WORKSHOP TO SCOPE AND PRESELECT INDICATORS FOR CRITERION D3C3 UNDER MSFD DECISION (EU) 2017/848 (WKD3C3SCOPE)

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i Executive summary

The workshop to scope and preselect indicators for Descriptor 3 criterion 3 under MSFD Commission Decision (EU) 2017/848 (WKD3C3SCOPE) provided a platform for experts from the EU member states and relevant regional bodies to meet and support development and progress the assessment methodology, based on a request by the EC (DGENV). WKD3C3SCOPE is the first of a series of three workshops (WKD3C3THRESHOLDS and WKSIMULD3) to provide guidance in relation to operational indicators for MSFD D3C3.

The workshop was organized as a series of presentations with intermittent group discussions. On the first day of the workshop the participants discussed what defines a 'healthy population structure' for species with different life history traits (ToR a). During the following days, the group discussed and identified relevant D3C3 indicators (ToR b) and developed criteria to select among the identified D3C3 indicators to allow further testing and setting of thresholds at WKD3C3THRESHOLDS (ToR c).

The participants found that overall, healthy fish stocks are characterized by high productivity, wide age and size structuring in the population, and the ability to quickly recover from disturbances. The groups noted that environmental factors, along with stock biomass and fishing pressure, influence the productivity and health of a stock, with environment playing a particularly large role in the recruitment of short-lived stocks. It was suggested that the age structure of a stock might be more relevant for evaluating the health of long-lived stocks. However, it was acknowledged that not all stocks have sufficient data to evaluate all proposed indicators, and a single indicator is unlikely to suffice for all stocks. Data availability, species-specific factors and regional or sub-regional variation are thus also important considerations.

In relation to ToR b, the participants presented their work on potential indicators including: recruitment time-series, proportion of fish larger than the mean size of first sexual maturation, F_{rec}/F_{bar}, length distribution L_{90}, relative proportion of old fish above A_{90}, indicators of spawner quality, and SSB/R. A discussion on pros/cons, benefits to the population of high or low indicator values, benefits supported by empirical evidence, applicability to data-poor stocks and benefits supported by simulation/theoretical considerations followed the presentations.

Finally, in relation to ToR c, the difficulty emerged in ranking the indicators alone without considering the data used to estimate them and a new set of evaluation criteria for use in WKD3C3THRESHOLDS were defined.

Based on the outputs of the meeting a list of indicators to be further evaluated has been drafted, which also emphasizes the stocks for which studies have empirically demonstrated effects on productivity. In addition to the listed indicators, indicators of genetic diversity and proportion of fish with parasite infestation were mentioned but to the knowledge of the participants, widespread data for these are currently not publicly available.

ii Expert group information

Expert group name	WKD3C3SCOPE –Workshop to scope and preselect indicators for criterion D3C3
Expert group cycle	Annual
Year cycle started	2023
Reporting year in cycle	1/1
Chair(s)	Anna Rindorf, Denmark
	Giuseppe Scarcella, Italy
Meeting venue(s) and dates	12-14 June 2023, online, 45 participants

1 Workshop approach

The meeting commenced with a brief introduction by EC (DGENV) on the motivation for the workshop and proceeded with a round of introduction of all participants. The workshop agenda was briefly described and agreed upon. The workshop was organized as a series of presentations with intermittent group discussions (6-8 people per group, participants randomly assigned). Groups were given a specific set of questions to address and reported back to plenary, where comments could be made and questions asked. Presentations focused on D3C3 of the MSFD, the use of state and pressure indicators in the MSFD and on specific suggested indicators.

1.1 Workshop background

The Marine Strategy Framework Directive aims to ensure the sustainable use of the marine environment across Europe and to achieve Good Environmental Status (GES) by 2020. Assessments of the state of fish and shellfish population are required under both the CFP and the MSFD Descriptor 3: Commercial fish and shellfish (D3).

The assessment of stock status under the CFP uses the well-established indicators fishing mortality rate (F) and spawning-stock biomass (SSB). These have also been adopted for use under the MSFD (criteria D3C1 and D3C2 of Commission Decision (EU) 2017/848) to ensure that a single-stock assessment can serve the purposes of both the CFP and the MSFD. Under the MSFD, a third criterion (D3C3) is included in order to evaluate good environmental status, reflecting the age and size distribution of individuals in a population, D3C3, defined as: *'Populations are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock'*).

ICES has previously advised on possible approaches to assessing D3C3 and made proposals for suitable indicators (ICES 2016, 2017) but common indicators and threshold values have yet to be agreed upon. Furthermore, it should be noted that Commission Decision (EU) 2017/848 also states that the Member States shall establish threshold values through regional or subregional cooperation for each population of species in accordance with scientific advice obtained pursuant to Article 26 of Regulation (EU) No 1380/2013. Previous ICES advice investigated indicators for aspects such as: number or biomass of old fish, proportion of large or old spawners and the 95th percentile of length of individuals in the population. The indicator mean length in the catch was considered to reflect fisheries selectivity and therefore not directly related to D3C3 while the indicator proportion of mature fish in the stock was considered to be highly impacted by recruitment.

Since then, additional suggestions include indicators for CFP management like size selectivity of fisheries ('Lopt', STECF 2020) and the age-based selectivity indicator for juvenile fish (Vasilakopoulos et al., 2020). While these indicators have a clear link to the objectives of the CFP, it remains unclear whether they are appropriately placed under D3C3 as they are linked directly to fishing pressure rather than stock status and health.

The recently published MSFD guidance (European Commission, 2022) highlighted the need to develop D3C3 indicators with threshold values that are compatible with the threshold values of D3C1 and D3C2 to ensure simultaneous assessment of GES and to expand the focus of D3C3 beyond size and age to include aspects of recruitment, individual growth, condition and natural mortality.

DGENV requested ICES to:

1. Define characteristics of a *'healthy population structure'* for species with different life history traits and identify relevant indicators for these characteristics.
2. Identify thresholds of *'healthy population structure'* indicators and for species with different life history characteristics.
3. Explore the relationship between population traits/dynamics and healthy population structure' indicators and thresholds through simulations and infer cases where management in the context of CFP objectives -and equally of MSFD D3C1 and D3C2- alone may be insufficient and additional management measures should be envisaged. In such cases, and depending for example on the characteristics and exploitation patterns of the populations concerned, suggest a set of management options, ranked in decreasing order of expected effectiveness.
4. Advise indicators and thresholds most suitable for D3C3 assessment for species with different life history characteristics, giving preference to indicators that are derived from easily collected data (*e.g.* data routinely collected under the DCF).
5. Prepare a framework for comprehensively assessing D3 criteria for commercially-exploited fish and shellfish populations (= stocks), including data-limited stocks

To answer this request, ICES will organize 3 workshops. WKD3C3SCOPE, WKD3C3THRESHOLDS and WKSIMULD3. For details on dates and terms of reference, please see the ICES webpage: https://www.ices.dk/community/groups/Pages/WKD3C3SCOPE.aspx

1.2 Setting of WKD3C3SCOPE in relation to WKD3C3THRESHOLDS and WKSIMULD3

The three workshops on D3C3 in this series each cover separate aspects. The first workshop WKD3C3Scope identifies characteristics of healthy populations, indicators to measure these health characteristics and criteria to select among indicators at the second workshop WKD3C3THRESHOLDS (18-21 September 2023). At WKD3C3THRESHOLDS, the aim is to calculate for as many as possible of the suggested D3C3 indicators, and to validate and evaluate for a selection of stocks representing different life-histories, data availability and MSFD (sub)regions. Subsequently, thresholds for these indicators are to be suggested together with consequences for the stock if health indicators fall below the threshold. The consistency and complementarity with D3C1 (FMSY) and D3C2 (MSYBtrigger) is evaluated and a framework for the comprehensive assessment of D3 stocks is to be drafted. The framework will include data requirements to assess D3, recommended indicator(s) for the assessment of D3C3 that are compatible with D3C1 and D3C2 and methods to set thresholds and reference levels. The third workshop WKSIMULD3 will explore the relationships between indicators of population traits/dynamics and healthy population structure through simulation. The workshop will infer cases where management under CFP objectives alone may be insufficient and rank potential management options in decreasing order of expected effectiveness to remedy adverse effects on or of stock health.

1.3 Setting of D3C3 among D1, D3 and D4 criteria

The MSFD potentially includes commercial fish under three descriptors: D1 Biodiversity, D3 Commercial Fish and Shellfish and D4 Foodwebs. The three descriptors differ in the species and stocks addressed as well as in the criteria evaluated. Under Descriptor 1, species sensitive to human pressure and/or listed in the Habitat Directive are in focus but these can be supplemented with assessment of species that are commercially exploited, in which case their status is assessed using the criteria from Descriptor 3. Under Descriptor 3, the stocks contributing the most to landings weight and value, as listed by WKD3Lists2, are included. Under Descriptor 4, all species contribute to the biomass, diversity and productivity of their guild but they are not evaluated as individual species. The criteria used under D1C1 to C3 are similar to those used under D3C1 to C3. An overview with example species is given in table 1.1.

Table 1.1. Overview of species and indicators included under Descriptors 1, 3 and 4.

Descriptor	D1	D3	D4
Species/stocks covered	Species sensitive to human pressure and/or listed in the Habitat Directive	Stocks making up the majority of commercial landings see WKD3Lists2)	All species allocated to guilds
Example species	Conger eel, Monkfish, elasmobranchs	Hake, Anchovy, Monkfish	All species monitored
Example indicators	Bycatch numbers or rate in fisheries (D1C1), Catch rate in surveys (D1C2), production of young/condition/length structure (D1C3), extent of distribution and favourable habitat (the last only if not assessed under D3, D1C4 and D1C5)	Fishing mortality (D3C1), spawning biomass (D3C2), further indicators as identified under WKD3C3SCOPE (D3C3)	Diversity of guild in species (D4C1) and size (D4C3), total biomass of e.g. planktivores and top predatory fish (D4C2), productivity of guild (could be recruitment/growth, D4C4)

1.4 State and pressure indicators under the CFP and MSFD D3C1, D3C2 and D3C3

The Commission Decision (EU) 2017/848 ('GES Decision' hereafter) divides the MSFD Descriptors into those '*linked to* (…) *anthropogenic pressures*', i.e. D2, D3, D5, D6 (D6C3-C5), D7, D8, D9, D10, D11, and those '*linked to* (…) *ecosystem elements*', i.e. D1, D4, D6 (D6C1-C2). These descriptors are commonly referred to as 'pressure' and 'state' Descriptors respectively. D3 is specified as a 'pressure' Descriptor, as it refers to commercial fisheries (EU 2017). However, most Descriptors carry criteria related to both state and pressure. For example, D3C1 is the only D3 Criterion referring to a pressure *per se* (fishing mortality; F), while D3C2 and D3C3 refer to the state of commercial stocks; i.e. spawning-stock biomass and population structure, respectively (Table 1.2). D3C3, as it is currently worded in the GES Decision, refers to a 'state' attribute of a 'pressure' Descriptor.

The D3 criteria also differ in other ways (Table 1.2). D3C1 and D3C2 are quantified using a single type of indicator: F and SSB (or similar), respectively, and are closely linked to the CFP and their thresholds are based on the MSY principle. For D3C3, several types of indicators have been suggested and the principles on which their thresholds should be defined are not always clear or harmonized. Reporting by Member States (MS) in response to MSFD Art. 8, 9 and 10 (Vasilakopoulos et al. 2021), and MSFD Art. 11 (Tornero Alvarez et al. 2023) is far more comprehensive for D3C1 and D3C2 than D3C3 (Table 1.2).

The low reporting under D3C3 compared to D3C1 and D3C2 is largely due to the scarcity of specific or harmonized indicators with associated thresholds and a lack of EU regulations, other than the MSFD, relevant to D3C3. A recent cross-descriptor analysis of the availability of threshold-setting methods and threshold values for the different MSFD Criteria showed how links to mature EU regulations can benefit the development of indicators and associated thresholds for the MSFD (Vasilakopoulos et al., 2022).

Table 1.2 Main characteristics of the three D3 Criteria.

D3 Criteria	Type	Indicator	Related regulation	Reporting/Monitoring by MS
D3C1: Fishing mortality rate is at or below levels which can produce MSY	Pressure	F or similar	CFP	Good
D3C2: Spawning-stock biomass is above levels capable of producing MSY	State	SSB or similar	CFP	Good
D3C3: The age and size distribution of individuals is indicative of a healthy population	State	Several	-	Poor

Candidate indicators relevant to D3C3 could be either of the ‘state’ or the ‘pressure’ type (Table 1.3). The GES Decision text on D3C3 refers to two indicator groups: those related to the age/length structure of the population and those related to maturity. Nevertheless, more indicators have been explored and proposed by dedicated ICES workshops (WKIND3.3i & ii; ICES 2016; 2017), the ICES technical guidance document (ICES, 2021), the MSFD guidance document and scientific papers (Vasilakopoulos et al. 2020; Probst et al. 2021; Probst 2023) (Table 1.3). While the pressure indicators have a clear link to the objectives of the CFP, it remains unclear whether they are appropriately placed under D3C3 as they are linked directly to fishing pressure rather than stock status and health.

Table 1.3. Some candidate indicators for D3 split according to type ('state' or 'pressure') and their rationale. The set of indicators is not exhaustive. CFP: Common Fisheries Policy (Regulation (EU) 1380/2013, EU 2013); TMR: Technical Measures Regulation (Regulation (EU) 2019/1241, EU 2019)

Type	Indicators	Rationale	Refs	Comments
State	Number or biomass of old fish	Ensure stock resilience by maintaining high numbers or proportion of old and large spawners	ICES 2016; 2017; 2021; Probst et al. 2021	Reflect GES Decision 2017/848 and guidance document (European Commission, 2022) Evaluated but not operationalized by WKIND.3.3i & ii
	Proportion of large or old spawners			
	95th percentile of length of individuals in the population			
	Proportion of fish in the stock that are mature			considered by WKIND3.3ii (ICES 2017) to be highly impacted by recruitment
	Recruitment or Recruitment/SSB	Adjustment D3C1 and D3C2 thresholds if necessary due to changes in productivity of stock reflecting environmental conditions	ICES 2021, European Commission 2022	Expanding the scope of D3C3 as suggested in guidance (European Commission 2022)
	Growth			
	Condition			
	Natural Mortality			
	Maturity, PMRN	Assess impacts of fisheries induced evolution	Heino et a. 2002	
	SSB/R	Assess impacts of selective fishing	Probst 2023	
Pressure	Maintain or increase mean length in the catch, possibly relative to Lopt	Assess fisheries selectivity for comparison with levels needed to safeguard juveniles	ICES 2016; 2017;	

Type	Indicators	Rationale	Refs	Comments
	Maintain or increase length/age at first capture		ICES 2016; 2017; Vasilakopoulos et al. (2016); STECF (2021)	considered by WKIND3.3ii to reflect fisheries selectivity and therefore not directly related to D3C3 Provide closer link to fisheries regulations (CFP; TMR) Can be managed and regulated more directly
	Maintain or decrease F of juveniles relative to older fish (e.g. Frec/Fbar; Fjuv/Fmax etc.)		Vasilakopoulos et al. (2020); Probst et al. (2021); STECF (2020; 2021)	Some selectivity indicators work better than others (Vasilakopoulos et al. 2020) Ongoing work in the framework of TMR

2 ToR a: Define characteristics of a 'healthy population structure' for species with different life history traits

Participants were randomly divided into five groups and asked to discuss what healthy means in the context of fish stocks. Each participant then suggested identifying characteristics of specific stocks for them to be considered healthy and the group then discussed why these characteristics are important to the health of the stock and whether there were common characteristics across the examples mentioned.

2.1 Group 1

The group considered it a central paradigm that healthy stocks provide good recruitment and allow population persistence under disturbance. Recruitment depends on spawning-stock biomass (SSB) with a good age structure as well as the environmental factors. As a generic rule, for short lived species environmental factors may be more important than the size and condition of the spawning stock, whereas stock age structure could be more relevant for longer lived species. Recruitment refers to the recruitment to the fishery, which always depends on natural mortality (M). Monitoring natural mortality might provide a good indicator of the potential that a stock can thrive. However, recruitment to the targeted size and age classes of a stock may also be impaired by bycatch of juveniles, especially in mixed-fisheries such as demersal fisheries in the North Sea.

Especially for long-lived species, a healthy stock age and/or size structure could include the occurrence of megaspawners (very large and old individuals). Maturity was also considered as an important generic life-history trait, which, however, is already captured to an extent within the metric of spawning-stock biomass (SSB). The group also noted that there was a generic optimal size selectivity for the fishery, a factor that could also warrant further exploration.

2.2 Group 2

The group considered that a healthy stock is characterized by a low fishing mortality (F), high SSB (values of either maximum SSB or SSB corresponding to MSY were mentioned), a good age structure/length distribution, genetic diversity, few parasites and high individual condition. Stocks suggested as examples being in good health were round sardine, horse mackerel and red mullet.

2.3 Group 3

The group considered it a central theme that the stock must be able to maintain recruitment and biomass and therefore should be able to recover quickly from perturbations such as a few poor recruitment or survival years. It was considered that a wide age distribution with larger and older individuals in the stock would enhance this persistence. The proportion of older fish may however be more relevant for long lived species than for short lived species where different/other metrics will be needed. The group suggested that the healthiest stock would be a stock that is not fished and that this could therefore be used as a starting point in the definition of thresholds. The group also considered that MSY management could be used as a guide to set thresholds that will ensure MSY. Finally, the group noted that the MSFD is assessed over 6 years and there may be a lag in D3C3 status that is not present in pressure indicators such as fishing mortality.

2.4 Group 4

The group considered that a healthy stock is not overexploited, diverse in size and genetic composition, has a biomass above agreed reference points and has a high productivity (high recruitment and growth, low natural mortality). Other health characteristics were considered to be a good proportion of large individuals, the capability of the stock to provide enough yield and foodweb services, high genetic diversity, reproductive potential and stock resilience and ability to recover from fluctuations. The group also discussed that it was unclear how distributional and range changes impacts stock health. The characteristics of a healthy stock may differ between short lived species, cephalopods and longer-lived species. It is preferable if variation in the indicators relative to their associated thresholds reflects shifts from a healthy to non-healthy state.

2.5 Group 5

The group considered that healthy stocks are characterized by resilient populations, that can support human needs as well as foodweb needs even when facing perturbations. The group also discussed that there is already, in essence, a definition of healthy stocks in the MSFD and whether that should be used instead of the more open approach we employ here. The group considered that some stocks may need specific indicators (e.g. region or stock specificity), and it is not likely that one indicator will meet the needs of all. It is important for the evaluation of the health characteristics that the necessary data are there and that the principles used under D3C3 are in line with principles of other descriptors. The group noted that it is important to decide on the list of species and stock. Recreational fishing can be important for some stocks (even more than commercial fishing) and for these stocks, it is necessary to include recreational data in stock assessments. Stock data categories are also important as not all health characteristics can be measured for all types of data: many stocks do not have recruitment, age or even length information and using indicators based directly on these will not be possible (ICES 2023a). Thus, the work here should try to define core principles for the assessment approach to D3C3.

2.6 Synthesis of characteristics of healthy populations

It was broadly considered a central paradigm that healthy stocks allow population persistence under disturbance by exhibiting a sufficiently high productivity through high recruitment, condition and growth, a sufficiently low natural and fisheries related mortality. As a result of these aspects, a healthy stock will have a high biomass with a relatively wide age structure for the given species and will be able to recover quickly from perturbations such as a few poor recruitment or survival years. Several groups noted that a wide age distribution may be important. This and other factors may have greater benefits in long lived than short lived stocks, and as a result, these stock types may require different definitions of a healthy stock. Other characteristics of healthy populations identified included a diverse age and/or length distribution, high genetic diversity, healthy maturity ogives and low parasite load. The issue of the D3 approaches in general being developed for fish and only rarely applied to cephalopods, molluscs and to some degree crustaceans was also mentioned. It was mentioned that environment as well as stock biomass impacts productivity and health of a stock, and that the effect of environment is particularly high for recruitment and short lived stocks whereas stock age structure could be more relevant for longer lived stocks. Further, not all stocks will have data available to estimate all suggested indicators. It was considered unlikely that one indicator will meet the needs of all stocks as is the case for D3C1 and D3C2.

A range of principles which potentially can be used to define healthy stock indicator thresholds (the topic of WKD3C3THRESHOLDS) were mentioned. These included in random order:

- Level of the indicator when the stock is fished according to MSY principles and provides for human needs
- Level of the indicator when the stock provides for foodweb needs
- Level of the unfished stock
- Level at which the indicator aspect is not healthy (e.g. recruitment declines) following principles of D3C2
- Level of indicator of stocks considered to be in good health (round sardine, horse mackerel and red mullet)

The characteristics of a fishing mortality and biomass being, consistent with thresholds defined under D3C1 and D3C2 was also mentioned by several groups, but as these descriptors already have indicators and thresholds defined, they were not included in this synthesis.

3 ToR b: Identify relevant D3C3 indicators for characteristics

3.1 Approach

In advance of the meetings, participants were encouraged to present potential indicators. The aim was to gather as many as possible approaches presented in a harmonized format to facilitate review. The list therefore cannot be considered all-encompassing but does provide a strong overview of potential indicators. Transferring all options through the subsequent testing and evaluation phases will also be a key component of the work ahead.

Indicator presentations were associated with an indicator overview stating:

- Name of the indicator
- Short description
- Reference
- Pressure or state indicator?
- Aspect of health addressed
- Benefit to the population of high or low indicator values
- Benefits supported by empirical evidence
- Benefits supported by simulation/theoretical considerations
- CV of indicator

The information presented at the workshop was not restricted to these topics.

3.2 Summary of indicators suggested in the Article 8 MSFD Assessment Guidance

The D3C3 indicators mentioned in the Article 8 MSFD Assessment Guidance 2022 (European Commission, 2022) were summarized and included:

- Length - Median, 95 % or other quantiles of length of individuals in the population.
- Age distribution - Median/mean, 95 % or other quantiles of age of individuals in the population
- Maturity - Length at 50 % maturity or age at 50 % maturity
- Recruitment or Recruitment per spawner.
- Individual growth - Mean weight-at age-anomaly averaged across appropriate ages
- Condition - Mean condition or mean relative condition
- Natural mortality - Estimated natural mortality

3.3 Indicators in use in Spain in 2012

In 2012, ICES undertook a process to provide guidance to support EU Member States (MS) in the implementation of the Marine Strategy Framework Directive, focused on Descriptor 3 (D3), commercially exploited fish and shellfish (ICES, 2012). Based on the assessment a potential framework for a core set of ICES indicators on ecological impacts of fishing was proposed. They were merged in two groups: i) Species covered by stock assessments and ii) Species covered by survey monitoring programmes. For commercial populations that do not have full assessments, scientific monitoring surveys were identified as a potential data source for calculating some secondary indicators. For species covered by stock assessments, the indicators were i1. Fishing mortality F and i2. Spawning-stock biomass SSB. For species covered by survey monitoring programmes, the indicators were ii1. Ratio between catch and biomass index; ii2. Biomass indices; ii3. Proportion of fish larger than the mean size of first sexual maturation; ii4. Mean maximum length across all species found in research vessel surveys; ii5. 95% percentile of the fish length distribution observed in research vessel surveys and ii6. Size at first sexual maturation. In 2012, Spain reported the results of D3 based on indicators i.1 and i.2 and indicators ii.3, ii.4 and ii.5. Since then, the only indicators provided were those for species covered by stock assessments. The following indicators could potentially also be included: a) Recruitment (obtained from stock assessment or from surveys, but this would require growth information); b) Proportion of fish larger than the mean size of first sexual maturation (requires periodic maturity sampling); c) Average somatic condition (calculated as the ratio between individual weight and potential weight based on a length-weight relationship).

This indicators of relevance to D3C3 are summarized below (Table 3.1, 3.2).

Table 3.1. Summary of indicator 'r'

Name of the indicator	R
Short description	Time-series recruitment (from stock assessment or from scientific surveys)
Reference	RFMO and other assessment bodies
Pressure or state indicator?	State indicator
Aspect of health addressed	Productivity of the stock
Benefit to the population of high or low indicator values	Increasing trends will mean increasing productivity
Benefits supported by empirical evidence	High values mean the stock has high productivity
Benefits supported by simulation/theoretical considerations	
CV of indicator	

Table 3.2. Summary of Indicator 'Proportion of fish larger than the mean size of first sexual maturation – spawners and somatic'

Name of the indicator	Proportion of fish larger than the mean size of first sexual maturation
Short description	Part of the population which are potential spawners
Reference	ICES.2012 Marine Strategy Framework Directive - Descriptor 3+, ICES CM 2012/ACOM:62. 173 pp.
Pressure or state indicator?	State indicator
Aspect of health addressed	Proportion mature
Benefit to the population of high or low indicator values	Increasing trends will result from a wide age distribution or declining recruitment

Name of the indicator	Proportion of fish larger than the mean size of first sexual maturation
Benefits supported by empirical evidence	Wide age distribution makes the stock more resilient to recruitment failure in one or a few years.
Benefits supported by simulation/theoretical considerations	
CV of indicator	
Name of the indicator	Somatic condition
Short description	Physiological status or health of an individual, based on length-weight relationships
Reference	Hayes and Shonkwiler (2001); Lloret et al. (2014)
Pressure or state indicator?	State indicator
Aspect of health addressed	Productivity of the stock
Benefit to the population of high or low indicator values	Maintained high somatic condition leads to higher growth and productivity. Low fish condition may increase natural mortality and suppress reproduction, through late maturity, low fecundity, and low larval and juvenile survival
Benefits supported by empirical evidence	Low condition decreases fecundity (Marteinsdottir G. and Begg G.A. (2002)).
Benefits supported by simulation/theoretical considerations	
CV of indicator	

3.4 Frec/Fbar

Fisheries science distinguishes between two distinct aspects of exploitation of commercial stocks: exploitation rate, capturing the fishing intensity and typically quantified by Fbar, and population selectivity, capturing the way that fishing is distributed across the different demographic components of a population. Population selectivity is a result of both the gears used (e.g. choice of mesh size) and fish availability (e.g. due to choice of fishing time and location).

Vasilakopoulos et al. 2020 introduced three ‘utility criteria’ for fisheries selectivity management indicators: i) the ability to track selectivity changes in the fishery; ii) robustness to recruitment variability; iii) robustness to changes in Fbar. Subsequently, a range of different candidate selectivity indicators were tested against these three criteria. First, changes in selectivity, recruitment and Fbar were simulated on a virtual fish stock to study the indicators under controlled conditions. Then, the indicators were applied to six European fish stocks with a known history of technical measures to explore the indicators’ response in real-world situations. This process identified indicators estimated as the ratio of F of small/juvenile fish (Frec – F of the first recruited age class - or similar) to the F of fully selected fish (Fbar or similar) as those fulfilling the three utility criteria. By contrast, catch-based and abundance-based indicators were found to be sensitive to recruitment fluctuations.

Further applications of F-based selectivity indicators were carried out by STECF 20-02 (STECF 2020), STECF 21-07 (STECF 2021), Probst et al. (2021) and Probst (2023). These works applied F-based selectivity indicators to a great variety of fish stocks, illustrating that alternative realizations of the Frec/Fbar indicator, such as Fjuv/Fbar (Fjuv: the average F of the juvenile age classes) and Fjuv/Fapical (Fapical: the F of the fully selected age class), could be also informative.

Currently, the JRC is conducting further research on selectivity indicators to support the implementation of the TMR (Regulation (EU) 2019/1241, EU 2019). This work aims to sharpen the F-based indicator through comparisons of the behaviour of Frec/Fbar, Fjuv/Fbar and Fjuv/Fapical on empirical stocks, and identify relevant thresholds based on the MSY principle.

A key strength of the Frec/Fbar (or similar) indicator is that it reflects processes related to the fisheries selectivity in a way that is robust to both recruitment variability and overall fishing pressure. Additionally, being a ‘pressure’ indicator it responds more directly to management decisions than ‘state’ indicators. Finally, the use of this selectivity indicator would link D3C3 with fisheries regulations (TMR and CFP), similarly to D3C1 and D3C2.

The main limitations of the indicator is that it can be only applied to stocks with age-structured stock assessments and that the quality of the indicator estimates depends on the quality of the stock assessment. The indicator is summarized in the table below.

At present, selectivity indicators such as Frec/Fbar are not explicitly addressed within D3, a fact that has already been noted by Probst et al. (2016). These authors suggest that D3 could reflect the impacts of fishing on exploited stocks more comprehensively, if selectivity was included as an additional pressure indicator within D3.

Table 3.3. Summary of Indicator ‘Frec/Fbar’

Name of the indicator	Frec/Fbar
Short description	Selectivity indicator capturing the differential exploitation of ‘small’ and ‘big’ fish. ‘Small fish’ may refer to first recruited age class (Frec) or juvenile age class(es) (Fjuv), ‘big fish’ may refer to fully recruited age classes (Fbar) or fully selected age class (Fapical)
Reference	Vasilakopoulos et al. 2020
Pressure or state indicator?	Pressure
Aspect of health addressed	Protection of juveniles to attain higher long-term SSB and yields
Benefit to the population of high or low indicator values	Lower values indicate lower relative exploitation of small fish/juveniles, hence the fishery allows more fish to enter the adult fraction.
Benefits supported by empirical evidence	Increased mid/long-term SSB (Vasilakopoulos et al. 2011)
Benefits supported by simulation/theoretical considerations	Increased mid/long-term SSB and yields (Vasilakopoulos et al. 2020; STECF 2021)
CV of indicator	Stock-dependent, but generally lower than catch-based or population-based indicators. Typically <1.

3.5 L90

A suite of size indicators for coastal fish communities in the Baltic Sea have been suggested. including mean and median length, 10th and 90th-percentile of the length distribution (L10, L90), mean length of the 10% largest fish (Lmax), Large Fish Indices, Size-spectra slope and Size-diversity. Östman et al (in press.) compared this suite of size indicators and found good precision and accuracy of most indicators at realistic sample sizes, except for Size-spectra and Size-diversity. Different size indicators were correlated among sites, indicating similar responses to environmental variation. Most size indicators responded positively to lower fishing pressure, especially indicators emphasizing the largest individuals in the population (e.g. L90 and Lmax), whereas eutrophication and physical disturbances had less impact on indicator variation. Östman et al. (in prep.) concluded that size-based indicators aiming at describing the occurrence of larger fish, like L90 and Lmax, are useful for establishing management targets and evaluate the status of coastal fish. Within HELCOM, the indicator L90 was thus agreed upon and implemented in HELCOM HOLAS 3 (the Helcom core indicator 'Size structure of coastal fish', https://indicators.helcom.fi/indicator/coastal-fish-size/) to assess the status of key coastal (non-commercial) fish species. A threshold for good status has been developed (Bolund et al in prep) and likewise implemented within HELCOM HOLAS 3 for the key species perch. A similar logic was also applied to examine some commercial fish stocks in the Baltic Sea (HOLAS 3 Thematic Assessment of Biodiversity). The indicator is summarized in table 3.4.

Table 3.4 Summary of Indicator 'Survey-based L90 for perch in Baltic Sea'

Name of the indicator	Survey-based L90 for perch in the Baltic Sea
Short description	The indicator evaluates the size structure of perch in the Baltic Sea using the size of the fish at the 90th percentile of the length distribution (L90) from fisheries independent surveys (using gillnets and fyke nets). The indicator is also associated with a threshold representing good environmental status.
Reference	Östman et al. in press. ICES J Mar Sci; Bolund et al. in prep; HELCOM HOLAS 3 indicator report: Size structure of coastal fish
Pressure or state indicator?	State
Aspect of health addressed	Size structure of coastal fish populations/stocks in the Baltic Sea
Benefit to the population of high or low indicator values	An indicator value above the threshold indicates a more natural size structure where large fish in the population are present. The presence of large fish does in turn have positive effects for reproduction and trophic regulation in the foodweb.
Benefits supported by empirical evidence	Yes
Benefits supported by simulation/theoretical considerations	To some extent theoretical considerations
CV of indicator	Moderate to low concerning both spatial and temporal variation in the Baltic Sea. The CV of the data used to establish a threshold for the Baltic Sea is 0,1005 in the raw data and 0,0761 in the predicted data from the statistical model used to set the threshold.

3.6 Length-based indicators

The proposed indicator is based on a simulative approach. The model simulates the population dynamic of a fishing stock according to basic parameters such as natural mortality, growth, length-weight relationship, maturity, stock-recruitment relationship, selectivity. Based on these parameters, the simulation generates the population size structure under different fishing mortality (F) scenarios, both in terms of the population at-sea and the catches from commercial fisheries. Regardless of the F value chosen in the initial settings, the simulation considers a period of population growth without fishing mortality that ensures the equilibrium is reached before the stock begins to be exploited.

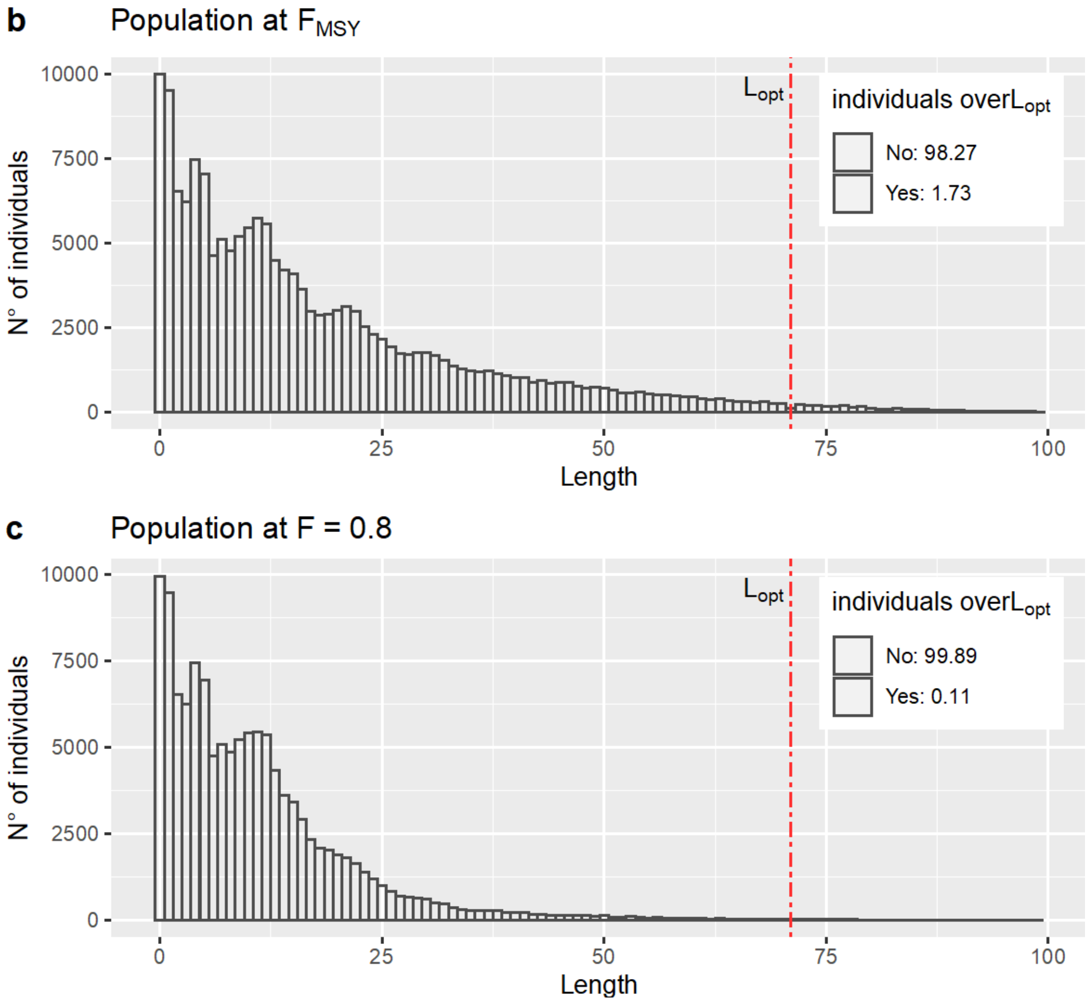

Figure 3.1. Analysis of the population structure for the FAO-GSA 16 (South of Sicily) European hake (Merluccius merluccius) stock. The Length-frequency-distribution (LFD) of the population at sea is displayed, comparing: the simulated structure for a population at a sustainable level of fishing mortality (FMSY) (B) and the population structure at the current level of exploitation (Fcurr) (C). The estimated value of Lopt is represented with a two-dashed red line. The proportion of individuals above Lopt (blue) is also reported in the legend panel.

Simulations can estimate reference points for the most commonly used population structure indicators. These reference values are derived from simulations at F_{MSY}, and both at-sea population structure and catches can then be compared with observed indicator values on commercial catches and scientific survey data. The simulations are carried out under equilibrium conditions, which means under constant recruitment and population parameters over time.

Then, it is possible to extract from the simulations the reference points for the chosen indicators from both a natural population not subject to fishing mortality and from populations exploited at different levels of F. The following indices can be obtained from the simulation:

- **SSB:** Spawning-stock biomass
- **L_{95}**
- **p > L_{50}**: proportion of individuals with size above L_{50}, here understood as the size at which 50% of the individuals are mature (corresponding to L_{mat} in the model parameters)
- **p > L_{95}**: proportion of individuals with size greater than L_{95}
- The same proportions can be also calculated in terms of biomass

These simulations provide an additional tool for calculating the reference points that can also be used for species that are not subject to an official stock assessment. For many of these species, the available data are often lacking and do not allow the application of quantitative stock assessment approaches based on catch/survey data time-series. Simulations were initially conducted on a species already subject to stock assessment and whose parameters are well known (*Mullus barbatus*), to validate the methodology. The approach had been thus extended to species where a stock assessment is lacking (*Helicolenus dactylopterus*, *Phycis blennoides*, *Scyliorhinus canicula*, *Raja clavata*). Simulations were conducted for increasing values of F so that the effect of fishing mortality on population structure could be directly investigated. The simulated population structures obtained were then visually compared with the observed population structures (MEDITS or Commercial Catch) to infer the F_{curr} levels to which the stocks are exposed.

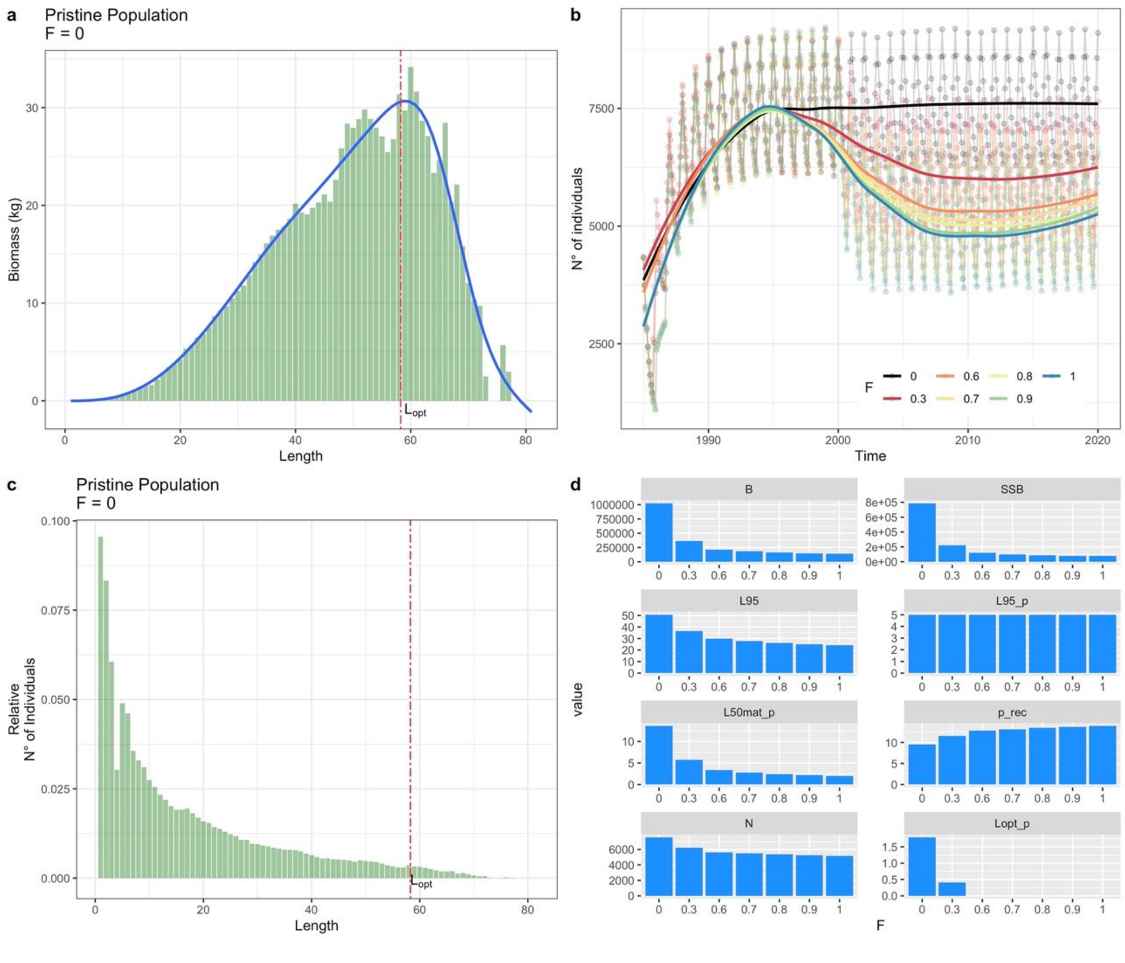

Figure 3.2. Summary of the simulation outputs obtained for the GSA 16 greater forkbeard (Phycis blennoides) stock. Population structure in terms of biomass (A) and relative number of individuals (C) in a pristine population. The red two-dashed line represent Lopt. Number of individuals over a 35-year simulated period under different scenarios of fishing mortality (B). Indicators comparison assuming different degrees of exploitation. The considered indicators are: B – biomass; SSB – Spawning-stock biomass; L95 – L95; L95_p – proportion of individuals > L95; L50mat_p – proportion of individuals > L50; p_rec – recruits percentage over the population; N – total number of individuals; Lopt_p – proportion of individuals > Lopt.

All preliminary simulations were performed using a modified version of the vitualPop() function contained in the "fishdynr" R package (M. Taylor and Mildenberger, 2015).

For a more comprehensive assessment of the impact of fishing on population structure, it was decided to consider an additional parameter: L_{opt}. Although it is not implemented in the Marine Strategy Framework, L_{opt} represents a proxy for the reproductive capacity of the stock. In fact, it indicates the length at which biomass is maximum in a hypothetical unexploited cohort (Froese et al., 2016). The portion of the population above L_{opt} constitutes the fraction of larger/older individuals, including the so-called "mega spawners" that contribute significantly to the reproductive capacity of the stock itself. The L_{opt} value was obtained by considering the maximum value taken by the biomass curve as a function of size class in a pristine simulated population (F = 0). The indicator is summarized below (Table 3.5).

Table 3.5 Summary of Indicator 'Survey-based L90 for perch in Baltic Sea'

Name of the indicator	Length-frequency distribution from a simulated population
Short description	The model simulates the population dynamic to reconstruct the length structure of the stock under different scenarios of fishing mortality
Reference	Moro et al., in prep.
Pressure or state indicator?	State
Aspect of health addressed	It allows to infer the F_{curr} for data-poor species and to extract reference points from simulated population structures at F_{MSY}
Benefit to the population of high or low indicator values	Since it is more an approach than a specific indicator there are no low/high indicator values
Benefits supported by empirical evidence	
Benefits supported by simulation/theoretical considerations	Simulation showed a good adaptation with data-rich species even if some refinements must be done for data-poor stocks
CV of indicator	Since it is a deterministic approach there is no uncertainty in the estimates. However, the simulation considers some randomness in the parameters

3.7 Relative proportion of old fish above A90

The new age-based indicator for commercial stocks (called ABI_{MSY}) describes the proportion of older fish currently in a population (in a given year) relative to the proportion of older fish at equilibrium under constant fishing at F_{MSY} (Griffiths et al. 2023; Figure 4.7.1). Older fish are defined as fish above the age closest to the 90th percentile of the numbers-at-age distribution (often referred to as A90 and shown as A_{MSY} is Figure 4.7.1) at equilibrium when fishing at F_{MSY}. To date, ABI_{MSY} has been applied to 72 Category 1 stocks in the Northeast Atlantic. These data are taken from the FLR (Fisheries Library in R; Kell et al., 2007) stock assessment database that was collated at WKREF1 and is freely available from ICES (ICES, 2022). ABI_{MSY} requires an age-based analytically stock assessment and therefore is only relevant for data-rich stocks.

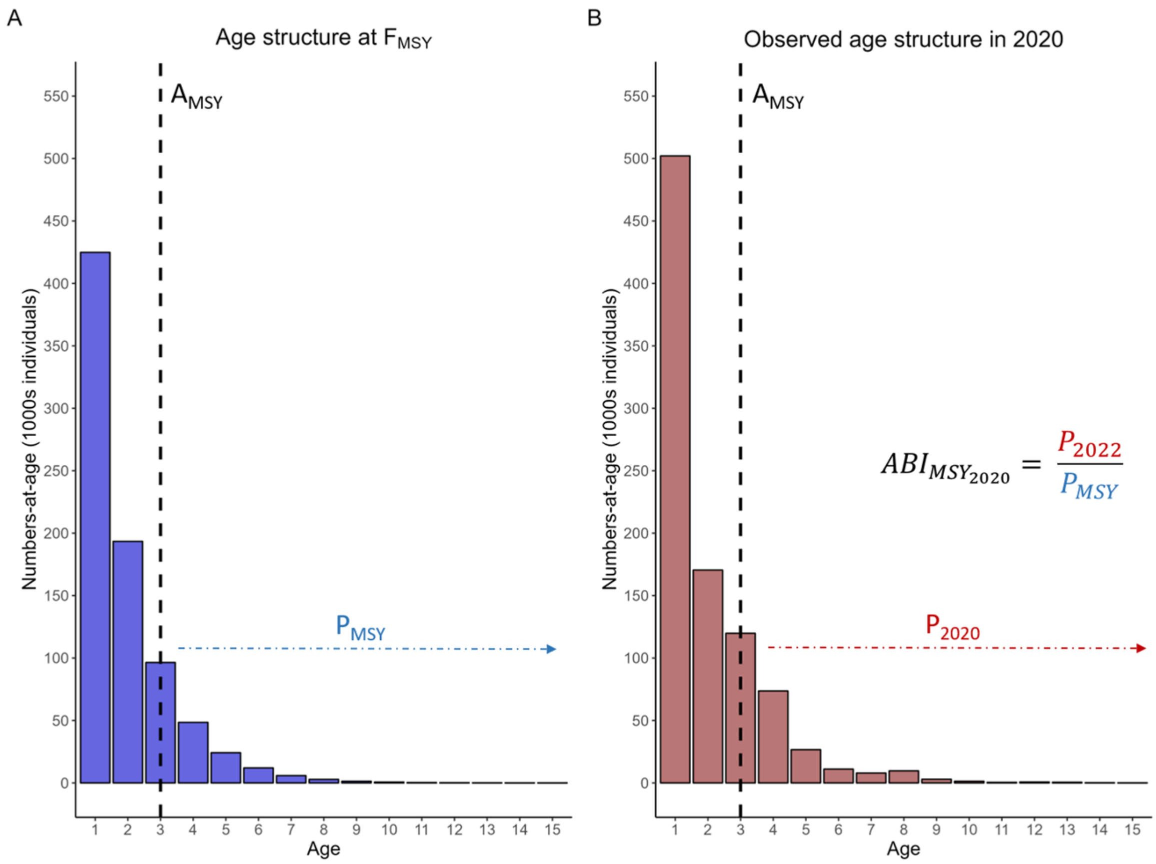

Figure 3.3. Graphical example of the methods used to calculate ABI_{MSY}. Shown is the theoretical age structure at equilibrium under F_{MSY} (A) and the estimated age structure in the final year of the assessment (B). Both age structures relate to the hake (*Merluccius merluccius*) stock (hke.27.3a46-8abd) in the Greater North Sea, Celtic Seas, and the northern Bay of Biscay. Dashed vertical lines illustrate the reference age under F_{MSY} (black; A_{MSY}) conditions, whereby the reference age is the closest age to the 90th percentile of the fish numbers-at-age distribution (the A90 age). P_{MSY} and P_{2020} then represent the proportion of individuals above A_{MSY} and are used to calculate ABI_{MSY} in a given year (here 2020).

The framework (method used to simulate the age structure of a stock to equilibrium) behind ABI_{MSY} is built to be flexible and can consider any biological and fishing pattern assumptions as well as any chosen F (in terms of target F used). To date we have taken assumptions directly from each stock's assessment model, such that they represent our 'best' current understanding of the stock's status, its biology and the F pattern.

The main benefit of ABI_{MSY} is that it is based on the same methodology used for the calculation of SSB and F (and their respective reference points; B_{MSY} and F_{MSY}) and therefore fits nicely within the stock assessment and advice process. It also has a suggested reference point (and threshold), namely the age structure at equilibrium under F_{MSY} (or an F target is F_{MSY} is not available) and therefore shares a common currency with assessments of D3C1 and D3C2. On the topic of GES, we have also calculated ABI_0 which is an additional indicator that compares the proportion of older fish in a population to the proportion of older fish at equilibrium under no future fishing.

The rationale behind ABI_{MSY} is based on the value of having older (and larger) fish in the population, as they are expected to provide greater spawning potential and resilience to perturbations (Barnett et al. 2017; Hixon et al. 2014). An added benefit of ABI_{MSY} is that by comparing to a MSY reference level, indicator values around 1 will indicate the number of older fish that are needed to theoretically sustain B_{MSY} (and F_{MSY}) in the long term.

The current version of ABI_{MSY} is deterministic but work (and funding applications) are ongoing to define both the indicator and the reference point in terms of probability via stochastic simulations. Such future work should also look at recruitment patterns such as pulse recruitment, as seen in stocks like North Sea haddock (*Melanogrammus aeglefinus*; had.27.46a20) and Norwegian spring-spawning herring (*Clupea harengus*; her.27.1-24a514a).

The simulation framework for determining ABI_{MSY} has the potential to test impacts of various ranges of pressure indicators (i.e. F and selectivity indicators) on the stock status (i.e. SSB and the size/age structure), thereby providing an assessment platform that allows to explore the complex interplay between all pressure and state indicators and their potential thresholds. Such a simulation platform could explore the trade-offs between yield and stock size trying to find 'sweet spots' where yield is high while the impacts on the stock size and size/age structure are relatively low. The indicator is summarized below (table 3.6.)

Table 3.6 Summary of Indicator 'ABI_{MSY}'

Name of the indicator	ABI_{MSY}
Short description	ABI_{MSY} describes the proportion of older fish in a population in a given year relative to the proportion of older fish in the population at equilibrium under constant fishing at F_{MSY}. To define older, we have used the number of fish above the 90th percentile of the numbers-at-age distribution. To date, we have applied ABI_{MSY} to 72 Category 1 stocks in the Northeast Atlantic. The framework behind ABI_{MSY} is built to be flexible and can consider many biological and fishing pattern assumptions as well as any chosen F (in terms of target F used; e.g. F target associated to any given B target or F_{SPR0}). Indicator values under F0 are available for comparison. The main benefit of ABI_{MSY} is that is based on the same methodology used for the calculation of SSB and F (and their respective reference points) and therefore fits nicely within the stock assessment and advice process. It also has a reference point, namely the age structure at equilibrium under a given target F.
Reference	Griffiths et al. (2023). Including older fish in fisheries management: a new age-based indicator and reference point for exploited fish stocks. *Fish and Fisheries*. ABI_{MSY} was also presented to WGECO this year (ICES, 2023b) ABI_{MSY} is also used in HELCOM HOLAS III thematic assessment (in prep.)
Pressure or state indicator?	State
Aspect of health addressed	Age structure
Benefit to the population of high or low indicator values	Low indicator values = low relative abundance of older fish possibly limiting spawning potential, resilience and recovery High indicator values = high relative abundance of older fish indicating good spawning potential and resilience and recovery.

Name of the indicator	ABI_{MSY}
Benefits supported by empirical evidence	
Benefits supported by simulation/theoretical considerations	Simulation work has shown that ABI_{MSY} has a good classification skill for the biomass threshold of 80% of B_{MSY} and is capable of tracking changes in both B and F in a range of stocks.
CV of indicator	The current version of ABI_{MSY} is deterministic but work (and funding applications) are ongoing to define both the indicator and the reference point in terms of probability via stochastic simulations.

3.8 Indicators of spawner quality (weight at age, mean age and proportion of old spawners)

Three potential indicators for the age or size structure (average weight-at-age weighted by numbers-at-age), average age in the stock, and the proportion of old spawners) were analysed by (van Deurs et al., 2023) and the contribution of age/size composition to positive recruitment investigated.

The Proportion of old spawners (POS) is defined as

$$POS = \frac{SSB_{old}}{SSB}$$

Where SSB_{old} if the spawning-stock biomass (SSB) over the age a_{old}. This age will vary among stocks. The indicator essentially defined the fraction of the mature stock that it is comprised of old fish. It is measured in biomass rather than in numbers as was the case for the indicator in section 4.7 to reflect that older fish are rarer but produce more spawning products.

The second indicator is the average spawner age (ASA) which is defined as

$$ASA = \frac{\sum_{a_{min}}^{a_{max}} n_a\, m_a\, a}{\sum_{a_{min}}^{a_{max}} n_a\, m_a}$$

Where a is age, n is numbers-at-age, and m is maturity. This indicator calculates the average spawner age, weighted by the cohort sizes, also in biomass.

The final is indicator is the average spawner weight, which takes into account that different years may have changes in weight at age, calculated as

$$ASW = \frac{\sum_{a_{old}}^{a_{max}} n_a \frac{w_a}{\overline{w}_a}}{\sum_{a_{old}}^{a_{max}} n_a}$$

Where w_a is the weight at age, and $\overline{w}_a$is the weight of old spawners. This indicator monitors the relative change in weight across age groups.

A high proportion of old fish and a high average age of spawners did not correlate with high recruitment success. Instead, all stocks showed negative impact of high proportion of old fish and average age, and these relationships were significant for five out of 11 stocks (Figure 3.4). In contrast, mean weight of individuals ASW had a positive effect on 8 of the 10 stocks with significant positive relationships for 3 stocks. Hence, weight-at-age indicators seemed more promising as indicators of aspects aiming to safeguard recruitment.

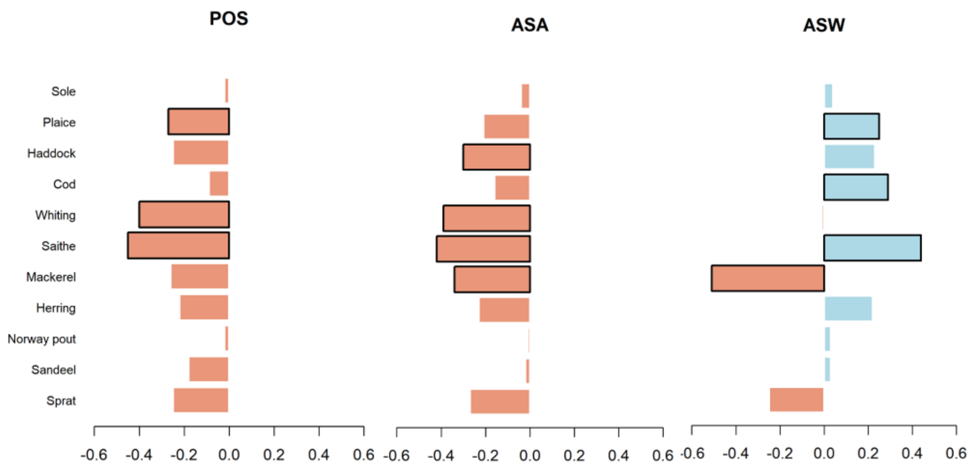

Figure 3.4. Correlation of the annual values of indicators POS, ASA and ASW to recruitment success of stocks in the North Sea. Bars with black outline are significant at the 5% level.

The indicators are summarized below (Tables 3.7, 3.8 and 3.9).

Table 3.7. Summary of Indicator 'Proportion of old spawners (POS)'

Name of the indicator	Proportion of old spawners (POS)
Short description	The indicator measures the relative change in old (age) spawners. $$POS = \frac{SSB_{old}}{SSB_y}$$
Reference	Van deurs et al. 2023
Pressure or state indicator?	State
Aspect of health addressed	Age structure of the spawning stock to provide good recruitment
Benefit to the population of high or low indicator values	Increased fecundity with high values
Benefits supported by empirical evidence	Several studies in the literature, see e.g. Hixon et al 2014
Benefits supported by simulation/theoretical considerations	Some, however the proposed effect on recruitment is unclear.
CV of indicator	

Table 3.8 Summary of Indicator 'Average spawner age'

Name of the indicator	Average spawner age
Short description	The indicator measures the average age of the population $$ASA = \frac{\sum_{a_{min}}^{a_{max}} n_{a,y}\, mat_y a}{\sum_{a_{min}}^{a_{max}} n_{a,y}\, mat_y}$$
Reference	Van deurs et al. 2023
Pressure or state indicator?	State
Aspect of health addressed	Age structure of the entire stock to provide good recruitment
Benefit to the population of high or low indicator values	Increased fecundity with high values
Benefits supported by empirical evidence	Several studies in the literature, see Hixon et al 2014
Benefits supported by simulation/theoretical considerations	Some, however the proposed effect on recruitment is unclear.
CV of indicator	

Table 3.9 Summary of Indicator 'Average spawner weight'

Name of the indicator	Average spawner weight
Short description	The indicator measures the average weight of spawning individuals in a stock $$POS = \frac{SSB_{old}}{SSB_y}$$
Reference	Van deurs et al. 2023
Pressure or state indicator?	State
Aspect of health addressed	Condition and age structure of the stock
Benefit to the population of high or low indicator values	Increased fecundity with high values
Benefits supported by empirical evidence	Several studies in the literature, see Hixon et al 2014
Benefits supported by simulation/theoretical considerations	Some, indication of positive effects on recruitment of some stocks.
CV of indicator	

3.9 SSB/R

Probst (2023) identified SSB/R as a very good proxy for the annual mean age (A_{mean}) within a stock (Figure 4.9.1). Contrary to A_{mean}, SSB/R has the advantage of being easily implementable for a wide array of stocks as time-series of SSB and R are readily accessible (e.g. through the R-package 'icesSAG' or ICES Advice sheets), whereas matrices of number-at-age from analytical stock assessments - which are necessary to calculate A_{mean} - are often only accessible from stock assessment working group reports (from which data has to be cut and copied manually).

The time-series of SSB/R can be assessed in the sense of a surveillance indicator similar to R (see section 4.10). Surveillance indicators are indicators which trigger additional management action once the indicator metric leaves known bounds (Shephard et al., 2015; Rufino et al., 2018). Such additional management actions could be the initiation of a research program or the implementation of more restrictive (and thereby precautionary) management measures.

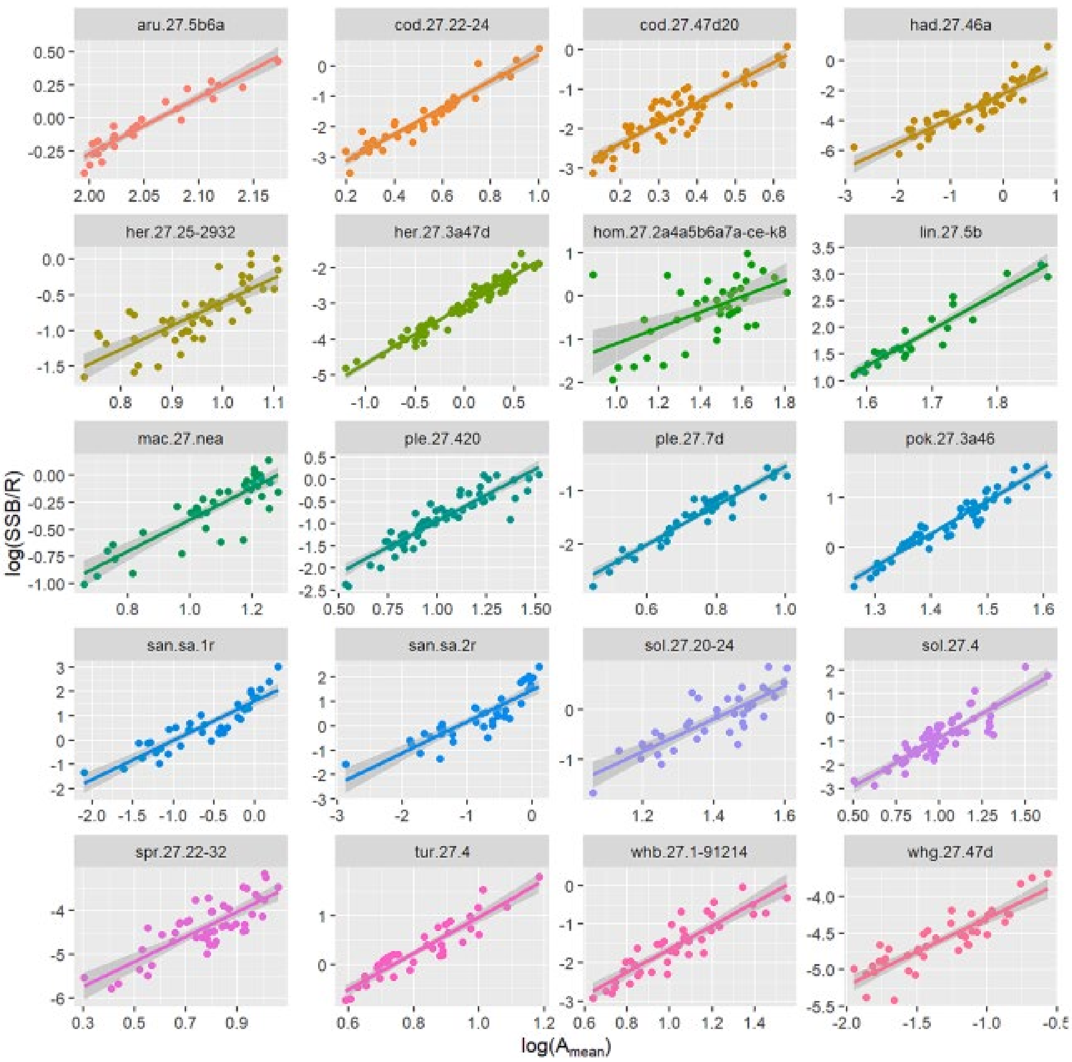

Figure 3.5. Relationships between mean age (A_{mean}) and SSB/R for 24 fish stocks from the North Atlantic. Note the logarithmic scale on both axes.

The indicator is summarized below (Table 3.10).

Table 3.10. Summary of indicator 'SSB/R'

Name of the indicator	SSB/R
Short description	Time-series of ratio SSB/R Threshold is minimum of historic time-series
Reference	Probst, 2023
Pressure or state indicator?	State indicator
Aspect of health addressed	Proportion of old individuals (proxy for mean Age [A_{mean}])
Benefit to the population of high or low indicator values	At high values relative high abundance of old individuals
Benefits supported by empirical evidence	Stocks with large proportion of old individuals might indicate low fishing pressure and hence good conditions for growth and survival
Benefits supported by simulation/theoretical considerations	High abundance of large individuals buffers recruitment against environmental variation
CV of indicator	10s – 100s

3.10 Recruitment indicators

Recruits can be considered as an essential component of the stocks age/size structure representing the productivity of a stock (Probst, 2023). Afterall, recruitment will determine the persistence of a stock through time and will shape other fundamental metrics of the stock such as stock biomass (B or SSB) or the abundance of old individuals in subsequent years. Hence, recruitment is a vital stock parameter and its assessment as a surveillance indicator (Shephard et al., 2015) can be used to determine if a stock is threatened in its persistence and if more precautionary harvest options might need to be considered.

Time-series of recruitment (R) are already a standard product of analytical stock assessments. but it is usually not assessed within the management framework of the CFP. To assess R (and SSB/R as proxy for A_{mean}) the approach by Probst (2023) applies segmented regression to the time-series of R within a reference period to determine a historic minimal mean against which average recruitment in the MSFD assessment cycles (2004-2009, 2010-2015 and 2016-2021) are assessed (Figure 3.6).

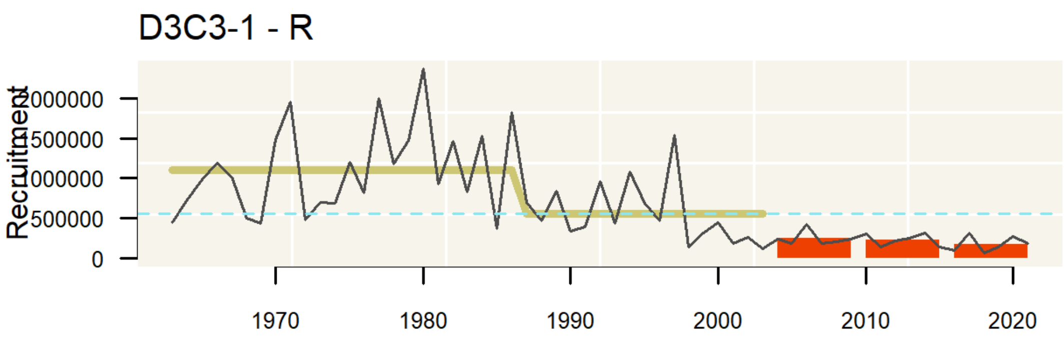

Figure 3.6. Time-series-based assessment of recruitment of North Sea cod Gadus morhua (cod.27.47d20). The brown line represents the segmented regression of the reference time-series to obtain the minimal mean (blue dashed line), which is used as assessment threshold for the six-year means of R in the according MSFD assessment cycles (here red bars).

Recruitment time-series may not be available for all stocks that need to be assessed within the MSFD, but for some stocks proxies for R could be obtained from survey data as suggested by Froese et al. (2015), who converted survey CPUE of juveniles (i.e. individuals < mean-size-at-first-maturity A_{mat}) into biomasses of recruits using length-weight relationships.

The indicator is summarized below (Table 3.11).

Table 3.11. Summary of indicator 'Recruitment (R)'

Name of the indicator	**Recruitment (R)**
Short description	Time-series of recruitment (obtainable from ICES advice sheets) Threshold is minimum of historic time-series
Reference	ICES Advice, STECF
Pressure or state indicator?	State indicator
Aspect of health addressed	Productivity of the stock
Benefit to the population of high or low indicator values	At high values population is viable
Benefits supported by empirical evidence	Stocks with high recruitment will persist, while stocks with low recruitment become scarce and eventually may disappear
Benefits supported by simulation/theoretical considerations	Recruitment is a fundamental process of population dynamics, see Beverton and Holt (1957), (Jennings et al., 2001)
CV of indicator	In the range of recruitment fluctuations

4 ToR C: Develop criteria to select among the identified D3C3 indicators for further testing and setting of thresholds at WKD3C3THRESHOLDS

The participants were divided into five groups and asked to take the evaluation criteria of the Workshop to develop recommendations for potentially useful foodweb indicators (WKFOOWI) as a starting point, identify criteria that were not relevant and add criteria that were missing. The WKFOOWI criteria can be seen in Table 5.1. During the groups, it was considered that it was difficult to rank the indicators alone without considering the data used to estimate them. Further, the criteria ranking was approached quite differently by the different groups. During the reporting back in plenary, the group results were therefore integrated in a joint new set of evaluation criteria for use in WKD3C3THRESHOLDS. These criteria are listed in Table 4.2.

Table 4.1. Criteria from WKFOOWI

Availability of underlying data (Measurable)	Existing and ongoing data, Relevant spatial coverage, Relevant temporal coverage
Quality of underlying data (Sensitivity) (Responsive)	Indicators should be technically rigorous (tangible), Reflects changes in health of stocks, Magnitude, direction and variance of indicator estimable
Conceptual (Theoretical Basis)	Scientific credibility, Associated with Key processes, UnAmbiguous
Communication (Concrete)	Comprehensible
Management (Measurable) (Sensitivity)(Responsive)	Relevant to management, [MSFD] management thresholds (targets) estimable, Cost-effectiveness

Table 4.2. Criteria agreed by WKD3C3SCOPE for WKD3C3THRESHOLDS

Topic	Issue
Availability of underlying data (Measurable)	Data accessible and easy to use for many stocks
	Relevant spatial coverage
	Relevant temporal coverage
Quality of underlying data (Sensitivity) (Responsive)	Indicators should be technically rigorous (well described) and peer reviewed (tangible)
	Reflects changes in health of stocks/key process (identify which)
	Magnitude, direction and variance of indicator estimable
Conceptual (Theoretical Basis)	Threshold clearly linked to poorer health
	Unambiguous

Topic	Issue
Communication (Con'crete) (PubleAware)	Comprehensible – was considered fulfilled for most if not all
Management	Responsive to management decisions - describe which and whether reactive (e.g. climate impact where we need to adapt other criteria targets) or regulatory (e.g. length distribution which can be changed through adapting F)
	Threshold estimable and CV of estimated threshold acceptable
	Cost-effectiveness – not considered relevant for indicators where data are already collected but possibly for new data
Indicator suites (Redundancy)--post criteria evaluation	Indicator correlation and ambiguity – information from indicators that are correlated in time can be useful if a change in correlation will tell you something useful
Type of stock	Fish or shellfish, short-lived or long-lived, sensitive or other
	data needed (age based, length based, catch only)

5 Results for input to WKD3C3THRESHOLDS

Based on the presentations made at WKD3C3SCOPE, participants did not consider that there was a basis for excluding suggested indicators in this first evaluation. Hence, following the workshop, the list of indicators to be evaluated is given in table 6.1 which also emphasis for which stocks studies have empirically demonstrated effects on productivity (all indicators had potential theoretical effects). In addition to the listed indicators, indicators of genetic diversity and proportion of fish with parasite infestation were mentioned but to the knowledge of the participants, widespread data for these are currently not publicly available. Further, the number of stocks with estimated annual values of natural mortality and maturity-at-age are limited. Participants of WKD3C3THRESHOLDS are encouraged to estimate a selection of these indicators and report the information needed to evaluate the indicator for each stock using the criteria in Table 4.2.

Table 5.1. For references, see Table 1.3 and section 3.

Type	Indicators	Rationale
State	Number or biomass of old fish	Ensure stock recruitment and resilience by maintaining high numbers or proportion of old and large spawners
	Proportion of large or old spawners in SSB	
	90^{th} percentile of length of individuals or biomass in the population	
	90^{th} percentile of age of individuals or biomass in the population	
	Proportion of fish in the stock that are mature	
	Maintain or increase mean length in the stock, possibly relative to Lopt	
	Maintain or increase mean age in the stock	
	Recruitment	Adjustment D3C1 and D3C2 thresholds if necessary due to changes in productivity of stock reflecting environmental conditions.
	Recruitment/SSB	
	Recruitment anomaly from stock recruitment relationship	
	Growth: Mean weight at age of all fish or of spawners relative to average weight of the age group	
	Condition: average	
	Natural Mortality	
	Maturity: PMRN	Assess impacts of fisheries induced evolution
	Maturity: Size at first maturity	
	SSB/R	Assess impacts of selective fishing

Type	Indicators	Rationale
Pressure	Maintain or increase mean length in the catch, possibly relative to Lcopt	Assess fisheries selectivity for comparison with levels needed to safeguard juveniles
	Maintain or increase length/age at first capture	
	Maintain or decrease F of juveniles relative to older fish (e.g. Frec/Fbar; Fjuv/Fmax, Fjuv/Fbar etc.)	

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Annex 2: Resolutions

The workshop to scope and preselect indicators for criterion D3C3 under MSFD Decision (EU) 2017/848, chaired by Anna Rindorf, Denmark and Giuseppe Scarcella, Italy, will meet online from 12-14 June to:

a) Define characteristics of a 'healthy population structure' for species with different life history traits
b) Identify relevant D3C3 indicators for these characteristics.
c) Develop criteria to select among the identified D3C3 indicators for further testing and setting of thresholds at WKD3C3THRESHOLDS (18-21 September 2023, pending approval from ACOM)

WKD3C3SCOPE will report by 30 of June 2023 for the attention of ACOM.

Annex 3: Agenda

Time	Issue	Responsible
Terms of Reference	a) Define characteristics of a 'healthy population structure' for species with different life history traits b) Identify relevant D3C3 indicators for these characteristics. c) Develop criteria to select among the identified D3C3 indicators for further testing and setting of thresholds at WKD3C3THRESHOLDS (18-21 September 2023, pending approval from ACOM)	
Monday **June 12th**		
10.00-10.30	Welcome, round of presentation, discussion of scope and terms of reference and adoption of agenda	Anna
10.30-10.45	State and pressure indicators under the CFP and MSFD D3C1, D3C2 and D3C3	Paris
10.45-11.00	Initiatives in the Mediterranean on D3C3	Guiseppe
11.00-11.15	Intro to characteristics of a healthy stock: which characteristics and why are they important?	Anna
11.15-11.45	Definition of characteristics of a healthy stock (tor a)	Groups
11.45-12.00	Coffee break	
12.00-12.30	Definition of characteristics of a healthy stock continued (tor a)	Groups
12.30-13.00	Plenary discussion of characteristics of a healthy stock	Anna
13.00-14.00	Lunch break	
14.00-14.15	Intro criteria D3C3 indicators should fulfil according to the guidance	Anna
14.15-15.15	Definition of criteria D3C3 indicators should fulfil (tor a)	Groups
15.15-15.30	Coffee break	
15.30-16.15	Plenary discussion of criteria for indicators of D3C3	Anna
16.15-16.30	Conclusion on evaluation criteria	
16.30-16.45	Various indicators previously used	Bea
16.45-17.00	Wrap up of day	Anna

Tuesday June 13th		
9.00-9.10	Synthesis of criteria	Anna
	Presentations of potential indicators (tor b)	
9.10-9.25	Frec/Fbar (or similar)	Paris
9.25-9.40	L90	Elisabeth
9.40-9.55	Length based indicators	Stefano
9.55-10.10	Proportion of old spawners	Chris
10.10-10.25	Indicators of spawner quality	Nis
10.25-10.40	R and SSB/R	Nik
10.45-11.00	Coffee break	
11.00-13.00	Presentations of potential indicators (tor b)	
13.00-14.00	Lunch break	
14.00-14.15	Intro to group work to rank potential indicators against agreed criteria (tor c) and discussion of which stocks each indicator is most relevant for (also including non-aged and data limited)	
14.15-15.00	Group work to rank potential indicators against agreed criteria (tor c) and discussion of which stocks each indicator is most relevant for (also including non-aged and data limited)	
15.00-15.30	Status in plenary on ranking	
15.30-15.45	Coffee	
16.00-16.45	Group work to rank potential indicators against agreed criteria continued (tor c)	
16.45-17.00	Wrap up of the day in plenary	
Wednesday June 14th		
9.00-10.45	Agree on criteria and indicators to be further investigated in simulations in WKSIMULD3	
10.45-11.00	Assigning writing tasks	
11.00-14.00	Write report	
14.00-15.30	Go through report conclusions in plenary	
15.30-16.00	Wrap up of the meeting in plenary	