whiting.

### 4.4.3 SOUTH WESTERN WATERS (ANNEX VII OF TMR)

For towed gears (trawl and seines) in South Western Waters (SWW) (i.e., ICES sub-areas 8, 9 and 10 (Union waters) and CECAF zones (24) 34.1.1, 34.1.2 and 34.2.0 (Union waters), the baseline mesh size according to Annex VII is at least 70mm (at least 55mm in ICES division 9a east of longitude 7°23′ 48″ W). Baseline mesh size for static nets is 100mm or at least 80mm in ICES division 8c and ICES sub-area 9.

None of the participating experts at the EWG 22-19 meeting had in depth knowledge of gear selectivity trials in SWW fisheries. Therefore the completeness of the list of studies listed in Annex 1 is probably the lowest among the regions.

In short and with regards to trawls, the selectivity estimates for 55mm and 70mm diamond mesh trawls have been selected and compared to the estimates for 70mm T90 and 80mm diamond mesh codends. For gillnets, of the analysis for hake in divisions in 8 a,b,d, the selectivity data from NWW for 100mm was selected and compared against the selectivity information for 120mm and 140mm. For division 8c and sub-area 9, the selectivity data for 80mm and 90mm from selectivity experiments in 9a were used, along with the estimates for 100mm from NWW. There is only very limited selectivity data for hake caught with longlines, emanating from one trial dating back to 2001. As there is no current legislation for hook size in the fishery, the largest and smallest hook sizes have been selected for the analysis.

### 4.4.4 BALTIC SEA (ANNEX VIII OF TMR)

Baltic Sea (BS) here covers union waters in ICES divisions 3b, 3c and 3d. Annex VIII of the TMR specifies that the baseline mesh size for towed gears in the Baltic region is 120mm T90 or at least 105mm fitted with a Bacoma exit window of 120mm. The baseline mesh size for static nets is 110mm. Smaller mesh sizes are allowed in certain directed fisheries if by-catches of cod do not exceed 10% of the total catch weight.

The TAC for both Baltic cod stocks are for bycatches only, since 2019 for the eastern and since 2022 for the western stock. This has meant that cod catches and bottom trawl effort have shown major reductions in recent years (ICES, 2022b; ICES, 2022c). Nowadays Baltic cod is caught as bycatch in fisheries for flatfish species (mainly flounder, plaice and sole).

Overall, selectivity in Baltic Sea cod fisheries is well studied. EWG 22-19 identified and used two reviews as the main sources of information to populate Annex 1. These reviews summarise most of the central work that has been done over the years: Madsen (2007) reviewed and summarised studies between 1970s-mid 2000s, while Stepputtis *et al.* (2020), and references therein, provided information about most of the work done since the Madsen review. The list of gears includes the two baseline gears (120mm T90 codend and 105mm codend with a 120mm Bacoma square mesh window) and various codend alternatives with improved larger mesh sizes of alternative mesh configurations (based on trials or modelled results).

EWG 22-19 is aware that the regional group of member states for the Baltic Sea (Baltfish) in 2021 submitted a joint recommendation (JR) that proposed to replace the TMR baseline trawls with three trawl alternatives that the JR claimed were better suited for targeting flatfish and with reduced cod bycatch rates (scientifically underpinned by Stepputtis *et al.*, 2020). The proposed gear alternatives are a 125mm square mesh codend, a two panel 125mm T90 codend with stabilizing lastridge ropes and a composite gear design called Nemos and Roofless. STECF PLEN 21-03 reviewed these alternatives with focus on equivalence of the proposed gears compared to the TMR baseline gears and not absolute gear selectivity per se (the focus on equivalence follows TMR art 15 about regional technical measures). Most focus in Stepputtis *et al.* (2020) was therefore on catch comparison results and not on absolute selectivity. Hence, gear selectivity estimates were not available and the three proposed alternative trawls from the Baltfish JR were not included in Annex 1.

### 4.4.5 MEDITERRANEAN SEA (ANNEX IX OF TMR)

The Mediterranean Sea is here the waters of the Mediterranean to the East of line 5°36′ W. Annex IX of the TMR specifies that the baseline mesh size for towed gears in the Mediterranean Sea is 40mm square mesh codend (or 50mm diamond mesh codend). The baseline mesh size for static nets is 16mm. Also, the mesh size of surrounding nets, purse seines and hook numbers for long lines are specified in Annex IX of the TMR.

EWG 22-19 recognised that according to Annex XIV of the TMR, species for selectivity performance indicators in the Mediterranean fishing zones are red mullet and hake. Following the relevant work of EWG 21-07 and ToR 1 of the current report, highest priority was assigned to identify and compile selectivity information about Mediterranean hake stocks. Due to their widespread occurrence among different depths and habitats, hake stocks are mainly exploited by bottom trawls, bottom-set gillnets and bottom-set longlines.

The group noted that in the Mediterranean Sea most of the fisheries are multispecific and target more than one species in one single fishing operation/trip. The most important gears in the region, in terms of landings, are 'towed gears' (e.g. trawls, beam trawls, dredges) where a range of different mesh sizes are used in order to optimize and adapt the gear to different biological characteristics and behaviour of targeted marine organisms. Static fishing gears, such as nets, longlines, traps, exhibit lower landings compared to towed gears. The mesh sizes and hook sizes used in different gears are generally designed to catch the most valuable species in the fishery (e.g. Nephrops, hake, shrimps, cephalopods, flatfish, etc.).

The current review on studies/selectivity estimates (summarised in Annex 1) was mostly based on reviews in recent projects (e.g., IMPLEMED) or publications (Lucchetti *et al.*, 2020; 2021; Sbrana, 2021). An attempt was made to identify parameters for all hake stocks in the Mediterranean Sea. When more than one selectivity study was available, the most recent study was chosen. Unfortunately, hake selectivity data are not available for all Mediterranean GSAs. In cases where no selectivity data of a hake stock appears in the table, data from a nearby stock or region can be used as best estimate. Depending on the experimental design adopted, some studies were excluded because they were based on catch comparison analysis and then it was not possible to obtain selectivity parameters.

EWG 22-19 notes that more favourable exploitation and selectivity pattern of the hake stocks could be obtained by use of passive/static fishing gears (Annex 1), which appear to have lower impact on the seabed compared to towed gears (e.g. see EWG 22-12 report; STECF, 2022). The group also notes that the otter trawl fishery is one of the most important fisheries in the Mediterranean and a potential gear change to passive gears such as gillnets or long lines will have significant socio-economic and ecological consequences. Therefore, most of the research effort has been focusing to improve trawl fisheries by changing/increasing trawl codend mesh sizes. This may lead to improvement of selectivity pattern of hake stock exploitation with the aim to advice on new possible technical measures. Considering that all assessed hake stocks in the Mediterranean are overexploited (in terms of SSB) and that overexploitation (F above $F_{MSY}$) is taking place (GFCM, 2022), changes in trawl codend mesh sizes and/or type may contribute to reducing current F in hake stocks. However, a whole set of tools, mainly awareness campaigns and economic incentives towards more selective fishing (e.g., selective licensing, eco-labelling) are totally absent or have very limited application in the Mediterranean Sea.

Regarding the bottom trawl regulation with 40mm square mesh codend (40SM), one aspect that could be of interest for further investigations is the influence of the codend length (which is currently not specified in the legislation). Literature data report many investigations on the codend circumference and twine tickness (Sala & Lucchetti, 2010; 2011; Sala *et al.*, 2016; 2018), but probably no research has been conducted on the influence of codend length on selectivity and even current legislation misses a clear specification of the codend section characteristics and its minimum allowed length. EWG 22-19 considers that the lack of a minimum codend length in Regulation (EU) 2019/1241 may undermine the intentions of the current legislation. This is due to current legislation still allowing fishers to use 40mm diamond meshes in the rear section of the extension piece; then, if the minimum 40SM codend length is not regulated, the use of short codends, can deteriorate selectivity to levels like that in Council Regulation (EC) No 1626/94, since the rear section of the extension piece could effectively work as codend.

## 4.5 Case studies of NE Atlantic priority stocks (ToR 1 & ToR 2)

Below, six case studies of the priority stocks from the NE Atlantic are presented. Each case study looks at an individual stock, detailing fleet characteristics, landings and discards, stock status, selectivity studies and the outcomes of the selectivity scenarios in terms of age and length. As in Chapter 4.2.1, 'current' F and selectivity refer to the average of the last three years available from the assessments (2018-2020).

### 4.5.1 COD (GADUS MORHUA) IN SUBDIVISIONS 22–24 (WESTERN BALTIC) (COD.27.22-24)

Western Baltic cod is exploited by a mixed commercial–recreational fishery. Traditionally however, commercial fisheries largely dominated the catches. Trawlers have been responsible for the main landings of cod in the western Baltic (63%), followed by gillnetters (37%) (ICES, 2021a). As a consequence of reduced commercial fishing opportunities, the proportion of the stock fished by recreational fisheries has increased. In 2020, recreational catches constituted 1,311 tonnes, 46% of the total catches, and were included in the stock assessment (ICES, 2021a). The commercial fishery targeting cod has changed substantially in the latest years: from being the main targeted species in the demersal fishery, directed fishing for cod is banned since 2021 and cod is nowadays a bycatch species in fisheries targeting flatfish. The stock is mainly fished by Denmark and Germany, with smaller amounts caught by Sweden and Poland.

The total commercial landings for human consumption in the management area sudivisions (SD) 22-24 (including the eastern Baltic stock component) in 2020 were 3,329 t (including BMS), with a quota utilization of 83% (4,000 t). In the last 10 years, slightly more than half of the total western Baltic area landings have been fished in SD 24, in 2019 this changed and was 20% in 2020. This change is due to a management regulation in place since mid-2019, prohibiting a directed cod fishery in SD 24 where the western cod stock intermixes with the eastern Baltic cod stock (ICES, 2021a).

Discard data from at-sea observer programs are available from Germany, Sweden and Denmark for SD 22–24. The discard rate in 2020 was estimated to be 5% (ICES, 2021a).

Based on the assessment of 2021, fishing pressure on the stock is above $F_{MSY}$ and between $F_{pa}$ and $F_{lim}$; spawning-stock biomass is below $MSYB_{trigger}$, $B_{pa}$ and $B_{lim}$ (ICES, 2021a) (Fig. 4.5.1.1).

The fishing mortality estimated from the assessment has remained high and the SSB considerably lower than was predicted. Such a pattern suggests that processes other than fisheries and assumed natural mortality are affecting the SSB of the western Baltic cod stock. The sources for the presumably additional unaccounted mortality are presently unclear but could involve e.g. increased natural mortality (due to increased predation, hypoxia, decreased condition, increased water temperatures) and unreported catches. The stock is currently exploited as bycatch in targeted fisheries for other species (mainly flatfish).

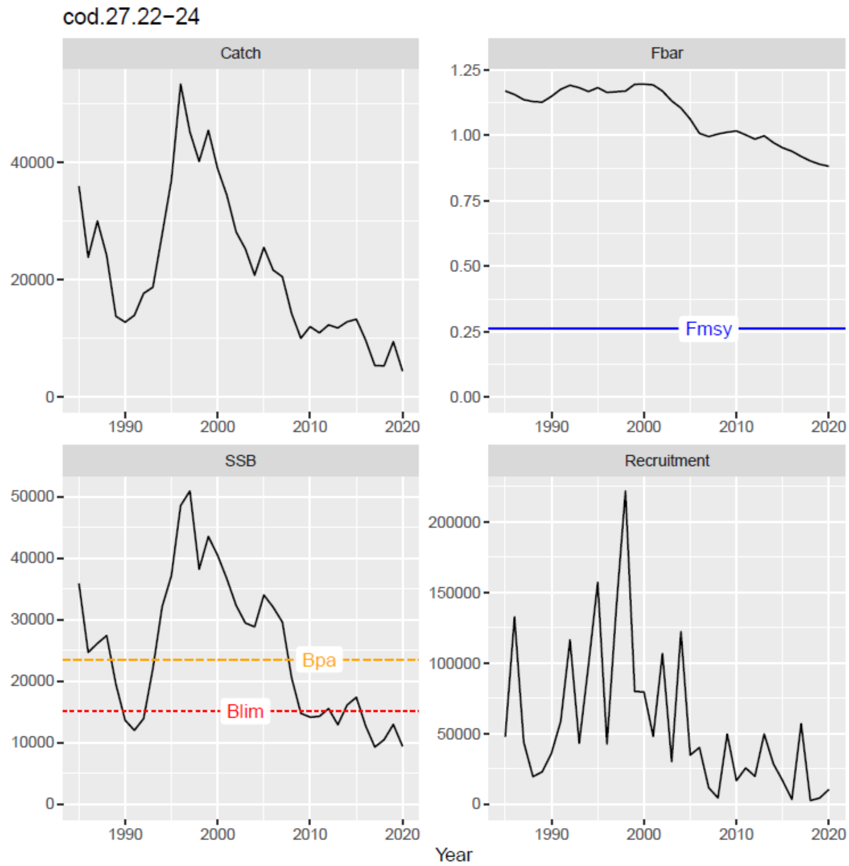


**Figure 4.5.1.1** Cod in subdivisions 22–24, western Baltic stock (cod.27.22-24). Summary of the stock assessment (ICES, 2021a).

The selectivity analysis indicates that the western Baltic cod stock may produce higher equilibrium yields under current F by shifting A50 by 3.3 y or L50 by 39.7 cm (Fig. 4.5.1.2; Table 4.2.1.1).

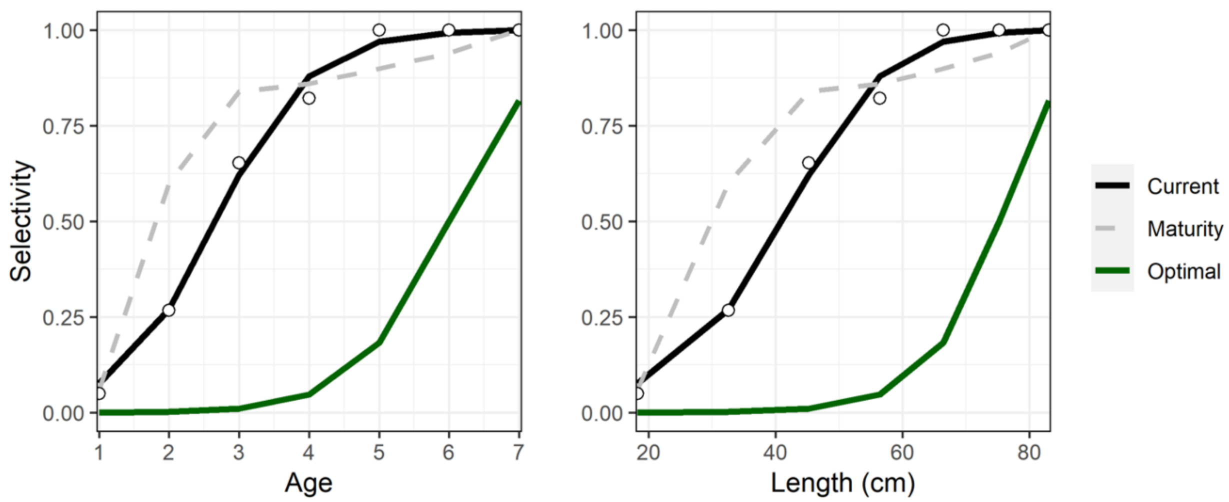


**Figure 4.5.1.2** Cod in subdivisions 22–24, western Baltic stock(cod.27.22-24). Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity.

Of the fleets that exploit the stock, OTB exhibits the lowest selectivity by selecting fish with an average size of 36.5 cm, i.e. 43.9 cm smaller than the optimal size. By contrast, gillnets and other passive gears exhibit higher selectivity by selecting fish with an average size of around 46 cm, which is still 34 cm lower that the optimal size (Fig. 4.5.1.3; Table 4.2.1.2).

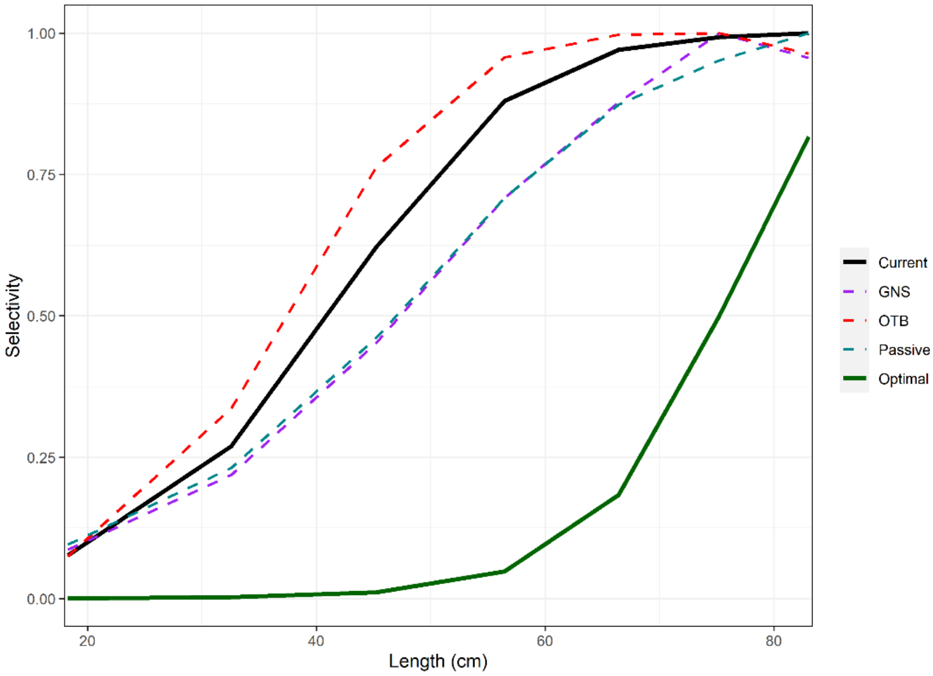


**Figure 4.5.1.3** Cod in subdivisions 22–24, western Baltic stock (cod.27.22-24). Fitted 'Current' and 'Optimal' (shifted) selectivity by length and fitted selectivity by fleet segment. GNS: Set gillnets; OTB: bottom otter trawls; Passive: other passive gear.

The gear selectivity parameters for the two current baseline codends ($L_g50$ = 42.3 cm, $SR_g$ = 6.7 cm for the 120mm T90 alternative and $L_g50$ = 38.7 cm, $SR_g$ = 8.0 cm for the 105mm with 120mm Bacoma alternative; Annex 1) were derived from Wienbeck *et al.* (2014), Herrmann (2008) and Herrmann *et al.* (2009). A more selective alternative codend corresponding to a full square mesh codend of 140mm from Steputtis *et al.* (2020) was also considered ($L_g50$ = 50.0 cm, $SR_g$ = 7.2 cm). Gear selectivity information for GNS were found in the literature but EWG 22-19 could not reproduce a selectivity function from the information provided there.

Although the T90 baseline according to the literature appears to exhibit somewhat better selectivity than the Bacoma baseline, both baseline trawl alternatives exhibit an $L_g50$ far lower (38-41 cm) than the optimal L50. The 140mm square mesh modification is an alternative with improved cod size selectivity, but it would still be likely to catch fish on average 30 cm smaller than the optimal size for this stock (Fig. 4.5.1.4, Annex 1).

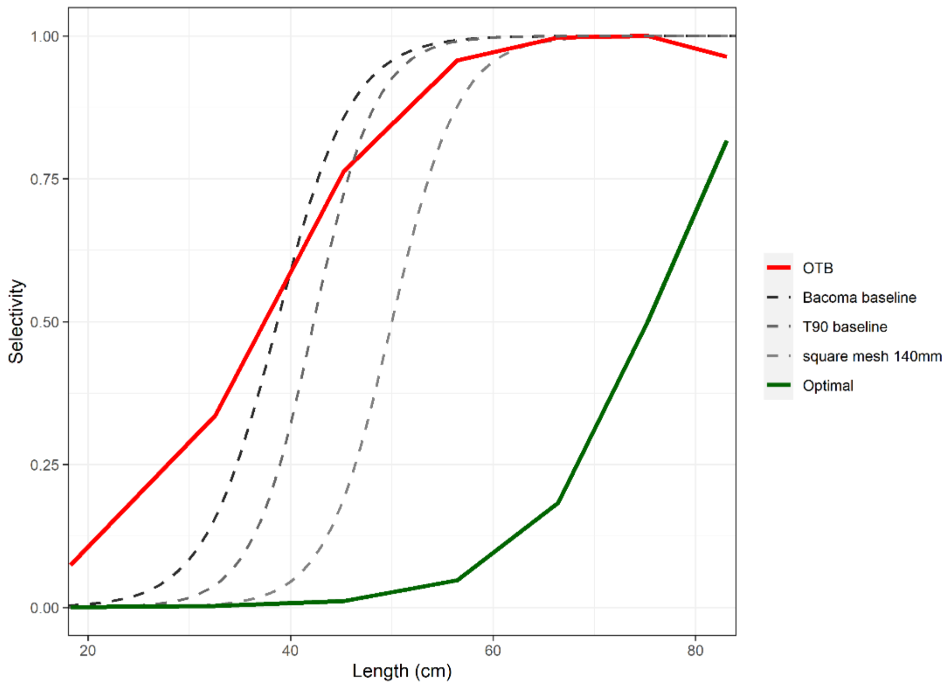


**Figure 4.5.1.4** Cod in subdivisions 22–24, western Baltic stock (cod.27.22-24). Fitted 'Optimal' (shifted) selectivity by length, fitted selectivity by the OTB fleet segment ('OTB'), gear selectivity curves for the baseline 120 mm T90 ('T90 baseline'), the baseline 105 mm with 120 mm square mesh window ('Bacoma baseline') and a more selective alternative: 140 mm square mesh codend ('square mesh 140mm').

Selectivity analysis under varying F, confirms that lowering F would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.5.1.5). When comparing current selectivity with the gear selectivity of the baseline and improved codend (140mm square mesh), it can be inferred that under current $F_{apical}$ the stock would still lie far from the highest equilibrium yields with either of the gears examined, although the 140mm square mesh would double both yield and SSB per recruit. Close-to-optimal yields (90% of maximum) would be extracted by shifting L50 to ca. 62 cm, while fishing at a $F_{apex}$ ca. 1/3 of current (Fig. 4.5.1.5). However, there is the caveat of isopleths and current selectivity referring to population selectivity, which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

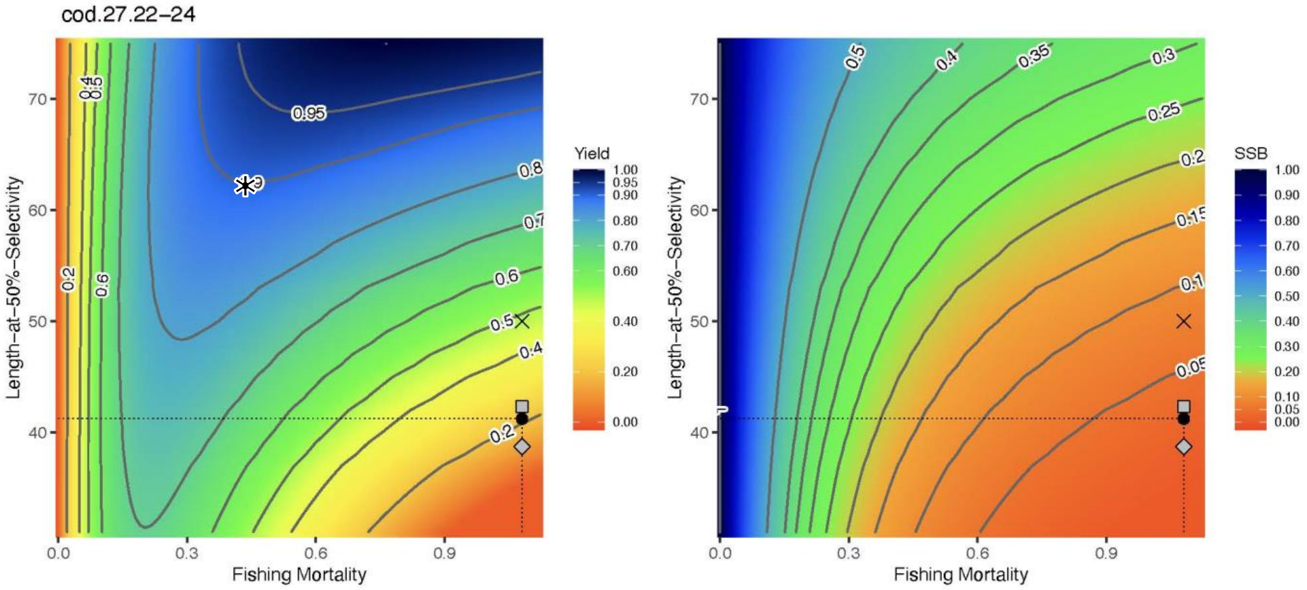


**Figure 4.5.1.5** Isopleths by length for western Baltic cod (cod.27.22-24). Equilibrium yield (left) and SSB (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 105/120 mm Bacoma codend baseline (◇), the $L_g50$ of the 120 mm T90 baseline (□) and for a more selective codend alternative: 140 mm square mesh codend (x). Also plotted is the combination of lowest L50 and $F_{apical}$ producing an equilibrium MSY at 90% of the maximum (*).

### 4.5.2 COD (GADUS MORHUA) IN SUBAREA 4, DIVISION 7.D, AND SUBDIVISION 20 (NORTH SEA, EASTERN ENGLISH CHANNEL, SKAGERRAK) (COD.27.47D20)

Landings data reported to ICES show that this stock is predominantly landed by demersal otter trawlers and seine netters utilising nets with mesh >100m (75%), followed by gillnets (10.5%), demersal trawlers using mesh 70 – 99mm (5.5%), beam trawls (4.5%), and other gears accounting for the smallest fraction (4.5%) (ICES, 2021b). All countries around the greater North Sea exploit this stock (ICES, 2021b) but largest catches are taken by UK, Denmark and Norway.

Recreational catches are estimated to account for 3.6–8.9% of total removals between 2010–2019, but values are provisional and not included in the assessment due to unknown age structure and uncertainty (ICES, 2021b).

Total landings for cod in Subarea 4, Division 7.d, and Subdivision 20 have varied around 25-35 thousand tonnes during the period 2009 to 2018 and decreased markedly in 2020 and 2021. In 2020 discards were estimated to be 4,701 tonnes, which corresponds to a discard rate of 19% (ICES, 2021b).

Fishing pressure on the stock is above $F_{MSY}$ but below $F_{pa}$ and $F_{lim}$; spawning-stock size is below $MSYB_{trigger}$, $B_{pa}$, and $B_{lim}$ (Fig. 4.5.2.1) (ICES, 2021b). The highest abundances of recruits are normally found in the Skagerrak and Kattegat with another hotspot of recruitment appearing east of Scotland over the last 10 years.

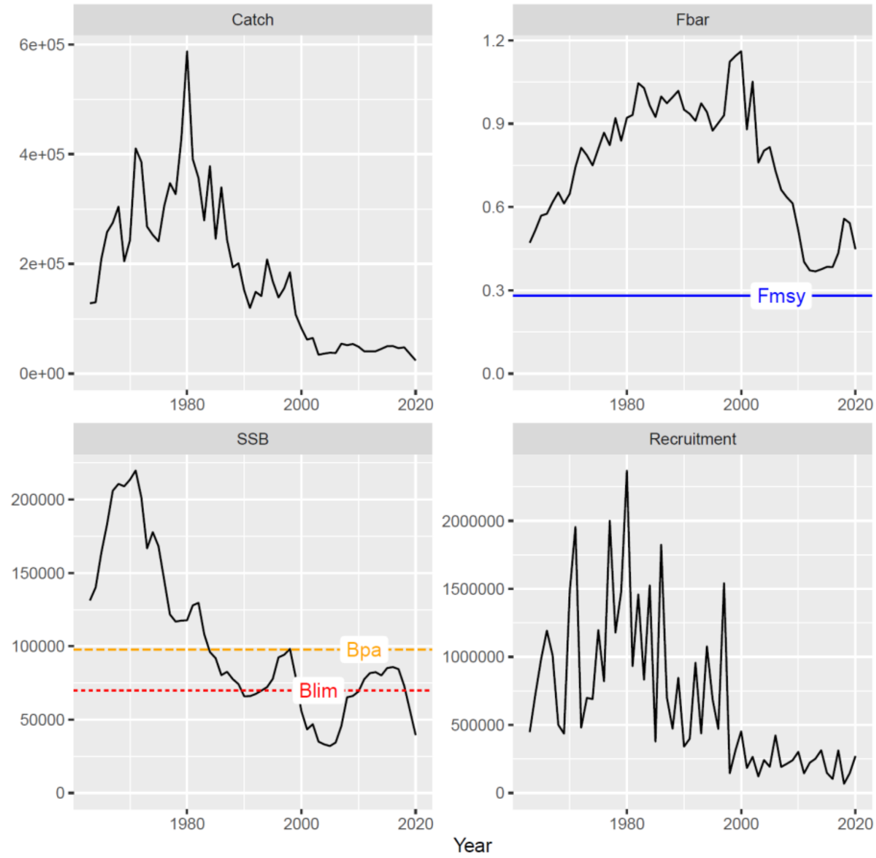


**Figure 4.5.2.1** Cod in Subarea 4, Division 7.d, and Subdivision 20 (cod.27.47d20). Summary of the stock assessment (ICES, 2021b).

The selectivity analysis indicates that the North Sea cod stock may produce the highest equilibrium yields under current F by shifting A50 by 2.5 y or L50 by 36.4 cm (Fig. 4.5.2.2; Table 4.2.1.1).

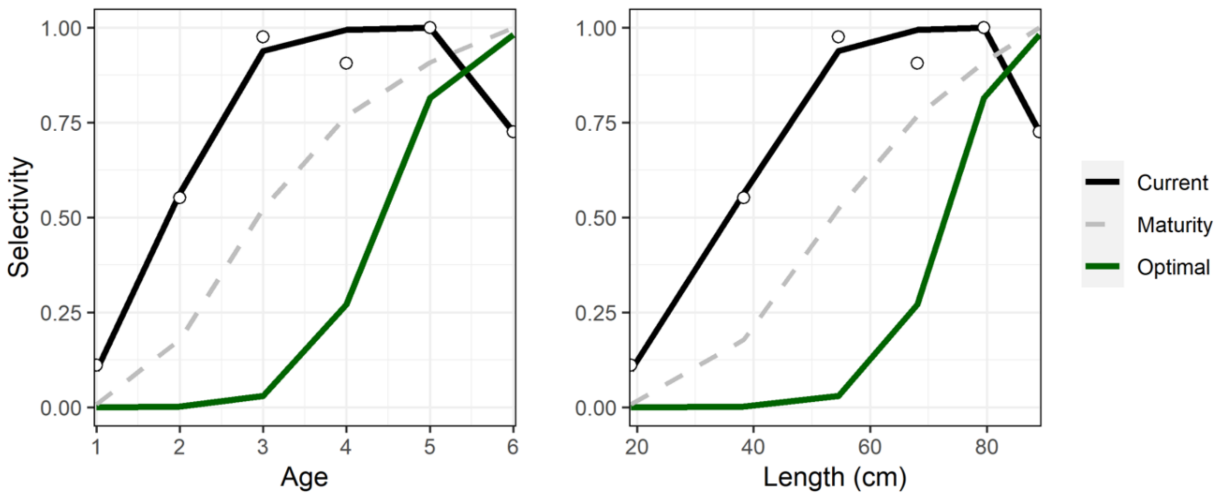


**Figure 4.5.2.2** Cod in Subarea 4, Division 7.d, and Subdivision 20 (cod.27.47d20). Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F plotted together with the maturity ogive. Points represent the observed selectivity.

Of the fleet segments exploiting the stock, TBB exhibits the worst selectivity followed by OTB. These fleets select fish on average 42.5 cm and 37.1 cm, respectively, smaller than the optimal size (Fig.

4.5.2.3; Table 4.2.1.2). GNS is the fleet with highest average selectivity, exhibiting an average L50 of 45.3 cm, i.e. still 27.6 cm lower than optimal size.

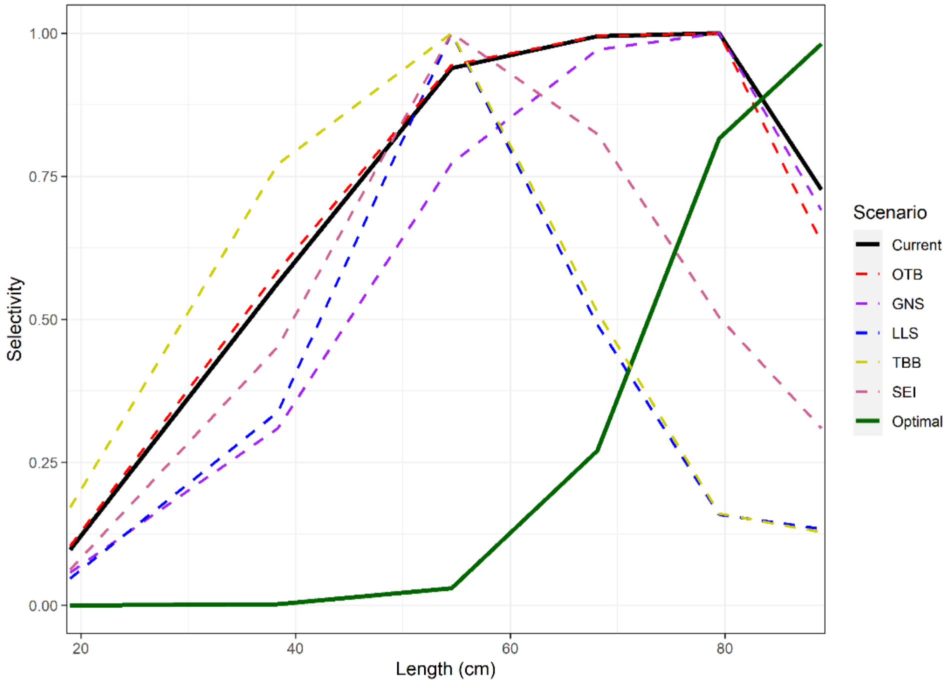


**Figure 4.5.2.3** Cod in Subarea 4, Division 7.d, and Subdivision 20 (cod.27.47d20). Fitted 'Current' and 'Optimal' (shifted) selectivity by length and fitted selectivity by fleet segment. GNS: Set gillnets; LLS: Set longlines; OTB: bottom otter trawls; SEI: seine nets

The gear selectivity parameters for the two baseline codends ($L_g50$ = 39.4 cm, $SR_g$ = 8.4 cm for the Subarea 4 baseline [120mm codend] and $L_g50$ = 33.8 cm, $SR_g$= 39.1 cm for the subdivision 20 (Skagerrak) baseline [90mm with a 270mm panel]; Annex 1) were derived from Madsen & Ferro (2003), STECF PLEN 20-01 and from Krag *et al.* 2016. Due to the lack of studies of trawl/codend designs for the stock with selectivity parameters closer to the optimal size for North Sea cod (72.9 cm), two more selective codend alternatives were obtained and used in the analysis: a 145mm T90 codend (T90_145mm) ($L_g50$ = 55.1 cm, $SR_g$ = 12.1 cm) and a 155mm codend ($L_g50$ = 61.3 cm, $SR_g$ = 8.7 cm). These results stem from trials in the Barents Sea by Brinkhof *et al.* (2022) and Sistiaga *et al.* (2009).

The estimated current selectivity of the OTB segment is somewhat lower than the gear selectivity of the Subarea 4 120mm baseline gear alone (Fig. 4.5.2.4). EWG 22-19 consider that this can be partly explained by the lower selectivity of the subdivision 20 (Skagerrak) baseline gear (90mm with 270 mmwindow) and the by the fact that cod is also caught as bycatch in trawls with smaller mesh sizes targeting other species (TR2 trawls for e.g. Nephrops, whiting etc.). Both baseline codends exhibit selectivity far lower than the optimum, with $L_g50$s 34 and 39 cm lower than the optimal L50 for the North Sea and the Skagerrak baseline respectively. Noticeable is that the two more selective codend alternatives (T90_145mm and 155mm) would bring trawl selectivity markedly closer to the optimal selectivity (Fig. 4.5.2.4, Annex 1).

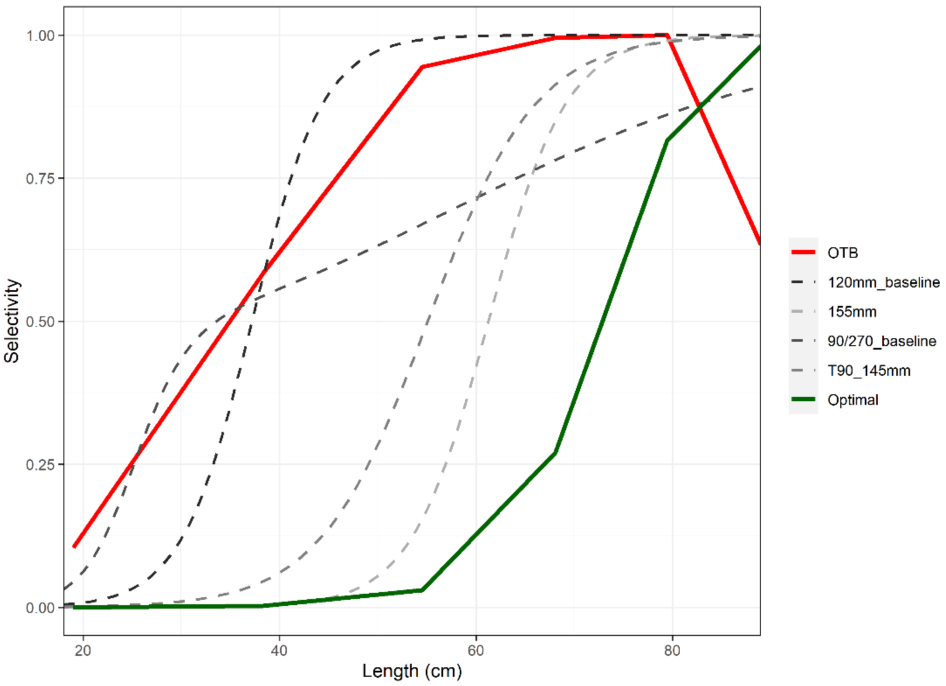


**Figure 4.5.2.4** Cod in Subarea 4, Division 7.d, and Subdivision 20 (cod.27.47d20). Fitted 'Optimal' (shifted) selectivity by length ('Optimal'), fitted selectivity by the OTB fleet segment ('OTB'), gear selectivity curves for the baseline 120mm ('120mm_baseline'), the Skagerrak baseline 90mm with 270mm window ('90/270_baseline') and two more selective alternatives: 155mm codend ('155mm') and 145mm T90 codend ('T90_145mm').

Selectivity analysis under varying F, confirms that lowering F would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.5.2.5). When comparing current selectivity with the gear selectivity of the baseline and improved codends (155mm and 145mm T90), it can be inferred that under current $F_{apical}$ the stock would be close to the highest equilibrium yields with the improved gears examined (especially the 155mm codend). Close-to-optimal yields (90% of maximum) would be extracted by shifting L50 to ca. 63 cm, while fishing at a $F_{apical}$ around 0.5 (Fig. 4.5.2.5). However, there is the caveat of isopleths and current selectivity referring to population selectivity, which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

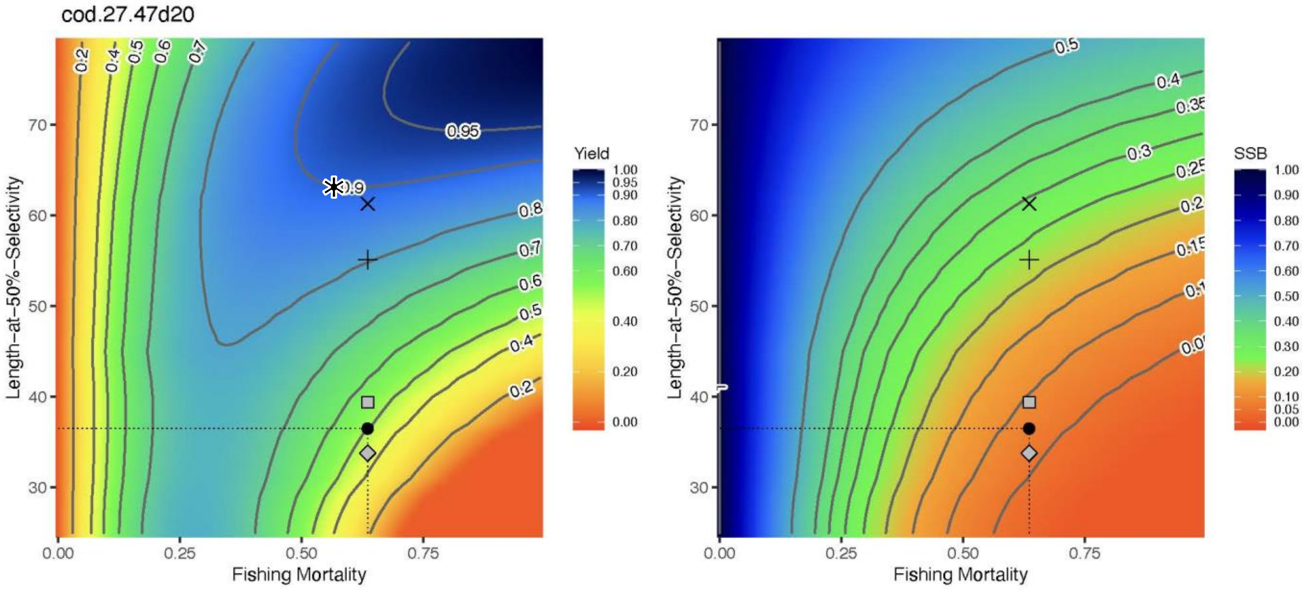


**Figure 4.5.2.5** Isopleths by length for North Sea cod (cod.27.47d20). Equilibrium yield (left) and SSB (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the L50 of the Skagerrak 90/270 mm baseline (◇), the L50 of the North Sea 120 mm baseline (□) and for two more selective codend alternatives: 155 mm (x) and 145 mm T90 codend (+) and the combination of lowest L50 and $F_{apical}$ producing an equilibrium MSY at 90% of the maximum (*).

### 4.5.3 COD (GADUS MORHUA) IN DIVISION 6.A (WEST OF SCOTLAND) (COD.27.6A)

This stock receives bi-annual advice, therefore this advice and assessment used in this analysis and referenced in this summary was completed in 2020 (ICES, 2020). Since 2012 there has been no directed fishery for cod in ICES division 6.a, with ICES advice of zero catch and a minimisation of bycatch and discards since 2003.

Landings are from bycatch in the mixed bottom trawl fishery targeting haddock, saithe, hake, anglerfish and megrim. The majority of the landings are taken by trawls targeting demersal finfish (92%), with those targeting Nephrops accounting for < 1%, gillnets < 2%, and other fishing gears accounting for around 4%. Area-misreported landings are a feature of this fishery (ICES, 2020). Estimated area-misreported landings (catches taken in Division 6.a, but reported elsewhere) account for over 40% of the total landings in recent years (average percentage 2017–2019). ICES has noted that measures to reduce area misreporting should be introduced (ICES, 2020).

Discarding has been considered high since 2007, with a peak of 3,867 tonnes in 2011. However, in 2019, there was a significant decrease in the proportion of discards due to an increase in TAC compared to recent years. For the period of 2016-2018 the average discard rate of cod was 75%. However, in 2019 the discard rate rapidly decreased to 9% (ICES, 2020)

Fishing pressure on the stock is above $F_{MSY}$, $F_{pa}$ and $F_{lim}$; spawning-stock size is below $MSYB_{trigger}$, $B_{pa}$, and $B_{lim}$ (ICES, 2020). Stock structure remains an issue for cod in Division 6.a. The issues of multiple stocks in Division 6.a and connectivity with the North Sea stock remain sources of uncertainty (ICES, 2020). Management measures taken so far have not resulted in a recovery of the stock. Even though fishing mortality declined between 2009 and 2016, it has shown an increase since. It is not known whether, and to what extent this increase is associated with the discontinuation of the days-at-sea regulation in 2017, which was part of the cod recovery plan (ICES, 2020).

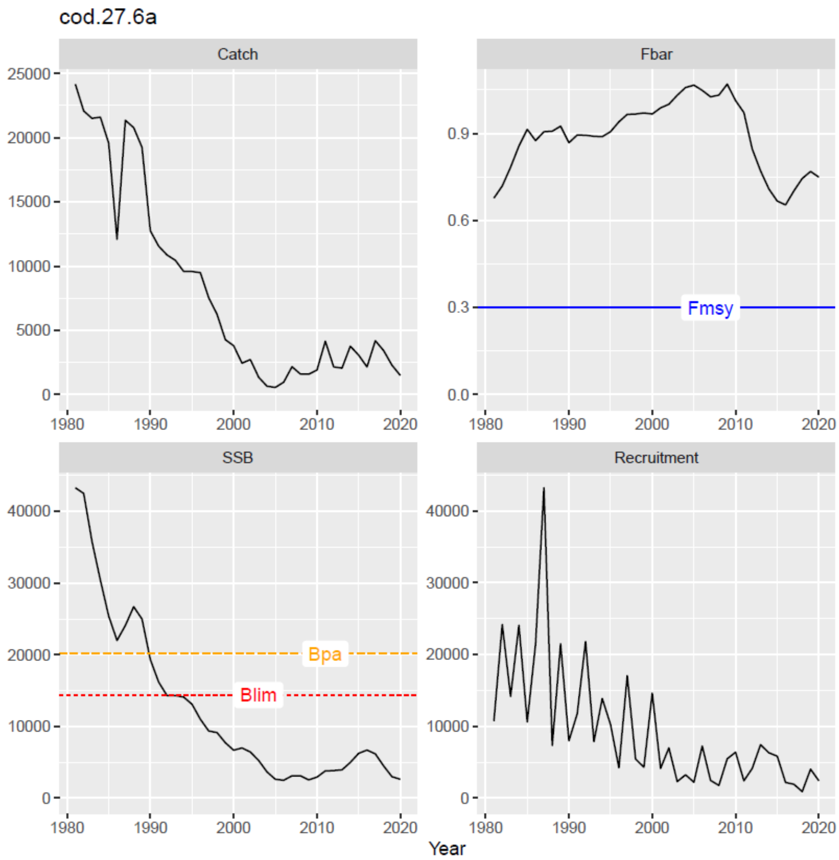


**Figure 4.5.3.1** Cod in Division 6.a (West of Scotland) (cod.27.6a). Summary of the stock assessment (ICES, 2020).

The selectivity analysis indicates that the West of Scotland cod stock may produce the highest equilibrium yields under current F by cranking A50 by 1.6 y or L50 by 24 cm. Almost as high equilibrium yield and maximum protection of juveniles can be achieved by shifting A50 by 1.8 y or L50 by 26.3 cm (Fig. 4.5.3.2; Table 4.2.1.1).

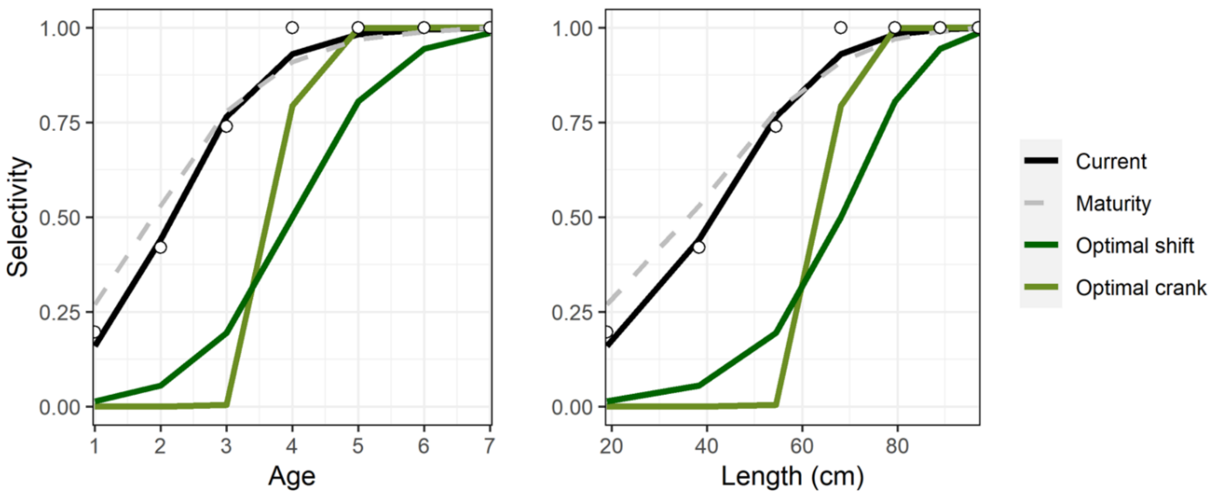


**Figure 4.5.3.2** Cod in Division 6.a (West of Scotland) (cod.27.6a). Fitted 'Current' and 'Optimal' (shifted and cranked) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity.

The selectivity of the OTB fleet is very similar to the total selectivity of all fleets ('Current'). Both are however far lower than the optimal selectivity (Fig. 4.5.3.3; Table 4.2.1.2).

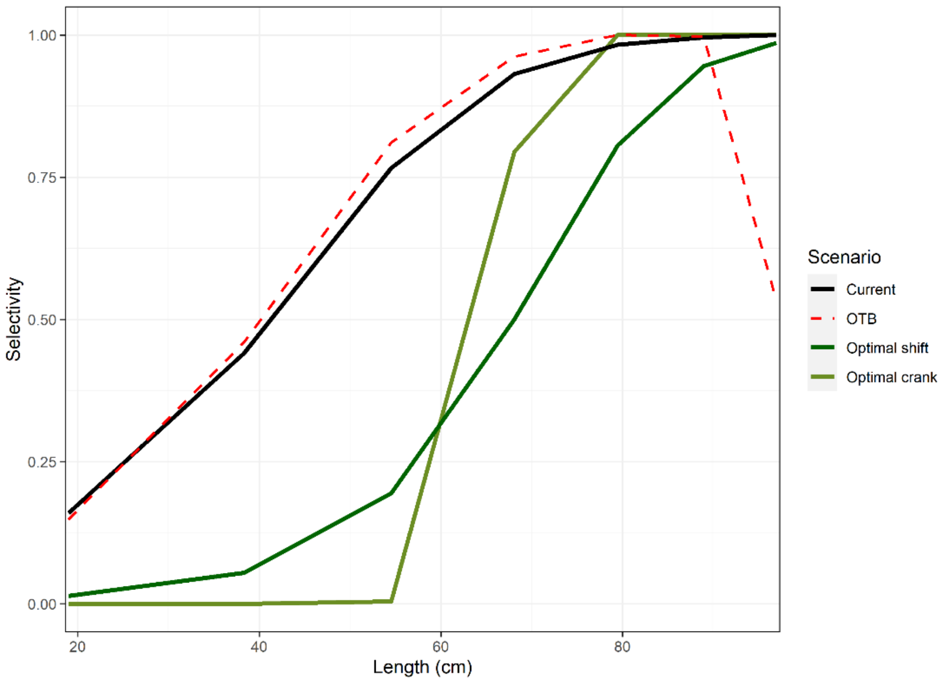


**Figure 4.5.3.3** Cod in Division 6.a (West of Scotland) (cod.27.6a). Fitted 'Current' and 'Optimal' (shifted and cranked) selectivity by length and fitted selectivity for the OTB fleet segment.

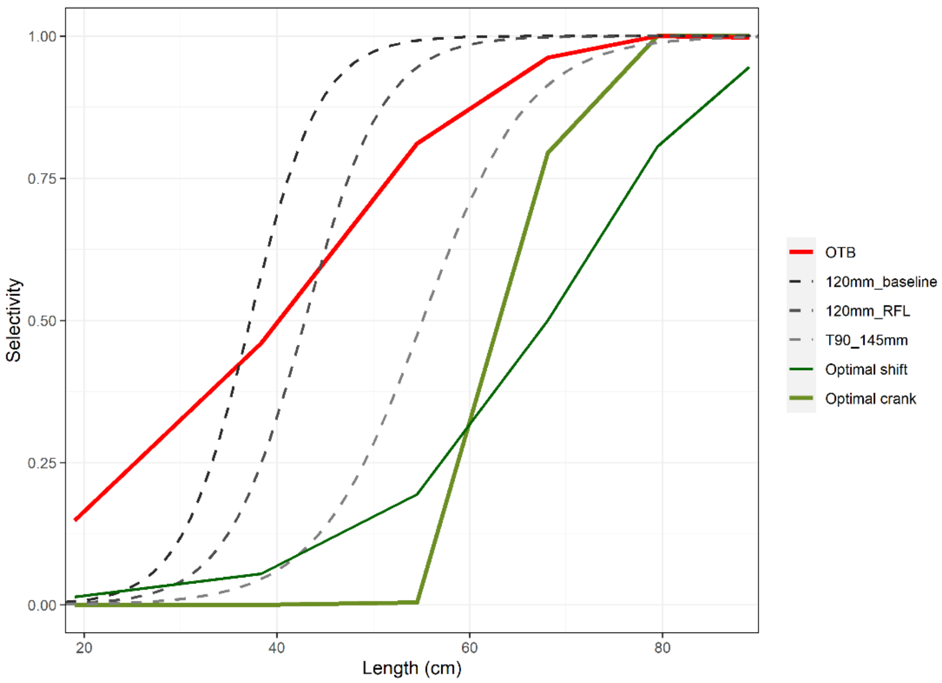


**Figure 4.5.3.4** Cod in Division 6.a (West of Scotland) (cod.27.6a). Fitted 'Optimal' selectivity by length ('Optimal shift' and 'Optimal crank'), fitted selectivity by the OTB fleet segment ('OTB'), gear selectivity curves for the baseline 120mm ('120mm_baseline'), 120mm in a trawl with 1m raised fishing line ('120_RFL') and a more selective alternative: 145mm T90 codend ('T90_145mm').

The gear selectivity parameters of the baseline codend ($L_g50$ = 39.4 cm, $SR_g$ = 8.4 cm; Annex 1) was derived from Madsen and Ferro (2003), and the parameters of the 120mm codend with 1m raised fishing line ($L_g50$ = 42 cm, $SR_g$ = 9 cm; Annex 1) is from STECF PLEN 20-01. Like for the North Sea cod case study, there is a lack of studies of trawl/codend designs for the stock with selectivity parameters closer to the optimal size for the West of Scotland cod (66–68 cm; Table 4.2.1.1). Therefore, a more selective codend from a gear trial in adjacent waters was used in the analysis: 145mm T90 codend (T90_145mm) with $L_g50$ = 55.1 cm, $SR_g$ = 12.1 cm). These results stem from gear experiments in the Barents Sea by Brinkhof *et al*. (2022).

Selectivity analysis under varying F, confirms that lowering F would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.5.3.5). When comparing current selectivity with the gear selectivity of the improved codend, it can be inferred that under current $F_{apical}$ the stock would come close to the highest equilibrium yields with the 145mm T90 codend (Fig. 4.5.3.5). Close-to-optimal yields (90% of maximum) would be extracted by shifting L50 to ca. 50 cm, while more than halving the $F_{apical}$ compared to current (Fig. 4.5.3.5). However, there is the caveat of isopleths and current selectivity referring to population selectivity, which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

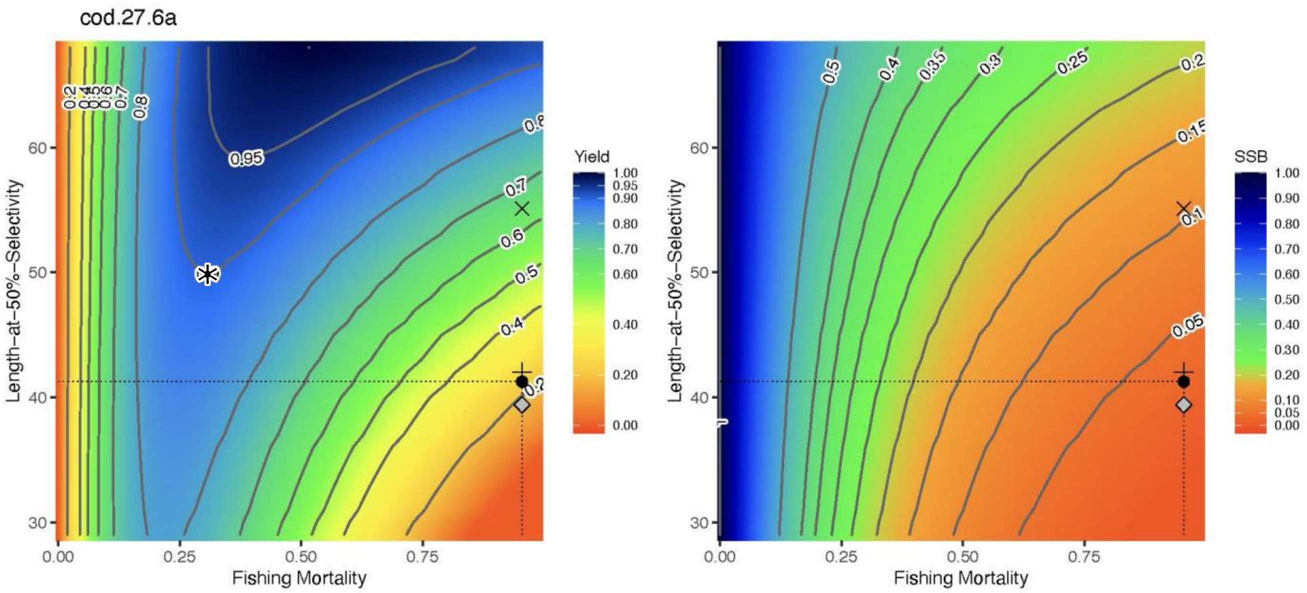


**Figure 4.5.3.5** Isopleths by length for West of Scotland cod (cod.27.6a). Equilibrium yield (left) and SSB (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the L50 of the 120 mm baseline codend (◇), the L50 of 120 mm with 1 m raised fishing line (+) and for a more selective codend alternative: 145 mm T90 (x). and the combination of lowest L50 and $F_{apical}$ producing an equilibrium MSY at 90% of the maximum (*).

### 4.5.4 COD (GADUS MORHUA) IN DIVISIONS 7.E–K (WESTERN ENGLISH CHANNEL AND SOUTHERN CELTIC SEAS) (COD.27.7E-K)

Celtic Sea cod is mainly exploited by otter trawlers, seine nets and beam trawlers. Cod is mainly caught in area 27.7.g, followed by areas 27.7.h, 27.7.e and 27.7.j. No landings are reported in 27.7.k and few in 27.7.j2 (ICES, 2021c).

Landings data reported to ICES show that Celtic Sea cod is mainly landed by otter trawlers (71%), seine nets (11%), beam trawls (9%), landings of gillnets and longlines accounting for the smallest fraction (< 9%) (ICES, 2021c). In 2020 this stock was landed by four countries: Ireland (487 tonnes, 53%), France (371 tonnes, 40%), UK (44 tonnes, 5%), and Belgium (18 tonnes, 2%), with other countries landing < 1% (ICES, 2021d).

Due to the rapid growth of cod in this area, discards are mostly composed of one and two-year old fish (ICES, 2021c). Since 2011, quotas were not restrictive, and the discard rate has been stable around 10– 15%. However, following the recent TAC reductions, TAC is now restrictive for most countries. The discards estimate for 2020 is 231 t, which corresponds to a discards rate of 20%, i.e. around the average of recent years (ICES, 2021d). Fleets discarding cod are otter trawlers (63%), seine nets (10%) and beam trawls (21%). Discards from gillnets and longlines account for the smallest fraction (< 6%) (ICES, 2021d).

Celtic Sea cod is currently assessed using SAM which is a state-space stock assessment model. Fishing pressure on the stock is above $F_{MSY}$, $F_{pa}$, and $F_{lim}$; spawning-stock size is below $MSYB_{trigger}$, $B_{pa}$, and $B_{lim}$ (ICES, 2021d). Mixed-fisheries issues could be responsible for maintaining F at high level, as fishing opportunities of other gadoids are higher. In this context, cod is no longer a target species but can be considered as bycatch in the fleet targeting haddock, whiting and Nephrops (ICES, 2021c).

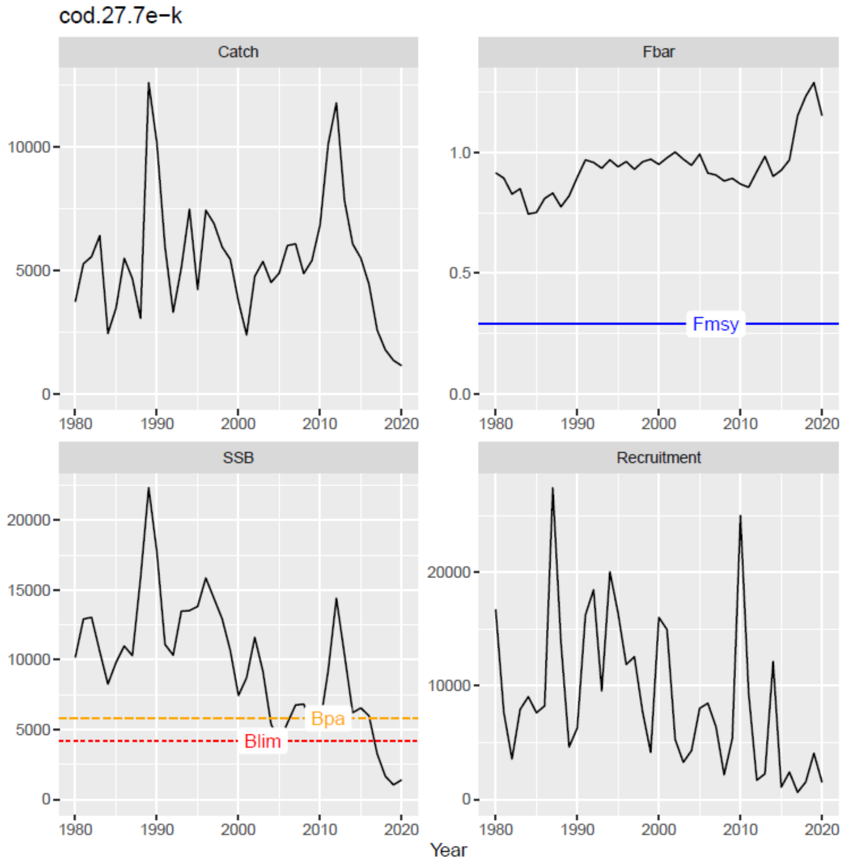


**Figure 4.5.4.1** Cod in divisions 7.e–k (western English Channel and southern Celtic Seas) (cod.27.7e-k). Summary of the stock assessment (ICES, 2021d).

The selectivity analysis indicates that this stock may produce the highest equilibrium yields under current F by shifting A50 by 3.5 y or L50 by 54.7 cm, in which case higher protection of juveniles would be also ensured (Fig. 4.5.4.2; Table 4.2.1.1 and Table 4.3.1).

Partial selectivity by fleet was not available for this stock, so some examples of gear selectivity of relevant trawl codends is also plotted in Fig. 4.5.4.2. Gear selectivity parameters corresponding to the current baseline codend mesh size ('100mm_baseline'; $L_g50$ = 32.7 cm, $SR_g$ = 7.0 cm) were derived from Madsen and Ferro (2003) (Annex 1). The other three gears plotted in Fig 4.5.4.2 are part of the remedial measures for the Celtic Sea cod (see section 4.4.2.1). These gears are 100mm T90 ($L_g50$ = 39 cm, $SR_g$ = 7.4 cm), 120mm ($L_g50$ = 42 cm, $SR_g$ = 9 cm) and 110mm with 120mm square mesh panel ($L_g50$ = 44 cm, $SR_g$ = 9.2 cm), all mounted in trawls with a 1m raised fishing line. The parameters for the three latter gears were all derived from STECF PLEN 20-01. Like for the other cod stocks, studies of trawl alternatives with size selectivity closer to the optimum size is lacking also for the Celtic Sea cod stock. Due to that Fig. 4.5.4.2 already shows four examples of gear selectivity, no codend alternative with a much higher size selectivity is shown here. Examples of such more selective trawl codends can be found in the other cod case studies and in Annex 1.

Current selectivity is slightly higher than the selectivity of the baseline gear, and around the selectivity of the three codend alternatives introduced as part of the remedial measures (i.e. an $L_g50$ slightly above 40 cm, Fig 4.5.4.3), which is however around 55 cm lower than the optimal size (Fig 4.5.4.2).

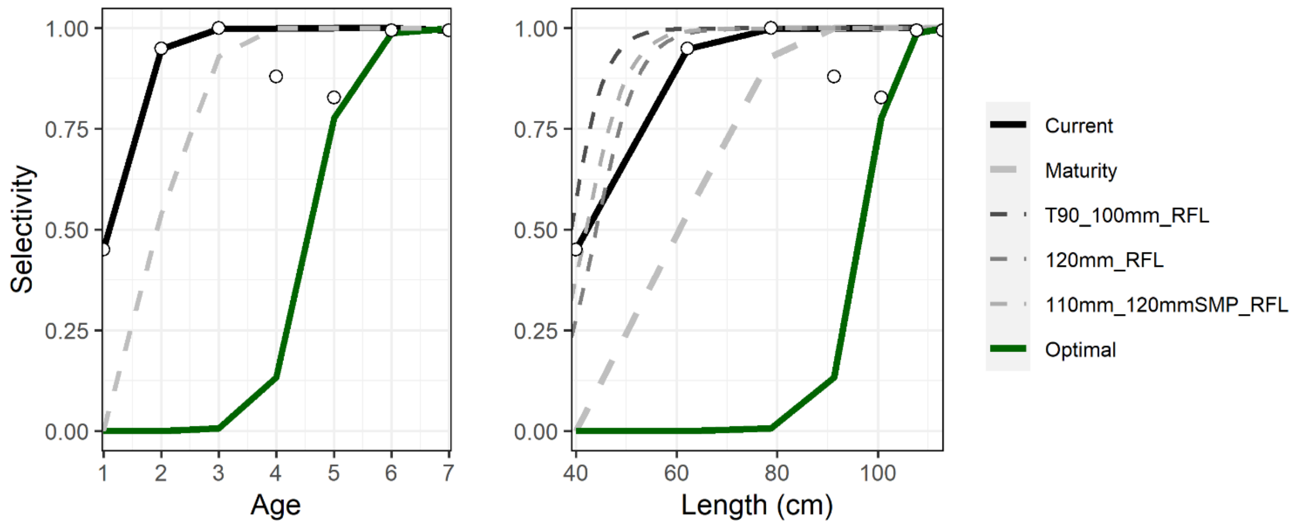


**Figure 4.5.4.2** Cod in divisions 7.e–k (western English Channel and southern Celtic Seas) (cod.27.7e-k). Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity. Also shown on the right are gear selectivity curves for the baseline 100mm ('100mm_baseline') and for three codend alternatives with 1m raised fishing line (RFL): A 100mm T90 alternative ('T90_100mm_RFL'), a 120mm diamond mesh alternative ('120mm_RFL') and a 110mm codend with 120 mm square mesh panel ('110mm_120mmSMP_RFL').

Selectivity analysis under varying F, confirms that lowering F would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.5.4.3). When comparing current selectivity with the gear selectivity of the baseline and improved trawl/codends, it can be inferred that under current $F_{apical}$ the stock would still lie far from the highest equilibrium yields with either of the gears examined (Fig. 4.5.4.3). Close-to-optimal yields (90% of maximum) would be extracted by shifting L50 to ca. 80 cm, while fishing at a $F_{apical}$ similar or lower than the current (Fig. 4.5.4.3). However, there is the caveat of isopleths and current selectivity referring to population selectivity which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

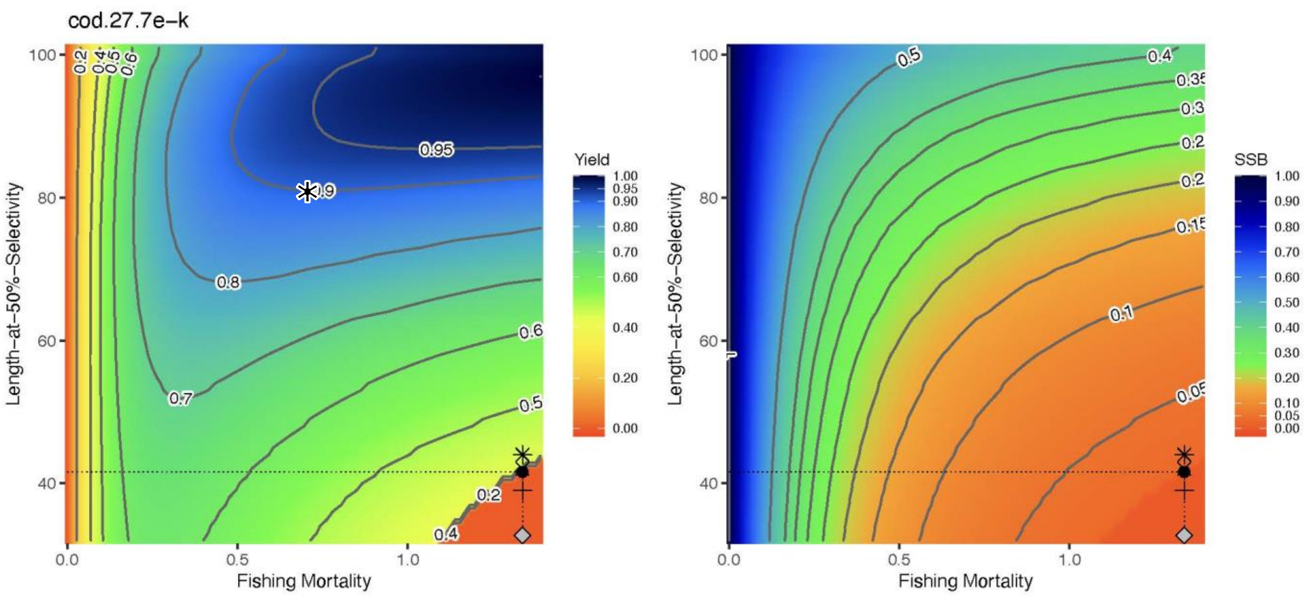


**Figure 4.5.4.3** Isopleths by length for cod in divisions 7.e–k (western English Channel and southern Celtic Seas) (cod.27.7e-k). Equilibrium yield (left) and SSB (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$s of the 120mm baseline codend (◇); the T90_100mm_RFL (+) alternative; the 120mm_RFL alternative (x) the 110mm_120mmSMP_RFL alternative (*), and the combination of L50 and $F_{apical}$ producing an equilibrium MSY at 90% of the maximum (*).

### 4.5.5 WHITING (MERLANGIUS MERLANGUS) IN DIVISION 7.A (IRISH SEA) (WHG.27.7A)

Landings data reported to ICES show that Irish Sea whiting is mainly landed by otter trawlers targeting demersal finfish (94.5%), some from otter trawlers targeting Nephrops (0.3%), while landings from other gears account for a minor fraction (5.2%) (ICES, 2021e). In 2020 this stock was landed mainly by three countries: Ireland (56 tonnes, 54%), UK (42 tonnes, 41%), and Belgium (5 tonnes, 5%), with other countries landing < 1% (ICES, 2021e).

As reported by ICES (2021f), the majority of whiting catches in the Irish Sea have not been landed but discarded in the last couple of decades. These discards are mostly associated with the Nephrops directed fleets of Ireland and the UK. Despite recent increased sampling levels, discard information remains very imprecise. This has contributed to the highly fluctuating fishing pressure estimates in recent years. The main fleets landing whiting are finfish directed fleets from Ireland and Northern Ireland. In recent years, landings were submitted for the PTM_SPF metier. These are likely from trips targeting herring where whiting was a bycatch. Total discard estimate was 1030 t in 2020, resulting in a discards rate of 92% (ICES, 2021e). Otter trawlers targeting Nephrops account for 98% of discards, therefore the effort in the Nephops fishery is the main driver of discarding for Irish Sea whiting.

Most of the whiting caught are discards in the Nephrops fishery and are below the minimum conservation reference size (MCRS). The introduction of further highly selective gears to reduce finfish catch and discards in the Nephrops fishery appears to have reduced whiting catches in the last three years. Discard rate however remain high relative to the total catches (ICES, 2021e)

The Irish Sea whiting is currently assessed using ASAP (Age-Structured Assessment Programme; NOAA toolbox) (ICES, 2021f). Fishing pressure on the stock is above $F_{MSY}$, $F_{pa}$, and $F_{lim}$; spawning-stock size is below $MSYB_{trigger}$, $B_{pa}$, and $B_{lim}$ (ICES, 2021e). Mixed-fisheries issues are responsible for maintaining F at high level. In this context, whiting in the Irish sea is not considered a target species but a bycatch in the fleet targeting Nephrops (ICES, 2021e).

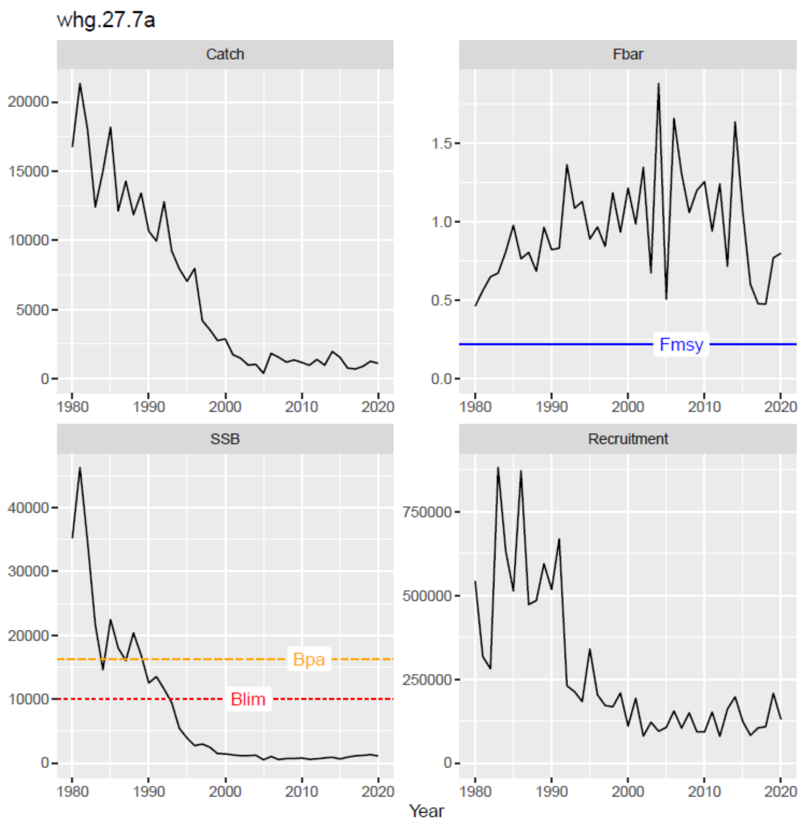


**Figure 4.5.5.1** Whiting in Division 7.a (Irish Sea) (whg.27.7a). Summary of the stock assessment (ICES, 2021f)

The selectivity analysis indicates that this stock may produce the highest equilibrium yields under current F by cranking A50 by 0.7 y or L50 by 7.6 cm. Almost as high potential equilibrium yield with similar protection of juveniles can be achieved by shifting A50 by 1.2 y or L50 by 12 cm (Fig. 4.5.5.2; Table 4.2.1.1 and Table 4.3.1).

Partial selectivity by fleet was not available for this stock, so some examples of gear selectivity estimates of relevant trawl codends is also plotted in Fig. 4.5.5.2. Gear selectivity parameters corresponding to the current baseline codend mesh size ('120mm_baseline'; $L_g50$ = 38.7 cm, $SR_g$ = 14.5 cm) and an 80mm codend with 120mm square mesh panel, the baseline mesh gear in the Nephrops fishery, i.e. the fishery that contributes to the majority of the discards ('80_120SMP'; $L_g50$ = 32.9 cm, $SR_g$ = 9.4 cm), are shown. Additional Nephrops measures are in place under the TMR but the main gear used in the Nephrops fishery, an 80 mm codend with 300 mm square mesh panel, was outside the parameters of the model of Madsen & Ferro (2003). Selectivity parameters for both gears were derived from Madsen & Ferro (2003) (Annex 1).

Current estimated population selectivity (10.6 cm) is lower than the optimal size (18.2-22.6 cm) and, somewhat surprisingly, much lower than the gear selectivity of both the 120mm_baseline codend (38.7 cm) and the 80_120SMP codend (32.9 cm) (Fig. 4.5.5.2, 4.5.5.3). Whiting in 7a is smaller at age than in other areas (ICES, 2023), resulting in many small sized fish interacting with the commercial fleet which is very much a bycatch fishery as the majority of the stock is taken by discards in the Nephrops fishery. The failure of selective gears to improve population selectivity of Irish Sea whiting may be due to the relatively small size of whiting in the Irish Sea leading to reduced swimming ability and fatigue or different behaviour, i.e. staying low rather than exiting escape panels like larger whiting. It should be also noted that the gear selectivity parameters of the 80_120SMP codend coming from Madsen & Ferro (2003) could be outdated; current population selectivity estimates refer to 2018-2020, biological parameters used to estimate optimal selectivity come from the 2021 assessment (ICES, 2021e) and von Bertalanffy parameter estimates used for the age-to-length conversion refer to 2008-2021 (Table 4.1.1.1).

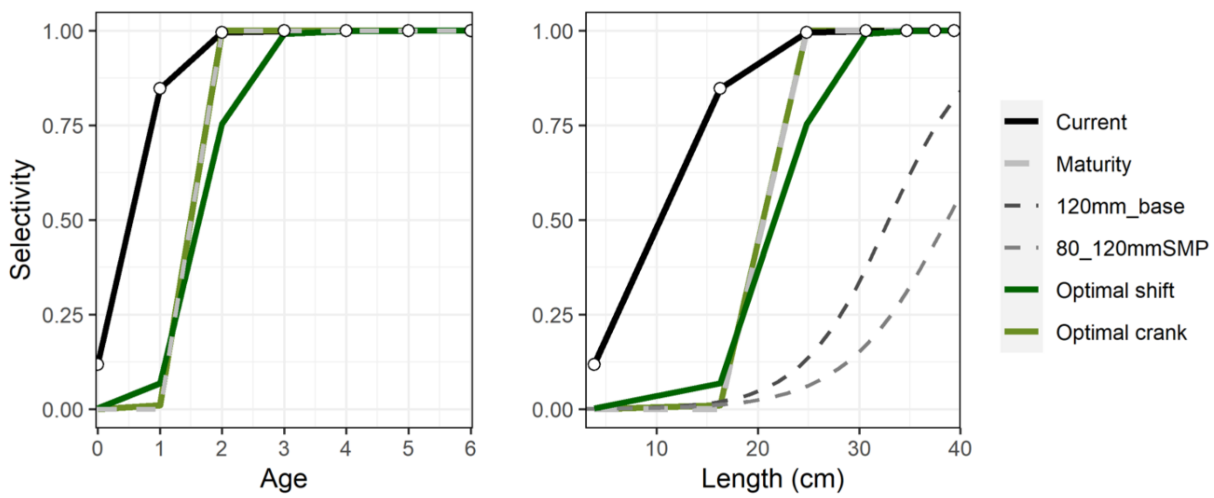


**Figure 4.5.5.2** Whiting in Division 7.a (Irish Sea) (whg.27.7a). Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity. Also shown on the right are gear selectivity curves for the baseline 120mm ('120mm_baseline') and for the 80mm codend with 120mm square mesh panel that is the main gear in the Nephrops directed fishery ('80mm_120mmSMP').

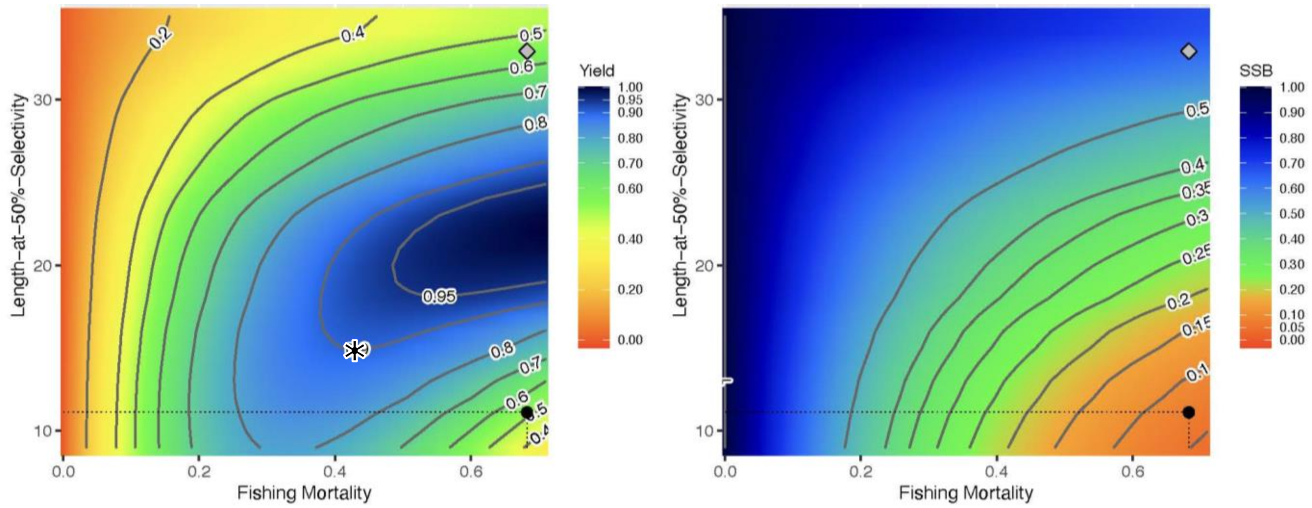


**Figure 4.5.5.3** Isopleths by length for whiting in Division 7.a (Irish Sea) (whg.27.7a). Equilibrium yield (left) and SSB (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of 80mm codend with 120mm square mesh panel (◇) and the combination of L50 and $F_{apical}$ producing an equilibrium MSY at 90% of the maximum (*).

### 4.5.6 SAITHE (POLLACHIUS VIRENS) IN SUBAREAS 4 AND 6, AND IN DIVISION 3.A (NORTH SEA, ROCKALL AND WEST OF SCOTLAND, SKAGERRAK AND KATTEGAT) (POK.27.3A46)

Saithe in ICES divisions 27.3a, 27.4 and 27.6 is fished commercially by 14 countries, but mainly Norway, Germany, and France (ICES, 2021h). Landings have varied between 63 and 88 thousand tonnes during the last decade. The stock is mainly landed by otter trawlers (84%), gillnets (6%) and other gears (10%) (ICES, 2021h). Discarding is estimated to be around 4% of the catch.

The stock is currently assessed using age-based analytical assessment SAM that uses catches in the model and in the forecast (ICES, 2021h). Fishing pressure on the stock is above $F_{MSY}$ but below $F_{pa}$ and $F_{lim}$; spawning-stock size is below $MSYB_{trigger}$ and between $B_{pa}$ and $B_{lim}$ (ICES, 2021g).

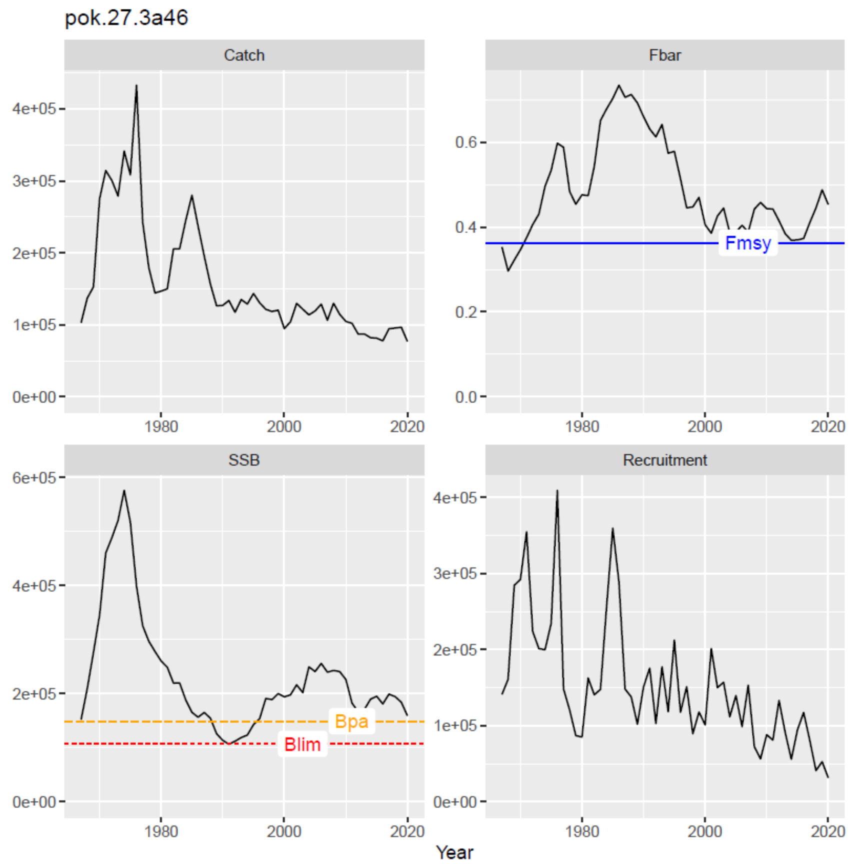


**Figure 4.5.6.1** Saithe in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) (pok.27.3a46). Summary of the stock assessment (ICES, 2021h).

The selectivity analysis indicates that the saithe stock may produce the highest equilibrium yields under current F by shifting A50 by 4.3 y or L50 by 27.2 cm (Fig. 4.5.6.2; Table 4.2.1.1).

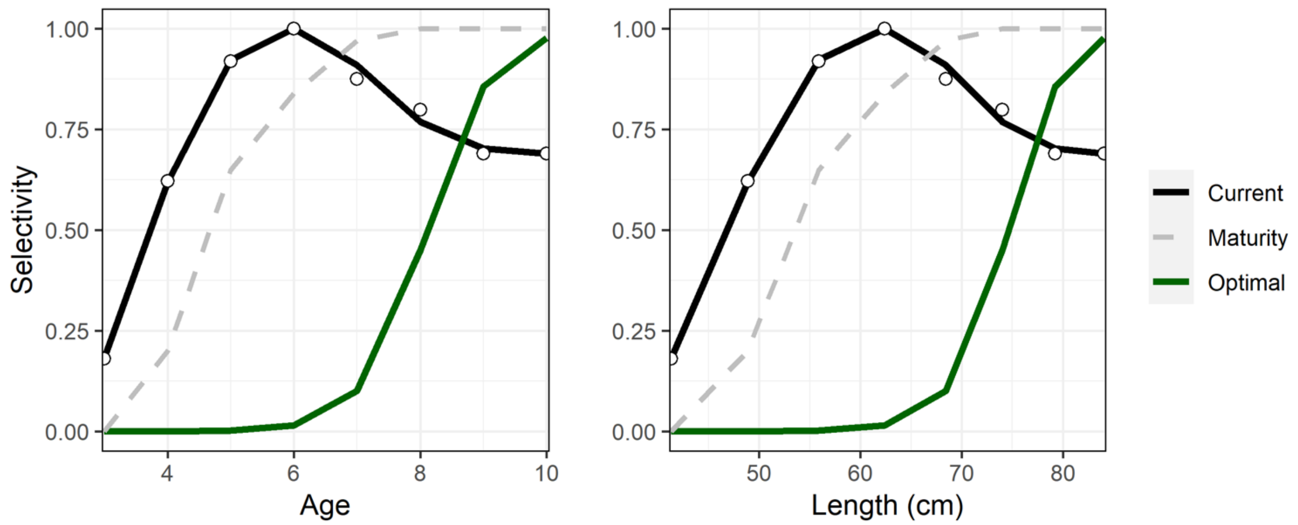


**Figure 4.5.6.2** Saithe in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) (pok.27.3a46). Optimal selectivity scenarios ('shift' scenario) by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity.

OTB largely dominates the current selectivity on the stock, which is indicated by the very similar shapes of the total ('Current') and OTB selectivity curves in Fig. 4.5.6.3. The OTB fleet selects fish at an average size of 46.7 cm (i.e. 27.9 cm smaller than the optimal size). The GNS fleet show an average selectivity close to the optimal size (70.7 cm, i.e. only 3.9 cm below optimum, Fig. 4.5.6.3; Table 4.2.1.2)

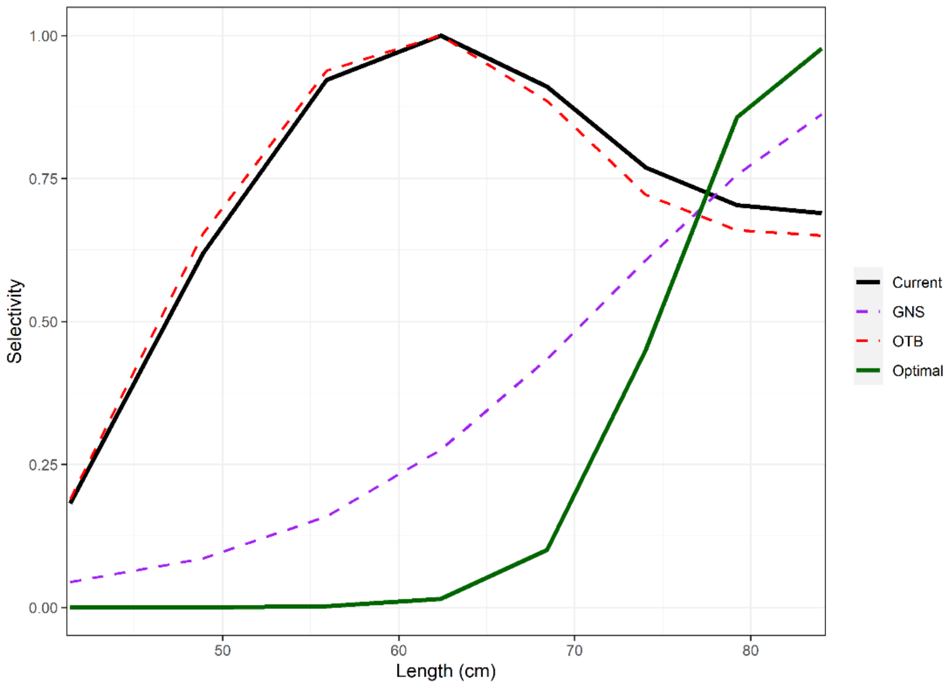


**Figure 4.5.6.3** Saithe in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) (pok.27.3a46). Fitted 'Current' and 'Optimal' (shifted) selectivity by length and fitted selectivity by fleet segment. GNS: Set gillnets; OTB: bottom otter trawls.

Gear selectivity parameters ($L_g50$ = 46.4 cm, $SR_g$ = 9.3 cm), corresponding to the current baseline codend mesh size (120mm diamond) were derived from gear trials for the stock reported by Graham *et al.* (2004) (Annex 1). Due to the lack of studies of trawl/codend designs from the area with selectivity parameters closer to the optimal size (74.6 cm), a more selective codend alternative was used in the analysis (145mm T90 codend, with a $L_g50$ = 56.2 cm, $SR_g$ = 8.5 cm). The selectivity of the T90_145 was estimated from trials in the Barents Sea by Brinkhof *et al.* (2022).

The T90_145 gear modification came closer to the optimal selectivity than the baseline 120mm diamond mesh codend and the current selectivity of the OTB fleet segment, but would still be catching fish on average 18 cm before their optimal size (Fig. 4.5.1.4).

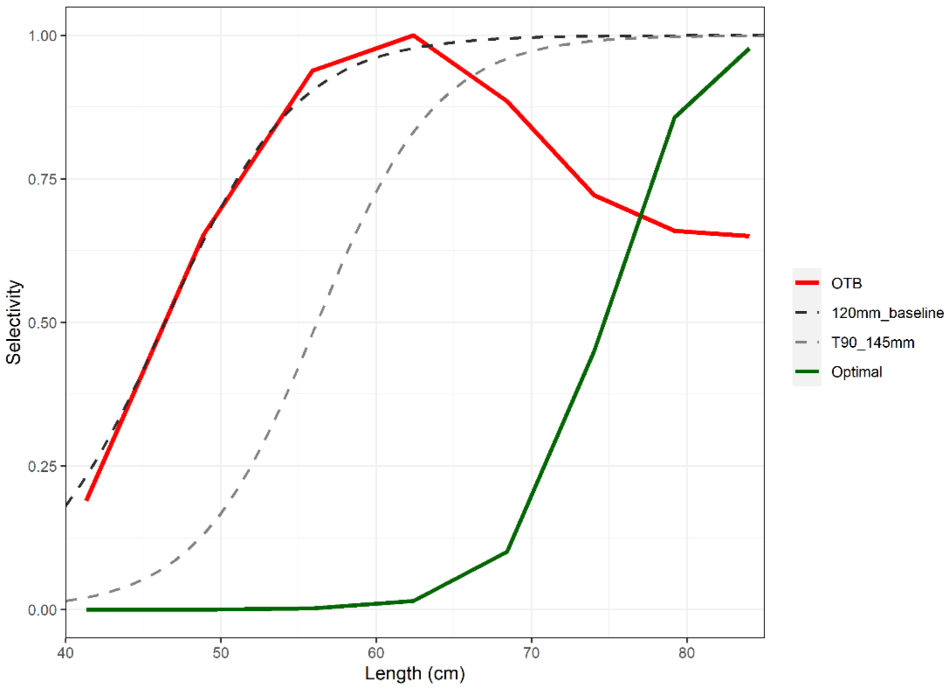


**Figure 4.5.6.4** Saithe in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) (pok.27.3a46). Fitted 'Optimal' (shifted) selectivity by length, fitted selectivity by the OTB fleet segment ('OTB'), gear selectivity curves for the baseline 120mm ('120mm_baseline') and a more selective alternative 145mm T90 codend ('T90_145mm').

Selectivity analysis under varying F, confirms that lowering F somewhat would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.5.6.5). The current selectivity and the gear selectivity of the baseline is very similar which can likely be explained by that the fishery on the stock is dominated by 120mm trawls (i.e. baseline trawls). The more selective alternative codend (145mm T90) would improve equilibrium yield (to around 80% of maximum) at current F. Close-to-optimal yields (90% of maximum) would be achieved by shifting L50 to ca. 65 cm, while fishing at a $F_{apical}$ around 0.5 (Fig. 4.5.6.5). However, there is the caveat of isopleths and current selectivity referring to population selectivity which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

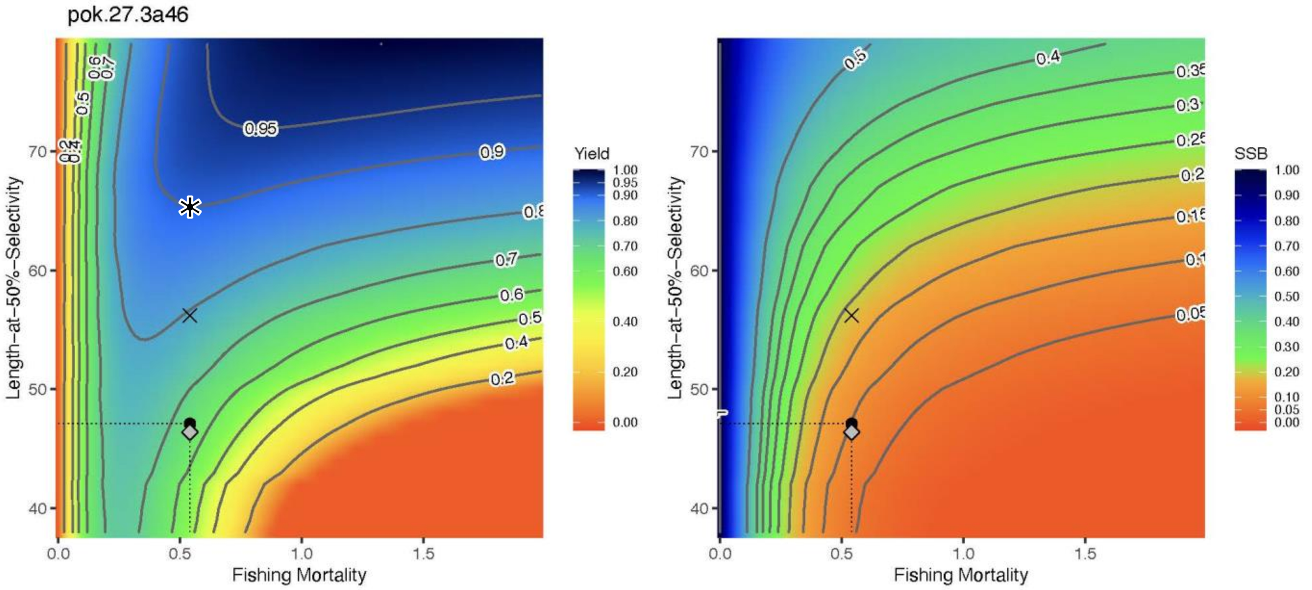


**Figure 4.5.6.5** Isopleths by length for saithe in subareas 4 and 6, and in Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat) (pok.27.3a46). Equilibrium yield (left) and SSB (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 120mm codend baseline (◇) and one more selective codend alternative: 145mm T90 codend (x), and the combination of L50 and $F_{apical}$ producing an equilibrium MSY at 90% of the maximum (*).

## 4.6 Case studies of Mediterranean priority stocks (ToR 1 & ToR 2)

Below, five case studies of the priority stocks from the Mediterranean Sea are presented. Each case study looks at an individual stock, detailing fleet characteristics, landings and discards, stock status, selectivity studies and the outcomes of the selectivity scenarios in terms of age and length. As in Chapter 4.2.1, 'current' F and selectivity refer to the average of the last three years available from the assessments (2017-2019). Note that in the Mediterranean hake stocks the geometric mean of recruitment was used in all projections to estimate optimal selectivity. Therefore, for Mediterranean hake stocks equilibrium yield-per-recruit (YPR) and SSB-per-recruit (SBR) have been estimated rather than equilibrium yield and SSB.

### 4.6.1 HAKE (MERLUCCIUS MERLUCCIUS) IN GSAS 1, 5, 6 AND 7 (NORTHERN ALBORAN SEA, BALEARIC ISLANDS, NORTHERN SPAIN, GULF OF LIONS) (HKE.01-05-06-07)

This stock is mainly exploited by trawlers operating on the continental shelf and slope as part of a mixed fisheries, and polyvalent small-scale fisheries using long lines, gill nets and trammel nets. In GSA 5, hake exploitation is attributed exclusively to bottom trawlers, as catches from gillnets and longlines are negligible, while total landings fluctuate considerably along the time series. In the Gulf of Lions (GSA 7), hake is exploited by two countries' fleets, namely French trawlers, French gillnetters, Spanish trawlers and Spanish longliners.

DCF data made available to EWG 20-09 (STECF, 2020b) illustrate that in GSAs 1, 5, 6 and 7, most of the hake landings come from otter trawls. The combined contribution of set nets and longlines to the total value of landing is approximately 8% (roughly 4% for each of the two fleets). Discards data, also available through the DCF, show that the highest discard rates were observed at the bottom trawl fishery; for the other gears the discard rate is negligible.

The stock assessment carried out by EWG 20-09 suggested that hake in GSAs 1, 5, 6 and 7 has been overexploited for the entire time series (Fig. 4.6.1.1). Fishing mortality in 2019 ($F_{2019}$ = 1.58) was four times higher compared to the reference point $F_{0.1}$, which is the proxy of $F_{MSY}$ ($F_{0.1}$= 0.388). SSB has been increasing in the last 3 years of the assessment (Fig. 4.6.1.1).

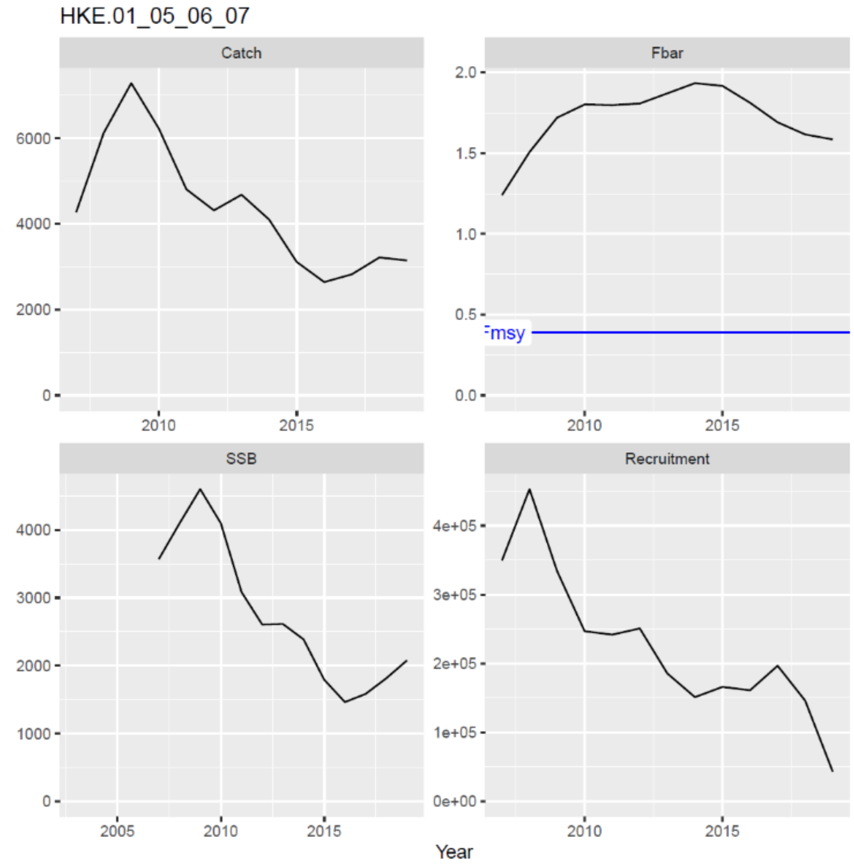


**Figure 4.6.1.1** HKE.01-05-06-07. Summary of the stock assessment (STECF, 2020b).

The selectivity analysis suggested that this stock may produce the highest equilibrium yields under current F by shifting A50 by 3.4 y or L50 by 45 cm (Fig. 4.6.1.2; Table 4.1.2.3).

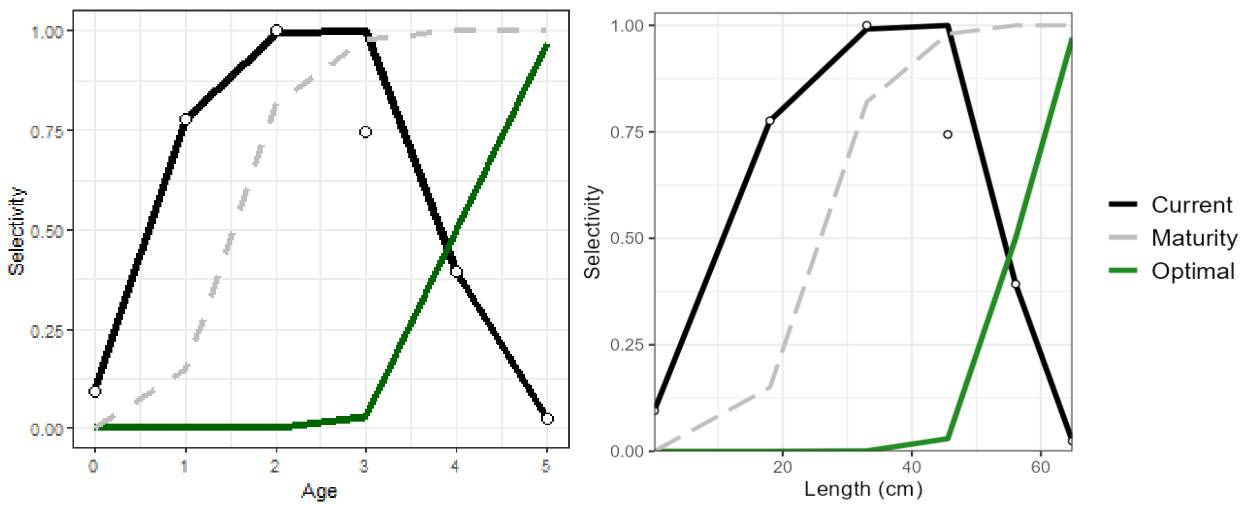


**Figure 4.6.1.2** HKE.01-05-06-07. Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity.

Of the fleet segments exploiting the stock, OTB exhibits the worst selectivity pattern, catching fish on average 48.6 cm smaller than the optimal size (Fig. 4.6.1.3; Table 4.1.2.4). By contrast, LLS is the fleet segment operating closest to the optimal selectivity, catching fish on average just 11.7 cm under their optimal size.

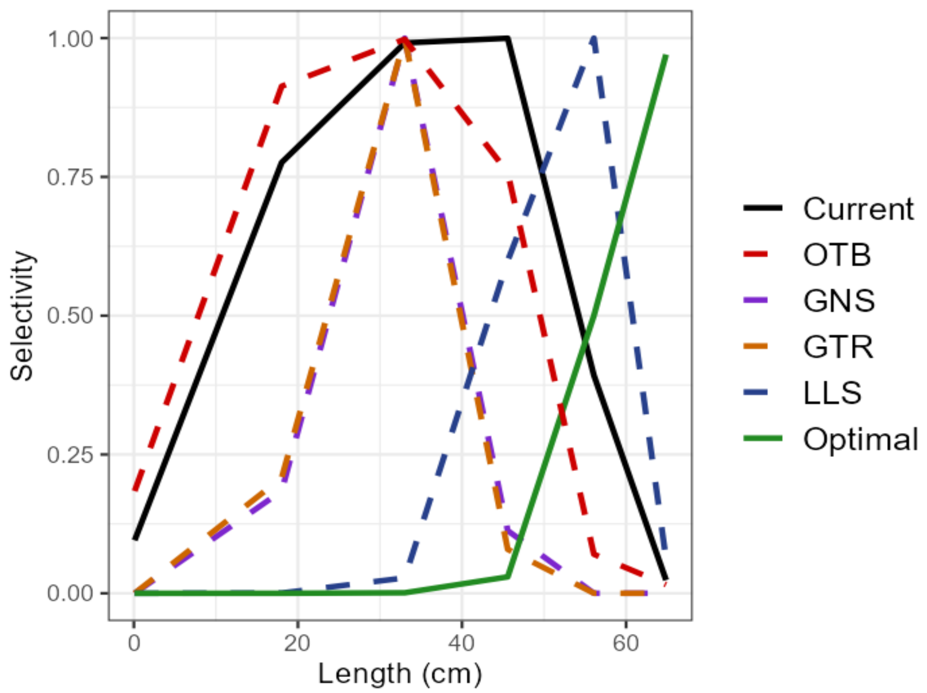


**Figure 4.6.1.3** HKE.01-05-06-07. Fitted 'Current' (2019) and 'Optimal' (shifted) selectivity by length and fitted selectivity by fleet segment. GNS: Set gillnets; GTR: Trammel nets; LLS: Set longlines; OTB: bottom otter trawls.

Gear selectivity parameters ($L_g50$ = 17.64 cm, $SR_g$ = 7.4 cm), corresponding to the current baseline codend mesh size (40mm square mesh – 40SM) were derived from gear trials in GSA 6 performed in the framework of the IMPLEMED project (Sbrana, 2021) (Annex 1). A more selective set of gear selectivity parameters ($L_g50$ = 22.19 cm, $SR_g$ = 5.03 cm) corresponding to a square mesh size of 50mm (50SM) coming from the same project was also considered. No gear selectivity parameters were found in the literature for non-OTB gears in the area.

The 50SM gear modification came closer to the optimal selectivity, than both the default 40SM gear and the current selectivity of the OTB fleet segment, but would be still catching fish on average 33 cm before their optimal size (Fig. 4.6.1.4).

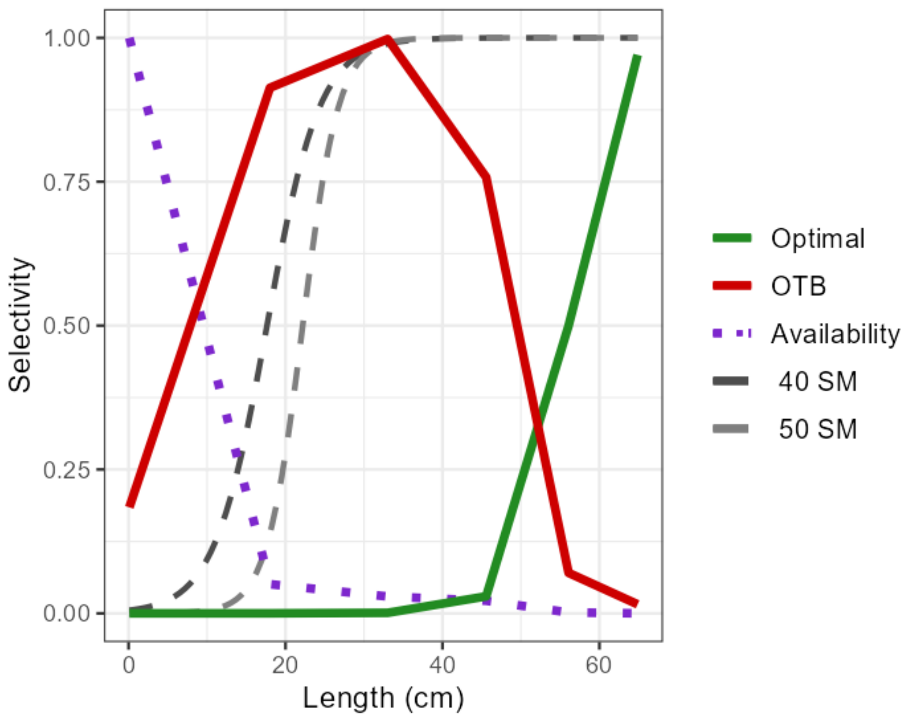


**Figure 4.6.1.4** HKE.01-05-06-07. Fitted 'Optimal' (shifted) selectivity by length, fitted selectivity by the OTB fleet segment ('OTB'), gear selectivity curves for the baseline 40 mm square mesh trawler ('40 SM') and the 50 mm square mesh codend trawler ('50 SM') and presumed relative 'Availability' of different sizes (inferred as the ratio 'OTB'/'Gear 40 SM' scaled to 1), assuming total and unbiased implementation of the 40 SM by the OTB fleet segment.

It is notable that the baseline 40SM gear exhibits better gear selectivity for smaller fish than the partial population selectivity of the OTB fleet segment, which is based on partial F-at-age (Fig. 4.6.1.4). This discrepancy could be due to technical tweaks (e.g. using a shorter codend – see Chapter 4.4.5) and/or operational choices by the fishers that would result in different gear selectivity of the 40SM than that observed in the gear trials. For example, selectivity trials are usually performed under experimental conditions (e.g., shorter tow duration, standard towing speed at 3 knots, etc.), while commercial fishing is characterized by long tow durations (up to 3-4 hours on the shelf or at the shelf break). This could determine the filling of the codend, reducing the selectivity of the net. Another explanation could be that there are other gears included within the OTB fleet segment selecting more juvenile hake than the 40SM. Assuming that the OTB fleet segment is dominated by the 40SM gear and that the 40SM gear selectivity in the field is similar to the one observed in gear trials, another explanation for the discrepancy between the 40SM gear selectivity and the partial population selectivity of OTB could be the differential availability of different fish sizes. Based on equation (1) (Chapter 2.1), assuming that the non-avoidance probability has been adequately captured by the gear trials and is reflected in gear selectivity, it can be inferred that availability to the baseline trawling gear is much higher for smaller fish than bigger ones compared to the gear trials (Fig. 4.6.1.4). This could be related to the place/time that trawling takes place and could hint towards spatiotemporal measures needed to improve selectivity, which could be easier to implement than securing gear specifications compliance on board. For example, commercial trawling on the shelf and shelf break is potentially performed close to hake nursery areas when targeting deep-water rose shrimp, thus increasing the availability of small hakes to the trawl net. Additionally, a FRA has been established in GSA 7 to protect big hakes (spawners) (REC.CM-GFCM/33/2009/1), therefore decreasing the availability of big fish to OTB gears.

Selectivity analysis under varying F, confirms that lowering F would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.6.1.5). When comparing current selectivity with the gear selectivity of the baseline and improved trawler, it can be inferred that under current $F_{apical}$ the stock would still lie far from the highest equilibrium yields with either of the gears examined (Fig. 4.6.1.5). However, there is the caveat of isopleths and current selectivity referring to population selectivity, which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1). Close-to-optimal yieds (90% of maximum) would be extracted by shifting L50 to ca. 48 cm, while fishing at a $F_{apical}$ ca. three times lower than current (Fig. 4.6.1.5).

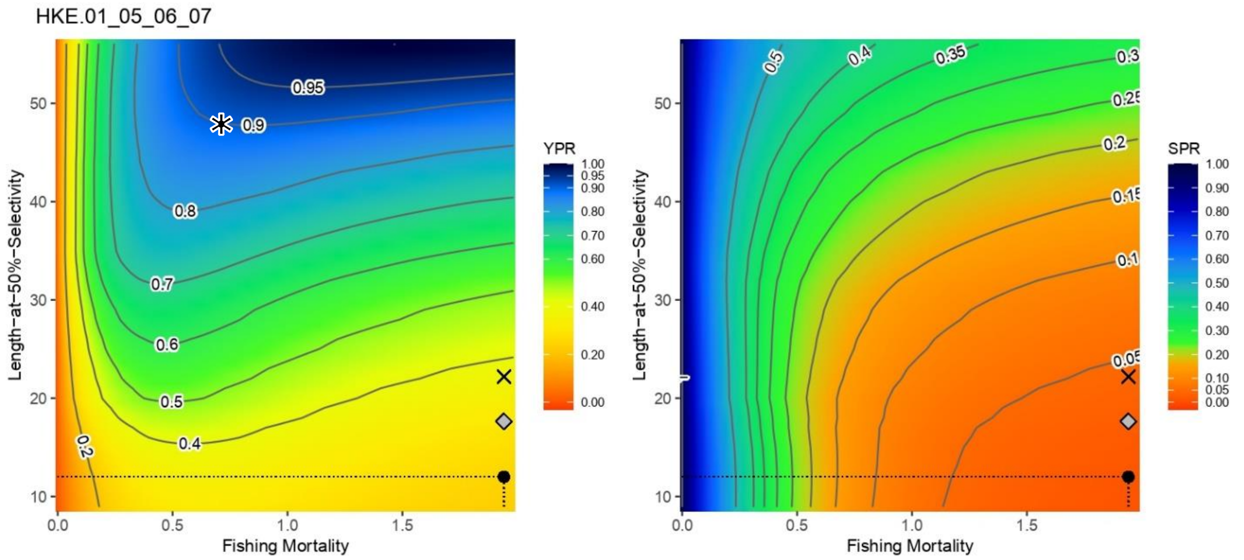


**Figure 4.6.1.5** Isopleths by length for HKE.01-05-06-07. Equilibrium yield-per-recruit (left) and SSB-per recruit (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 40mm square mesh baseline trawler (◇), the $L_g50$ of the 50mm square mesh trawler (x) and the combination of the lowest L50 and $F_{apical}$ producing an equilibrium yield at 90% of the maximum (*).

## 4.6.2 HAKE (MERLUCCIUS MERLUCCIUS) IN GSAS 8, 9, 10 AND 11 (CORSICA, LIGURIAN SEA, TYRRHENIAN SEA, SARDINIA) (HKE.08-09-10-11)

European hake represents the most important target species in this region in terms of landings, income, vessels involved and socioeconomic synergies. In GSAs 9 and 10, it is exploited mainly by trawlers on the shelf and slope as part of a mixed fishery, but some considerable quantities are also landed by small-scale fisheries using set nets (gillnets and trammel nets) and bottom longlines. In Sardinia (GSA 11), although hake is not actively targeted by the fleets operating in the area, it is considered one of the most important species in terms of biomass landed coming as a bycatch in the above mentioned gears. In Corsica (GSA 8), few small bottom trawlers are active producing negligible hake bycath quantities together with some even smaller quantities coming from small-scale fisheries. It should be noted that due to the bottom bathymetry trawlers can only operate at the eastern part of Corsica.

Based on EWG 20-09 (STECF, 2020b), in GSAs 9, 10 and 11, the majority of the hake landings come from otter trawls. In GSAs 9 and 10, set nets contribute around 35% of the landings, while in GSA 10 longlines contribute around 17% of the landings. In GSA 11, hake landings come solely from bottom trawl fishery. Discard rates vary greatly among GSAs, although in GSA 9, 10 and 11 for some years such data were not available. On average, in GSA 9, discard rate of hake is 18%, in GSA 10 it is around 4% and in GSA 11 it is 32%.

Fishing mortality in 2019, estimated as the average F over age-classes 1-3, was $F_{2019} = 0.57$, which was more than three times higher than $F_{0.1}$ ($F_{0.1} = 0.17$). This indicates that the hake stock in GSAs 8, 9, 10 and 11 is overexploited (Fig. 4.6.2.1).

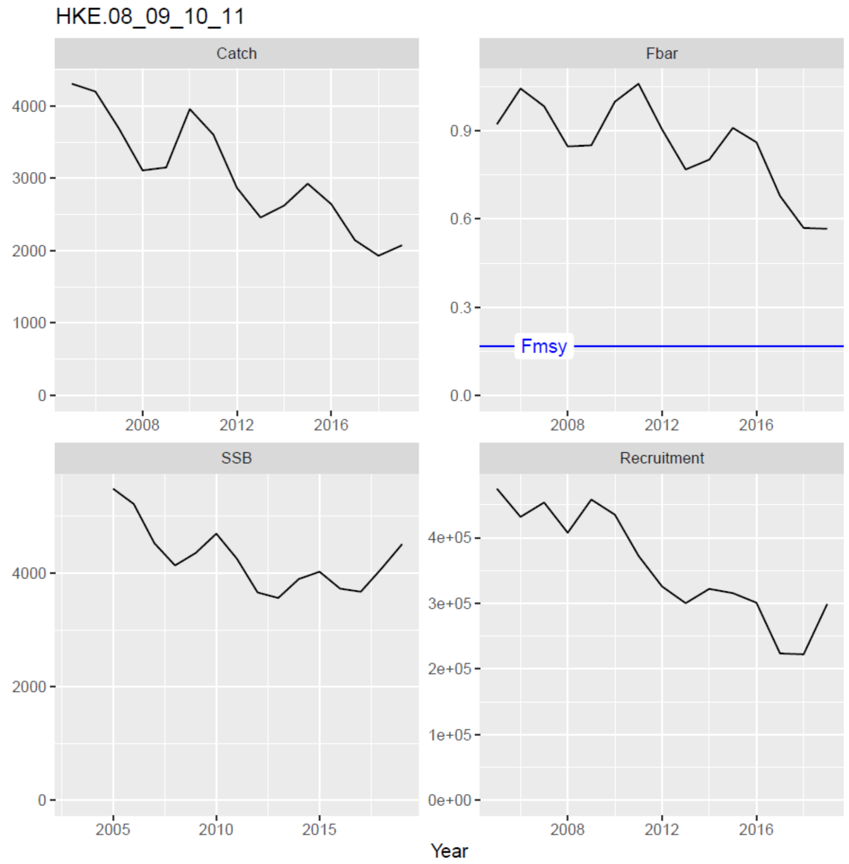


**Figure 4.6.2.1** HKE.08-09-10-11. Summary of the stock assessment (STECF, 2020b).

The selectivity analysis suggested that this stock may produce the highest equilibrium yields under current F by shifting A50 by 5.3 y or L50 by 52.1 cm, in which case high protection of juveniles would be also ensured (Fig. 4.6.2.2; Table 4.1.2.3).

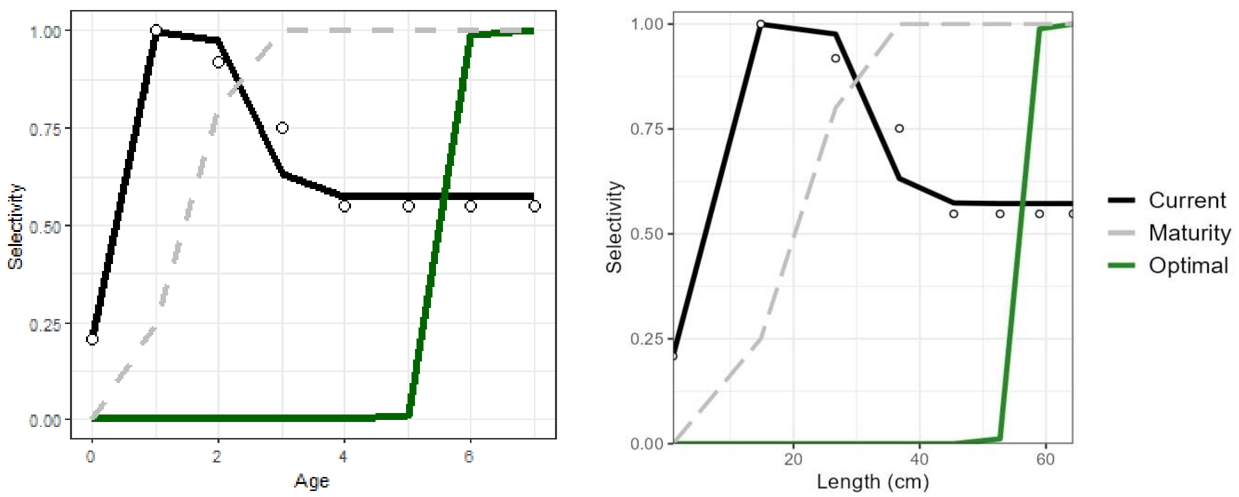


**Figure 4.6.2.2** HKE.08-09-10-11. Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity.

Of the fleet segments exploiting the stock, OTB exhibits the worst selectivity, selecting fish on average 52.9 cm smaller than the optimal size (Fig. 4.6.2.3; Table 4.1.2.4). By contrast, LLS is the fleet segment operating closest to the optimal selectivity, selecting fish on average just 11 cm under their optimal size.

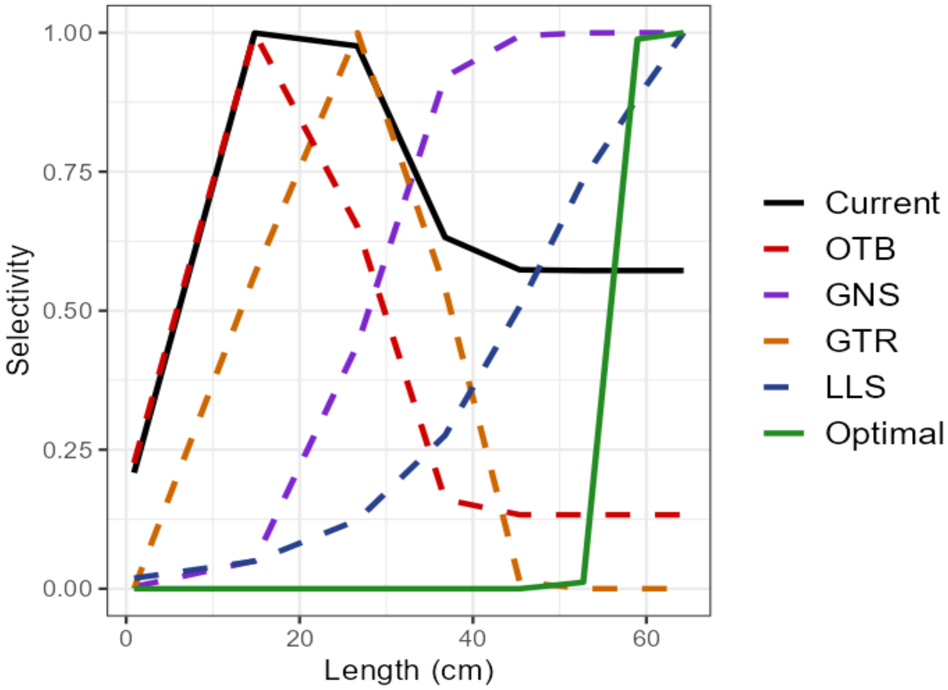


**Figure 4.6.2.3** HKE.08-09-10-11. Fitted 'Current' and 'Optimal' (shifted) selectivity by length and fitted selectivity by fleet segment. GNS: Set gillnets; GTR: Trammel nets; LLS: Set longlines; OTB: bottom otter trawls.

Gear selectivity parameters ($L_g50$ = 17.62 cm, $SR_g$ = 6.35 cm), corresponding to the current baseline codend mesh size (40mm square mesh – 40SM) were derived from gear trials in GSA 9 (Brčić et al. 2018) (Annex 1). Due to the lack of recent selectivity studies in the area on codend meshes higher than 40SM or 50DM, a more selective set of gear selectivity parameters ($L_g50$ = 20.46 cm, $SR_g$ = 8 cm) corresponding to a square mesh size of 55mm (55SM) was obtained from a meta-analysis by Lucchetti *et al.* (2021).

The 55SM gear modification came closer to the optimal selectivity, than both the default 40SM gear and the current selectivity of the OTB fleet segment, but would be still catching fish on average 35.5 cm smaller than their optimal size (Fig. 4.6.2.4). It is notable that, as in the case of HKE.01-05-06-07, the baseline 40SM gear exhibits a lower gear selectivity for smaller fish than the partial population selectivity of the OTB fleet segment (which is based on the partial F-at-age). Possible reasons for this discrepancy are discussed in detail in the previous Chapter 4.6.1. Assuming total and unbiased implementation of the 40SM by OTB in the area and that the non-avoidance probability is reflected in gear selectivity, it can be inferred that availability to the baseline trawling gear is much higher for smaller fish than bigger ones compared to the gear trials (Fig. 4.6.2.4). This could be related to the place/time that trawling takes place and could hint towards spatiotemporal measures needed to improve selectivity. Some of the most important nursery areas of hake are found in the Tyrrhenian and Sardinian Seas (Bartolino *et al.*, 2008; Colloca *et al.*, 2009, 2015; Ligas *et al.*, 2015). This can further increase the availability of juvenile hakes to the OTB fisheries in this area.

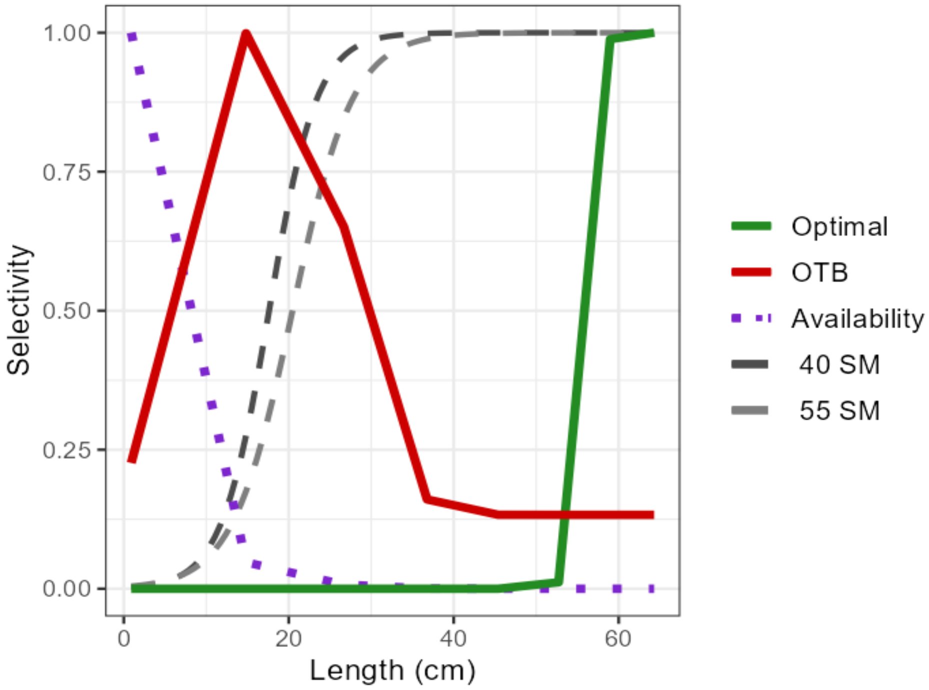


**Figure 4.6.2.4** HKE.08-09-10-11. Fitted 'Optimal' (shifted) selectivity by length, fitted selectivity by the OTB fleet segment ('OTB'), gear selectivity curves for the baseline 40mm square mesh trawler ('40 SM') and the 55mm square mesh codend trawler ('55 SM') and presumed relative 'Availability' of different sizes (inferred as the ratio 'OTB'/'40 SM' scaled to 1), assuming total and unbiased implementation of the 40SM by the OTB fleet segment.

Additionally, gear selectivity parameters were obtained from Sbrana *et al.* (2007) for gillnets operating in GSA 9, with 53mm mesh size (baseline – 33cm modal length) and 82mm mesh size (improved – 51cm modal length). These gear selectivity parameters were then plugged to the bi-modal selectivity function obtained by Millar & Fryer (1999).

The 82mm gillnet modification came closer to the optimal selectivity than both the baseline 53mm gillnet gear and the current selectivity of the GNS fleet segment, and would be catching fish on average just 13 cm smaller than their optimal size (Fig. 4.6.2.5).

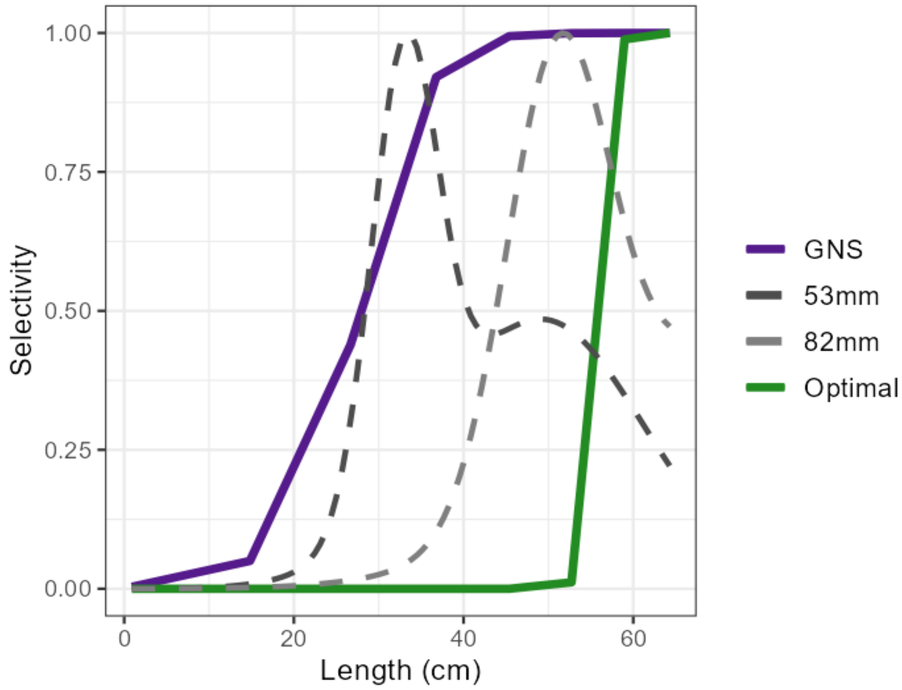


**Figure 4.6.2.5** HKE.08-09-10-11. Fitted optimal ('shift') selectivity by length ('Optimal'), fitted selectivity by the GNS fleet segment ('GNS'), gear selectivity curves for the baseline 53mm gillnet ('53mm') and a more selective 82mm gillnet ('82 mm').

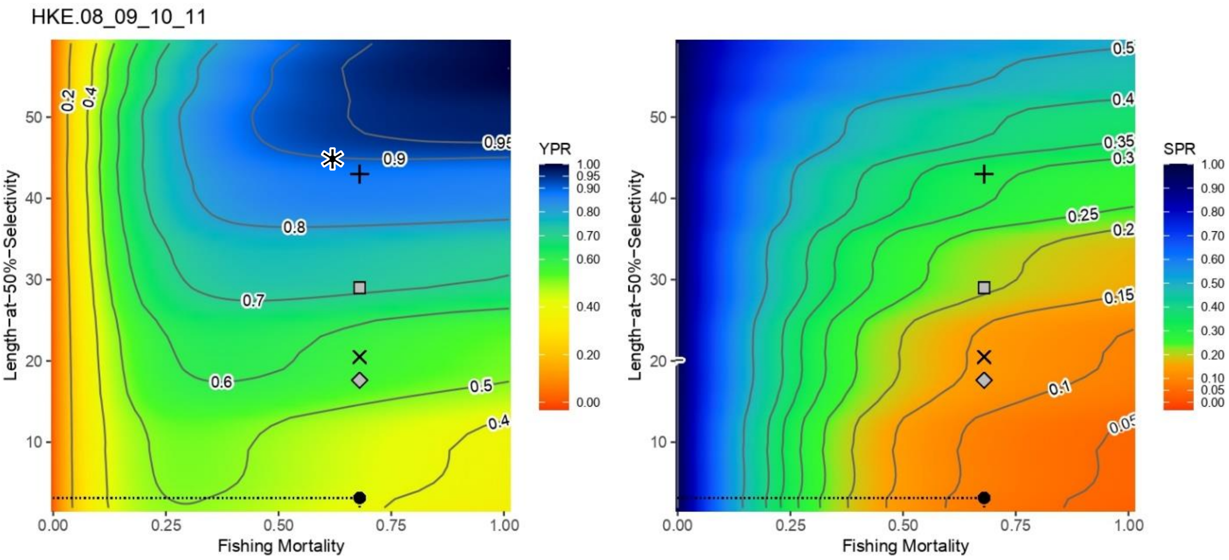


**Figure 4.6.2.6** Isopleths by length for HKE.08-09-10-11. Equilibrium yield-per-recruit (left) and SSB-per-recruit (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 40mm square mesh baseline trawler (◇), the $L_g50$ of the 55mm square mesh trawler (x), the $L_g50$ of the 53mm baseline gillnet (□), the $L_g50$ of the 82mm gillnet (+), and the combination of the lowest L50 and $F_{apical}$ producing an equilibrium yield at 90% of the maximum (*).

When comparing current selectivity with the gear selectivity of the baseline and improved trawler, it can be inferred that under current $F_{apical}$ the stock would come closer to the highest equilibrium yields but not quite there, with either of the trawlers examined (Fig. 4.6.2.6). Close-to-optimal yieds (90% of maximum) would be extracted by shifting L50 to ca. 45 cm, while fishing at similar levels with current $F_{apical}$ (Fig. 4.6.2.6). Notably, the 82mm gillnet offers an $L_g50$ very close to that level ($L_g50$ = 43 cm). However, there is the caveat of isopleths and current selectivity referring to population selectivity which is different than gear selectivity, as the former is the result of all gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

### 4.6.3 HAKE (MERLUCCIUS MERLUCCIUS) IN GSAS 17 AND 18 (ADRIATIC SEA) (HKE.17-18)

Fleets exploiting hake in the Adriatic are trawlers, gillnetters and longliners. This stock is exploited in a mixed fishery together with other important stocks (red mullet, mantis shrimp and sole). Based on genetic results of the MAREA StockMed project, hake exploited in GSAs 17 and 18 consist a distinct sub-population in the Adriatic Sea (Fiorentino *et al.* 2015).

EWG 22-19 notes that, in accordance with Articles 17 and 21 of the TMR, a fishery restricted area (FRA) in the Jabuka/Pomo Pit region in the Adriatic Sea has been established by GFCM (Rec GFCM/41/2017/3 and Rec GFCM/44/2021/2). This FRA was established with the aim to contribute to the protection of vulnerable marine ecosystems and essential fish habitats (i.e. spawning and nursery grounds) for important demersal stocks exploited by Adriatic trawl fishery such as European hake and Norway lobster. Establishment of this FRA can be viewed as a technical measure that, in synergy with others, contributes to the objectives of CFP, in particular protection of juveniles and spawning aggregations of hake and other demersal stocks in the Adriatic Sea, reduction of catches of undersized hake specimens, minimization of the negative environmental fishing impact on the seabed habitat within Jabuka/Pomo Pit FRA, and eventually improving the overall selectivity of the trawl fishery. EWG 22-19 notes that more studies are needed to demonstrate the effects of Jabuka/Pomo Pit FRA, and additional measures aimed to improve trawl codend selectivity are likely to act in synergy with FRAs in order to contribute in optimising the exploitation pattern of hake stocks in the Adriatic and beyond.

A recent study (Chiarini *et al.*, 2022) evaluated the early effects of Pomo/Jabuka Pit FRA as a technical measure (based on abundance indices), analysing CPUE changes in the period 2012-2019 for the five commercially and/or ecologically important species (Norway lobster, hake, deep water rose shrimp, blue whiting and *Munida* spp.) in three different FRA strata. In general, it seems that in case of hake FRA effects are mainly positive, but due to large confidence intervals these first results should be interpreted with caution, suggesting the need to continue with FRA effects monitoring.

Most of the landings in GSAs 17 and 18 come from the bottom trawler fleet, followed by longlines and to a lesser extent gillnet fishery and 'rapido' trawls only in the case of GSA 17 (STECF, 2020c). In earlier years, there were no discard estimates available and as a result only a deterministic mean discard ratio could be applied. The majority of discards come from the OTB fleet.

The relevant stock assessment by EWG 20-15 (STECF, 2020c) is considered to include a complete stock unit as it includes both commercial data (landings and discards) from the DCF and data provided by Albania and Montenegro coming from the GFCM framework. Fishing is well above the reference points, with the 2019 level of fishing mortality ($F_{2019}$ = 0.41) calculated to exceed the reference point $F_{MSY}$ ($F_{MSY}$ = 0.179), suggesting that the stock is being overexploited (Fig. 4.6.3.1).

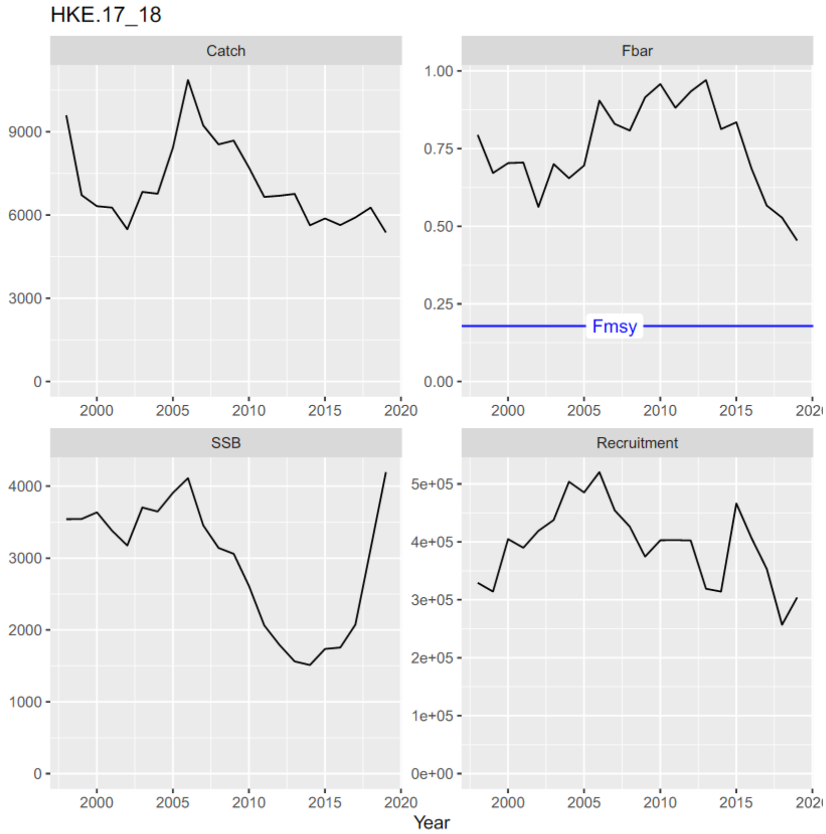


**Figure 4.6.3.1** HKE.17-18. Summary of the stock assessment (STECF, 2020c).

The selectivity analysis suggested that this stock may produce the highest equilibrium yields under current F by shifting A50 by 5.8 y or L50 by 40.3 cm, in which case high protection of juveniles would be also ensured (Fig. 4.6.3.2; Table 4.1.2.3).

The partial selectivity by fleet segment was not available for this stock, so the gear selectivity of two gears has been also plotted on Fig. 4.6.3.2. Gear selectivity parameters ($L_g50$ = 15.7 cm, $SR_g$ = 7.56 cm) corresponding to the current baseline codend mesh size (40mm square mesh – 40SM) were derived from gear trials (Sala & Lucchetti, 2010) (Annex 1). Due to the lack of recent selectivity studies in the area on codend meshes higher than 40SM or 50DM, a more selective set of gear selectivity parameters ($L_g50$ = 20.46 cm, $SR_g$ = 8 cm) corresponding to a square mesh size of 55mm (55SM) was obtained from a meta-analysis by Lucchetti *et al.* (2021).

Current selectivity was slightly better than the gear selectivity of the baseline 40SM trawler, owing to overall selectivity incorporating also more selective gears than trawlers ((Fig. 4.6.3.2). It should be also noted that the establishment of a FRA in GSA 17 probably reduced the availability of small hake to the OTB gear. The 55SM gear modification came only slightly closer to the optimal selectivity, than both the default 40SM gear and the current selectivity, but it would be still catching fish on average 39.2 cm smaller than their optimal size (Fig. 4.6.3.2).

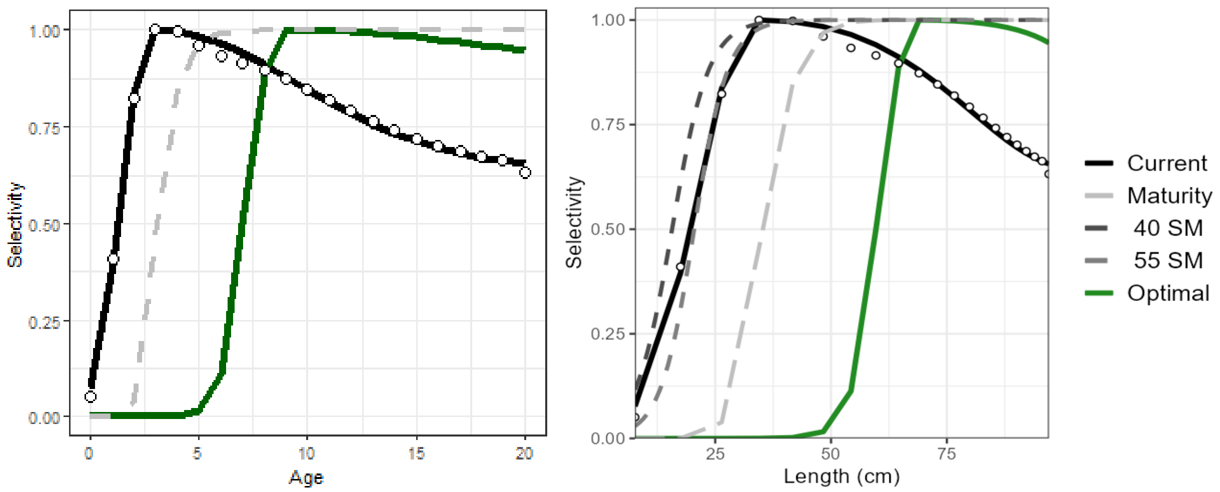


**Figure 4.6.3.2** HKE.17-18. Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F plotted together with the maturity ogive. Points represent the observed selectivity. Also shown on the right are the gear selectivity curves for the baseline 40mm square mesh trawler ('40 SM') and the 55mm square mesh trawler ('55 SM')

Selectivity analysis under varying F, confirms that lowering F would allow selectivity improvements to be more effective in taking the stock closer to MSY (Fig. 4.6.3.3).When comparing current selectivity with the gear selectivity of the improved trawler, it can be inferred that under current $F_{apical}$ the stock would come only marginally closer to the highest equilibrium yields (Fig. 4.6.3.3). However, there is the caveat of isopleths and current selectivity referring to population selectivity, which is different than gear selectivity, as the former reflects the effect of all the gears acting on the fishery, while also being affected by availability (see Chapter 2.1). Close-to-optimal yieds (90% of maximum) would be extracted by shifting L50 to ca. 37 cm, while halving the $F_{apical}$ compared to current (Fig. 4.6.3.3).

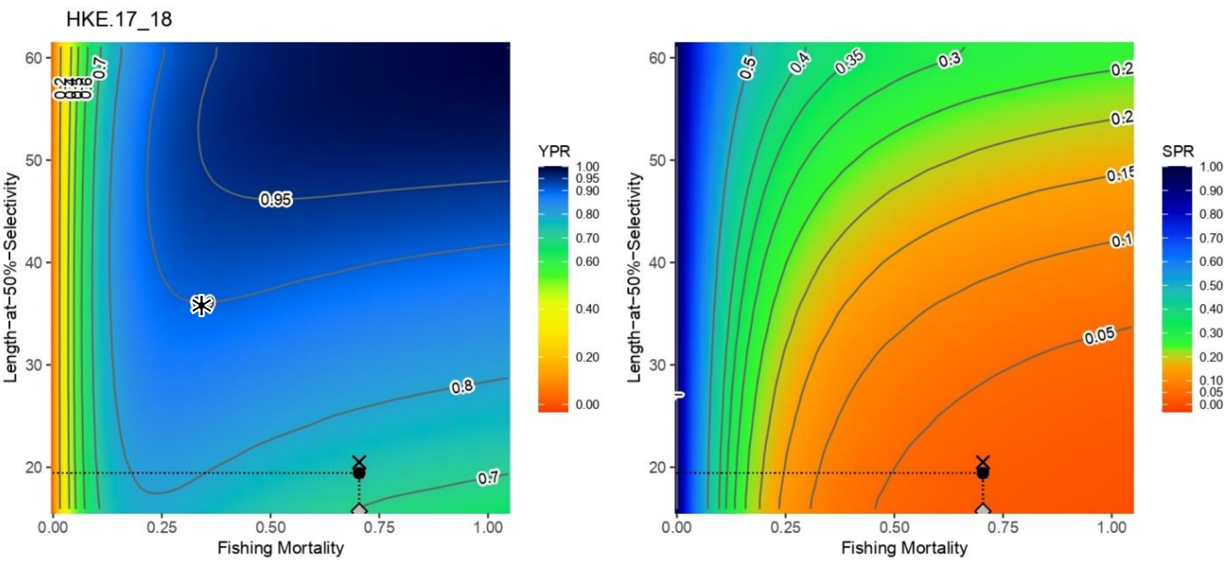


**Figure 4.6.3.3** Isopleths by length for HKE.17-18. Equilibrium yield-per-recruit (left) and SSB-per-recruit (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 40mm square mesh baseline trawler (◇), the $L_g50$ of the 55mm square mesh trawler (x) and the combination the lowest L50 and $F_{apical}$ producing an equilibrium yield at 90% of the maximum (*).

## 4.6.4 HAKE (MERLUCCIUS MERLUCCIUS) IN GSA 19 (WESTERN IONIAN SEA) (HKE.19)

Hake in GSA 19 is mainly exploited by trawlers, longlines, gillnets and trammel nets. On average, catches from longlines (LLS) represent approximately 20% of total hake landings, from gillnets and trammel nets combined (GNS and GTR) approximately 20%, and from trawlers 60% (OTB).

The data from DCF analysed by the EWG 20-07 (STECF, 2020c) showed that total catch, landings and discards have been decreasing since 2004. While the landings are reported for all years, discards are missing from 2002 to 2005 and from 2007 to 2008, as collection of discard data was not foreseen by DCF. Discard data were subsequently reconstructed for the missing years. Catches after a peak in 2004 decreased to low values during the last 8 years (Fig. 4.6.4.1). Latest (2019) landings of approximately 700 tons were approximately 2.3 times lower than landings levels in 2004 (1630 tons). Discards also followed a decreasing trend.

The bulk of catches are taken by bottom otter trawls (OTB) and longlines (LLS) for the landing fraction, and by OTB for the discard component. Discards varied from year to year and were about 1.5-6% of landings. Taking into account the fleets targeting hake, the decrease in landings in bottom trawlers is contrasted by the increasing of landings in longlines and nets.

Length frequency distributions from catches show that hake is dominated by individuals up to 30 cm and a variation in size selectivity between gears is evident.

The 2020 stock assessment indicated that the hake stock in GSA 19 was overexploited, given that $F_{2019}$ = 0.325, higher than $F_{0.1}$ ($F_{0.1}$ = 0.135). STECF EWG 20-15 advised that fishing mortality in 2021 should be no more than 0.135 and corresponding catches of hake in 2021 to deliver this value should not exceed 379 tonnes. It is noted that the SSB is increasing after 2016, as a result of a decreasing fishing mortality (Fig. 4.6.4.1).

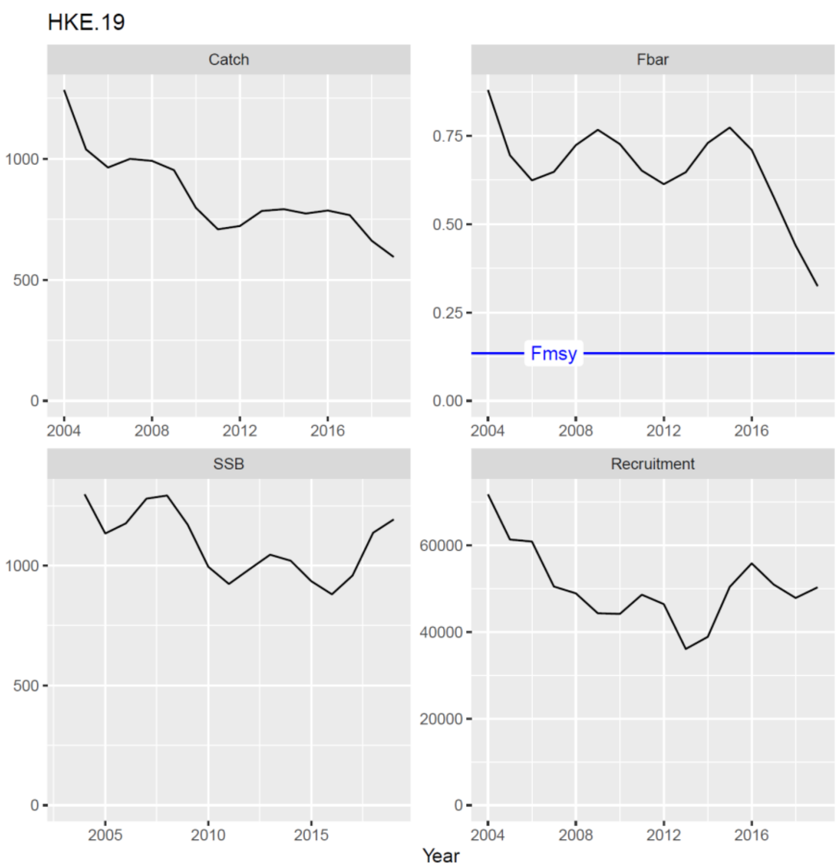


**Figure 4.6.4.1** HKE.19. Summary of the stock assessment (STECF, 2020c).

The selectivity analysis suggested that this stock may produce the highest equilibrium yields under current F by shifting A50 by 5.4 y or L50 by 42.8 cm, in which case high protection of juveniles would be also ensured (Fig. 4.6.4.2; Table 4.1.2.3).

The partial selectivity by fleet segment was not available for this stock, so the gear selectivity of two gears has been also plotted on Fig. 4.6.4.2. For this area, it was not possible to find any recent studies on gear selectivity curves, on either the baseline or an improved trawler. Therefore, gear selectivity parameters ($L_g50$ = 14.88 cm, $SR_g$ = 4.5 cm), corresponding to the current baseline codend mesh size (40mm square mesh – 40SM) and a more selective set of gear selectivity parameters ($L_g50$ = 20.46 cm, $SR_g$ = 8 cm) corresponding to a square mesh size of 55mm (55SM) were obtained from a meta-analysis by Lucchetti *et al.* (2021).

Current selectivity was slightly worse than the gear selectivity of the baseline 40SM trawler (Fig. 4.6.4.2), but this could be due to the absence of gear trials in the GSA 19, or due to reasons discussed in detail in Chapter 4.6.1. The 55SM gear modification came slightly closer to the optimal selectivity than both the default 40SM gear and the current selectivity, but would be still catching fish on average 30.8 cm smaller than their optimal size (Fig. 4.6.4.2).

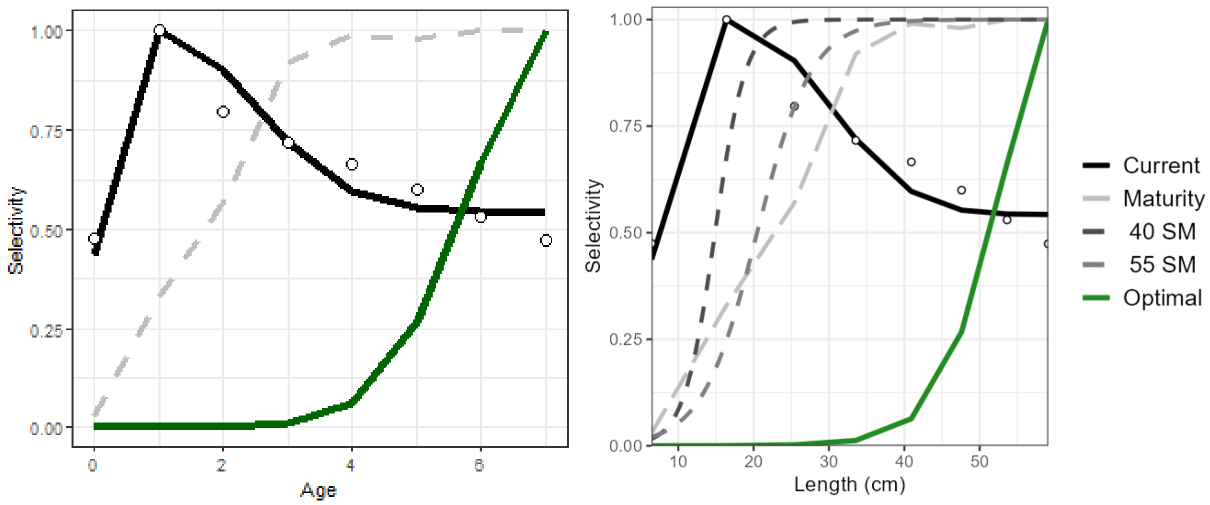


**Figure 4.6.4.2** HKE.19. Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F plotted together with the maturity ogive. Points represent the observed selectivity. Also shown are the gear selectivity curves for the baseline 40mm square mesh trawler ('40 SM') and the 55mm square mesh trawler ('55 SM').

When comparing current selectivity with the gear selectivity of the improved trawler, it can be inferred that under current F the stock would come slightly closer to the highest equilibrium yields (Fig. 4.6.4.3). Close-to-optimal yieds (90% of maximum) would be extracted by shifting L50 to ca. 42 cm, with and $F_{apical}$ between 0.60 and 0.70 (Fig. 4.6.4.3). However, there is the caveat of isopleths and current selectivity referring to population selectivity, which is different than gear selectivity, as the former reflects the effect of all the gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

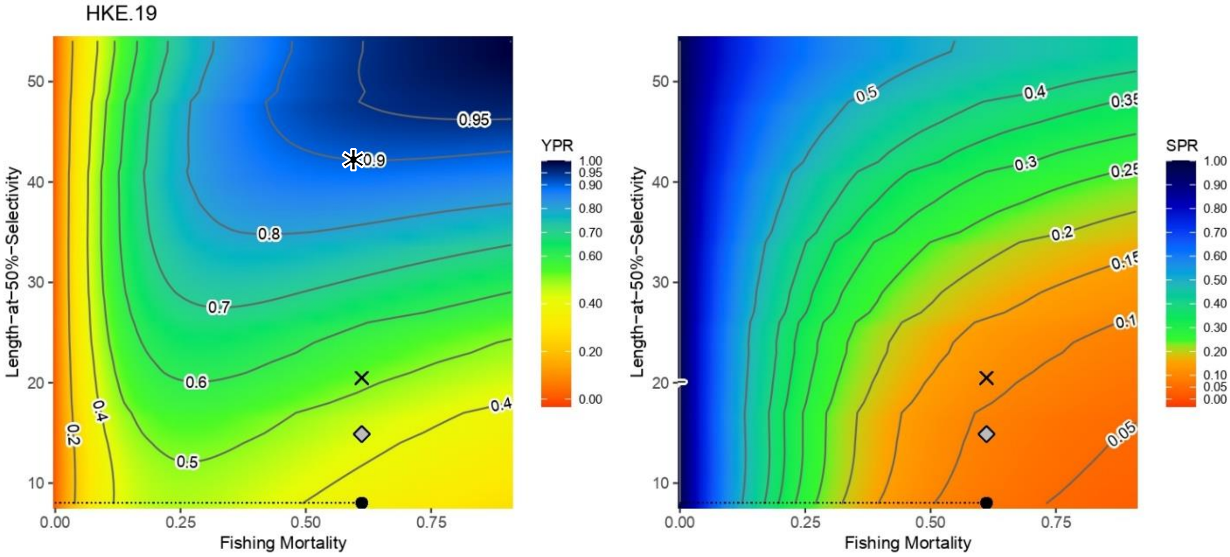


**Figure 4.6.4.3** Isopleths by length for HKE.19. Equilibrium yield-per-recruit (left) and SSB-per-recruit (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 40mm square mesh baseline trawler (◇), the $L_g50$ of the 55mm square mesh trawler (x) and the combination of the lowest L50 and $F_{apical}$ producing an equilibrium yield at 90% of the maximum (*).

## 4.6.5 HAKE (MERLUCCIUS MERLUCCIUS) IN GSA 20 (EASTERN IONIAN SEA) (HKE.20)

In GSA 20 (Eastern Ionian Sea), hake mainly inhabits muddy substrates at depths ranging from 50 to 600 m. Hake is mainly targeted by the bottom trawl fishery as well as fisheries with nets (gillnets and trammel nets) and longlines. The gill nets are set at depths ranging from 80 to 300 m and the mesh size used is usually 48 to 64 mm. This fishery is mainly carried out during summer, when bottom trawl fishery is prohibited. Longline fishery for hake also operates mainly during the summer at deeper waters, down to 500 m.

The official landings of hake in GSA 20 are recorded by the Hellenic Statistical Authority (ELSTAT) and the same values are also reported in the FAO/GFCM databases. However, the structure of the dataset changed after 2015 and includes the landings of an extra small-scale coastal fleet of 10,000 vessels (Tsikliras *et al.*, 2020). To account for these additional landings that inflated the landings time series after 2016, a correction of the hake landings from 1982 to 2015 was implemented multiplying by 1.31, which is the difference of hake with and without the extra fleet. The DCF dataset contains too many missing points and is inconsistent in terms of landings as the landings reported for 2003-2006 are very high, probably owing to a raising factor error. Towards the end of the time series, the DCF dataset seems to converge with the official one.

The bottom trawl fishery in Greece is described as mixed, operating 24hr per day. Bottom trawl fishing targeting hake takes place mainly during daytime over muddy bottoms at depths ranging from 80 to 400 m. Other important targeted species in the hake fishery are shrimps, anglerfish, blue whiting, and red mullet. After an increase during the period from 2000 to 2008, the official landings of hake have been continuously declining, with a slight increase during the last three years (Fig. 4.6.5.1).

According to the Greek DCF, the discards of hake in GSA 20 were over 750t in the mid-2000s and have been declined to negligible values (< 15t) for OTB since 2013, while GNS and GTR produced discards that exceed 30t after 2016. The highest proportion of total discards (88% in 2018) is no longer attributed to OTB but to nets, which is strange as nets with large mesh size do not usually discard much fish.

The stock was overexploited in 2019, although decreasing in the last six years of the time-series, as Fbar ($F_{2019}$ = 0.74) was above $F_{0.1}$ ($F_{0.1}$ = 0.36) (Fig. 4.6.5.1). SSB shows an increasing trend in the last four years of the assessment period.

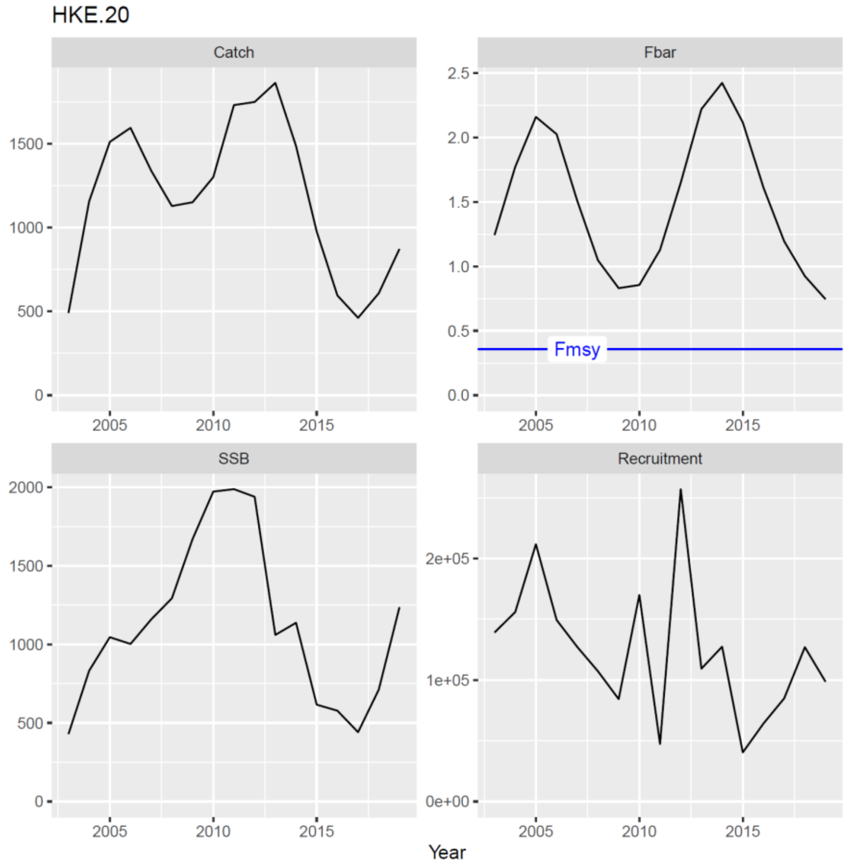


**Figure 4.6.5.1** HKE.20. Summary of the stock assessment (STECF, 2020c).

The selectivity analysis suggested that this stock may produce the highest equilibrium yields under current F by shifting A50 by 1.9 y or L50 by 19 cm, in which case high protection of juveniles would be also ensured (Fig. 4.6.5.2; Table 4.1.2.3).

The partial selectivity by fleet segment was not available for this stock, so the gear selectivity of two gears has been also plotted on Fig. 4.6.5.2. For hake in GSA 20, as in GSA 19, it was not possible to find any recent studies on gear selectivity curves, either the baseline or an improved trawler. Therefore, gear selectivity parameters ($L_g50$ = 14.88 cm, $SR_g$ = 4.5 cm), corresponding to the current baseline codend mesh size (40mm square mesh – 40SM) and a more selective set of gear selectivity parameters ($L_g50$ = 20.46 cm, $SR_g$ = 8 cm) corresponding to a square mesh size of 55mm (55SM) were obtained from a meta-analysis by Lucchetti *et al.* (2021).

Current selectivity was worse than the gear selectivity of the baseline 40SM trawler (Fig. 4.6.5.2), but this could be due to the absence of gear trials in GSA 20, or due to reasons discussed in detail in Chapter 4.6.1. The 55SM gear modification came closer to the optimal selectivity than both the default 40SM gear and the current selectivity, and would be catching fish on average just 9.3 cm smaller than their optimal size (Fig. 4.6.5.2).

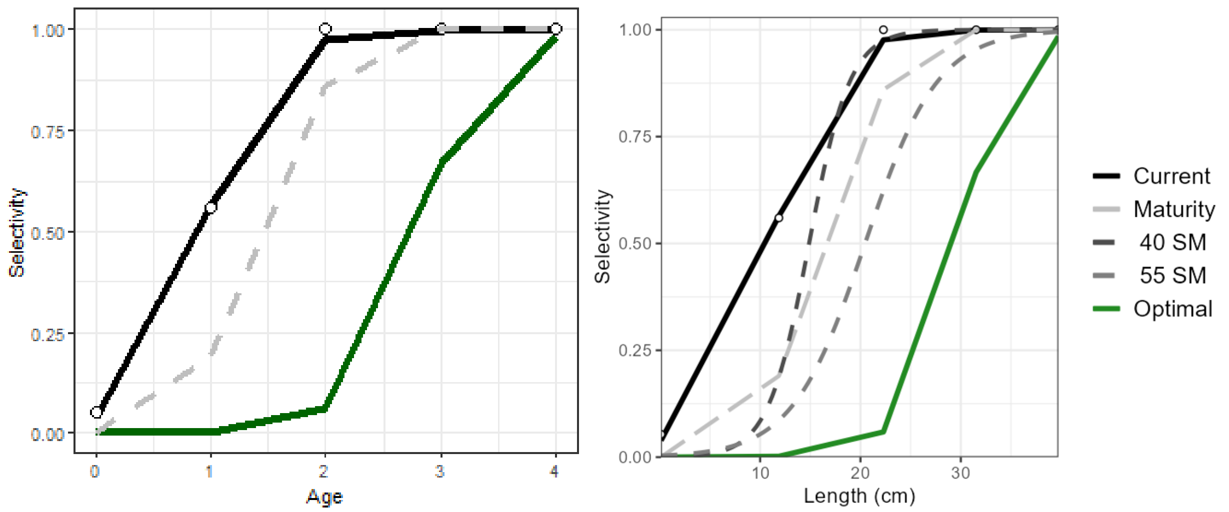


**Figure 4.6.5.2** HKE.20. Fitted 'Current' and 'Optimal' (shifted) selectivity by age (left) and by length (right) under current F, plotted together with the maturity ogive. Points represent the observed selectivity. Also shown are the gear selectivity curves for the baseline 40mm square mesh trawler ('40 SM') and the 55mm square mesh trawler ('55 SM').

When comparing current selectivity with the gear selectivity of the improved trawler, it can be inferred that under current F the stock would come close to the MSY (Fig. 4.6.5.3). Close-to-optimal yieds (90% of maximum) would be extracted by shifting L50 to ca. 26 cm, with a $F_{apical}$ of ca. 1.4 (Fig. 4.6.9.3). However, there is the caveat of isopleths and current selectivity referring to population selectivity which is different than gear selectivity, as the former reflects the effect of all the gears acting on the fishery, while also being affected by availability (see Chapter 2.1).

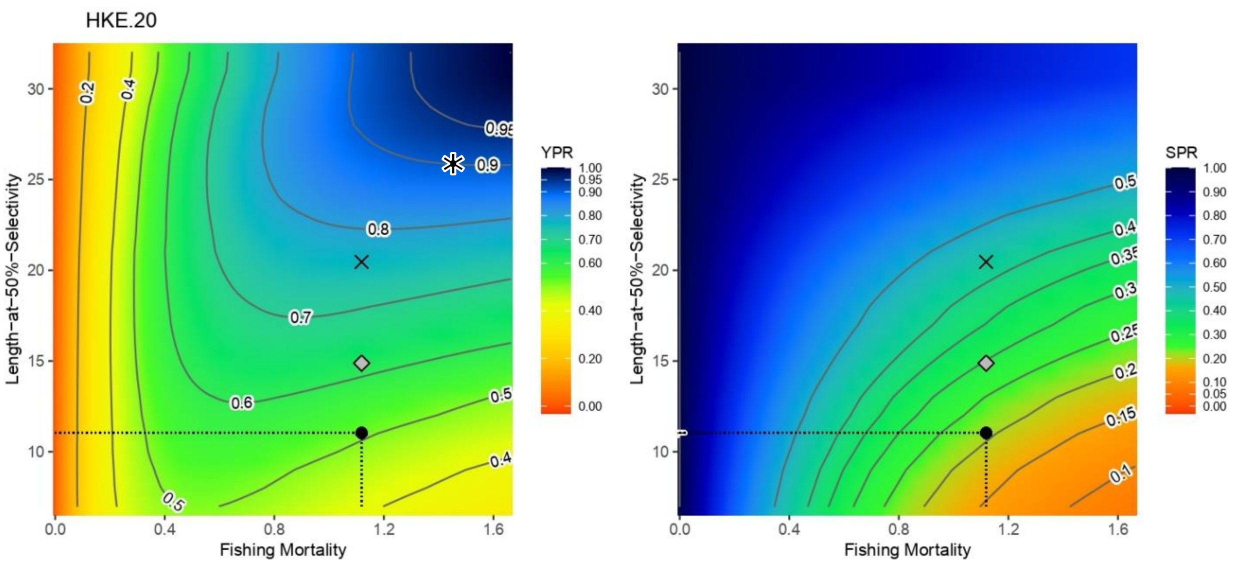


**Figure 4.6.5.3** Isopleths by length for HKE.20. Equilibrium yield-per-recruit (left) and SSB-per-recruit (right) under varying ('shifting') length-at-50%-selectivity (L50; cm) and fishing mortality ($F_{apical}$). Plotted are the current L50 and $F_{apical}$ (•), the $L_g50$ of the 40mm square mesh baseline trawler (◇), the $L_g50$ of the 55mm square mesh trawler (x) and the combination of the lowest L50 and $F_{apical}$ producing an equilibrium yield at 90% of the maximum (*).

## 4.7 Identify possible operational changes needed to realise the transition to higher yields (ToR 3)

According to Haasnoot *et al.* (2016), it is entirely possible that fishers can positively influence their impact on the sustainability of fish stocks through operational changes. However, technological change leading to a shift of fishing gears or fishing operations that improve sustainability is complex and challenging to achieve. This is due to the inherent uncertainty and the underlying perception of the fishing industry that such changes will lead to significant capital outlay and economic loss.

EWG 22-19 has identified three types of operational change that could be implemented to improve selectivity and increase yields as follows:

a) Gear modifications (e.g., through increases in mesh size or use of a selectivity device)
b) Gear changes (e.g., moving from active to static gears)
c) Spatiotemporal measures (e.g., through closed areas or seasons)

As the focus of EWG 22-19 is on gear selectivity and gear shifts, spatiotemporal measures to avoid or limit fishing activity in specific areas or at specific times of the year are not considered further in this ToR. However, EWG 22-19 notes that such measures can constitute another method to improve selectivity and lead to increased yields over time. By way of an example, EWG 22-19 refers in particular to the assessment of the closures under the Western Mediterranean MAP as reported by EWGs 20-13, 21-01, 21-13, 22-01 and 22-11.

a) <u>Gear modifications</u>. Such modifications are among the simplest and common operational changes used to improve yields via increased selectivity. They can be in the form of simple increases in codend mesh size and changes in mesh configuration, or the mandatory/voluntary use of selectivity devices such as square mesh panels or sorting grids. They can be used in specific fisheries where the relevant species may be a target species or an important bycatch. The widespread use of increasing mesh size or a selectivity device over time will potentially increase yield depending on uptake and compliance. However, biological benefits are not easy to evaluate (Suuronen & Sardà, 2007) and may not systematically lead to the desired increased size selectivity (Yang & Herrmann, 2022).

Gear modifications can be introduced over several years using a stepwise approach, 'slow and steady increase' (e.g., change in mesh size) or immediately when the state of the stock dictates urgent action (e.g., mandatory use of a selection device such as a grid).

As described in EWG 21-07, the capital cost implications for making such changes are generally reasonably low (e.g., €1,000-€10,000). However, the short-term loss of earnings as a result of reduced catches of marketable fish may be significant and depending on the gear modification made, may never return the vessel to the level of earnings post-change. For example, moving to significantly larger codend mesh size (140mm) in a mixed gadoid fishery targeting cod would result in the almost total and permanent loss of whiting catch in the fishery, due to the differences in selectivity and potential size of the two species.

Introducing gear modifications is usually based on technical trials that demonstrate the benefits of such modifications in terms of reduced catches of juveniles, as well as the corresponding losses (if any) of marketable catch associated with them. In the past, such modifications have usually met resistance from industry and unless introduced into legislation, uptake has been slow. Where gear changes have been introduced in a stepwise process, change has been easier (e.g., under Regulation (EU) 1241/2019 fishers were allowed two years to transition to the baseline mesh size of 120mm in North Western waters).

According to STECF EWG 12-20, the successful introduction of gear modifications is related to the incentives that are in place to support the change, particularly when it will result in short-term losses, as well as acceptance that the measures are needed. While support through grant aid to offset some of the modification costs is useful and often necessary, it is usually not always sufficient to encourage the smooth transition to any new gear.

Co-management or stakeholder integrative approaches are now commonly accepted as being alternatives to compulsory measures and provide positive ecological, social and economic benefits in various fisheries over the world, mainly for SSF (Chuenpagdee & Jentoft, 2007; Ratana & Jentoft, 2007; Macher *et al.*, 2018; Smallhorn-West *et al.*, 2022). These strategies can represent additional tools, especially in a context of growing social society demand for natural common resource management.

During the Horizon 2020 project DiscardLess, numerous measures to reduce unwanted or undersized catches were tested and modelled over a wide range of EU fishing fleet segments (i.e., a related exercise to that in ToR 3 of the current report). The DiscardLess project produced guidelines and a toolkit for fishers, scientists and managers to assess the validity and the economic consequences of future selective gears to be developed and experimented by the fishing industry. These guidelines could be useful in helping to develop methodologies for assessing the impacts of operational change.

In the example of the trawl fishery for hake in the western Balearic a simulation study showed a positive result as a result of operational change. The scenario of avoiding immature hake (<30 cm) implied increases in yield and SBB as well as income, crew wages and profit with a resulting significant reduction in fishing mortality. Similar results were obtained for Spanish trawlers operating in the Bay of Biscay targeting hake when the mesh size was increased from 100 to 120 mm (Prellezo *et al.*, 2017).

Nonetheless, a gradual increase in gear selectivity is no guarantee for successful implementation and improvements in yield. Suuronen *et al.* (2007) showed that no obvious change in fleet selectivity, nor decreased discarding of young fish, took place in spite of several gradual regulatory changes intended to increase size selectivity in the Baltic cod trawl fishery in the 1990s and early 2000s. The authors suggested that the regulatory changes had been nullified by circumvention of the measures introduced based on an unwillingness to accept short-term economic losses and the lack of acceptance of the decision-making process.

b) Gear changes. As described by Suuronen *et al.* (2012), transitioning from one gear type to another is seldom easy or practical. The size and design of existing fishing vessels and their machinery, vessel layout and equipment often limit the possibilities of changing fishing method. Additionally, fishing gears, fishing vessels, operations, and practices have evolved over a considerable period of time, around specific fishing operations and fishing patterns. Accordingly, the evolved fishing gear and practices are “tailor-made” to catch specific target species or species groups in a manner that is often perceived to be optimised to the best technical and economic scenarios. Furthermore, where fishing practices are rooted in tradition, there is often a strong resistance to change. Therefore, such changes require considerable lead-in time to achieve, depending on the scale of the gear shift.

Gear changes also imply significant investment in both the gear and the vessel. As described in EWG 21-07, this could be in the region of €250,000 - €500,000. Additionally, there will be losses due to downtime needed to convert the vessel, as well as likely short-term loss of earnings as a result of reduced catches of marketable fish as the crew adapt to the new fishing method. Depending on the gear change, earnings may never return the vessel to the level of earnings post-change due to the lower efficiency of the gear. Such reductions may be partially offset by the increased value per kg of the catch from a larger proportion of bigger fish in the catch or from reduced operational costs such as fuel.

Moving to alternative gears generally needs a detailed economic and technical assessment of costs to change and likely revenues once converted, as fishers need a level of assurance that the new gear will have benefits in the long-term. Additionally, such changes are probably only an option for small discrete fisheries involving a relatively small number of vessels as converting significant number of vessels is likely to lead to extremely large capital investment. Large-scale shifts may also lead to effort displacement and potentially have market implications. Nevertheless, the case studies described in Chapters 4.5 & 4.6 indicate that for some of the priority stocks it is the change of gear (from active to passive), rather than modifications of existing active gears, that would bring stocks closer to the optimal selectivity regimes.

### 4.8 Identify the technical support required to assess at the regional level, the potential socio-economic implications of fisheries-based transition plans for improving yields (ToR 3)

There are certain barriers to transitioning to modified or alternative fishing gears (Glass *et al.*, 2007; Jennings & Revill, 2007; Suuronen *et al.*, 2007, Gascoigne & Willsteed, 2009). These include:

- Lack of familiarity with cost-effective and practical alternatives;
- A fear to lose a level playing field among countries/fleets;
- Availability of technologies;
- Incompatibility of vessels with alternative gear;
- Risk of losing marketable catch;
- Additional work for crew making recruitment and retention difficult;
- Concerns with safety at sea by using unfamiliar gears or strategies;
- High investment costs;
- Lack of capital or restricted access to capital;
- Ineffective technology infrastructure support; and
- Inflexible fisheries management systems.

In order to achieve successful transition, Suuronen *et al.* (2007) described a range of factors and steps that need to be taken to affect change. Research and development priorities should be established with work undertaken to support development and uptake of modified or alternative fishing. These include:

- Promoting and funding studies of cost-effective gear designs and fishing operations to commercialize economically viable, practical and safe alternatives to current fishing methods;
- Analysis and review of best practice operations across fisheries, both at EU and globally;
- Provide training to improve the technical ability among fishers to adapt to alternative gears;
- Establishment of appropriate incentives, and execution of robust but flexible fishery management policies that support the transition to modified or alternative technologies;
- Close cooperation between the fishing industry, scientists, managers and other stakeholders to enable development and introduction.

The DiscardLess project developed a three-step process to assess operational changes (O'Neill & Noble, 2017):

1. Assess the difference in key outcome measures between the benchmark (baseline) gear and the experimental gear for the trial;
2. Estimate the annual implications of adopting the experimental gear based on results of the trial;
3. Indicate whether the trial gear has met specific targets or goals for the vessel operator. It should be noted that this method focuses on short to medium term implications of gear change for the vessel operator.

To measure the socio-economic implications, in addition to technical trials and estimates of the improvement in yield, data to estimate short-term and long-term costs and potential revenues, as well as estimates of capital costs for conversion/modifications of gear and vessels are needed. The impact on operational costs (e.g., crew retention, labour costs and fuel) also need to be factored into any assessment (e.g., it is likely that converting from active to static gears would have a positive impact on fuel consumption but may lead to an increase in crew required as static gears are more labour intensive).

In all cases, technical trials to establish whether the operational changes are viable are needed. The results of these trials should inform the trade-off between long-term viability against short-term losses and feed into model simulations to support the transition. There are several bio-economic models available that could be used to project the potential economic outcomes. These include models such as FLBeia, MEFISTO, BEMTOOL. Particularly for conversion to alternative gears, technical trials to support such initiatives are not necessarily straightforward and would require much longer trials to demonstrate practicality and viability, compared to gear modifications that are easier to assess.

In relation to change management in fisheries, Pol & Eayrs (2019) suggest that fishers, scientists and managers are reluctant to change and they identify deficits in information and motivation as the drivers of this reluctance. They suggest changing management strategies to improve voluntary uptake of fishing gears that promote sustainability, while mandatory implementation of selective gears was identified as one means of successfully implementing change. The TMR lays down mandatory baseline mesh sizes with the facility for alternative gears to be implemented on the basis of equivalent selectivity. Since the TMRs introduction in 2019 Member States have therefore been motivated to recommend the addition of multiple alternative gears to the TMR.

The CFP goal that all stocks are managed at or above levels capable of producing MSY remains a challenge for certain stocks. Regional multi-annual plans include safeguards that require the implementation of remedial measures to reduce fishing mortality where stocks are assessed to be below certain targets (e.g. $B_{lim}$). These measures should ensure the rapid return of a given stock to MSY and their implementation should be based on the best scientific evidence available. Gear-based remedial measures have been implemented for cod and whiting in parts of the Celtic Sea and for cod in the North Sea. These measures aims to drive changes in the selectivity of the fishery but the basis for their implementation is not always defined in terms of the shift in fishing mortality. To evaluate the effects of the measures are further complicated by the fact that the practical implementation level is unclear. An example is that in the North Sea cod case (art. 16 of Council Regulation (EU) 2022/109), member states can avoid the implementation of the stricter remedial gear measures by so called national cod avoidance plans containing other (gear or non-gear) measures to limit cod catches.

The current process (EWG 22-19) addresses this deficit in information and provides fishers, gear technologists and managers with clear goals in respect of fishing mortality. It also provides motivation to question whether currently implemented selective gears are likely to achieve target fishing mortality and identify or develop of gears that are more likely to reach targets. For instance, issues such as unaccounted/ cryptic mortality for fishing gear escapees (Gilman *et al.*, 2013) which likely effects fish < MCRS to a greater extent than larger fish (Sangster et al., 1996), are driving development and implementation of gears that provide escape opportunities earlier in the catching process (Krag *et al.*, 2010; Melli *et al.*, 2018; McHugh *et al.*, 2017; 2019; Browne *et al.*, 2022). The development process takes time and resources. By addressing deficits in information such as target fishing mortality and providing motivation EWG 22-19 is promoting change.

# 5 DISCUSSION

The work carried out by EWG 22-19, extends the work carried out by EWG 21-07 to facilitate the implementation of the TMR by offering analytical tools (FLSelex; FLSelexLen) and approaches to assess selectivity. The work combines the typically rather theoretical focus of stock assessments and projections with the more practical elements of gear trials and gear selectivity, and packages these two elements together in a rather hands-on tool (the isopleth diagrams) to assess trade-offs of different management options. This work illustrates the potential of improved selectivity in conjunction with changes in F to realise higher yields at lower level of stock depletion and maps relevant pathways to that end, thus serving results-based management. Additionally, the approach followed for the selectivity analysis presented in the case studies of Chapters 4.5 - 4.6 is readily transferable to the stock assessment process and could contribute to enhance our understanding of the state and yield potential of fish stocks. This can be seen as a first step towards the establishment of harvest control rules and catch advice in which the catch option tables would not only feature fishing mortality options, but also alternative options of selectivity and combinations thereof.

## 5.1 Caveats of the analysis

The analysis conducted by EWG 22-19 to infer the optimal age/size that fish should be caught to optimise yields is based on projections that often lead to stock sizes that have not been observed in recent history, especially in the case of the priority stocks. As with any extrapolation beyond available observations, this comes with large uncertainty. Projections are subject to the assumptions on processes such as the spawner-recruit relationship (SRR), growth, natural mortality (M) etc. Such assumptions are based on the average population state in most recent years and may be appropriate for assessments and short-term forecasts, but may not necessarily hold for long-term forecasts. Moreover, potential changes in the ecosystems, such as regime shifts, may largely affect the population dynamics of the exploited stocks, e.g. through a distortion in the SRR. In such cases, a change in fishing mortality or selectivity could have minor influence and might not automatically lead to an expected recovery of the stock (e.g. as is the case for the eastern Baltic cod stock; ICES, 2022c). Therefore, the results presented here should interpreted with caution; they are informative about the direction of change in yield, juvenile catches etc., but the absolute changes may be under- or over-estimated.

Optimisation of selectivity under both current and varying F and the associated optimal L50s estimated here refer to population selectivity. When comparing population selectivity (L50) with gear selectivity ($L_g50$) it should be noted that these are different; population selectivity reflects the effect of all the gears acting on the fishery, while also being affected by availability (see Chapter 2.1). Hence, such comparisons between L50 and $L_g50$ should be interpreted with caution.

The use of A50/L50 as a 'selectivity currency' in this report should be treated with care, considering its limitations to quantify the underlying selectivity pattern across all ages. A50 is only one of the five parameters used to construct selectivity curves in FLSelex (STECF, 2021), and while it is typically the most influential parameter of a selectivity curve with regards to yield outcomes (Vasilakopoulos *et al.*, 2016), different equilibrium yields could still emerge from potential changes in the shape of the selectivity curve that would leave A50/L50 unchanged. In actual stocks, population selectivity curves can take many different shapes that may also differ from year to year (Sampson & Scott, 2012). For some of these curves (e.g. saddle-shaped ones), A50/L50 could be a poor indicator of selectivity. A50/L50 was deemed adequate to summarize selectivity in the context of the simulated projections to equilibrium employed here, which were designed to illustrate how far different stocks lie from an optimal selectivity. However, it would be precarious to only use A50/L50 to track interannual changes in the actual selectivity, as estimated from annual stock assessments. For monitoring purposes, an F-based selectivity metric would be more adequate (Vasilakopoulos *et al.*, 2020; STECF, 2020a).

Another challenge for this analysis was the absence of relevant or recent gear trials to produce representative gear selectivity curves for some of the stocks examined. In some cases, the results of gear trials performed a long time ago (e.g. whg.27.7a) and/or in other areas (e.g. HKE.19; HKE.20) had to be used, with their applicability being questionable. Moreover, while static gears often exhibited the greatest potential for optimising selectivity of the priority stocks, there was a general scarcity of published gear selectivity parameters for static gears that would allow us to study their effect in more detail.

## 5.2 Next steps

There is need to systematically tackle and follow-up the implementation of the TMR in order to identify potential needs for increased selectivity. The work by EWG 21-07 and now EWG 22-19 has identified data needs, an analytical framework, and a tool to evaluate trade-offs in fishing mortality and selectivity. Furthermore, EWG 22-19 offered an outline and a qualitative assessment of the operational changes needed to realise the transition to higher yields and associated socio-economic implications in response to ToR 3. This work needs to be extended in order to facilitate that the TMR works in practice. A natural next step would be to work through one or a few more concrete case studies/examples of how increased selectivity through the adoption of new/modified gears could be implemented, including an operational transition plan and assessment of socio-economic consequences.

The TMR stipulates (paragraphs 38-39) that every three years: "*the Commission should report to the European Parliament and to the Council on the implementation of this Regulation.* (…) *That report should assess the extent to which technical measures* (…) *have contributed to achieving the objectives and reaching the targets of this Regulation. For the purpose of that report, adequate selectivity indicators* (…) *could be used as a reference tool to monitor progress over time towards* *the CFP objective of minimising unwanted catches*”. This suggest that there is a need to develop selectivity indicators to track the implementation of the TMR. Soon after the TMR came into force, a JRC-led study tested the suitability of several candidate metrics, shortlisting F-based indicators (such as $F_{rec}/F_{bar}$) as the most suitable to track changes in selectivity (Vasilakopoulos *et al.*, 2020). EWG 20-02 applied $F_{rec}/F_{bar}$ to a large number of stocks to track changes in selectivity, identifying the cases (e.g. stocks, stock assessment types) where this indicator worked better than others and the reasons for that. EWG 20-02 concluded that there were still open issues, such as the exact form that the F-based indicator should take, the need to link the selectivity indicator to a threshold/reference point and the need for a better understanding of how changes in the indicator are related to specific technical measures. EWG 21-07 and EWG 22-19, while not focusing on tracking selectivity changes, advanced some of these issues; e.g. EWG 21-07 proposed $F_{juv}/F_{apical}$ as an alternative to $F_{rec}/F_{bar}$ and both EWGs systematised a selectivity optimisation approach through FLSelex that could be used as the base for inferring selectivity thresholds. In any case, the work on selectivity indicators initiated at EWG 20-02 needs to be continued in order to facilitate the implementation of the TMR.

# 6 CONCLUSIONS

The main conclusions of EWG 22-19 can be summarised as follows:

- EWG 22-19 concludes that improvements in selectivity would most strongly benefit long-living, late-maturing stocks characterized by greater growth overfishing (e.g., Mediterranean hake stocks, NE Atantic cod stocks).
- EWG 22-19 concludes that generally stocks that are heavily overfished would gain substantially in both yield and SSB if selectivity is increased together with a decrease in F. The heavier the overfishing the greater the distance from optimal selectivity; lowering F would allow selectivity improvements to be more effective in taking the stocks closer to MSY.
- EWG 22-19 concludes that in the case of the priority stocks, i.e. the ones with the highest potential gains in yield and/or juvenile protection from a selectivity increase, no known gear can readily produce optimal yields under current fishing mortality. Only exception was whg.27.7a, due to the biological particularities of the stock and possibly outdated gear selectivity estimates.
- EWG 22-19 notes that partial population selectivity of OTB is sometimes worse (i.e. shifted to smaller fish) than expected from the published gear selectivity of the baseline codends. This could be due to technical tweaks or operational choices taken during commercial fishing that change the actual gear selectivity, the catch of juveniles in smaller-meshed trawl fisheries targeting other species, or it could be indicative of a higher availability of smaller than larger fish to the commercial trawlers. Nevertheless, there are also stocks that are largely caught with the baseline gear only, where the partial population selectivity of OTB is very similar to the selectivity of the baseline gear, as expected (e.g. pok.27.3a46). In any case, gear selectivity alone is not always a reliable predictor of population selectivity.
- EWG 22-19 concludes that in the case of priority stocks, the often scarce information available suggests that static gears (GNS, GTR, LLS) generally capture fish closer to their optimal size than active gears (OTB, TBB).
- EWG 22-19 notes the limited availability of gear selectivity studies for static gears compared to the availability of gear selectivity studies for active gears, which hindered a more thorough evaluation of the potential impact of static gears.
- EWG 22-19 suggests there is a need for more gear selectivity studies estimating the selectivity curves of static gears. More studies of active gears with a selectivity closer to the optimal sizes identified here would also be valuable.

- EWG 22-19 concludes that any transition in gear selectivity comes with implementation challenges and short-term economic losses, which are greater in the case of gear change (e.g., from active to static gears) than in the case of gear modification (e.g., codend mesh increase in trawlers). By contrast, the potential gains in yield and protection of juveniles are usually greater for gear changes than for gear modifications.
- EWG 22-19 concludes that the results from any trial testing gear modifications or gear changes are case specific, and any operational change would require a detailed cost-benefit study prior to the introduction of technical modifications, as well as a transition plan based on an assessment of the impacts to address any issues with implementation.
- EWG 22-19 notes that technological change is complex and challenging to achieve due to the inherent uncertainty and the underlying perception of the fishing industry that such changes will lead to significant capital outlay and economic loss. Moving to modified or alternative gears requires not only technical trials, but also an accompanying socio-economic and technical assessment, as fishers need a level of assurance that the new gear will have benefits in the long-term.
- EWG 22-19 suggests that further work will be needed to develop advanced technical support tools, most likely tailored to specific regions and fisheries, at a later stage.

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## 8 LIST OF ANNEXES

**Annex 1.** Gear specifications and gear selectivity curve parameters by stock. 'Plotted' refers to gear selectivity curves being plotted in the case studies (i.e. Chapters 4.5-4.6) SM: square mesh codend; DM: diamond mesh codend; SMP: square mesh panel; RFL: raised fishing line; OTB: bottom otter trawls; GNS: Set gillnets; LLS: Set longlines

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | NEA | BS | cod.27.22-24 | OTB | 120 | Bacoma | Y | 38.7 | 8 | Wienbeck *et al.*, 2014 | |
| | NEA | BS | cod.27.22-24 | OTB | 146 | Bacoma | N | 45.2 | 10.3 | Wienbeck *et al.*, 2014 | |
| | NEA | BS | cod.27.22-24 | OTB | 120 | SM | N | 42.4 | 7.2 | Wienbeck *et al.*, 2014 | |
| | NEA | BS | cod.27.22-24 | OTB | 130 | SM | N | 46.1 | 7.2 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| Y | NEA | BS | cod.27.22-24 | OTB | 140 | SM | N | 50 | 7.2 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| Y | NEA | BS | cod.27.22-24 | OTB | 120 | T90 | Y | 42.3 | 6.7 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | cod.27.22-24 | OTB | 130 | T90 | N | 44.5 | 6.7 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | cod.27.22-24 | OTB | 140 | T90 | N | 48 | 6.7 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | cod.27.22-24 | OTB | 120 | 2x4 mm | N | 35.6 | 9.3 | Madsen, 2007 | |
| | NEA | BS | cod.27.22-24 | OTB | 130 | 2x4 mm | N | 40.3 | 10 | Madsen, 2007 | |
| | NEA | BS | cod.27.22-24 | OTB | 140 | 2x4 mm | N | 44.9 | 10.8 | Madsen, 2007 | |
| | NEA | BS | cod.27.22-24 | GNS | 110 | 1.5x4; hanging ratio 50% | Y | 45.5 | | Madsen, 2007 | modal size, bell shaped selection curve |
| | NEA | BS | ple.27.21-23 | OTB | 120 | Bacoma | Y | 21.4 | 2 | Wienbeck *et al.*, 2014 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEA | BS | ple.27.21-23 | OTB | 146 | Bacoma | N | 24.9 | 4.3 | Wienbeck *et al.*, 2014 | |
| | NEA | BS | ple.27.21-23 | OTB | 120 | SM | N | 20.8 | 3 | Wienbeck *et al.*, 2014 | |
| | NEA | BS | ple.27.21-23 | OTB | 130 | SM | N | 22.3 | 3 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | ple.27.21-23 | OTB | 140 | SM | N | 24.4 | 3 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | ple.27.21-23 | OTB | 120 | T90 | Y | 24.3 | 2.1 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | ple.27.21-23 | OTB | 130 | T90 | N | 26 | 2.1 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | ple.27.21-23 | OTB | 140 | T90 | N | 29 | 2.1 | Herrmann, 2008; Herrmann *et al.*, 2009 | |
| | NEA | BS | ple.27.21-23 | OTB | 90 | 120 mm SMP | Y | 18.8 | 5.1 | Frandsen *et al.*, 2009 | |
| | NEA | BS | ple.27.21-23 | OTB | 120 | 4 mm, 100 meshes around, 300 kg | N | 26.4 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | BS | ple.27.21-23 | OTB | 130 | 4 mm, 100 meshes around, 300 kg | N | 28.3 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | BS | ple.27.21-23 | OTB | 140 | 4 mm, 100 meshes around, 300 kg | N | 30.2 | 2.6 | O´Neill *et al.*, 2020 | |
| Y | NEA | NS | cod.27.47d20 | OTB | 90 | 270 mm escape window (SELTRA) | Y | 33.8 | 39.1 | Krag *et al.*, 2016 | Baseline trawl gear in 3a (SD 20+21) |
| Y | NEA | NS | cod.27.47d20 | OTB | 120 | | Y | 39.4 | 8.4 | Madsen & Ferro 2003, STECF PLEN 20-01 | Baseline trawl gear in 4 and 7d |
| | NEA | NS | cod.27.47d20 | OTB | 120 | and 0.6 m RFL | N | 42.0 | 9.0 | STECF PLEN 20-01 | |
| | NEA | NS | cod.27.47d20 | OTB | 135 | 1x8 mm | N | 52.14 | 5.64 | Sistiaga *et al.*, 2009 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | NEA | NS | cod.27.47d20 | OTB | 155 | 1x8 mm | N | 61.26 | 8.67 | Sistiaga *et al.*, 2009 | Barents Sea study but included for contrast |
| | NEA | NS | cod.27.47d20 | OTB | Flexigrid | 55 mm grid/ 135 mm codend | N | 50.45 | 11.27 | Sistiaga *et al.*, 2009 | |
| | NEA | NS | cod.27.47d20 | OTB | Sort-V | 55 mm grid/ 135 mm codend | N | 52 | 10.93 | Sistiaga *et al.*, 2009 | |
| | NEA | NS | cod.27.47d20 | OTB | Flexigrid | 55 mm grid/ 130 mm codend | N | 52.7 | 8.1 | Brinkhof *et al.*, 2022 | |
| | NEA | NS | cod.27.47d20 | OTB | 135 | T90 | N | 50.2 | 9.7 | Brinkhof *et al.*, 2022 | |
| Y | NEA | NS | cod.27.47d20 | OTB | 145 | T90 | N | 55.1 | 12.1 | Brinkhof *et al.*, 2022 | Barents Sea study but included for contrast |
| | NEA | NS | cod.27.47d20 | OTB | Grid | 35 mm grid/90 mm codend | Y | 19.63 | | Frandsen *et al.*, 2009 | (bell shaped selection curve: 19.63; 5.32; 0.44) |
| | NEA | NS | cod.27.47d20 | SDN | 124 | 2x4 mm, 97 meshes | N | 41.6 | 12.6 | Noack *et al.*, 2017 | |
| | NEA | NS | had.27.46a20 | OTB | 90 | 120 mm SMP | Y | 43.8 | 18.6 | Frandsen *et al.*, 2009 | |
| | NEA | NS | had.27.46a20 | OTB | 120 | 2x4 mm; 100 meshes | Y | 35.9 | 6 | Madsen & Ferro, 2003, STECF PLEN 20-01 | |
| | NEA | NS | had.27.46a20 | OTB | 120 | and 0.6 m RFL | N | 35.9 | 6 | Madsen & Ferro, 2003, STECF PLEN 20-01 | |
| | NEA | NS | had.27.46a20 | OTB | 135 | 1x8 mm | N | 45 | 6.62 | Sistiaga *et al.*, 2009 | |
| | NEA | NS | had.27.46a20 | OTB | 155 | 1x8 mm | N | 56.36 | 6.46 | Sistiaga *et al.*, 2009 | |
| | NEA | NS | had.27.46a20 | OTB | Flexigrid | 55 mm grid/ 135 mm codend | N | 46.67 | 11 | Sistiaga *et al.*, 2009 | |
| | NEA | NS | had.27.46a20 | OTB | Flexigrid | 55 mm grid/ 130 mm codend | N | 51.9 | 9.2 | Brinkhof *et al.*, 2022 | |
| | NEA | NS | had.27.46a20 | OTB | Sort-V | 55 mm grid/ 135 mm codend | N | 49.22 | 9.61 | Sistiaga *et al.*, 2009 | |
| | NEA | NS | had.27.46a20 | OTB | 135 | T90 | N | 49 | 8.8 | Brinkhof *et al.*, 2022 | |
| | NEA | NS | had.27.46a20 | OTB | 145 | T90 | N | 51.6 | 8.5 | Brinkhof *et al.*, 2022 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEA | NS | had.27.46a20 | OTB | Nephrops grid | 35 mm grid/90 mm codend | Y | 16.26 | | Frandsen *et al.*, 2009 | (bell shaped selection curve: 16.26; 5.56; 0.15) |
| | NEA | NS | ple.27.420 | SDN | 124 | 2x4 mm, 97 meshes | Y | 29.1 | 2.2 | Noack *et al.*, 2017 | |
| | NEA | NS | ple.27.420 | OTB | 90 | 120 mm SMP | Y | 18.8 | 5.1 | Frandsen *et al.*, 2009 | |
| | NEA | NS | ple.27.420 | OTB | 100 | 4 mm, 100 meshes around, 300 kg | Y | 22.6 | 2.6 | O´Neill *et al.*, 2020 | Baseline gear south of 57.30 |
| | NEA | NS | ple.27.420 | OTB | 110 | 4 mm, 100 meshes around, 300 kg | N | 24.5 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.420 | OTB | 120 | 4 mm, 100 meshes around, 300 kg | Y | 26.4 | 2.6 | O´Neill *et al.*, 2020 | Baseline gear north of 57.30 |
| | NEA | NS | ple.27.420 | OTB | 130 | 4 mm, 100 meshes around, 300 kg | N | 28.3 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.420 | OTB | 140 | 4 mm, 100 meshes around, 300 kg | N | 30.2 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.7d | OTB | 100 | 4 mm, 100 meshes around, 300 kg | N | 22.6 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.7d | OTB | 110 | 4 mm, 100 meshes around, 300 kg | N | 24.5 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.7d | OTB | 120 | 4 mm, 100 meshes around, 300 kg | Y | 26.4 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.7d | OTB | 130 | 4 mm, 100 meshes around, 300 kg | N | 28.3 | 2.6 | O´Neill *et al.*, 2020 | |
| | NEA | NS | ple.27.7d | OTB | 140 | 4 mm, 100 meshes around, 300 kg | N | 30.2 | 2.6 | O´Neill *et al.*, 2020 | |
| Y | NEA | NS | pok.27.3a46 | OTB | 120 | 2x5 mm, 100 meshes | Y | 46.4 | 9.3 | Graham *et al.*, 2004 | |
| | NEA | NS | pok.27.3a46 | OTB | 90 | 120 mm SMP | Y | 37.1 | 1.8 | Frandsen *et al.*, 2009 | |
| | NEA | NS | pok.27.3a46 | OTB | Flexigrid | 55 mm grid/ 130 mm codend | N | 54.5 | 7.3 | Brinkhof *et al.*, 2022 | |
| | NEA | NS | pok.27.3a46 | OTB | 135 | T90 | N | 50.8 | 7.7 | Brinkhof *et al.*, 2022 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | NEA | NS | pok.27.3a46 | OTB | 145 | T90 | N | 56.2 | 8.5 | Brinkhof *et al.*, 2022 | |
| | NEA | NS | whg.27.47d | OTB | 120 | 2x4 mm; 100 meshes | Y | 41.7 | 11.9 | Madsen & Ferro, 2003 | |
| | NEA | NS | whg.27.47d | OTB | 120 | and 0.6 m RFL | N | 41.7 | 11.4 | Madsen & Ferro, 2003, STECF PLEN 20-01 | |
| Y | NEA | NWW | cod.27.6a | OTB | 120 | | Y | 39.4 | 8.4 | Madsen & Ferro, 2003, STECF PLEN 20-01 | |
| Y | NEA | NWW | cod.27.6a | OTB | 120 | And 1 m RFL | N | 42 | 9 | STECF PLEN 20-01 | |
| Y | NEA | NWW | cod.27.6a | OTB | 145 | T90 | N | 55.1 | 12.1 | Brinkhof *et al.*, 2022 | Barents Sea study but included for contrast |
| Y | NEA | NWW | cod.27.7e-k | OTB | 100 | T90 and 1 m (RFL) | N | 39 | 7.4 | STECF PLEN 20-01 | |
| Y | NEA | NWW | cod.27.7e-k | OTB | 110 | 120 mm SMP and 1 m RFL | N | 44 | 9.2 | STECF PLEN 20-01 | |
| Y | NEA | NWW | cod.27.7e-k | OTB | 120 | 1 m RFL | N | 42 | 9 | STECF PLEN 20-01 | |
| Y | NEA | NWW | cod.27.7e-k | OTB | 100 | 2x4 mm; 100 meshes | Y | 32.7 | 7 | Madsen & Ferro, 2003 | |
| | NEA | NWW | had.27.6b | OTB | 120 | | Y | 32.1 | 6.1 | Madsen & Ferro, 2003 | |
| | NEA | NWW | had.27.6b | OTB | 110 | 110mm SMP/9-12m | N | 33.13 | 7.67 | BIM, 2009 | |
| | NEA | NWW | had.27.6b | OTB | 110 | 110mm SMP/9-12m | N | 34.03 | 13.81 | BIM, 2009 | |
| | NEA | NWW | had.27.6b | OTB | 120 | 120mm SMP/9-12m | N | 38.07 | 10.07 | BIM, 2009 | |
| | NEA | NWW | had.27.6b | OTB | 100 | 120mm SMP/6-9m | N | 39.17 | 10.83 | BIM, 2009 | |
| | NEA | NWW | had.27.7a | OTB | 120 | | Y | 33.3 | 6.6 | Madsen & Ferro, 2003 | |
| | NEA | NWW | had.27.7b-k | OTB | 80 | | N | 24.23 | 11.2 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 90 | | N | 27.67 | 13.05 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 90 | 120mm SMP/9-12m | N | 34.47 | 18.3 | BIM, 2010 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEA | NWW | had.27.7b-k | OTB | 100 | | Y | 27.95 | 11.86 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 120 | | N | 42.73 | 9.02 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 80 | | N | 21.33 | 11.57 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 80 | 120mm SMP/9-12m | N | 28.21 | 14.84 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 110 | | N | 32.39 | 19.45 | BIM, 2010 | |
| | NEA | NWW | had.27.7b-k | OTB | 100 | T90 and 1 m RFL | N | 32.9 | 5.8 | STECF PLEN 20-01 | |
| | NEA | NWW | had.27.7b-k | OTB | 100 | 160 mm SMP and 1 m RFL | N | 38.8 | 15.2 | STECF PLEN 20-01 | |
| | NEA | NWW | had.27.7b-k | OTB | 110 | 120 mm SMP and 1 m RFL | N | 36.4 | 8.6 | STECF PLEN 20-01 | |
| | NEA | NWW | had.27.7b-k | OTB | 120 | And 1 m RFL | N | 35.9 | 6 | STECF PLEN 20-01 | |
| | NEA | NWW | ple.27.7a | OTB | 120 | | Y | 26.4 | 2.6 | STECF PLEN 20-01 | |
| | NEA | NWW | whg.27.6a | OTB | 110 | 110mm SMP/9-12m | N | 38.67 | 8.9 | BIM, 2009 | |
| | NEA | NWW | whg.27.6a | OTB | 110 | 110mm SMP/9-12m | N | 36.17 | 10.19 | BIM, 2009 | |
| | NEA | NWW | whg.27.6a | OTB | 120 | 120mm SMP/9-12m | N | 47.2 | 12.09 | BIM, 2009 | |
| | NEA | NWW | whg.27.6a | OTB | 100 | 120mm SMP/6-9m | N | 48.72 | 17.5 | BIM, 2009 | |
| Y | NEA | NWW | whg.27.7a | OTB | 120 | | Y | 38.7 | 11.1 | Madsen & Ferro, 2003 | |
| Y | NEA | NWW | whg.27.7a | OTB | 80 | 120 mm SMP | N | 32.9 | 9.4 | Madsen & Ferro, 2003 | |
| | NEA | NWW | whg.27.7b-ce-k | OTB | 100 | T90 and 1 m (RFL) | N | 38.4 | 10 | STECF PLEN 20-01 | |
| | NEA | NWW | whg.27.7b-ce-k | OTB | 100 | 160 mm SMP and 1 m RFL | N | 52.2 | 13.5 | STECF PLEN 20-01 | |
| | NEA | NWW | whg.27.7b-ce-k | OTB | 110 | 120 mm SMP and 1 m RFL | N | 42.3 | 11.9 | STECF PLEN 20-01 | |
| | NEA | NWW | whg.27.7b-ce-k | OTB | 120 | And 1 m RFL | N | 41.7 | 11.4 | STECF PLEN 20-01 | |
| | NEA | NWW | whg.27.7b-ce-k | OTB | 90 | | N | 31.06 | 9.57 | BIM, 2010 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEA | NWW | whg.27.7b-ce-k | OTB | 90 | 120mm SMP/9-12m | N | 37.24 | 9.01 | BIM, 2010 | |
| | NEA | NWW | whg.27.7b-ce-k | OTB | 100 | | Y | 35.96 | 14.04 | BIM, 2010 | |
| | NEA | NWW | whg.27.7b–ce–k | OTB | 110 | | N | 37.43 | 17.97 | BIM, 2010 | |
| | NEA | SWW | hke.27.3a46-8abd | OTB | 55 | | Y | 19.77 | 12.84 | Valerias *et al.*, 2014 (DESCARSEL) | Baseline mesh size in 9a |
| | NEA | SWW | hke.27.3a46-8abd | OTB | 70 | T90 | N | 22.45 | 8.26 | Valerias *et al.*, 2014 (DESCARSEL) | |
| | NEA | SWW | hke.27.3a46-8abd | OTB | 55 | | Y | 13.5 | | Anon., 2022 | Baseline mesh size in 9a |
| | NEA | SWW | hke.27.3a46-8abd | OTB | 70 | | Y | 23.1 | | Anon., 2022 | Baseline mesh size except in 9a |
| | NEA | SWW | hke.27.3a46-8abd | OTB | 80 | | N | 15.68 | 7.92 | Cuende *et al.*, 2022 | |
| | NEA | SWW | hke.27.3a46-8abd | OTB | 60 | | N | 23.49 | 4.36 | Cuende *et al.*, 2022 | |
| | NEA | NWW | hke.27.3a46-8abd | OTB | 110 | 110mm SMP/9-12m | N | 30.6 | 33.96 | BIM, 2009 | |
| | NEA | NWW | hke.27.3a46-8abd | OTB | 120 | 120mm SMP/9-12m | N | 50.07 | 29.68 | BIM, 2009 | |
| | NEA | NWW | hke.27.3a46-8abd | OTB | 100 | 120mm SMP/6-9m | N | 37.4 | 21.6 | BIM, 2009 | |
| | NEA | NWW | hke.27.3a46-8abd | OTB | 90 | | N | 30.68 | 12.87 | BIM, 2010 | |
| | NEA | NWW | hke.27.3a46-8abd | OTB | 90 | 90+120 mm SMP | N | 32.3 | 17.8 | BIM, 2010 | |
| | NEA | NWW | hke.27.7e-k | OTB | 110 | | N | 38.11 | | BIM, 2010 | |
| | NEA | NWW | hke.27.7e-k | GNS | 94 | | N | 65.9 | | Anon., 1993 | |
| | NEA | NWW | hke.27.7e-k | GNS | 106 | | N | 74.3 | | Anon., 1993 | |
| | NEA | NWW | hke.27.7e-k | GNS | 115 | | N | 80.6 | | Anon., 1993 | |
| | NEA | NWW | hke.27.7e-k | GNS | 126 | | N | 88.3 | | Anon., 1993 | |
| | NEA | NWW | hke.27.7e-k | GNS | 155 | | N | 108.6 | | Anon., 1993 | |
| | NEA | NWW | hke.27.7e-k | GNS | 80 | | Y | 56,28±9,3 | | BIM, 2011 | Baseline mesh size in 8c and 9 |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEA | NWW | hke.27.7e-k | GNS | 100 | | Y | 70,36±11,63 | | BIM, 2011 | Baseline mesh size except in 8c and 9 |
| | NEA | NWW | hke.27.7e-k | GNS | 120 | | N | 84,43±13,95 | | BIM, 2011 | |
| | NEA | NWW | hke.27.7e-k | GNS | 140 | | N | 98±16,06 | | BIM, 2011 | |
| | NEA | NWW | hke.27.7e-k | GNS | 80 | | Y | 54±8,2 | | Revill *et al.*, 2007 | Baseline mesh size in 8c and 9 |
| | NEA | NWW | hke.27.7e-k | GNS | 100 | | Y | 63±7,3 | | Revill *et al.*, 2007 | Baseline mesh size except in 8c and 9 |
| | NEA | NWW | hke.27.7e-k | GNS | 120 | | N | 76±8,7 | | Revill *et al.*, 2007 | |
| | NEA | NWW | hke.27.7e-k | GNS | 140 | | N | 88±10,2 | | Revill *et al.*, 2007 | |
| | NEA | SWW | hke.27.8c9a | OTB | 55 | DM | N | 15.9 | 3 | Campos *et al.*, 2003 | |
| | NEA | SWW | hke.27.8c9a | OTB | 60 | DM | N | 17.4 | 3.8 | Campos *et al.*, 2003 | |
| | NEA | SWW | hke.27.9a | GNS | 70 | | N | 40,1±2,42 | | Dos Santos *et al.*, 2001 | |
| | NEA | SWW | hke.27.9a | GNS | 80 | | Y | 46,7±2,82 | | Dos Santos *et al.*, 2001 | Baseline mesh size in 8c and 9 |
| | NEA | SWW | hke.27.9a | GNS | 90 | | N | 51,1±3,08 | | Dos Santos *et al.*, 2001 | |
| | NEA | SWW | hke.27.9a | LLS | | Hook size 10 | N | 45,6±4,98 | | Dos Santos *et al.*, 2001 | |
| | NEA | SWW | hke.27.9a | LLS | | Hook size 9 | N | 45,6±4,71 | | Dos Santos *et al.*, 2001 | |
| | NEA | SWW | hke.27.9a | LLS | | Hook size 7 | N | 44,4±4,61 | | Dos Santos *et al.*, 2001 | |
| | NEA | SWW | hke.27.9a | LLS | | Hook size 5 | N | 45,3±4,97 | | Dos Santos *et al.*, 2001 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 100 | 90mm SMP/6-9m | N | 28.55 | 12.77 | BIM, 2008 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 110 | 90mm SMP/6-9m | N | 31.02 | 7.35 | BIM, 2008 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 110 | 120mm SMP/6-9m | N | 32.04 | 9.74 | BIM, 2008 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 90 | | N | 33.75 | 17.38 | BIM, 2010 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 90 | 120mm SMP/9-12m | N | 33.2 | 14.58 | BIM, 2010 | |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NEA | NWW | meg.27.7b-k8abd | OTB | 100 | | Y | 34.61 | 11.03 | BIM, 2010 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 120 | | N | 41.24 | 9.53 | BIM, 2010 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 80 | 120mm SMP/9-12m | N | 29.09 | 15.59 | BIM, 2010 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 100 | 120mm SMP/9-12m | N | 38.8 | 16.16 | BIM, 2010 | |
| | NEA | NWW | meg.27.7b-k8abd | OTB | 110 | | N | 38.53 | 14.74 | BIM, 2010 | |
| | NEA | NWW | hke.27.3a46-8abd | OTB | 110 | | N | 38.11 | 7.56 | BIM, 2010 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 40 | 20 mm grid/40 mm codend | N | 18.9 | 3.4 | Massutì *et al.*, 2009 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 40 | 20 mm grid/40 mm codend | N | 16.8 | 4.1 | Sardà *et al.* 2004 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 50 | DM | Y | 14.5 | NA | Larraneta *et al.*, 1969 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 52 | DM | N | 15.2 | NA | Larraneta *et al.*, 1969 | |
| Y | MED | WM | HKE.01_05_06_07 | OTB | 40 | SM | Y | 17.64 | 7.4 | Sbrana *et al.*, 2022 | |
| Y | MED | WM | HKE.01_05_06_07 | OTB | 50 | SM | N | 22.19 | 5.03 | Sbrana *et al.*, 2022 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 50 | SM | N | 20.9 | 5.1 | Sbrana *et al.*, 2022 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 40 | SM | Y | 17.2 | 2.4 | Baro *et al.*, 2007 | |
| | MED | WM | HKE.01_05_06_07 | OTB | 40 | SM | Y | 16 | 4.8 | Bahamon *et al.*, 2006 | |
| Y | MED | WM | HKE.08_09_10_11 | OTB | 40 | SM | Y | 17.62 | 6.35 | Brcic *et al.*, 2018 | |
| | MED | WM | HKE.08_09_10_11 | OTB | 50 | DM | Y | 13.71 | 3.37 | Brcic *et al.*, 2018 | |
| | MED | WM | HKE.08_09_10_11 | OTB | 60 | DM | N | 15.5 | 4.8 | Lembo *et al.*, 2002 | |
| | MED | WM | HKE.08_09_10_11 | GNS | 53 | DM | N | 29 | | Sbrana *et al.*, 2007 | estimated by applying the bi-modal function SELECT method, |
| | MED | WM | HKE.08_09_10_11 | GNS | 62.5 | DM | N | 34 | | Sbrana *et al.*, 2007 | estimated by applying the bi-modal function SELECT method, |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MED | WM | HKE.08_09_10_11 | GNS | 70 | DM | N | 38 | | Sbrana *et al.*, 2007 | estimated by applying the bi-modal function SELECT method, |
| | MED | WM | HKE.08_09_10_11 | GNS | 82 | DM | N | 43 | | Sbrana *et al.*, 2007 | estimated by applying the bi-modal function SELECT method, |
| | MED | ALL | HKE.08_09_10_11 | OTB | 40 | SM | Y* | 14.88 | 4.5 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| Y | MED | ALL | HKE.08_09_10_11 | OTB | 55 | SM | N* | 20.46 | 8 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | CEM | HKE.17_18 | OTB | 60 | DM | N | 16.6 | 4.6 | Soldo, 2004 | |
| Y | MED | CEM | HKE.17_18 | OTB | 40 | SM | Y | 15.7 | 8.68 | Sala & Lucchetti, 2010 | |
| | MED | CEM | HKE.17_18 | OTB | 56 | DM | N | 16.25 | 7.56 | Sala & Lucchetti, 2011 | |
| | MED | CEM | HKE.17_18 | OTB | 54 | T90 | N | 21.26 | 7.02 | Petetta *et al.*, 2020 | |
| Y | MED | CEM | HKE.17_18 | OTB | 55 | SM | N* | 20.46 | 8 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | CEM | HKE.19 | OTB | 40 | SM | Y | 14.9 | 5.9 | Aydin & Tosunoglu, 2010 | L50 and SR From GSA 22 paper cited in Lucchetti *et al.* 2021 |
| | MED | CEM | HKE.19 | OTB | 50 | DM | Y | 14.4 | 6.3 | Dereli & Aydin, 2016 | L50 and SR From GSA 22 paper cited in Lucchetti *et al.* 2021 |
| Y | MED | ALL | HKE.19 | OTB | 40 | SM | Y* | 14.88 | 4.5 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| Y | MED | ALL | HKE.19 | OTB | 55 | SM | N* | 20.46 | 8 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| Y | MED | ALL | HKE.20 | OTB | 40 | SM | Y* | 14.88 | 4.5 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | MED | ALL | HKE.20 | OTB | 55 | SM | N* | 20.46 | 8 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | HKE.20 | OTB | 40 | SM | Y | 14.9 | 5.9 | Aydin & Tosunoglu, 2010 | L50 and SR From GSA 22 peper cited in Lucchetti *et al.* 2021 |
| | MED | ALL | HKE.20 | OTB | 50 | DM | Y | 14.4 | 6.3 | Dereli & Aydin, 2016 | L50 and SR From GSA 22 peper cited in Lucchetti *et al.* 2021 |
| | MED | EM | HKE.22 | OTB | 50 | DM | Y | 11.4 | 4.6 | Tosunoglu *et al.*, 2008 | |
| | MED | EM | HKE.22 | OTB | 50 | DM | Y | 14.4 | 6.3 | Dereli & Aydin, 2016 | |
| | MED | EM | HKE.22 | OTB | 40 | SM | Y | 15.5 | 4.7 | Özbilgin *et al.*, 2012 | |
| | MED | ALL | HKE.22 | OTB | 55 | SM | N* | 20.46 | 8 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | EM | HKE.22 | LLS | | Hook VMC brand - size 6 | NA | 60.09 | | Öztekin *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |
| | MED | EM | HKE.22 | LLS | | Hook VMC brand - size 7 | NA | 51.45 | | Öztekin *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |
| | MED | EM | HKE.22 | LLS | | Hook VMC brand - size 8 | NA | 46.43 | | Öztekin *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |
| | MED | EM | HKE.22 | LLS | | Hook VMC brand - size 9 | NA | 40.11 | | Öztekin *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |
| | MED | EM | HKE.28 | GNS | 28 | DM | N | 30.61 | | Deniza *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |
| | MED | EM | HKE.28 | GNS | 30 | DM | N | 32.8 | | Deniza *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |
| | MED | EM | HKE.28 | GNS | 32 | DM | N | 34.99 | | Deniza *et al.*, 2020 | estimated by applying the bi-modal function SELECT method, |

| Plotted | Region | Area | Stock | Gear type | Mesh size | Gear Specification | Baseline | $L_g50$ (cm) | $SR_g$ (cm) | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | MED | ALL | HKE | OTB | 40 | DM | N* | 10.86 | 3 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | HKE | OTB | 40 | DM | N* | 10.18 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 40 | SM | Y* | 14.88 | 4.5 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 40 | SM | Y* | 12.67 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 50 | DM | Y* | 13.58 | 5 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 50 | DM | Y* | 12.73 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 50 | SM | N* | 18.6 | 7 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 50 | SM | N* | 15.84 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 55 | SM | N* | 20.46 | 8 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 55 | SM | N* | 17.42 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 60 | DM | N* | 16.29 | 6 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 60 | DM | N* | 15.27 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 70 | DM | N* | 19.01 | 6.5 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 70 | DM | N* | 17.82 | | Lucchetti *et al.*, 2021 | |
| | MED | ALL | HKE | OTB | 75 | DM | N* | 20.36 | 7 | Lucchetti *et al.*, 2021 | SR estimated from Fig. 1 in Lucchetti *et al.* 2021 |
| | MED | ALL | MUT | OTB | 75 | DM | N* | 19.09 | | Lucchetti *et al.*, 2021 | |

* Hypothetical $L_g50$ scenario based exclusively on the mean Selection Factor (SF) calculated using the data and mesh size and geometry obtained from the review.

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## 10 List of Background Documents

Background documents are published on the meeting's web site on: https://stecf.jrc.ec.europa.eu/ewg2219

List of background documents:

EWG-22-19 – Doc 1 - Declarations of invited and JRC experts (see also section 7 of this report – List of participants)

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STECF

The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.