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Report of the Workshop on guidance on development of operational methods for the evaluation of the MSFD criterion D3.3 (WKIND3.3ii)

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Contents

Executive summary

WKIND3.3ii was held from 1–4 November.2016 at ICES headquarters in Copenhagen, Denmark. The meeting was chaired by W. Nikolaus Probst and attended by 12 participants from eight countries.

The workshop was the second part of a workshop series hosted by ICES and requested by the EU-Commission to provide guidance on development of operational methods for the evaluation of MSFD criterion D3.3.

WKIND3.3ii addressed the request by the EU-Commission by addressing the following terms of references (ToR):

a) Explore the data requirements to assess the size distribution of a stock

b) Explore potential size-based indicators (SBI) that are not redundant to D3C1 and D3C2

c) Explore methods to describe the trend over time in SBI

d) Explore the setting of thresholds and reference levels for any potential methods

Based on the outcomes of WKIND3.3i and the preliminary revision process of 2010/477/EU, WKIND3.3ii considered predominantly four different SBI:

- L_{95}: The 95th-percentile of the length-frequency distribution in survey catches (for some stocks may be also obtained from commercial data)
- $cpue_{mega}/SSB_{mega}$: The abundance of mega spawners, either from survey data or from stock assessment data
- P_{mega} : proportion of mega spawners
- P_{mat}: proportion of mature individuals (originally not considered as useful by WKIND3.3i, but maintained by WKIND3.3ii due to the preliminary results of the 2010/477/EU revision).

WKIND3.3ii divided into four sub-groups (SG), which explored data requirements and issues as well as advancing SBI concepts (**SG1**), analysed relationships and potential redundancies between stock indicators (spawning stock biomass, recruitment and fishing mortality) and SBI (**SG2**), reviewed methods for time series based assessments (**SG3**), and modelled SBI performances under different scenarios of fishing (**SG4**). The main findings of the SG were:

- Depending on the considered data sources, the values of SBI will differ. Commercial data may indicate higher abundances of large individuals, whereas survey data may be biased towards higher proportion of small individuals. Careful consideration of best data sources is necessary, probably stock by stock.
- The use of cut-off values (e.g. average-size-at-50%-first maturity, L_{m50}) for L_{95} reduces variability of this indicator due to reduced sensitivity against recruitment. However, cut-off values make L_{95} dependent on the ratio between length at maturity (L_{m50}/L_{inf}) and maximum length (L_{inf}), which is considerably higher e.g. in small pelagic species. Maybe initial reference points may have to be adopted.

- Potential reference points for L_{95}-variants may be based on size of largest cohort biomass (L_{opt}). However, these reference points need further verification especially with regard to potential operationality for GES assessment within the MSFD.
- Absolute SBI i.e. the abundance indices of megaspawners (SSB_{mega} and $cpue_{mega}$) are related to stock size indicators (SSB). Their use in the D3-assessment suggests redundancy between D3.2 and D3.3. However, in restored stocks achieving unprecedented stock sizes, relationships between SSB and SBI may not remain linear and additional information on the stock status may be gained from the assessment of absolute SBI.
- SBI do not show predictable and constant relationships to stock indicators (SSB, R and F). Further work is required to improve understanding of these relationships by including selectivity as a factor and by basing investigations on more exemplary data from a larger variety of stocks. The understanding of relationships between stock indicators and SBI will help to validate and develop new and meaningful reference points.
- Many methods for the time series based assessment of indicators are available. However, at the best, time series based assessment methods can identify different states of an indicator in the past. They cannot replace conceptual reference points based on understanding of mechanistic relationships, but instead may be used as a fall-back option to allow fast implementation of indicators.
- Population models (EQSIM) allowed estimating which SBI-values can be expected under prevailing conditions assuming different intensities of fishing. These values indicate that higher SBI-values can be expected for North Sea cod (cod-347d) when fishing with F_{MSY}. For North Sea plaice (ple-nsea) the SBI values are predicted to remain in the current range. For North Sea autumn spawning herring (her-47d3) SBI are expected to get lower than the current values (because recruitment is predicted to become less productive and hence stock size may become smaller).
- The here presented analysis demonstrates that population models can be helpful tools in predicting the implications of changing fishing intensities on the size structure of the stock. However, the applied models did not account for selectivity and thus fisheries may be further optimised with regards to stock size structure.
- Further work is required to identify if and how GES-thresholds can be derived from population models.

1 Opening of the meeting

WKIND3.3ii was held from 1–4 November 2016 at ICES headquarters in Copenhagen, Denmark. The meeting was chaired by W. Nikolaus Probst and attended by 12 participants from eight countries.

2 Introduction

The Marine Strategy Framework Directive (MSFD) requires each member state of the European Union to assess the status of commercially exploited fish stocks. Additional to assessing the exploitation rate and stock size of all relevant stocks, the MSFD requires the assessment of the stock size or age structure. To facilitate the national MSFD assessments, the European Commission requested advice from ICES on how to perform these assessments. A preceding workshop (WKIND3.3i, 14.–17 March 2016) identified several size-based indicators (SBI) to be potentially relevant for this task. These indicators can be derived from the length-frequency distribution of the stock.

Unfortunately, none of the candidate SBI has currently well-established, biological meaningful assessment reference points. The aim of WKIND3.3ii was to explore methods for establishing such assessments reference points based on biological concepts and/or empirical data.

This led to the formulation of the following advice from ICES in May 2016:

"To provide the requested guidance, ICES evaluated the proposed indicators for MSFD Criterion D3C3 of the size distribution of the stock, the selectivity pattern of the fishery, and the genetic effects of exploitation on the stock, concluding that the indicators are currently neither operational nor fit for the purpose of the assessment of good environmental status (GES). Consequently, ICES advises that these indicators should not be used until usable reference points have been developed."

The current terms of references for WKIND3.3ii were adjusted according to the outcomes of WKIND3.3i and the subsequent ICES advice, in consultation with DGENV as following:

"In light of the recent ICES MSFD guidance on operational methods for the evaluation of the MSFD Criterion D3C3 that concluded that the indicators are currently neither operational nor fit for the purpose of the assessment of good environmental status (GES), the succeeding technical service should be adapted. Instead of a workshop and process to further roll out any new D3C3 methods, ICES is requested to further develop methods to describe the size distribution of a stock. The exploration should focus on:

ToR a) the data requirements to assess the size distribution of a stock

ToR b) potential size-based indicators (SBI) that are not redundant to D3C1 and D3C2

ToR c) methods to describe the trend over time in SBI

ToR d) the setting of thresholds and reference levels for any potential methods"

The revision process of the EU/477/2010 and the outcomes of WKIND3.3i suggest that the workshop should focus on the L_{95} and indicators, which relate to the mature proportion of the stock. However, WKIND3.3i also concluded that P_{mat} by itself is not an appropriate indicator to assess size distributions of fish stocks, but that it would be more meaningful to assess the fraction of the stock, which represents the large, fertile and experienced spawners (so called megaspawners). These individuals may be of special importance for the concept of stock health as specified by the EU/477/2010 (see above).

Hence, WKIND3.3ii analysed the following SBI:

- L_{95}: The 95th-percentile of the length-frequency distribution in survey catches (for some stocks may be also obtained from commercial data)
- $cpue_{mega}$/SSB_{mega}: The abundance of mega spawners, either from survey data or from stock assessment data
- P_{mega} : proportion of mega spawners:
- P_{mat}: proportion of mature individuals

WKIND3.3ii divided into four sub-groups addressing i) advances in relative size-based indicators (SBI), ii) relationships between stock indicators and SBI, iii) reviewing time series based assessment methods and iv) exploring the influence of fishing scenarios on SBI using population models.

3 Sub-group 1: Advances in relative size-based indicators

3.1 Introduction

The size-based indicators (SBI) identified in WKIND3.3i were considered partly to be sensitive to influences of recruitment, which is a well-known problem of relative SBI (Trenkel *et al.*, 2007; Rochet *et al.*, 2010; Trenkel and Rochet, 2010; Probst *et al.*, 2013b). To improve the performance of relative SBI, WKIND3.3ii aimed to test the effect of using various cut-off points in the length-frequency distribution (LFD) to exclude early juveniles from the calculation of SBI. These cut-off points should ensure that mostly the mature fraction of the stock is considered when estimating the 95th-percentile of the length-frequency distribution (L_{95}) or the proportion of megaspawners (P_{mega}).

WKIND3.3ii decided to compare SBI time series of L_{95} against classical fisheries population reference points such as L_{m50}, L_{opt} or $L_{inf,}$ in order to identify possible reference points. WKIND3.3ii analysed time series of SBI and compared the LFD with the indicator performances against potential reference points across several stocks from the Baltic and North Sea.

The objectives of SG1 were to:

- Evaluate different data sources of LFD
- Adjust potential relative size-based indicators (SBI) by using different cut-off points to improve their performance
- Explore potential reference points
- Apply relative SBI to a variety of stocks
- Review strengths and weaknesses

3.2 Material and Methods

Length frequency distributions were aggregated from DATRAS data (‘cpue-by-length-by-subarea’) for the NS-IBTS and for the BITS surveys. Length frequencies were aggregated by length class across all sub-areas and by year. DATRAS cpue-by-length-by-subarea gave better results for length frequencies (higher numbers, no gaps) than DATRAS cpue-by-length-by-area. Length frequencies thus were aggregated by length class across all sub-areas, in which the stock was distributed according to ICES stock assessment descriptions.

DATRAS SMALK data for females were used to determine length-at-50%-maturity (L_{m50}) by fitting an ogive. This worked well for most stocks, with the exception of Baltic sprat (spr-2232) and flounder in the Sounds and Belt Sea (fle-2223), for which too few data were available (see Annex 2). A Wetherall-analysis was used to get a preliminary estimate of asymptotic length (L_{inf}) from the SMALK data. If this method did not converge or the results looked unreasonable compared to the observed maximum lengths, then the median of all annual maximum lengths in DATRAS CPUE-by-length-by-subarea was used to derive a proxy for L_{inf}.

The L_{95} was calculated in three different ways: The normal L_{95} was calculated from the length frequencies of all observed length classes, the $L_{95.mat}$ calculated the 95th-percentile from all frequencies at lengths ≥ $L_{m50,}$ and the $L_{95.5}$ from frequencies at lengths ≥ 0.5 L_{inf}.

The potential reference points, used for the L_{95}-variants (L_{95}, $L_{95.mat}$ and $L_{95.5}$) were calculated as L_{opt} and 1.1 * L_{opt}, where L_{opt} is the length where unexploited cohorts reach maximum biomass, here approximated as 2/3 L_{inf} (Froese *et al.*, 2016).

The R-code (SMALK&CPUE_Analysis_12.r) and the data used (SMALK_NS-IBTS_2016-10-31.csv, NSCPUE per length per subarea_2016-11-02 16_43_26.csv, SMALK_BITS_2016-10-31.csv, BalticCPUE per length per subarea_2016-11-01 15_32_54.csv) are available from the WKIND3.3ii sharepoint in the SG1 directory.

The proportion of mature individuals (P_{mat}) was also calculated from LFD as the ratio between the number of mature individuals and the total number of individuals. The proportion of megaspawners in the mature stock ($P_{mega.mat}$) was calculated as the ratio between the numbers of mature individuals and the number of megaspawners. The number of mature individuals was calculated as the number of all individuals multiplied by the proportion of maturity from the maturity ogive for each length class. The number of megaspawners was calculated as the number of individuals with a size equal to or larger than 1.1 L_{inf}.

The DATRAS data were used to calculate time series of all SBI for 17 stocks. Additionally, for three stocks (North Sea cod, Eastern Baltic cod and North Sea plaice) LFD from commercial catch data and surveys were analysed to compare the representativeness of commercial catch and survey data.

3.3 Results

3.3.1 Differences between commercial and survey data

LFD from commercial catch data were available from WKIND3.3i only for three stocks: Eastern Baltic cod (cod-2532), North Sea cod (cod-347d) and North Sea plaice (ple-nsea).

For Eastern Baltic cod the LFD obtained from commercial data showed a single-modal distribution, whereas the survey LFD from the same years (2000 and 2014, respectively) included different size classes (Figure 3.3.1.1). The representation of large individuals was similar for both data sources.

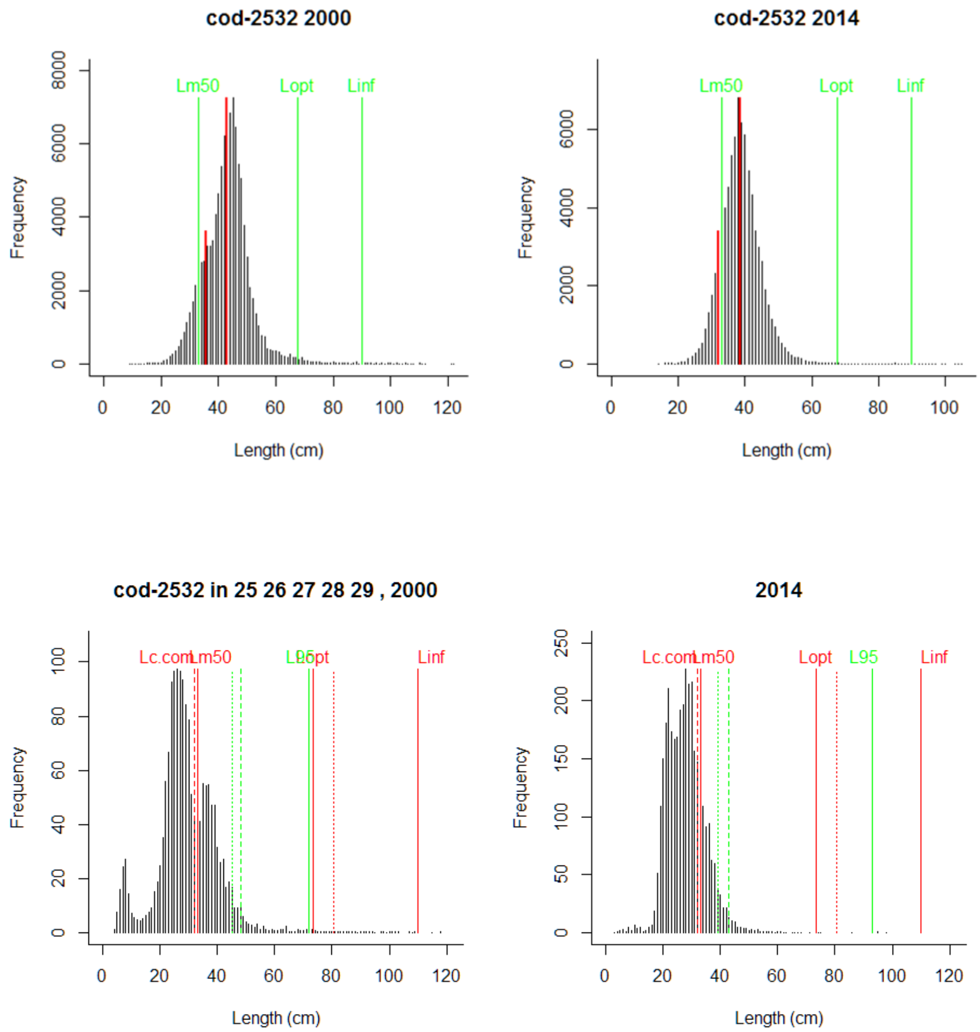

Figure 3.3.1.1. Length-frequency distributions of Eastern Baltic cod from commercial catch data in the years 2000 and 2014 (upper panels) and surveys in the same years (lower panels). In the upper panels the red lines represent values of size-at-first-capture (L_c) and mean-size-in-catch (L_{mean}, see WKIND3.3i report for further details). Green lines represent reference points for L_c (L_{m50}) and L_{mean} (L_{opt}). In the lower panels vertical red lines represent potential cut-off and reference points (LC=Lc.com, Lm50=size at which 50% of all individuals have first-time maturity, Lopt= size of maximum cohort biomass, Linf=maximum size from growth function). Green vertical lines are values of L95 (dotted), L95.mat (dashed) and L95.5 (solid).

Contrary, for North Sea cod the commercial LFD differed substantially from the LFD of survey data in 2010 and 2014 (Figure 3.3.1.2). The commercial catch LFD indicated a considerable higher proportion of large individuals than the survey LFD, in which the proportion of large individuals was substantially lower and indicated strong size truncation. It needs to be clarified why there is such a strong discrepancy between these LFDs.

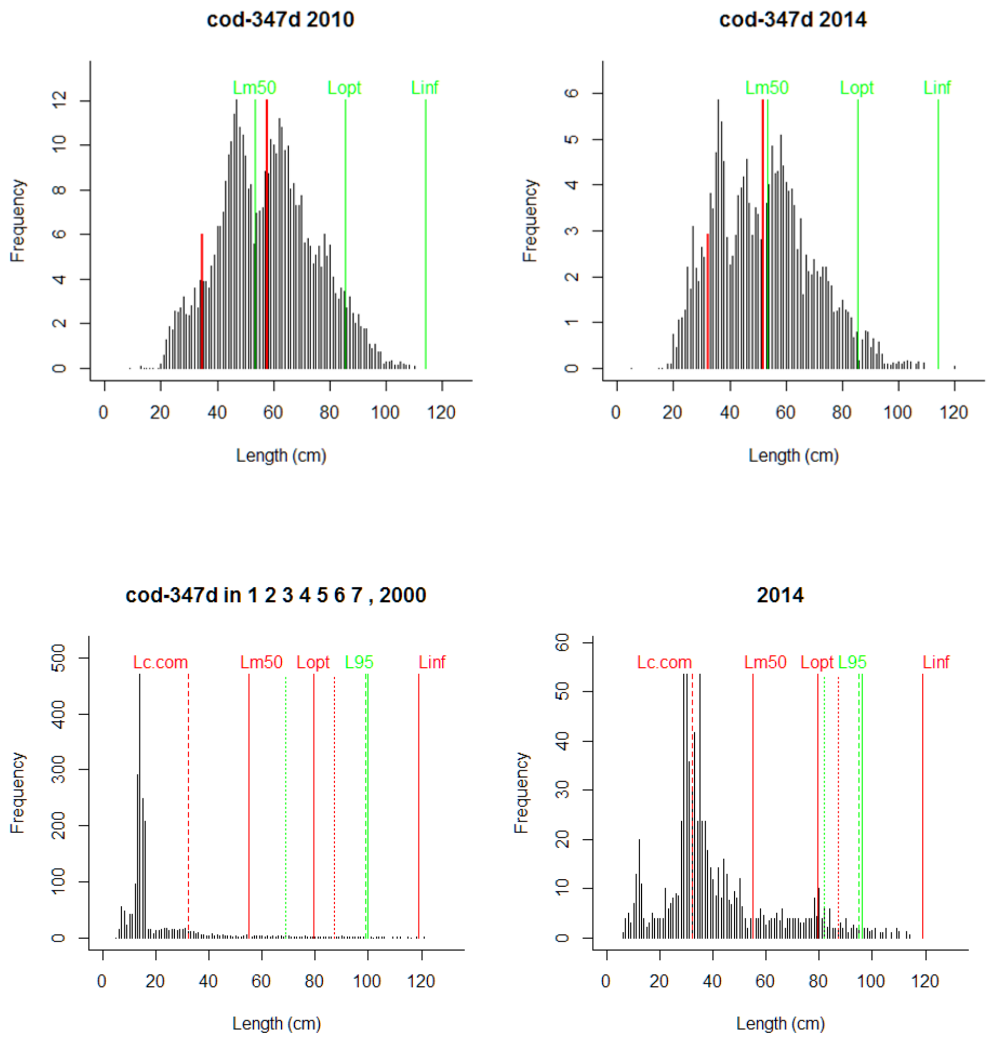

Figure 3.3.1.2: Length-frequency distributions of North Sea cod from commercial catch data in the years 2010 and 2014 (upper panels) and surveys in the years 2000 and 2014 (lower panels). See Figure 3.3.1.1 for details.

LFD from commercial catches and surveys were generally similar for North Sea plaice (Figure 3.3.1.3). However, the LFD from commercial catches appear to be smoother and thus more representative of the true size distribution within the stock, especially when considering the fraction of large individuals.

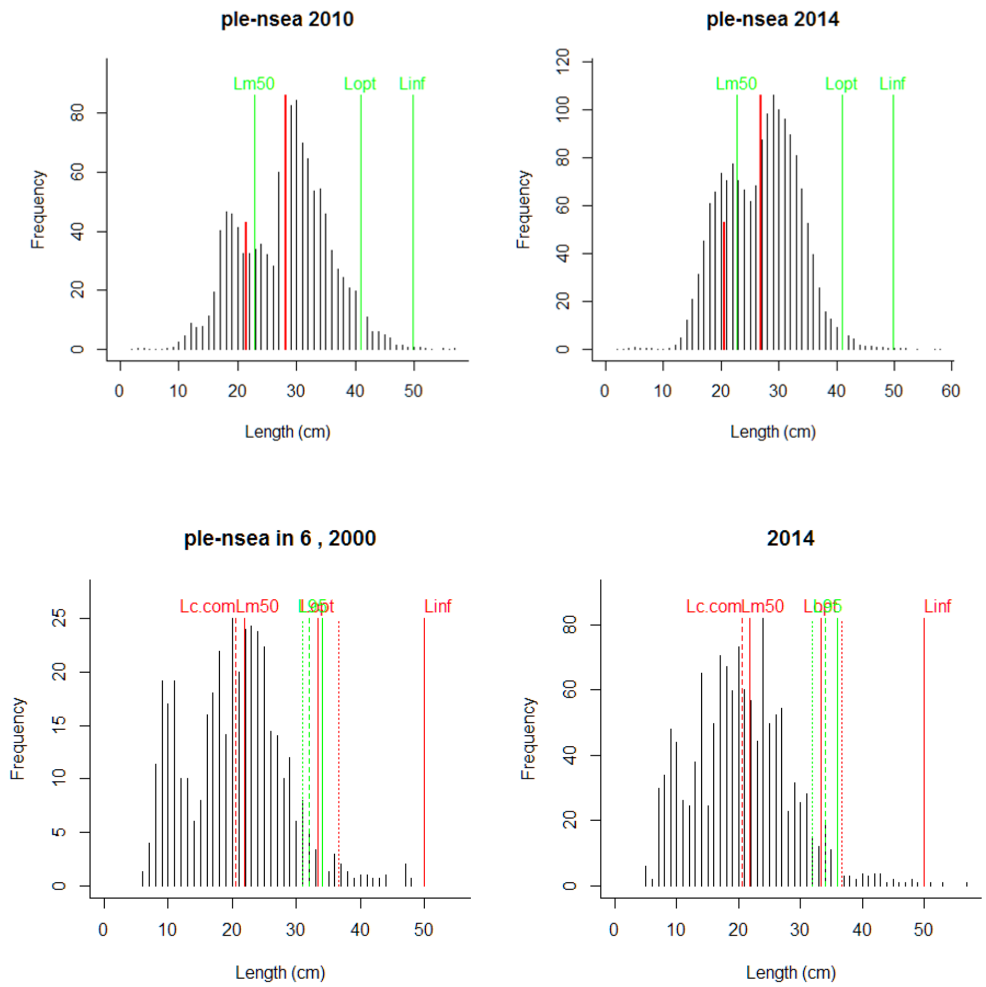

Figure 3.3.1.3. Length-frequencies of North Sea plaice (ple-nsea) in commercial catch in the years 2010 and 2014 (upper panels) and survey data in the years 2000 and 2014 (lower panels). See Figure 3.3.1.1 for details.

3.3.2 The use of different cut-off points for L_{95}

The time series of different L_{95}-variants differed for many stocks, e.g. for North Sea cod (Figure 3.3.2.1). The L_{95} based on all length class frequencies showed higher variability than the $L_{95.mat}$ and the $L_{95.5}$. This might be attributable to higher sensitivities of the L_{95} against recruitment, but the indicator may also better reflect the increasing abundance of megaspawners (see Chapter 4, Figure 4.2.2.1). Thus while $L_{95.mat}$ and $L_{95.5}$ seem to be less sensitive to fluctuations in recruitment, they tend to give more stable assessment results than L_{95}. Generally $L_{95.mat}$ and $L_{95.5}$ appear to be correlated to $P_{mega.mat}$ while L_{95} seems to correlate with P_{mat} (Figure 3.4). When looking at the LFD of North Sea cod from different years (Annex 2), $L_{95.mat}$ and $L_{95.5}$ appear to be also less sensitive to changes in the length structure and seem to underestimate cases of severe size truncation.

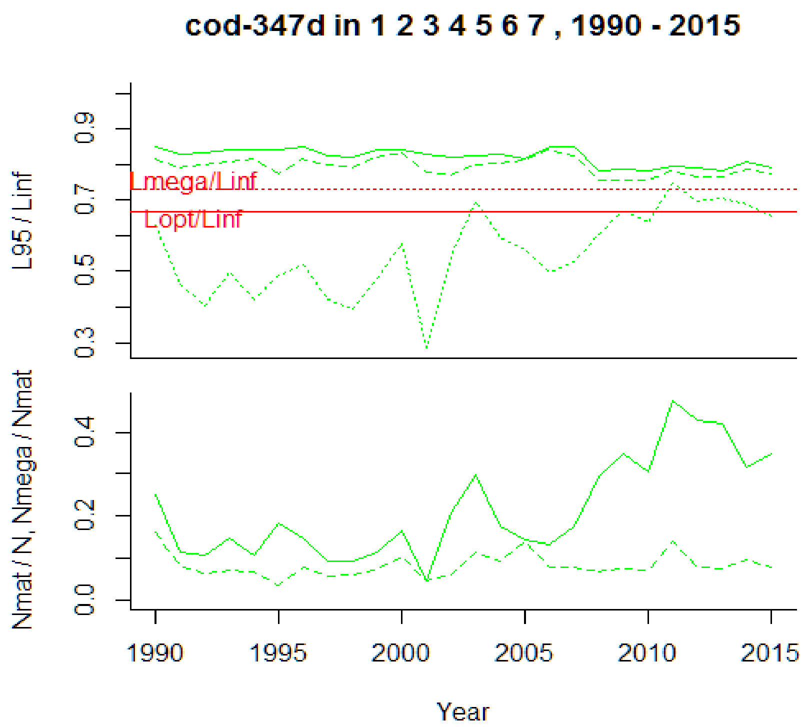

Figure 3.3.2.1. Time series of SBI for North Sea cod (green) calculated from survey data (here NS-IBTS). Upper panel shows the L95 (dotted line), the L95.mat (dashed line) and the L95.5 (solid line). Lower panel shows the proportion of megaspawners (dashed line) and mature individuals (solid line). Horizontal red lines indicate potential reference points.

Depending on the ratio between L_{m50} and L_{opt}, the time series of P_{mat} and $P_{mega.mat}$ were similar or different. For example for North Sea herring L_{m50} and L_{opt} are very close together and thus the indicator time series of $P_{mega.mat}$ and P_{mat} were identical (Figure 3.3.2.2).

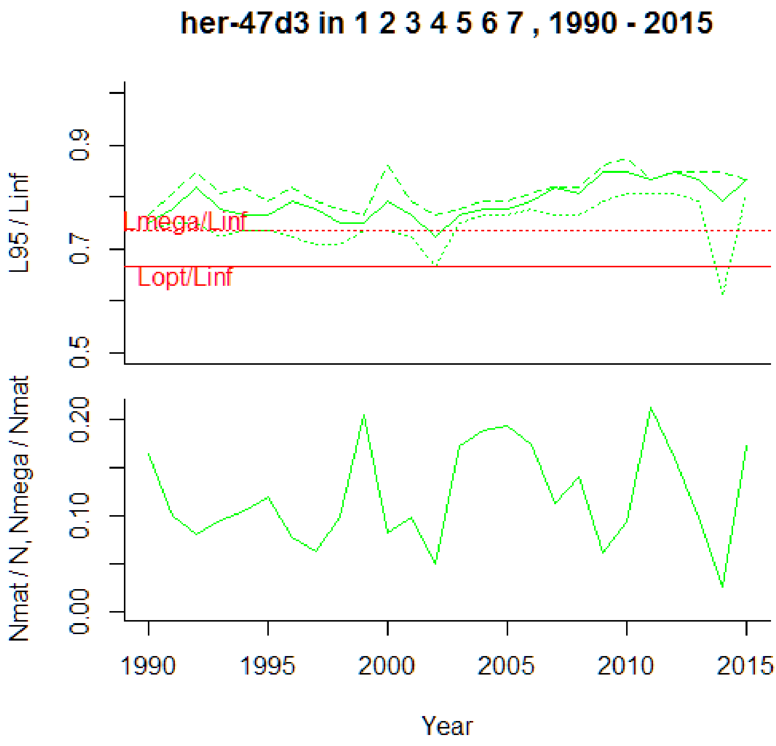

Figure 3.3.2.2. Time series of SBI for North Sea herring (green) calcualted from survey data (here NS-IBTS). Upper panel shows the L_{95} (dotted line), the $L_{95.mat}$ (dashed line) and the $L_{95.5}$ (solid line). Lower panel shows the proportion of megaspawners (dashed line) and mature individuals (solid line).

3.3.3 Potential SBI reference points

Reference points, used for all L_{95}-variants in the absence of operational reference points, were L_{opt} and 1.1 L_{opt} (=L_{mega}). The latter was considered to represent the minimum size of megaspawners.

The analyses showed that in stocks with truncated size structures L_{95} can be expected to fall below L_{opt} (e.g. in both Baltic cod stocks and North Sea whiting, Annex 2), yet L_{95} is still vulnerable to recruitment effects as well.

The ratio between L_{opt} and L_{inf} as well as between L_{mega} and L_{inf} was constant across all analysed stocks (below and above 0.7 for L_{opt}:L_{inf} and L_{mega}:L_{inf}, respectively).

Nevertheless L_{opt} and 1.1*L_{opt} were not tested and verified for their potential to be operational reference points for L_{95}. No operational reference points could be established for P_{mat} and $P_{mega.mat}$, too.

3.3.4 Applying relative SBI to a variety of stocks

Looking at the performance of the relative SBI across the 17 analysed stocks the assessment results between indicators and stocks differ (Table 3.3.4.1). $P_{mega.mat}$ and P_{mat} had a higher variability between the stocks than the L_{95}-variants. $P_{mega.mat}$ was generally lower for gadoid species than for small pelagic species such as sprat or herring due to the fact that for the latter, L_{m50} and L_{opt} were closer together.

The value of $L_{95.mat}$ was depending on the species-specific ratio between L_{m50} and L_{inf}. For late-maturing species $L_{95.mat}$ should be less sensitive to recruitment than the $L_{95.mat}$ of species, in which the ratio between L_{m50} and L_{inf} is much lower.

Table 3.3.4.1. Summary of applying size-based indicators to 17 stocks in the North Sea (NS_IBTS survey) and Baltic Sea (BITS survey). Stocks are sorted by taxonomic group to highlight similarities. Pmat is the proportion of mature individuals in the survey; Pmega.mat is the proportion of mega-spawners (L > 1.1 Lopt) among spawners; L95 is the 95th-percentile across all length classes; L95.mat is the 95th-percentile above Lm50 and L95.5 above half of Linf, each relative to Linf. The values in the indicator columns refer to the value of the last year in the time series. Colours indicate relation to potential reference values from L95-variants: green: L95, L95.mat and L95.5 ≥ Lopt/Linf, red: L95, L95.mat and L95.5 < Lopt/Linf

Species	Stock	P_{mat}	$P_{mega.mat}$	L_{95}	$L_{95.mat}$	$L_{95.5}$	Comment
Clupea harengus	her-47d3	**0.17**	**0.78**	**0.81**	**0.83**	**0.83**	Indicators seem to be working okay
	her-3a22	**0.04**	**0.01**	**0.55**	**0.76**	**0.59**	$L_{95.mat}$ too optimistic due to high L_{m50}/L_{inf} ratio
	her-2532-gor	**0.33**	**0.01**	**0.63**	**0.65**	**0.65**	Large individuals are missing
Sprattus sprattus	spr-2232	**0.27**	**0.52**	**0.77**	**0.77**	**0.77**	Gear may not be suitable
Gadus morhua	cod-347d	**0.35**	**0.08**	**0.65**	**0.77**	**0.79**	L_{95} seems to better reflect slight recovery of abundance of large size classes
	cod-2224	**0.55**	**0.00**	**0.44**	**0.46**	**0.64**	$L_{95.5}$ misses truncated age structure
	cod-2532	**0.34**	**0.00**	**0.37**	**0.42**	**0.53**	$L_{95.5}$ misses truncated age structure
Scomber scombrus	mac-nea	**0.48**	**0.24**	**0.77**	**0.82**	**0.80**	Indicators work well. Variability in P_{mat} could be reduced by moving average.
Melanogrammus aeglefinus	had-346a	**0.26**	**0.01**	**0.53**	**0.619**	**0.66**	L_{95} reflects slight recovery of large individuals better than $L_{95.mat}$ and $L_{95.5}$; high variability in P_{mat} could be reduced by moving average
Merlangius merlangus	whg-47d	**0.26**	**0.00**	**0.49**	**0.58**	**0.68**	Indicators work well; high variability in P_{mat} could be

							reduced by moving average
Pollachius virens	sai-3a46	**0.33**	**0.03**	0.56	0.59	0.62	Trends in indicators seem to work well despite few data; variability could be reduced by moving average
Trisopterus esmarkii	nop-34	**0.21**	**0.09**	0.63	0.71	0.71	Recruitment variability introduces noise in all indicators, but trends seem to work well.
Pleuronectes platessa	ple-nsea	**0.61**	**0.07**	0.70	0.72	0.74	Large individuals are apparently not retained by survey gear. Compare with commercial data.
	ple-2123	**0.87**	**0.03**	0.69	0.69	0.71	Large individuals apparently not retained by survey gear
	ple-2432	**0.79**	**0.01**	0.61	0.61	0.67	Large individuals apparently not retained by survey gear
Platichthys flesus	fle-2223	**0.96**	**0.07**	0.72	0.73	0.75	Large individuals apparently not retained by survey gear
	fle-2425	**0.95**	**0.01**	0.61	0.61	0.65	Large individuals missing
Average		**0.46**	**0.12**	**0.62**	**0.67**	**0.69**	
S.D.		**0.29**	**0.22**	**0.12**	**0.12**	**0.08**	

For small species such as sprat and Norway pout, relatively small differences in length can represent different year classes, and the time of capture within the year may influence the assessment, as individuals are larger in autumn and thus closer to the reference points. For herring and sprat the control catches of acoustic surveys may be more suitable than BITS and NS-IBTS. However, these data were not available to WKIND3.3ii (not in DATRAS).

3.3.5 Strengths and weaknesses of SBI and potential reference points

Currently no relative SBI is fully operational (Table 3.3.5.1). The major impairment is still the meaningful setting of reference points for the assessment of the size distribution within the stock. However, the reference points used for L95-variants appeared to be reasonable in the sense that indicator below the reference points indicated truncation of large individuals from the stock. Yet further testing and verification of these reference points is necessary.

WKIND3.3ii also advanced the development of relative SBI by exploring possible cut-off points, which made the L_{95} and P_{mega} less susceptible to impacts of recruitment, but increased the sensibility to relative late maturation (L_{mat} vs. L_{inf}) such as in sprat and herring, and weakened the significance of the indicator, as in cod and haddock.

Table 3.3.5.1. Evaluation of indicators analysed by WKIND3.3ii.

SBI	Data needed	Pot. thresholds	Strengths	Weaknesses
L_{95}	only LFD	L_{opt}; 1.1 L_{opt}	No assumptions on cut-off points Broad applicability across species Reference points related to theoretical parameter	Sensitive to recruitment Arbitrary metric in 1.1*L_{opt} 1.1 L_{opt} needs further validation
$L_{95.mat}$	LFD, L_{m50}	L_{opt}; 1.1 L_{opt}	Less sensitive to recruitment Reference points related to theoretical parameter	Can underestimate strong size truncation Performance depends on L_{m50}/L_{opt} ratio Reference point needs further validation Cut-off point (L_{m50}) may be changing through time
$L_{95.5}$	LFD, L_{inf}	L_{opt}; 1.1 L_{opt}	Less sensitive to recruitment Reference points related to theoretical parameter	Can underestimates strong size truncation Cut-off point (0.5 L_{inf}) may be changing through time Reference point needs further validation
P_{mat}	LFD and maturity ogive or estimate of L_{m50}	To be determined	Broadly applicable Easy to communicate	Sensitive to recruitment Conceptual weakness: not necessarily related to mega-spawners Different thresholds needed for different Linf/Lm50 ratios Unclear, if conceptual reference points will become available P_{mat} was not evaluated to be an appropriate indicator for the

				assessment of GES by WKIND3.3i
$P_{mega.mat}$	LFD, maturity ogive or estimates of L_{m50} and L_{inf}	To be determined	Conceptually sound: Directly related to megaspawners Low values may indicate true and severe size depletion Broadly applicable Easy to communicate	Different thresholds needed for different L_{m50}/L_{inf} ratios Unclear, if conceptual reference points will become available

The 95th-percentile of lengths across all length classes in the survey (L_{95}) reflected well the presence (e.g. in North Sea herring) or absence (e.g. in Eastern Baltic cod) of large individuals. Using $L_{95.mat}$ or $L_{95.5}$, however, sometimes led to positive signals even in severely truncated size structures (see e.g. North Sea cod). In many stocks the L_{95} thus appeared to better reflect size truncation. The down-side of using all length classes is the influence of recruitment on the indicator. This influence could, however, be reduced by smoothing the indicator time series using a moving average.

P_{mat} was evaluated as an inappropriate indicator for the assessment of GES by WKIND3.3i. The claimed weaknesses remain i.e. its sensitivity to recruitment and the ambiguous interpretation of indicator values. Furthermore, WKIND3.3ii does not foresee how conceptual reference values could be developed for this indicator. Thus WKIND3.3ii still concludes that P_{mat} should not be considered any further within D3C3 (see recommendation 4 by WKIND3.3i).

The number of large individuals i.e. megaspawners ($L >= 1.1\ L_{opt}$) relative to all mature individuals in the survey for a given year (P_{mega}) is an easy to obtain indicator. Note, however, that the definition of megaspawners is arbitrary and may need further species-specific refinement.

There are no generic reference points available for any of the here tested SBI, but simulations of long-term values based on assumptions about average fishing pressure ($F/_{MSY}$) and selectivity (L_c/L_{inf}) could be used to derive SBI thresholds. However, different L_{m50}/L_{inf} ratios, such as found in gadoids (L_{m50}/L_{inf} about half of L_{opt}) versus small pelagics (L_{m50}/L_{inf} near L_{opt}) would lead to different proportions of mature individuals or megaspawners in otherwise identical length frequency distributions. Therefore, such simulations would need to be stock specific.

3.4 Discussion

3.4.1 Choice of data sources

Length frequencies from BITS and NS-IBTS surveys were comparable with length frequencies from commercial fisheries and thus deemed representative of the population and fit for use with the examined gadoids (except for North Sea cod). For flatfish, it seemed that large individuals were under-represented in the surveys. Length structure of herring, sprat and mackerel seemed to be represented correctly, although there was some doubt with regard to large individuals.

The choice of the data source will influence the calculated SBI substantially. Depending on the included areas and subareas the SBI time series can look very different and hence a careful selection of appropriate data is important. This refers mostly to the choice of the survey with the most representative data. In this study the NS-IBTS and the BITS were used as data sources, but for some stocks better data sources may be available, e.g. control catches of acoustic survey for herring, sprat or mackerel or beam trawl surveys (BTS) for flatfishes in the North Sea. WKIND3.3ii did not have the resources to analyse this issue further, but it seems desirable that more and a wider range of survey data should become available (e.g. on DATRAS) to accommodate the assessment needs of Descriptor 3.

3.4.2 Potential reference points

WKIND3.3ii decided to use L_{opt} and L_{mega} as illustrative reference points for all L_{95}-variants, in the absence of any operational reference points. It may appear as intuitive that statistical indices of the LFD referring to the large fraction of the stock (i.e. the 95th-percentile) should also be related to classical references points from population models. Yet there is no clear biological understanding of how many individuals within a stock really should be above any potential threshold to consider the size distribution as "healthy". The 95th-percentile is an arbitrary statistic that is not related to any life-history trait of a species and hence even in non-exploited populations it may differ from species to species, which percentile of the LFD is actually above the here proposed reference points.

The reference points for P_{mat} and P_{mega} suggested or mentioned in the literature (Froese, 2004; Cope and Punt, 2009) were not considered by WKIND3.3ii. Obviously the ratio between L_{m50} and L_{opt} strongly influenced the value of $P_{mega.mat}$, which therefore can be expected to differ between species with different life-history traits (Cope and Punt, 2009). Generic reference points for $P_{mega.mat}$ in the range of >0.2 (Froese, 2004) may thus not seem to be applicable across all stocks. Furthermore, when developing $P_{mega.mat}$ reference points, the species-dependent catchability of survey gears should be accounted for. In the same survey, some species may be better caught as juveniles, whereas other species are mostly caught as adults.

For relative SBI thus the quest for finding meaningful and operational reference points continues. Modelling studies could provide further insights into the relationship between life-history traits, and relative SBI, but their applicability in the real world may be impaired by low and non-representative catchabilities of survey gears for certain fractions of stocks and certain species. In the end, time series based assessment methods may be the fastest way to identify SBI reference values (see Chapter 5).

3.4.3 Performance of SBI

The regular L_{95} (i.e. not based on cut-off points) generally had higher sensitivities towards any changes in the LFD and did not rely on estimates of cut-off points, which by themselves may be subject to change over time. For example, the average length-of-first-maturity has been demonstrated to be decreasing in exploited fish stocks (see Engelhard and Heino, 2004, but also report of WKIND3.3i). Hence, the use of L_{m50} as a cut-off point would introduce additional bias to the time series of $L_{95.mat}$ when using the L_{m50} of the according year. To avoid this problem, L_{m50} may be defined as a constant e.g. as average L_{m50} across all years.

P_{mat} showed high variabilities in many stocks and maybe more important, was considered by WKIND3.3i to be conceptually flawed. P_{mat} has been demonstrated to be strongly affected by recruitment while being insensitive to fishing pressure (Probst *et al.*, 2013b). More than any other of the here tested relative SBI, P_{mat} will always be susceptible to the annual recruitment and thus most time series of this SBI showed high variabilities. WKIND3.3ii thus considered this indicator mostly because it still seems to be included within the revised Commission Decision 2010/477/EU and further advice on its performance may be needed.

$P_{mega.mat}$ was strongly dependent on the catchability for large individuals of the analysed species. Thus it showed very low value ranges for many gadoid stocks, but also for some herring and flounder stocks in the Baltic Sea. However, these low values may also indicate severe size truncation, e.g. for North Sea whiting, for which the catchability of large individuals within the IBTS should be high. Given the variable catchability for large individuals between different surveys, it may be difficult to assess, whether truncated size distributions are due to sampling errors or related to impacts of growth overfishing.

3.5 Conclusions

- LFD from different data sources (commercial vs. survey) can be different depending on the catchability of surveys for a given species. In some cases the fraction of large individuals seems to be underestimated by survey catches.
- Differing LFD will lead to different values of SBI and hence the choice of data sources used in the assessment will have strong influences on the assessment results. Further effort is required to identify the best data sources which are representative of the true size distribution within the stock.
- None of the here analysed relative SBI and reference points can be considered as fully operational. However, the here presented analysis demonstrated a potential use of L_{95}-variants as assessable indicators for size-structure.
- Various cut-off points for L_{95} reduced the variability of the indicator time series, most likely because the indicators were less sensitive to recruitment. However; the use of cut-off points had the tendency to make assessment results more positive, because it was easier for the remaining LFD to achieve the here defined reference points
- Further testing is needed to analyse how cut–off values can reduce the sensitivity to recruitment while a meaningful relationship to reference values is maintained.
- P_{mega} is still considered as the conceptually most sound relative SBI, as it directly addresses the requirement of D3C3. However, the definition of which size-classes are referred to as megaspawners needs further refinement. The use of a cut-off point (L_{m50}) made the times series of this SBI less variable. Establishing generic conceptual and operational reference points for P_{mega} remains a challenge. For rapid implementation within D3C3 time series based assessment methods may be considered.

4 Sub-group 2: Relationships between stock indicators and SBI

4.1 Introduction

The first ICES Workshop on Guidance on development of operational methods for the evaluation of MSFD Criterion D3.3 (WKIND3.3i) concluded that there is no size-based indicator and reference point, which can be considered to be fully operational. Thus, there is no indicator allowing the assessment of stock size structure against good environmental status (GES). Yet WKIND3.3i identified three potential size-based indicators (SBI, namely L_{95}, P_{mega} and $cpue_{mega}/SSB_{mega}$, for explanation see M&M) for the assessment of the length structure within fish stock (ICES, 2016) which should be further explored for applicability within the MSFD. These three indicators were either considered as easy to implement (L_{95}) or particularly related to the abundance of old and mature individuals, as requested by the Marine Strategy Framework Directive (MSFD).

However, after WKIND3.3i it remained uncertain if and how these three SBI are related to the indicators of D3C1 (fishing intensity) and D3C2 (stock size). During WKIND3.3i concern was raised that some of the proposed SBI may be redundant especially to D3C2. Hence, a term of reference for follow-up workshops was issued to "*investigate on the redundancy between indicators from length–frequency distributions of commercial and survey catches to inform on the status of stock size distribution.*" This resulted in ToRb of WKIND3.3ii to focus on "*potential size-based indicators (SBI) that are not redundant to D3C1 and D3C2*".

Furthermore, WKIND3.3i considered it as important to understand the relationships between SBI and stock indicators such as spawning stock biomass (SSB), fishing mortality (F) or recruitment (R). These relationships may be helpful in understanding the benefit of assessing the size structure of exploited fish stocks additionally to stock size and fishing intensity.

Significant linear relationships between stock indicators and SBI may help to reveal unwanted influences or redundancies of stock indicators on SBI. An example is the demonstrated negative short-term relationship between the L_{95} and recruitment (Probst *et al.*, 2012; Probst *et al.*, 2013b). Significant non-linear relationships between stock indicators and SBI may help to identify potential reference values for SBI-assessments i.e. that GES for a SBI may only be achieved at a limited range of stock indicator values.

The objectives of WKIND3.3ii within SG2 were therefore:

1. Objective 1: Analyse the redundancy of SBI to D3C2 and D3C1.
2. Objective 2: Analyse whether expected relationships between SBI and stock indicators can be found in empirical data from exemplary stocks

4.2 Material & methods

WKIND3.3ii explored and tested several statistical models to analyse the relationships between F, SSB and R with size-based indicators (SBI). The SBI used in the analysis were previously put forward by WKIND3.3i in March 2016 as promising candidate SBI, although not being fully operational yet: The '95th percentile of the fish length-frequency distribution' (L_{95}), , the 'proportion of megaspawners' (P_{mega}) and the 'absolute abundance of mega-spawners in research vessel surveys' ($cpue_{mega}$). Furthermore WKIND3.3ii tested the 'abundance of mega-spawners (SSB_{mega}) from stock assessment data' as well as the 'proportion of fish larger than the mean-size-of-first-sexual-maturation' (P_{mat}), although the latter was evaluated by WKIND3.3i to not be an appropriate indicator for the assessment of GES and recommended to not be considered any further within the MSFD. By including P_{mat} into the current analyses the recommendation of WKIND3.3i shall not be reversed.

4.2.1 Selection of stocks

From an initial list of nine stocks from the North East Atlantic (Figure 4.2.2.1), WKIND3.3ii selected four stocks for further analysis (Table 4.2.1.1). These stocks were selected because the SBI relied on a single source of survey data and the survey area could be well related to the distribution of the stock. The survey gear was considered to catch the species representatively. Furthermore, the time series of the stocks showed strong variations in their indicator time series, suggesting that strong relationships should be found.

Table 4.2.1.1. Stocks used for the detailed analysis of stock indicators vs SBI.

Stock	Assessment code	Data sources	
		Survey	Assessment
North Sea cod	cod-347d	NS-IBTS	ICES stock summary data base 2015
North Sea plaice	ple-nsea	NS-IBTS	
North Sea whiting	whg-47d	NS-IBTS	
Plaice in the Kattegat	ple-2123	BITS	

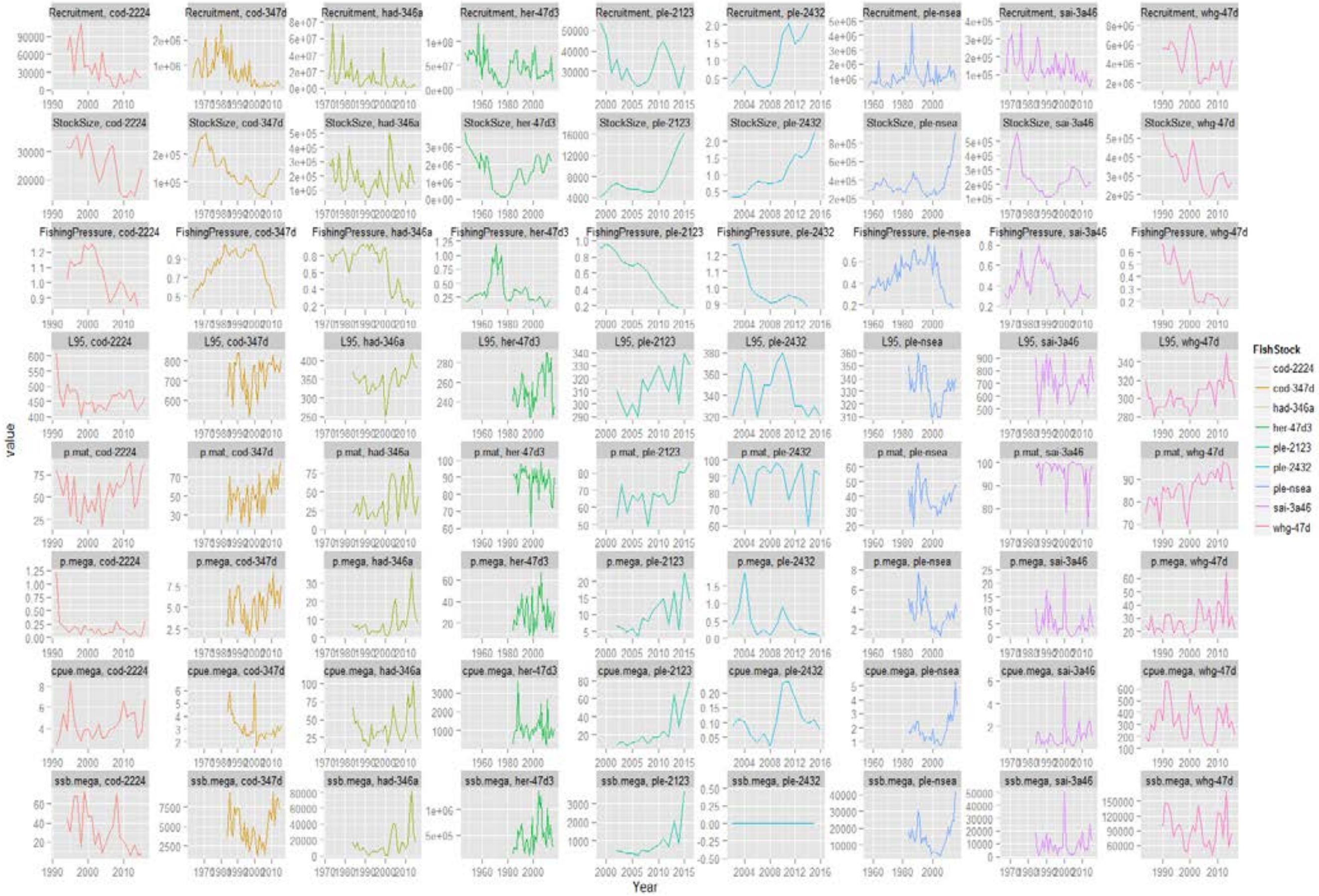

Figure 4.2.2.1. Time series of stock indicators and SBI for nine stocks from the North Atlantic.

4.2.2 Indicator calculations

The survey data were downloaded from the ICES DATRAS database as “number-per-hour-per-length-class” and were used to calculate the L_{95}, P_{mega}, $cpue_{mega}$ and P_{mat}. L_{95}, P_{mat} and P_{mega} were calculated from the length-frequency distribution of the given species in a survey aggregated by year. $cpue_{mega}$ was calculated as the average abundance of megaspawners by number per hour. Life-history parameters from Table 4.2.2.1 were used as cut-off points to determine the proportion of megaspawners (L_{opt} for P_{mega}) or mature individuals (L_{mat} for P_{mat}) and the abundance of megaspawners ($cpue_{mega}$). The P_{mega} from the survey data was multiplied with the SSB-values from the analytical stock assessments to obtain SSB_{mega}.

Table 4.2.2.1 Life-history parameters of nine stocks initially considered by WKIND3.3ii. If no estimate of Lopt was available from WKIND3.3i, this parameter was calculated after (Froese *et al.*, 2016) as $L_{opt}=L_{\infty}(3/(3+M/K))$, with M as estimate of natural mortality and K as growth parameter from the von Bertalanffy growth equation.

Species	Stock	L_{INF} (cm)	L_{MAT} (cm)	L_{OPT}/L_{MEGA} (cm)	M	K	Sources
Gadus morhua	cod-2224	119	31	87.3			WKIND3.3i
	cod-347d	117	53.4	85.8			WKIND3.3i
Pleuronectes platessa	ple-nsea	55	22.8	40.3			WKIND3.3i
	ple-2123	57	20	42.8	0.15	0.15	Fishbase (25.10.2016)
	ple-2432	57	20	42.8	0.15	0.15	Fishbase (25.10.2016)
Merlangius merlangus	whg-47d	41.4	27.5	29.8	0.34	0.29	Fishbase (25.10.2016)
Pollachius virens	sai-3a46	111	39.1	66.6	0.2	0.1	Fishbase (25.10.2016)
Melanogrammus aeglefinus	had-346a	70	34.9	49.4	0.3	0.24	Fishbase (25.10.2016)
Clupea harengus	her-47d3	34.6	23.8	25.4			WKIND3.3i

4.2.3 Definition of expected relationships between stock indicators and SBI

For the first objective particular focus was put on the relationships between D3C2 and the SBI, because some SBI should be very similar to SSB (i.e. $cpue_{mega}$ and SSB_{mega}), or should be positively correlated with SSB (i.e. L95, Probst *et al.*, 2013b). Contrary, F is a pressure indicator and a negative relationship between F and the SBI (if F is selective) can be expected, as state indicators should be sensitive to pressures (Rochet and Rice, 2005; ICES, 2015).

For the second objective WKIND3.3ii hypothesised on expected directions of relationships between the SBI and stock indicators (SSB, F, R) (Table 4.2.3.1). For example, it was assumed that SSB would have a positive impact on all SBI, but only at long-term scales. At short-term SSB was assumed to have positive effects only for SSBmega and cpue mega, but no short-term influence were assumed for L_{95}, P_{mega} and P_{mat}. Fishing mortality would have negative impacts on all SBI in the short- and long-term. Recruitment was assumed to have positive impacts on all SBI in the long-term, negative short-term impacts on all relative SBI (L_{95}, P_{mega} and P_{mat}) and no short-term impacts on SSB_{mega} and $cpue_{mega}$.

Table 4.2.3.1. Expected influences of stock indicators (spawning stock biomass – SSB, recruitment - R and fishing mortality F) on size-based indicators (SBI). '+' and '-' indicate positive or negative relationships, '0' indicates no expected relationship. Short-term influences refer to immediate impacts with zero or one year lag, long-term influences are expected to be lagged by age-at-first-maturity or longer.

SBI	SSB		R		F	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
L_{95}	0	+	-	+	-	-
SSB_{mega}	+	+	0	+	-	-
$cpue_{mega}$	+	+	0	+	-	-
P_{mega}	0	+	-	+	-	-
P_{mat}	0	+	-	+	-	-

4.2.4 Statistical approaches

For the first objective WKIND3.3ii analysed whether there were significant linear or non-linear relationships between SBI and SSB using a lagged GAM-approach, in which the smoothed time series of SSB and the SBI were progressively lagged to fit a generalised additive regression model (GAM) (Crawley, 2005; Crawley, 2007). The significance of the relationship assessed by the GAM, and the type of relationship (linear vs. non-linear) was evaluated visually.

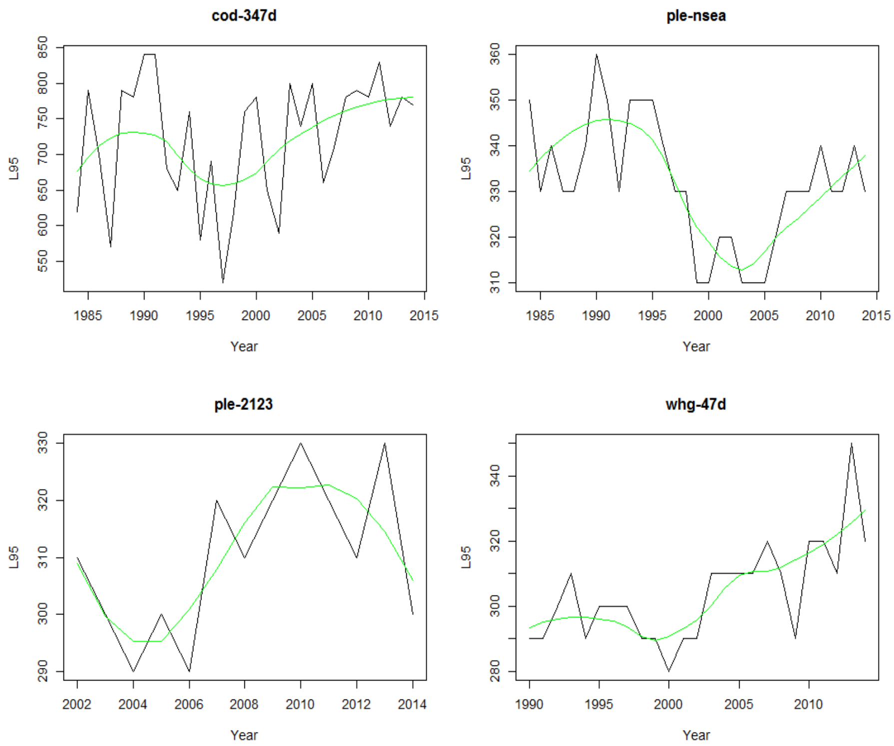

Figure 4.2.4.1 Examples for the impact of smoothing on SBI-time series for North Sea cod (cod-347d), North Sea plaice (ple-nsea), plaice in the Kattegat (ple-2123) and North Sea whiting (whg-47d).

For the second objective the relationships between stock indicators and SBI were analysed within single stocks using generalized linear models (GLM) (Crawley, 2005). The single-stock GLMs contained smoothed and unsmoothed (raw) time series of the SBI to test whether the strength of potential signals was enhanced by smoothing out annual variations in the SBI time series (Figure 4.2.4.1).

In a second step GAMs were used to verify the findings of the single-stock GLM. For the GAM models, the time series of all data were smoothed and standardised by dividing through their maximum.

4.3 Results

4.3.1 Objective 1

The lagged GAM regressions helped to identify the short- and long-term influences of SSB on the SBI. In Figure 4.3.1.1, showing an exemplary output for North Sea cod, the smoothed L_{95} had the strongest relationship with SSB at lag of seven years meaning that L_{95} follows the trend of SSB seven years later. At this lag, the relationship between SSB and L_{95} of North Sea cod was positive and curved.

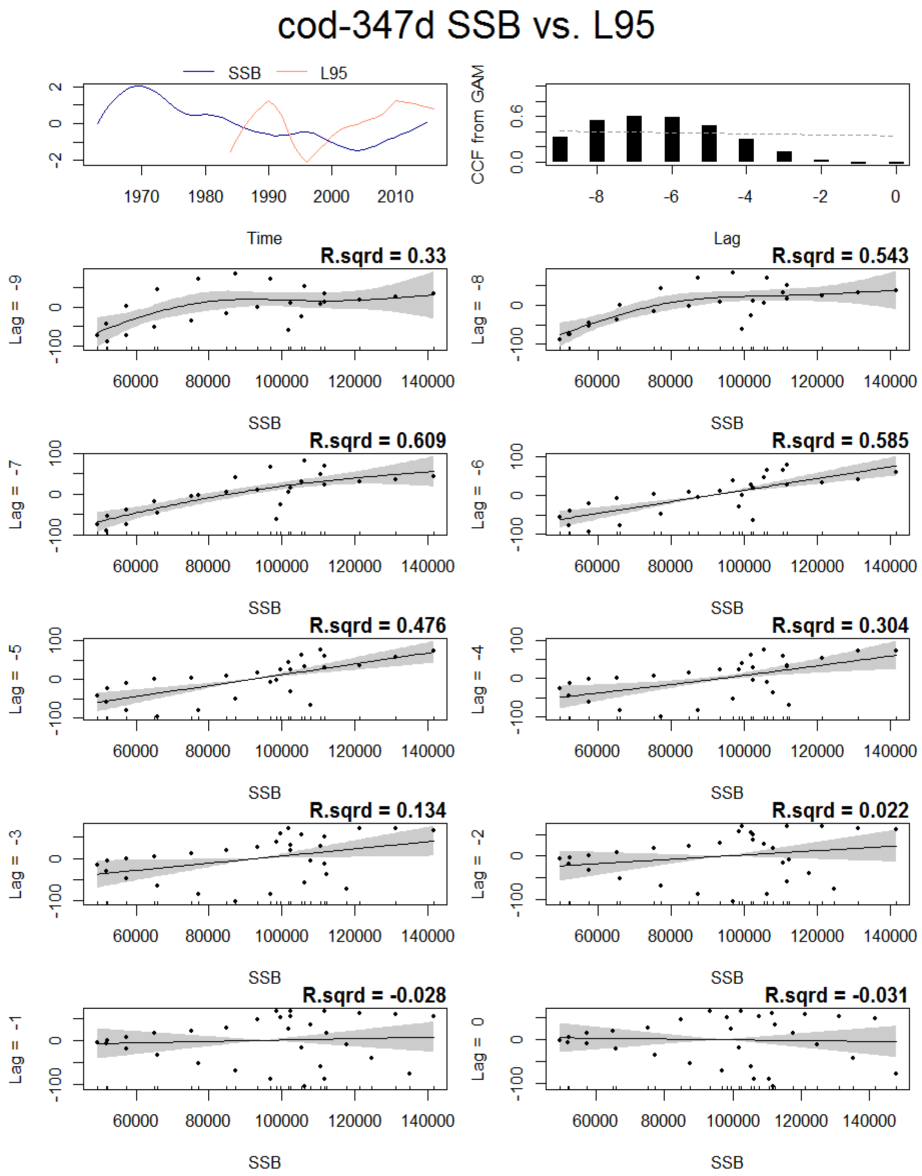

Figure 4.3.1.1 Example of lagged GAM-analysis for North Sea cod (cod-347d) vs. the L_{95}. The upper left panel shows the smoothed and standardised time series of SSB and L_{95}, the upper right panel shows the R^2-values of the lagged GAM-relationships. All other panels show the GAM-relationship between at the according lag with the GAM-model response at the y-axis.

The lagged relationships between SSB and the five SBI indicated that some SBI mostly met the expected relationships in the short-term ($cpue_{mega}$) or short- and long-term (L_{95}, SSB_{mega} and P_{mega}) (Table 4.3.1.1). Furthermore, the two non-relative SBI $cpue_{mega}$ and SSB_{mega} showed short- and partly long-term redundancy with SSB as indicated by their linear positive relationships with SSB. L_{95} indicated positive curved long-term relationships with SSB for three out of four stocks suggesting that it may include additional information to SSB and that it may be more consistent in its behaviour than the other SBI concerning the type of long-term relationship.

Table 4.3.1.1. Overview on temporally lagged GAM-relationships between SSB and SBI. Indicated are the type of the relationship, the direction (Dir., either '+' = positive or '-' = negative), the intensity (Int., expressed as the R^2 of the most significant GAM) and whether the observed relationship meets the expectations of Table 4.3.1.1. Italics indicate cases in which SBI was redundant to SSB. n.s.: relationship not significant.

SBI	Stock	Short-term (0–1 years)				Long-term (2–9 years)			
		Type	Dir.	Int.	As exp.?	Type	Dir.	Int.	As exp.?
L_{95}	cod-347d	n.s.	n.s.	n.s.	Y	curved	+	0.609	Y
	ple-nsea	n.s.	n.s.	n.s	Y	curved	-	0.893	N
	whg-37d	linear	-	0.526	N	curved	+	0.508	Y
	ple-2123	n.s.	n.s.	n.s.	Y	curved	+	0.825	Y
SSB_{mega}	cod-347d	*linear*	+	0.586	Y	curved	+	0.657	Y
	ple-nsea	*linear*	+	*0.767*	Y	curved	-	0.881	N
	whg-37d	*linear*	+	*0.377*	Y	*linear*	+	*0.688*	Y
	ple-2123	*linear*	+	*0.847*	Y	*linear*	+	*0.892*	Y
$cpue_{mega}$	cod-347d	curved	+	0.417	Y	n.s.	n.s.	n.s.	N
	ple-nsea	*linear*	+	*0.922*	Y	n.s.	n.s.	n.s.	N
	whg-37d	*linear*	+	*0.709*	Y	n.s.	n.s.	n.s.	N
	ple-2123	*linear*	+	*0.920*	Y	curved	+	0.912	Y
P_{mega}	cod-347d	n.s.	n.s.	n.s.	Y	*linear*	+	*0.598*	Y
	ple-nsea	n.s.	n.s.	n.s.	Y	curved	-	0.878	N
	whg-37d	n.s.	n.s.	n.s.	Y	curved	+	0.549	Y
	ple-2123	n.s.	n.s.	n.s.	Y	curved	+	0.960	Y
P_{mat}	cod-347d	n.s.	n.s.	n.s.	Y	curved	+	0.598	Y
	ple-nsea	n.s.	n.s.	n.s.	Y	curved	-	0.857	N
	whg-37d	linear	-	0.465	N	curved	-	0.607	N
	ple-2123	curved	+	0.722	N	n.s.	n.s.	n.s.	N

4.3.2 Objective 2

The use of smoothed time series increased the significance of many GLM. However, the overall pattern of influences of SSB, R and F on the SBI was not consistent across all stocks and SBI (Table 4.3.2.1).

The GLM-analyses confirm the results from the first objective, in which SSB was positively related to SSB_{mega} and $cpue_{mega}$ in the short term. F showed significant negative relationships for some SBI, but this relationship was not consistent across all stocks and SBI. The negative influence of F was most evident for P_{mega}, but not for all stocks (i.e. North Sea whiting). Furthermore, for some stocks F showed significant positive relationships to SBI (e.g. with L_{95} for North Sea plaice), which is contradictory to the expectations. Hence WKIND3.3ii could not identify any generic relationships between stock indicators and SBI.

Table 4.3.2.1. Overview on single-stock GLM analysing the linear relationships between stock indicators (F, SSB, R) vs. five SBI (L_{95}, SSB_{mega}, $cpue_{mega}$, P_{mega} and P_{mat}). Indicated are the model results from raw (unsmoothed) and smoothed time series of SBI. Signif. codes: '*': p<0.001 '**': p<0.01 '**, '*': p < 0.05, '.': p<0.1'.**

L_{95}			
		Direction of relationship	
Factor	*Fish stock*	*SBI raw*	*SBI smoothed*
F	whg-47d	-	-
	cod-347d	-	neg***
	ple-2123	-	neg*
	ple-nsea	-	pos**
SSB	whg-47d	-	-
	cod-347d	-	-
	ple-2123	-	neg.
	ple-nsea	pos.	pos**
R	whg-47d	-	neg.
	cod-347d	-	-
	ple-2123	-	-
	ple-nsea	-	-
SSB_{mega}			
F	whg-47d	-	-
	cod-347d	neg.	neg***
	ple-2123	-	neg***

	ple-nsea	-	pos**
SSB	whg-47d	pos***	pos**
	cod-347d	pos***	pos***
	ple-2123	-	pos***
	ple-nsea	pos***	pos***
R	whg-47d	neg*	neg*
	cod-347d	neg.	-
	ple-2123	-	pos**
	ple-nsea	-	-
$cpue_{mega}$			
F	whg-47d	-	-
	cod-347d	-	pos.
	ple-2123	-	neg***
	ple-nsea	-	-
SSB	whg-47d	pos**	pos***
	cod-347d	-	pos**
	ple-2123	-	pos***
	ple-nsea	pos***	pos***
R	whg-47d	-	-
	cod-347d	-	pos*
	ple-2123	-	neg*
	ple-nsea	-	-
P_{mega}			
F	whg-47d	-	-
	cod-347d	-	neg***
	ple-2123	-	neg***
	ple-nsea	-	neg***
SSB	whg-47d	-	-
	cod-347d	-	-
	ple-2123	-	neg*

	ple-nsea	-	pos**
R	whg-47d	neg*	neg*
	cod-347d	neg.	-
	ple-2123	-	pos*
	ple-nsea	-	-
P_{mat}			
F	whg-47d	neg*	neg.
	cod-347d	-	neg***
	ple-2123	-	neg.
	ple-nsea	-	pos**
SSB	whg-47d	pos**	-
	cod-347d	pos***	-
	ple-2123	-	-
	ple-nsea	-	pos**
R	whg-47d	neg***	neg.
	cod-347d	neg***	-
	ple-2123	-	-
	ple-nsea	-	-

When using GAMs to model the relationships between stock indicators and SBI in the short term, again the relationships are not consistent across indicators and stocks (Figures 4.3.2.1-4.3.2.5). However, with GAMs, the relationships between the SBI and SSB appear to be more consistent and predictable across the stocks and indicators (Table 4.3.2.2). On the other hand, the relationships between F and the SBI did not consistently show the expected negative trends.

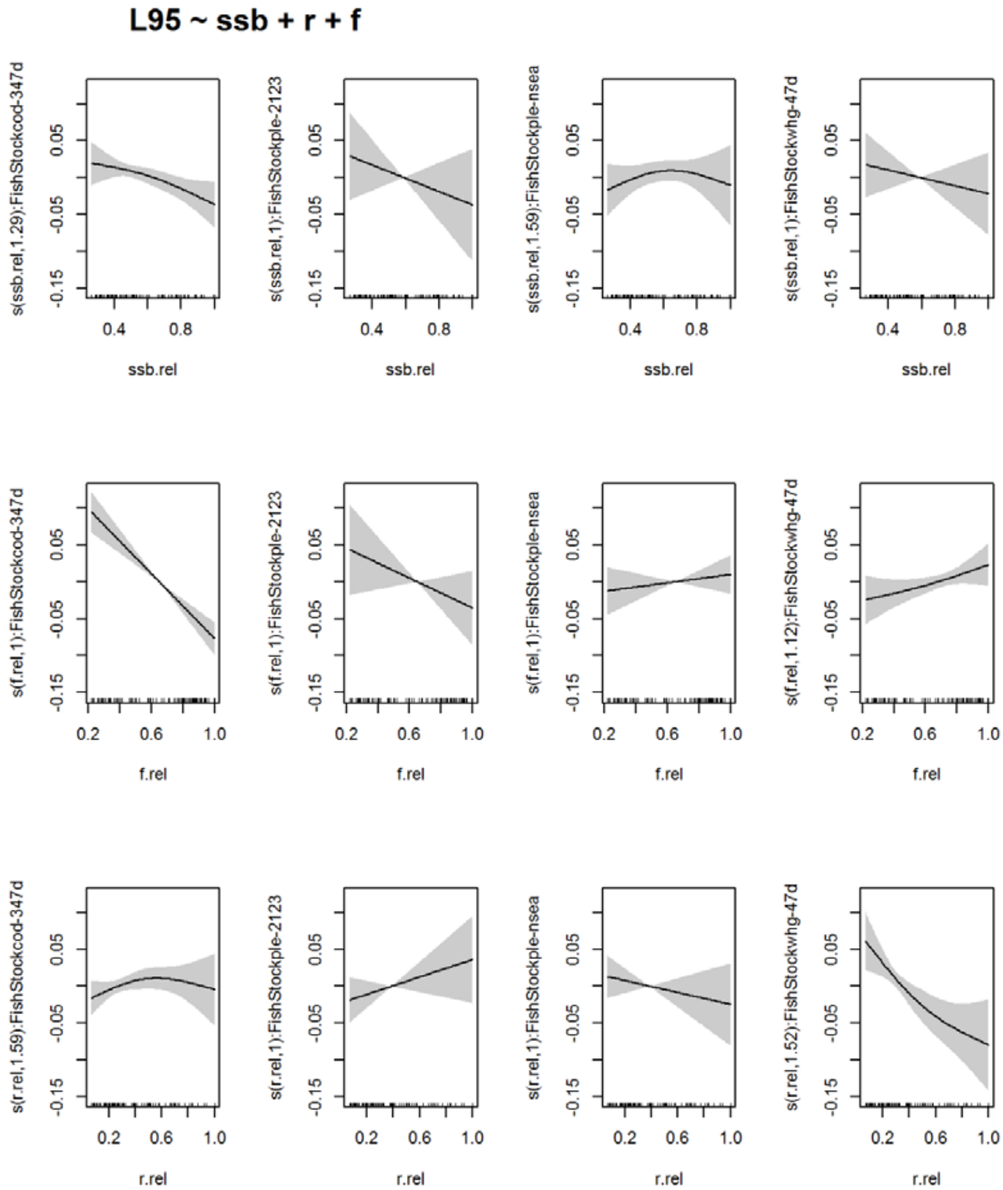

Figure 4.3.2.1. Overview on GAM-results of L_{95} vs. stock indicators SSB (ssb.rel), F (f.rel) and R (r.rel) for four different stocks (North Sea cod = cod-347d, North Sea plaice = ple-nsea, Kattegat plaice = ple-2123 and North Sea whiting = whg-47d). X-axis show the range of factor values (i.e. stock indicators), y-axis shows the magnitude of the effect on the dependent variable (L_{95}). All data were standardised to a maximum of 1. Grey shades represent confidence intervals of the relationships (solid lines).

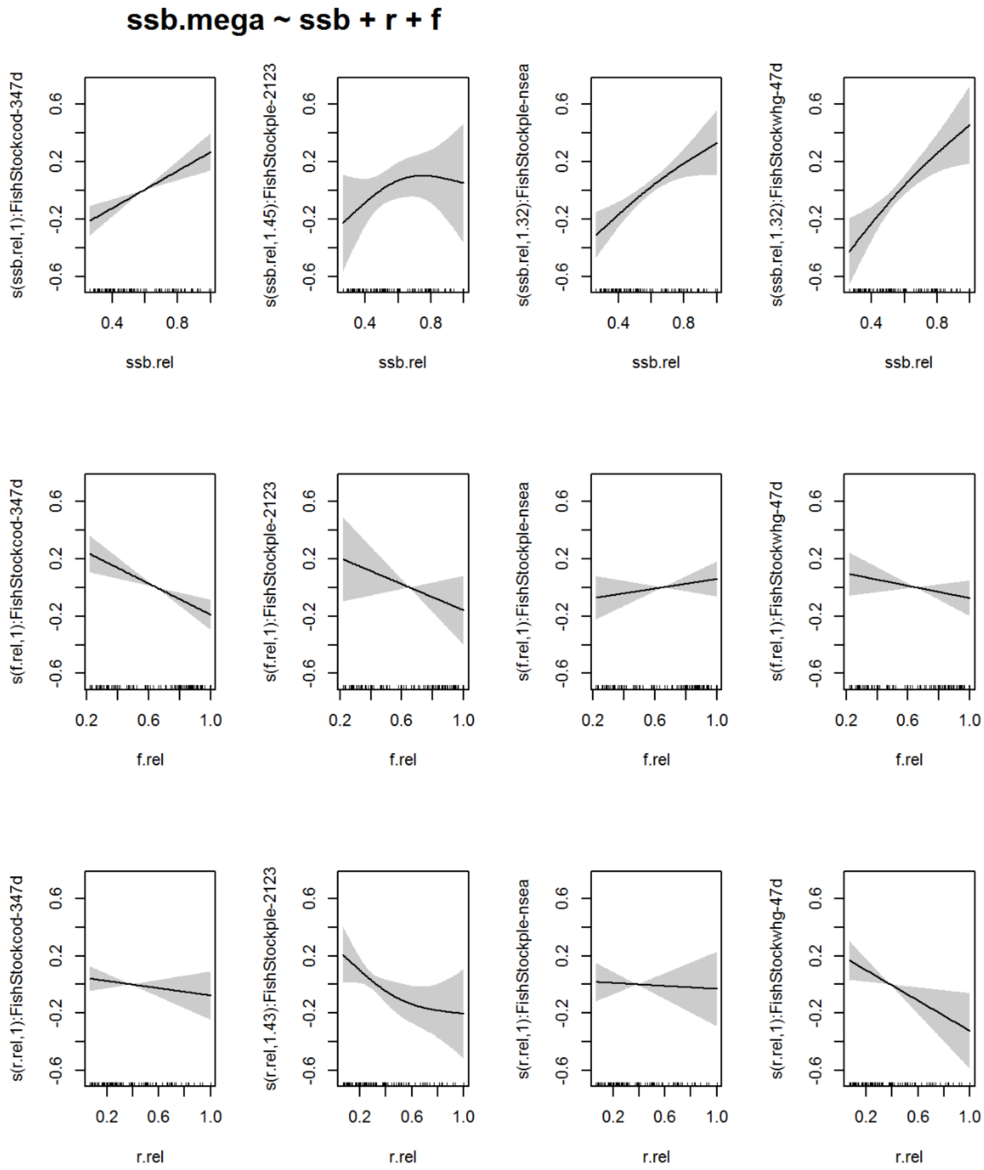

Figure 4.3.2.2. Overview on GAM-results of SSB_{mega} vs. stock indicators SSB (ssb.rel), F (f.rel) and R (r.rel) for four different stocks (North Sea cod = cod-347d, North Sea plaice = ple-nsea, Kattegat plaice = ple-2123 and North Sea whiting = whg-47d). X-axis show the range of factor values (i.e. stock indicators), y-axis shows the magnitude of the effect on the dependent variable (L_{95}). All data were standardised to a maximum of 1. Grey shades represent confidence intervals of the relationships (solid lines).

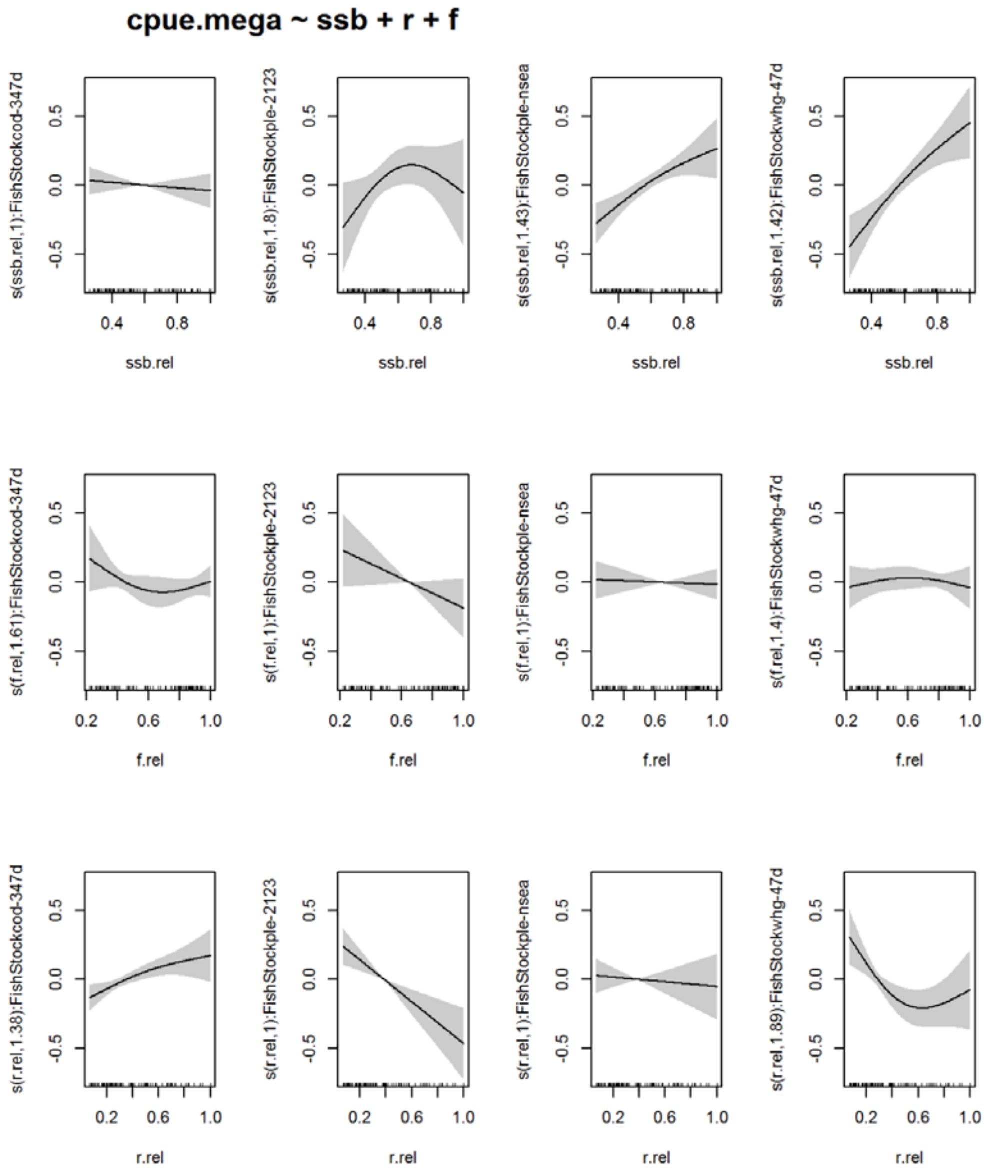

Figure 4.3.2.3. Overview on GAM-results of $cpue_{mega}$ vs. stock indicators SSB (ssb.rel), F (f.rel) and R (r.rel) for four different stocks (North Sea cod = cod-347d, North Sea plaice = ple-nsea, Kattegat plaice = ple-2123 and North Sea whiting = whg-47d). X-axis show the range of factor values (i.e. stock indicators), y-axis shows the magnitude of the effect on the dependent variable (L_{95}). All data were standardised to a maximum of 1. Grey shades represent confidence intervals of the relationships (solid lines).

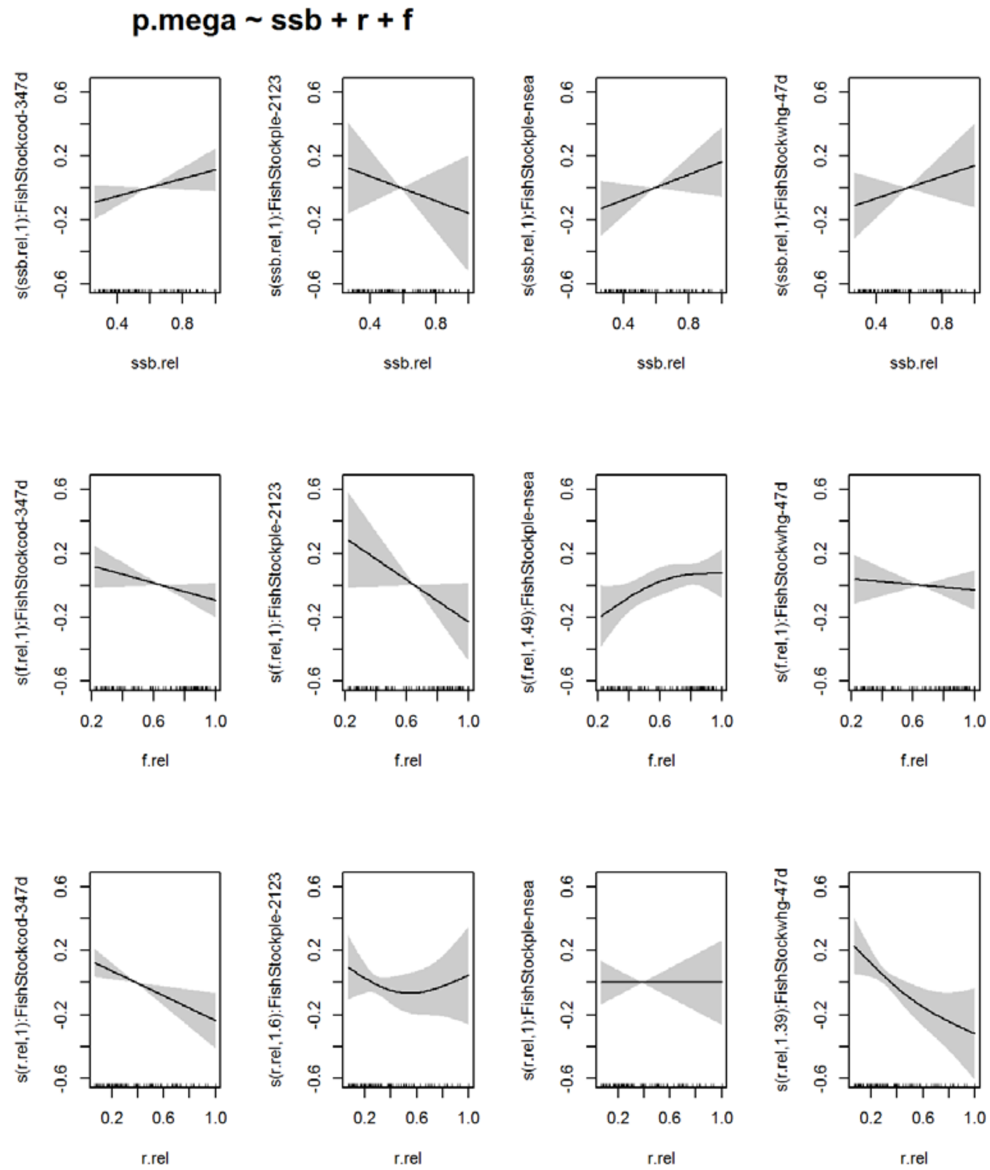

Figure 4.3.2.4. Overview on GAM-results P_{mega} vs. stock indicators SSB (ssb.rel), F (f.rel) and R (r.rel) for four different stocks (North Sea cod = cod-347d, North Sea plaice = ple-nsea, Kattegat plaice = ple-2123 and North Sea whiting = whg-47d). X-axis show the range of factor values (i.e. stock indicators), y-axis shows the magnitude of the effect on the dependent variable (L_{95}). All data were standardised to a maximum of 1. Grey shades represent confidence intervals of the relationships (solid lines).

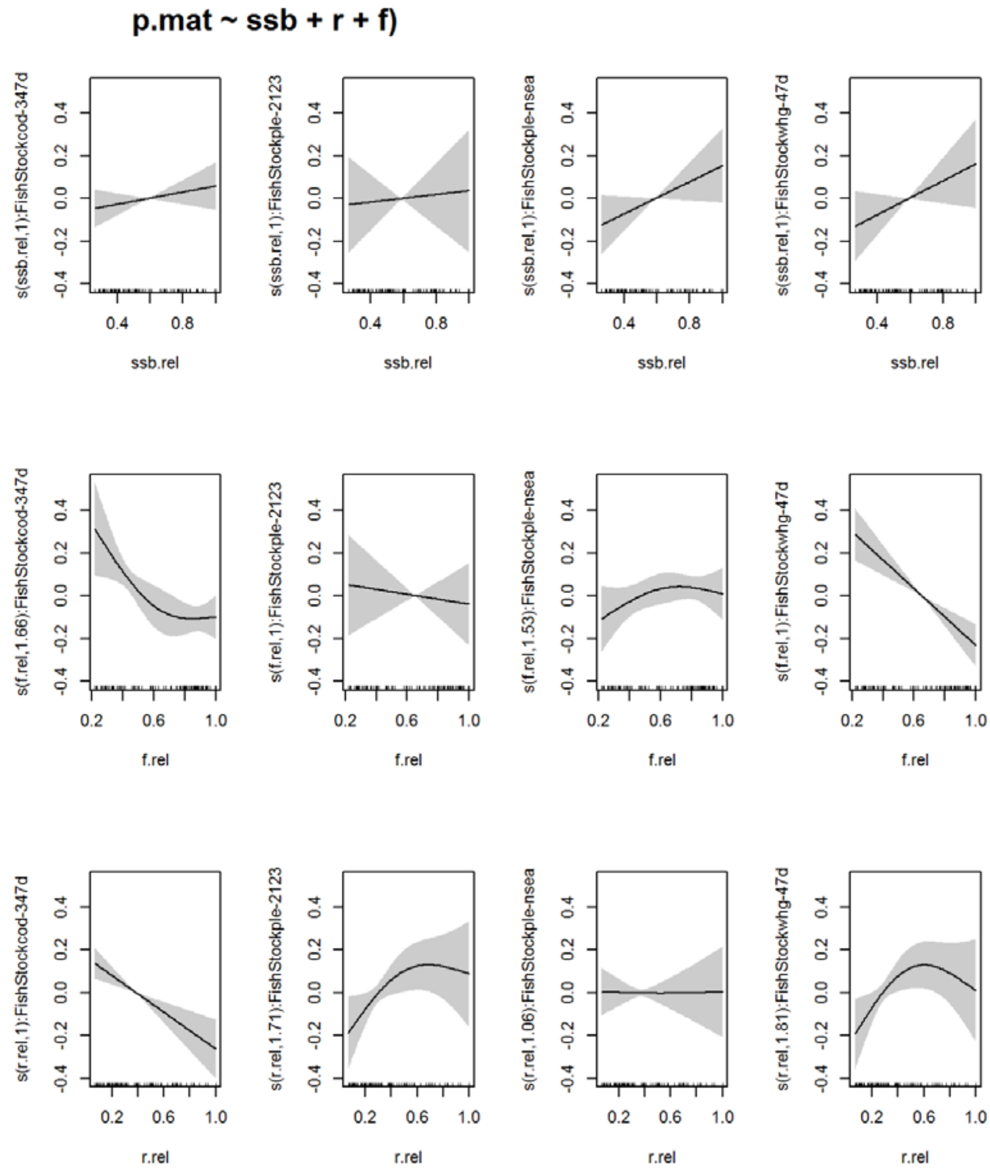

Figure 4.3.2.5. Overview on GAM-results of P_{mat} vs. stock indicators SSB (ssb.rel), F (f.rel) and R (r.rel) for four different stocks (North Sea cod = cod-347d, North Sea plaice = ple-nsea, Kattegat plaice = ple-2123 and North Sea whiting = whg-47d). X-axis show the range of factor values (i.e. stock indicators), y-axis shows the magnitude of the effect on the dependent variable (L_{95}). All data were standardised to a maximum of 1. Grey shades represent confidence intervals of the relationships (solid lines).

Table 4.3.2.2 Overview on expected behaviour of the relationships between stock indicators (SSB, R and F) vs. size-based indicators (SBI) using two different statistical models. Relationships from GLM were taken from Table 4.3.2.1 for smoothed SBI time series except for the relationship between R and SBI, where fluctuations in R will impact SBI. '0': no relationship expected, '-': negative relationship expected, '+': positive relationship expected. 'Y': expectation met, 'N': expectation failed.

SBI	Short-term expectations (SSB/R/F)	Stock	Model					
			GLM			GAM		
			SSB	R	F	SSB	R	F
L95	0/-/-	cod-347d	Y	N	Y	Y	N	Y
		ple-nsea	N	N	Y	Y	N	N
		whg-37d	Y	Y	N	Y	Y	N
		ple-2123	N	N	Y	Y	N	N
SSB_{mega}	+/0/-	cod-347d	N	Y	Y	Y	Y	Y
		ple-nsea	Y	Y	N	Y	Y	N
		whg-37d	N	Y	N	Y	N	N
		ple-2123	N	Y	Y	N	Y	N
$cpue_{mega}$	+/0/-	cod-347d	Y	N	N	N	N	N
		ple-nsea	Y	Y	N	Y	Y	N
		whg-37d	Y	Y	N	Y	N	N
		ple-2123	Y	N	Y	N	N	N
P_{mega}	0/-/-	cod-347d	Y	Y	Y	Y	Y	N
		ple-nsea	N	N	Y	Y	N	N
		whg-37d	Y	Y	N	Y	Y	N
		ple-2123	N	N	Y	Y	N	N
P_{mat}	0/-/-	cod-347d	Y	N	Y	Y	Y	Y
		ple-nsea	N	N	N	Y	N	N

whg-37d	Y	Y	Y	Y	N	Y
ple-2123	Y	N	Y	Y	N	N

4.3.3 Discussion

The results of SG2 should be treated with great caution and should be considered *only as indicative*. Considerable more work needs to be done by looking at a wider range of stocks with different life-history traits, different geographical distributions and different data sources. Especially for the latter, it needs to be ensured by the most competent persons that the right data from the most appropriate surveys and stock assessments are combined and treated appropriately. This refers to the choice of data sources, the filtering processes for selecting the correct data (e.g. by area, time, species, etc.), the methods of indicator calculation, the treatment of time series (smoothing, standardisation) as well as to the choice of statistical modelling methods (e.g. GAM, lagged GAM or cross-correlation analysis). WKIND3.3ii could only but touch some of these aspects looking at a very limited number of stocks applying only a few of many thinkable analysis methods.

With regards to the first objective the absolute SBI, SSB_{mega} and $cpue_{mega}$ seem to be directly related to SSB. Contrary, the relative SBI (L_{95}, P_{mega} and P_{mat}) seem to contain additional information to SSB as indicated by non-linear relationships between these SBI and SSB. This result implies that SSB_{mega} and $cpue_{mega}$ may be redundant to SSB (or any other indicator of stock size) reproducing the assessment results of D3C2. However, it should be considered that the indicators of the analysed four stocks, even though these were selected by their variability within the time series, may be only within a limited range of possible indicator values. All stocks have experienced intensive fishing pressure throughout the available time-series, and it seems that most of the stocks can sustain significant higher biomasses than has been observed in the recent past (1980s to 2010s) (Thurstan *et al.*, 2010; Bolster *et al.*, 2011; Fock *et al.*, 2014). It is therefore mostly unknown, how the size distribution within fish stocks under high stock biomasses will look like. Stocks like North Sea plaice, which is just drastically increasing in SSB, may provide valuable insights into the dynamics of SBI at high stock biomasses.

WKIND3.3ii analysed the relationships between stock indicators and SBI with different statistical models. Yet the demonstrated relationships between these two groups of indicators did not consistently meet the hypothesised relationships nor did consistent patterns emerge across stocks and SBI. Thus with regards to the second objective, WKIND3.3ii was not able to identify any clear patterns in the relationships between stock indicators and SBI. For example, SSB and P_{mega} showed significant relationships for all three stocks when analysed by a GAM, i.e. higher stock sizes correlate with a higher proportion of mega spawners. This meets the expectations hypothesised in Table 4.2.3.1. Contrary, the positive relationships between F and SSB_{mega} for North Sea plaice (Figure 4.3.2.2) did not meet the expectations (Table 4.2.3.1). WKIND3.3ii could not identify, whether these diverging relationships were attributable to data or methodological issues or in fact reflect ecosystem effects such as density dependent growth.

An important aspect in the observed ambiguity of the relationships between stock indicators and SSB may be found in the fact, that WKIND3.3ii was not able to include selectivity as a predictive variable into the statistical models. Selectivity is a very important factor affecting the size and age distribution within exploited fish stocks

(Beverton and Holt, 1957; Fauconnet and Rochet, 2016; Froese *et al.*, 2016). Looking only at fishing mortality may therefore not be enough to identify the relevant relationships between SBI and stock dynamics. Interestingly, WKIND3.3i suggested an indicator of selectivity (L_C, length-at-first-capture), which, if available for more stocks, might provide an important input variable for future analysis. This once more emphasizes the necessity and importance of data on selectivity by commercial fishing fleets to become more easily accessible.

According to fish population dynamics at high stock biomasses fish stocks should be dominated by large spawners i.e. individuals that fall in the size range of mega-spawners (Beverton and Holt, 1957). In case were stocks are far away from these high biomasses, the same SSB can be constituted of various proportions of large, intermediate and small spawners. Thus at any given SSB one could expect to observe different values of SBI, depending on the applied selectivity of the fisheries affecting the size composition within the stock. However, the overall selectivity in the fisheries of all the analysed stocks may have remained relatively constant and therefore the observed value ranges of the SBI may be relatively minor to what may be expected under different scenarios of selectivity. Therefore, it may be difficult to find clear evidence for the usefulness of SSB_{mega} and $cpue_{mega}$ in empirical data. Due to their conceptual strengths i.e. the lack of sensitivity against recruitment and the representativeness of megaspawners, both indicators should not be easily dismissed. Instead, more focus should be set on population modelling studies, in which the relationships between fishing intensity, selectivity and SBI can investigated without uncertainty from observation, measurement error or stochastic environmental processes.

4.4 Conclusion

Several curved long-term lagged relationships between SBI and SSB suggest strong correlation and hence redundancies. Especially SSB_{mega} and $cpue_{mega}$ seem to behave very similar i.e. being positively related to SSB. Thereby it does not appear to be of major importance whether the abundance of megaspawners is calculated by survey or the combination of survey and stock assessment data.

It needs to be further investigated whether SSB_{mega} and $cpue_{mega}$ contain additional information to SSB. The here analysed empirical data does not provide evidence for this, but situations, in which SSB and SBI diverged, may have not been experienced by the here analysed stocks and/or may be masked by internal population dynamics. Low stock biomasses and the lack of significant changes in selectivity may reduce the range of observed indicator values.

Population models may helpful to elucidate the question, whether large stock biomasses will inevitably result in large SBI values or if stable states are possible, in which SBI can remain small at high stock sizes.

Relationships between SSB, R & F and SBI are evident, but the patterns of these relationships were not consistent across indicators and stocks. In several cases the observed relationships between stock indicators and SBI were in line with the expectations of WKIND3.3ii, in other cases not. At the moment it is not possible to identify whether the identified differences in the stock indicator-SBI relationships are due to differences in data quality, data processing, fisheries impacts or ecological processes (e.g. density dependence in growth and mortality).

4.5 Recommendations

- WKIND3.3ii expects the relationships between stock indicators and SBI still to be generic and valid, even though this could not be unambiguously demonstrated. Therefore WKIND3.3ii recommends to further investigate the usefulness of SBI for the assessment of the status of exploited fish stocks.
- More work is needed to collect and combine the necessary data to compare stock indicators and SBI. For this purpose, the length-frequencies from commercial catch and from hydro-acoustic surveys (including control catches) should become available, to enable the inclusion of stocks for which demersal survey data may not appropriate for representing large individuals or length frequency distribution in general (e.g. pelagic species).
- Commercial length frequency data are needed to calculate selectivity indicators (e.g. L_c). These can be used to analyse the combined influence of F and selectivity on SBI.
- The use of population simulation models is considered as helpful in exploring the usefulness of SBI for the assessment of stock status i.e. GES. These models may also be helpful for identifying potential SBI- reference points.
- It could be explored whether the influence of mega-spawners (represented by SBI) on recruitment could be used to develop reference points for SBI (similar to SSB-reference points derived from SSB-R relationships).

5 Sub-group 3: Review on time series based assessment methods

5.1 Introduction

The sub-group performed a review of the ecological literature on statistical methods of time series analyses and evaluated their appropriateness and relevance for assessing size-based indicators (SBI). Time series-based assessments come into play in situations when time series of adequate length data are available, but no assessment reference points have been established. This situation can arise for indicators without any theoretical concept or known pressure-state relationship (Probst and Stelzenmüller, 2015) or for numerous data poor stocks and species in the ICES region. In the following, a review of analytical methods and a discussion of their applicability with relation to reference points for GES (Good Environmental Status) assessment is provided.

5.2 Review of time series analysis methods

Based on the literature review, we identified several paradigms in how trends in the indicators can be analysed with time series analysis. First, the value of an indicator may be gradually changing over time, in which case, a rate of change in the indicator is estimated. We group these methods under "trend analysis." Second, a time series can be divided into different periods with stable means. Shifts in the mean value of the indicator may occur and the timing of the shifts can be identified or estimated. These methods are termed "breakpoint methods". Third, the value of the indicator is not analysed per se, but the statistical properties of the time series of the indicator is evaluated. These methods are grouped under "dynamic methods."

5.2.1 Trend analysis

The most basic (time-series analysis *sensu stricto*) approach for analysing time-series of indicators is using slope estimates from linear (or non-linear) regression analyses to determine whether indicator values during the assessment period (AP) are shifting towards improvement of the indicator levels or not. This can be done either by using full length data series ("full trend analysis") or just for determination of short-term trends in the indicator values of latest years ("recent trend analysis").

Trend analysis can be extended to the entire time series and the rate of change in an environmental indicator over time can be tested for statistical significance. The method is described in mathematical detail by Fewster *et al.* (2000) and Trenkel and Rochet (2009). First, a generalized additive model (GAM) is fitted to the time series data and second, derivatives are calculated to determine whether the trend is accelerating. Statistical tests of significance of the second derivatives can be performed annually by bootstrapping the data (Fewster *et al.*, 2000). Another test was developed to determine whether recent increases (and decreases) in the indicator were statistically significant (Trenkel and Rochet, 2009). An application of this statistical test to survey indices of abundance for North Sea fish stocks is presented in Trenkel and Rochet (2009).

5.2.2 Breakpoint analysis

Two methods of breakpoint analysis were reviewed. First, the "multiple zero-slope" approach by Probst and Stelzenmüller (2015) analyses the indicator variable by fitting a series of zero-slope regression lines using the 'strucchange' R-package. The statistical methods used in the package balances the optimal number of break points with the sum of squares fit to the data. The years and duration of each regression line correspond to separate "regimes" in the indicator.

Second, we explored the "shiftogram" analysis which is developed in Gröger *et al.* (2011) and also applied in Lindegren *et al.* (2012). With this method, a series of linear models is fitted to the data, in which the model has an indicator variable for the breakpoint. A grid search is performed by repeating the model fit over different years. By searching for local minima in the AIC (Aikaike information criterion) among the candidate models, breakpoints can be selected for the indicator time series.

5.2.3 Dynamic methods

Two methods were reviewed by the subgroup which examined the statistical properties of indicator time series: (1) the "critical slowing down" method which uses a moving window to estimate the variance/autocorrelation of the indicator variable over time (Lindegren *et al.*, 2012), and (2) the CUSUM (cumulative sum) method (Mesnil and Petitgas, 2009).

Lindegren *et al.* (2012) examined the autocorrelation and variance of environmental indicator time series (zooplankton abundance) in the Baltic Sea to evaluate the ability of the method to detect the climate regime shift that was hypothesized to occurred in 1988. It was hypothesized that the variance of an environmental indicator increases preceding an abrupt change in climate due to habitat and population fragmentation (this was called "critical slowing down"). The time series was de-trended using a Gaussian smoother and the lag-1 autocorrelation and residual variance were estimated in the residuals of the observed data and smoothed predictions. This analysis was repeated with a moving window to produce a time series of variance and autocorrelation estimates. A sudden increase in the variance and decrease in the autocorrelation was inferred in the zooplankton time series at the time of the hypothesized regime shift.

The CUSUM (cumulative sum) method analyses the extent in which an indicator time series deviates from a pre-specified distribution to detect gradual and persistent changes (Mesnil and Petitgas, 2009). First, the values of the indicator are converted into deviates of a standard normal random variable. A running tally of positive and negative deviations are calculated forward in time. A positive deviate is added to the upper cumulative sum if the former exceeds the allowance parameter *k*. Similarly, a negative deviate is added to the lower cumulative sum if the former exceeds the allowance parameter less than -*k*. An "out of control" situation occurs when the lower or upper cumulative sum crosses the threshold control limit *h*. The study by (Pazhayamadom *et al.*, 2013) developed a "self-starting" algorithm which calculates the mean and variance based on the values of the indicator from previous years and is updated annually for the variable transformation into t-distribution deviates. This algorithm would be appropriate if stable conditions are assumed in the resource at the beginning of the time series. Guidance on the values of *k* and *h* and a simulation study of the CUSUM method using the mean length as the size-based indicator is also provided in that study.

5.3 Discussion

So far, all of the methods described have been used to analyse environmental indicator variables such as abundance, but only some have been used to analyse time series of size-based indicators. Recent trend analysis, the multiple zero-slope regression, and CUSUM methods have been used for SBI, although the CUSUM method has not been used for management purposes.

While simplicity and applicability to data deficient scenarios are strengths of recent trend analysis approach (for example, when the time series is very short), it is not possible to establish if GES has been achieved from this method alone (see Table 5.3.1).

Still, trend analyses is useful if applied together with other methods to monitor the direction of change of the indicator values during the AP (HELCOM, 2012; Probst and Stelzenmüller, 2015) as a surveillance indicator. It is also important to note that the value of the indicator cannot improve indefinitely because in theory, the slope should decrease in magnitude to zero when optimal conditions are reached. As a result, recent trend analysis should be used if few years of data are available or if it can be combined with other approaches.

Trend analysis can be simply extended to analyze the full time series method using GAMs and statistical tests for significance. Similarly, the shiftogram analysis can be an alternative method for estimating the breakpoints in the time series of SBI. The critical slowing down method can be used to explore whether the variance and correlation are increasing, stable, or decreasing. The application of this method so far has been used to detect abrupt climate regime shifts, which are assumed to affect the abundance of indicator species (Lindegren *et al.*, 2012). To use this method, the causality and interpretation of the variance and autocorrelation in SBI would need to be established.

Although no example applications were performed by the subgroup at this meeting, the reviewed methods have all been recently published in the peer-reviewed scientific literature. As such, they represent the best science available for the analysis of environmental indicators. For the methods with previous applications to SBI, we recommend their use for future assessments. For methods without previous applications to SBI, we also recommend future applications for their suitability to characterize historical trends in the SBI. While some expertise is required for the time series analysis, the relevant software is easily available for most methods (Table 5.1, Andersen et al., 2009). It is also important to note that a long time series is needed for most of the methods described, while recent trend analysis may be the only option available with a short time series.

5.3.1 Reference points

An example of a generic workflow of how to assess and set reference points to ecological indicators by various methods is presented in Stelzenmüller *et al.* (2015). If a reference point is available from theory or pressure-state relationship, one can simply evaluate whether the value of the indicator is currently above or below the reference point for GES assessment and management. In cases where the indicator lacks accepted reference points, the latter can be assigned on the basis from a time series analysis or some pre-determined concept (e.g. HELCOM, 2012).

A combination of several time series analyses (trend analysis and breakpoint analysis) have been developed for reference points of SBI. Probst and Stelzenmüller (2015) combined the break point analysis to develop indicator reference points such as best and worst means from the reference period (RP). Then, the recent trend analysis using a linear regression can be used in the assessment period (AP) to establish the value of the indicator relative to those reference points. Appropriate management action can be taken from the GES estimation from both the breakpoint analysis and the slope (rate and direction of change) in the indicator from the trend analysis.

If reference points (or reference levels of the time series) are not derived from the statistical analyses of existing time series of the indicator, then pre-set rules have been applied for the establishment of the reference points from a specific reference period of existing data. For example:

1. the median value from last stable five year period of an indicator is considered to represent a reference period (RP) and the median of the assessment period (AP) should be within the 5th and 95th percentile of the median distribution of the baseline data set in order to represent GES (e.g. HELCOM 2012);
2. the full time-series is considered to achieve GES, if the last value(s) is or are in the upper 25th percentile of all values (e.g. Greenstreet *et al.*, 2012);
3. values from the period of "pristine state" of the indicators are used as pre-set GES reference levels (e.g. Shephard *et al.*, 2014).

Table 5.3.1. Strengths and weaknesses for the methods of analyzing indicator time series and setting reference points.

METHOD	STRENGTHS	WEAKNESSES	CITATIONS
Trend analysis	• Easy to apply • Range of methods available (linear/polynomial regression, generalized additive model) • Applicable with short time series • Smoothing can reduce variability	• Reference points are not used • Older data are not used if only recent trend is assessed • Cannot establish if "true" GES has been attained • Trend cannot be indefinitely unidirectional	HELCOM (2012); (Probst and Stelzenmüller, 2015)
Simple statistics (means, quantiles of time series)	• Can be applied with short time series	• Cannot establish if "true" GES has been attained	Greenstreet *et al.* (2012); HELCOM (2012); Probst *et al.* (2013a)
Advanced statistics (breakpoint analysis, dynamic methods)	• Evaluates changes in indicators over time • Smoothing accounts for variability in indicator over time • Method may be used to establish reference points • Relevant software generally available (Table 1 of Andersen *et al.* 2009)	• Expertise required for some statistical methods • Requires longer and continuous time series • Length of time series and model specification can affect analysis • Cannot establish if "true" GES has been attained	Andersen *et al.* (2009); Trenkel and Rochet (2009); Trenkel and Rochet (2010); Lindegren *et al.* (2012); Pazhayamadom *et al.* (2013); Probst and Stelzenmüller (2015)

These methods allow for setting of easily calculated and understandable reference points that can be applied also in the case of relatively shorter time-series. However, this approach has several limitations of which the user should be aware. The application of pre-set reference limits (e.g. average and percentiles of the last stable period in the RP data) may result in overlooking meaningful parts of the time-series that do not fit the pre-set criteria. For example, relatively high fluctuations may be "biologically normal" in case of some species and often stable periods are common for stocks that are pressured to extremely low levels. Thus, application of pre-set reference limits (e.g. average and percentiles of the last stable period in the RP data) in the latter case would result in reference points of GES that refer to a heavily exploited state of the stock (see Figure 5.3.1.1). This is likely to happen if time-series of a particular stock are describing only a heavily exploited situation or if only very short time-series are available. In such cases, indicator values that would represent a "real GES" may not be present in the time series.

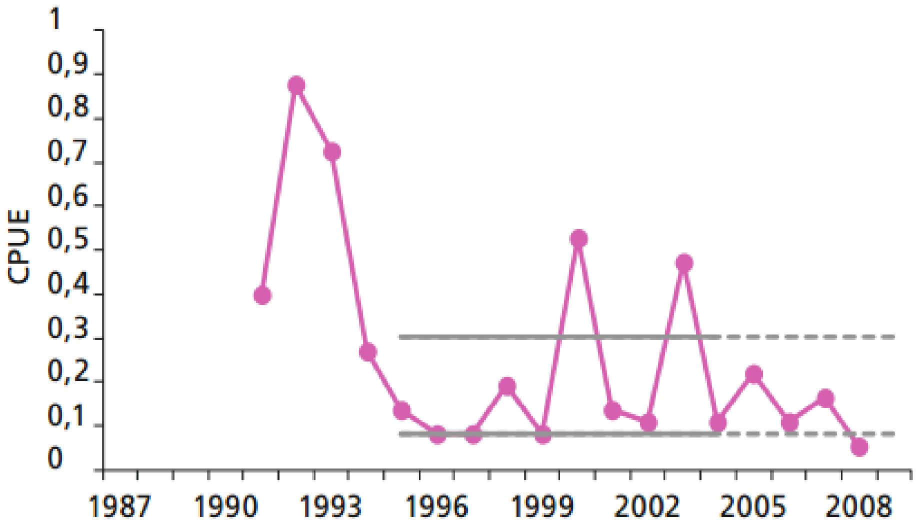

Figure 5.3.1.1. A time series of catch-per-unit-effort (CPUE) with horizontal grey lines for the 5th and 95th percentile of the time in the time series reference period of 1995 - 2004 (obtained from HELCOM, 2012). This is an example of reference points which may not reflect GES because the reference period does not include values in the earlier part of the time series (prior to 1995) that indicate a higher stock abundance.

5.4 Conclusions

- Plenty of time series based methods are available suited for all kinds of data situations.
- Advanced statistics can identify times of significant change and thus can help to establish reference points based on the past.
- No method can define conceptual reference points and thus deliberately refer to a "true" GES.
- Time series based assessment methods cannot replace conceptual reference points, but instead may be used as a fall-back option for indicator without any other reference points.

6 Sub-group 4: Exploring the influence of fishing scenarios on SBI using population models

6.1 Introduction

The ICES workshop WKIND3.3i identified several size-based indicators (SBI) to be potentially relevant for the evaluation of stock status under MSFD descriptor D 3.3. Unfortunately, none of these size based indicators (SBIs), derived from the length-frequency distribution of the catch or stock, have well-established, biological meaningful assessment reference points (sometimes referred to as reference levels or thresholds).

Without proper reference points for the chosen SBIs, it is difficult to make them operational for the purposes of determining stock status. This chapter addresses TOR d of the workshop *the setting of thresholds and reference levels for any potential methods.*

It was recommended at WKIND3.3i that population models used for the calculation of F_{MSY} (e.g. the EQSIM simulation framework) could be helpful in estimating length-frequency distributions in the stock when exploited at $F=F_{MSY}$.

The analyses presented here use EQSIM results to examine the size distribution in the population and the catch of three data-rich stocks in the North Sea, an example of a gadoid species: cod (cod-347d), of a flatfish species: plaice (ple-nsea), and of a pelagic species: herring (her-47d3). All three stocks have previously had F_{MSY} reference points estimated using this software and have category 1 (full analytical) age-based assessments allowing a good estimation of stock status. The estimated potential ranges of SBIs that could be expected under a range of F values, including F_{MSY}, are presented.

6.2 Methods

Age structure simulations of the three stocks were conducted using the EQSIM model (https://github.com/ices-tools-prod/msy). The number-at-age results were then converted to numbers-at-length using age-length keys derived from survey samples in the North Sea. These length frequencies were then used to calculate SBIs for each stock over time.

The latest assessment results for each stock are shown in Annex 4.

For each stock a set of F-values were simulated, ranging from zero fishing pressure to the maximum observed F (Table 6.2.1). Other values included F_{MSY}, F_{MSY} lower (the lowest F that provided at least 95% of the maximum sustainable yield in the long run) and $F_{P0.05}$ (the highest F with a less than 5% chance of SSB<B_{lim} in the long run i.e. the highest precautionary F).

Table 6.2.1. F-values simulated in the EQSIM simulations of the three stocks. These values are the current ICES estimates from the most recent analyses for each stock.

Stock	No fishing	F_{MSY} lower	F_{MSY}	$F_{P0.05}$	Maximum historical F
COD-347D	0	0.22	0.33	0.62	1.07
PLE-NSEA	0	0.13	0.19	0.48	0.77
HER-47D3	0	0.24	0.33	0.40	0.49

6.2.1 EQSIM

EQSIM is an age-disaggregated population simulation model that allows variation in population parameters (weights-at-age, recruitment), fishery parameters (selectivity) and management uncertainty in multiple iterations. This allows an estimation of likely future development taking into account the uncertainty we have about these population and fishery parameters. The EQSIM methodology developed at WKMSYREF3 (ICES, 2014), is now used as a standard methodology for determining F_{MSY} (ranges) by ICES.

The method was altered to start the long-term simulations from specific stock numbers-at-age and to output the stock-numbers- and fishing-mortality-at-age rather than simply long term reference points. The forecasting procedure and handling of uncertainty remained the same as in the original model. EQSIM accounts for uncertainty in the advised F (i.e. takes into account assessment error similar to that observed in recent years). This error is applied directly to the 'true' SSB and/or F in the advice year rather than to the numbers-at-age in the final assessment year. As such no forecast procedure is mimicked (inputted SSB and F uncertainty is calculated for the advice year).

EQSIM fits stock-recruitment curves stochastically accounting for variation in observed values. As such, each individual iteration has its own stock-recruitment parameters. This can be seen in the difference between the maximum possible recruitments for each individual iteration. Extreme recruitments are also truncated to have log-residuals within the range -2 to 2.

The settings used for the simulations of each stock are provided in Table 6.2.1.1. Full details of the EQSIM method can be found in the WKMSYREF3 report (ICES, 2014). All EQSIM code is available on Github: https://github.com/ices-tools-prod/msy/blob/master/R/eqsim.R. R version 3.1.3 (2015-03-09) -- "Smooth Sidewalk" was used to run the simulations.

Table 6.2.1.1 Settings used in the EQSIM simulations of the three stocks. These are the same as the most recent EQSIM reference point calculation settings used for each stock.

SPECIES	COD-347D		PLE-NSEA		HER-47D3	
Source	WKNSEA (ICES, 2015)		WKMSYREF3 (ICES, 2014)		WKMSYREF3 (ICES, 2014)	
Data and parameters	Setting	Comments	Setting	Comments	Setting	Comments
Stock-recruit relationships	'SegregB max'	Segmented regression with the breakpoint fixed at the maximum observed SSB	Ricker, Segmented regression and Beverton and Holt	All provide reasonable fits to the data	Ricker and Beverton and Holt	Appropriate for data
SSB-recruitment data	Recent data series (years classes 1987-2013;	R per SSB shows signs of reduced productivity in recent years	All years, excluding most recent estimates (1957-		Recent period (2002-2013)	R per SSB shows signs of reduced productivity in recent years

	excluding 1963-1986)		2013)			
Mean weights and proportion mature; natural mortality	2010-2014	There is an increasing trend in mean weight-at-age and predation mortality in the latest years	2006-2015	No significant trends over the last ten years	2004-2015	No significant trends over the recent period
Exploitation pattern	2010-2014	There is no change in exploitation pattern in the last 10 years	2006-2015	No significant trends over the last ten years	2004-2015	No significant trends over the recent period.
Assessment error in the advisory year. CV of F	0.22	WKNSEA 2015	0.189	WKMSYREF3 2014	0.24	WKMSYREF3 2014
Autocorrelation in assessment error in the advisory year	0.42	WKNSEA 2015	0.551	WKMSYREF3 2014	0.50	WKMSYREF3 2014
Number of iterations	200		200		200	
Number of years forecast	151		151		151	
Age range in assessment	1 - 6		1 - 10		0 – 8	
Max age in simulation	13		13		15	

6.2.2 Age-length keys

EQSIM conducts age-based simulations, so for the calculation of length frequency indicators it was necessary to convert these age structures to length structures. This was done using age-length keys (ALKs) determined from samples taken in the IBTS (International Bottom Trawl Survey).

The age-length keys almost always present zero frequencies and noisy information due to the complexity to obtain a representative sample of age composition. By means of statistical models it is possible to create a smooth distribution of age at given length.

Generalized Additive Models (GAMs) with continuation ratio logits were applied to fit the probability of age as a function of length and spatial covariates for three North Sea stocks: cod, plaice and herring. The models were applied to 30 years (1987–2016) of data from the IBTS obtained from the DATRAS database (www.datras.ices.dk). The samples were collected in the first quarters of the year for the three stocks. The methodology used is implemented in the DATRAS package for R (https://www.rforge.net/DATRAS/) and fully described in Berg and Kristensen (2012) Berg and Kristensen (2012).

The inverse of the smooth age-length keys, a matrix with the probability of an individual of age of having determined length, was used to transform number-at-age data estimated by the EQSIM model into numbers-at-length. These ALKs were applied retrospectively to historic estimates of numbers-at-age from the assessments are held constant over time in the simulations (i.e. no variation in past or future growth is accounted for in these analyses).

All the assessments of the stocks contain plus groups (one age group for all fish above a certain age) that trim the age-structure of the modelled populations in comparison to the age range available from the surveys. Since most of the SBIs focus on the proportion of larger (older) fish, the age structures obtained from the most recent assessments needed to be expanded out to the maximum reliable age from each ALK. In order to do this the population numbers from the assessment plus groups were expanded out to the maximum age-length key age, maintaining the same number of fish. In the absence of better information, it was assumed that weight-at-age and maturity (which affect SSB calculation) and the selectivity of the fishery were the same for all ages from the plus group up. However, a separate age-length relationship was estimated for each age.

6.2.3 Size based indicators

For each stock, the following length based indicators were calculated for the whole ('true') population and the catch (Table 6.2.3.1).

Table 6.2.3.1 Overview on the analysed size-based indicators.

SBI	Description
L_{95}	The 95th-percentile of the entire sample (population or catch)
L_{95_mat}	The 95th-percentile of the all lengths in the sample that are greater than the length at first maturity
L_{95_mls}	The 95th-percentile of the all lengths in the sample that are greater than the minimum landings/conservation size
P_{mat}	The proportion of the sample that is great than the length at first maturity
P_{mega}	The proportion of megaspawners in the sample (defined as spawners greater than $L_{mega} = 1.1*L_{opt}$)

Life history parameters collated by WKIND3.3i were used for the simulations (Table 6.2.3.2).

Table 6.2.3.2. Life history parameters from WKIND3.3i (ICES 2016) and minimum landings/conservation size (MLS) for the three simulated stocks.

Species	Stock	L_{INF}	L_{MAT}	L_{OPT}	L_{MEGA}	MLS
Gadus_morhua	cod-347d	117.0	53.4	85.8	94.4	32.0
Pleuronectes_platessa	ple-nsea	55.0	22.8	40.3	44.3	27.0
Clupea_harengus	her-47d3	34.6	23.8	25.4	27.9	20.0

The current simulations did not simulate the catchability of surveys, and therefore no estimates of the length frequency that would be expected in survey data was available. The estimates of survey catchability from the assessment models do not cover the full range of ages that are in reality sampled in the surveys.

6.3 Results

6.3.1 North Sea cod (cod-347d)

6.3.1.1 Selectivity, ALKs and simulated SSB development

Details of the recruitment simulated are shown in Annex 4, Figure 6.3.1.1.1. Recruitment varies around a lower level than historically observed (following the assumption of reduced productivity), with a high degree of auto-correlation (AR1=0.60).

The resampled selectivity curves of commercial catches in the simulations for cod are shown in Figure 6.3.1.1.2. Little variation in selectivity has been estimated by the cod assessment in recent years, with only slight differences present for ages 5 and 6+. Selectivity appears to be dome shaped for the assessed ages (1-6), but with no information available from the assessment for the older ages, it is not clear how selectivity may decrease or remain constant above age 6.

Figure 6.3.1.1.3 shows the resultant ALKs from the GAM analyses. It is clear that the maximum attainable length has not been sampled in the IBTS data. Hence for ages 9 and up, a high proportion of the numbers at age will be assigned the maximum length of 138cm. The poorer sampling of the larger sizes also affects the quality of the ALKs for older ages, with age 12 having a higher proportion of larger fish than age 13.

Figure 6.3.1.1.4 shows the development of SSB under the different F scenarios. Significant stock growth is possible under a scenario of zero fishing. However, since this leads to values much higher than previously observed, the real impact on individual growth and recruitment at such a large stock size has never been observed. Hence it is unknown whether such stock sizes could truly be supported by the ecosystem. Stock growth is also expected under F_{MSY} management and F_{MSY_lower}. F has been decreasing since 2000 in this stock from near the highest level observed to approximately F_{MSY} (see Annex 4, Figure A.4.4). This has allowed for gradual recovery in the stock, though SSB is still currently near B_{lim} (Annex 4, Figure A.4.1).

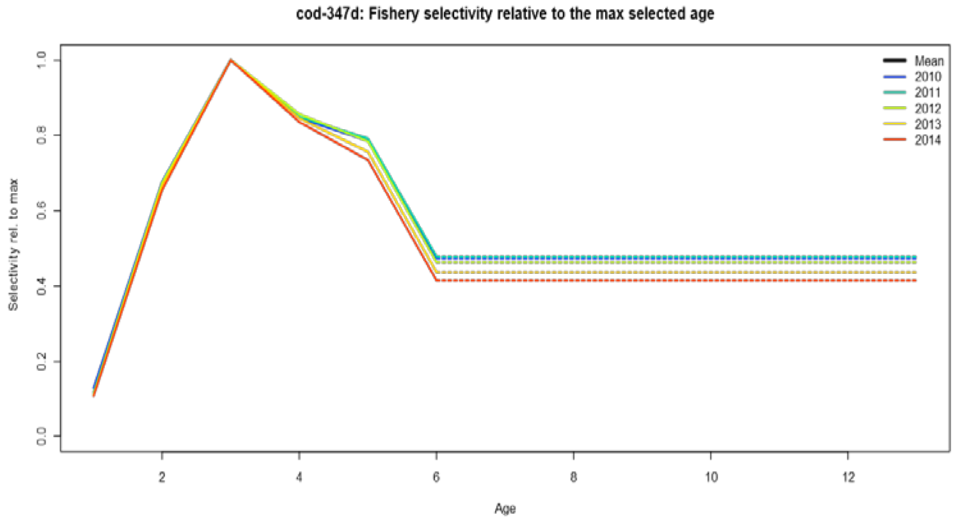

Figure 6.3.1.1.1. The assessment estimated selectivity curves of the cod fishery (solid lines; relative to the maximum selected age) for the years resampled in the simulations. Values from age 7 onwards (dashed lines) are assumed to be equal to the estimated plus group selectivity.

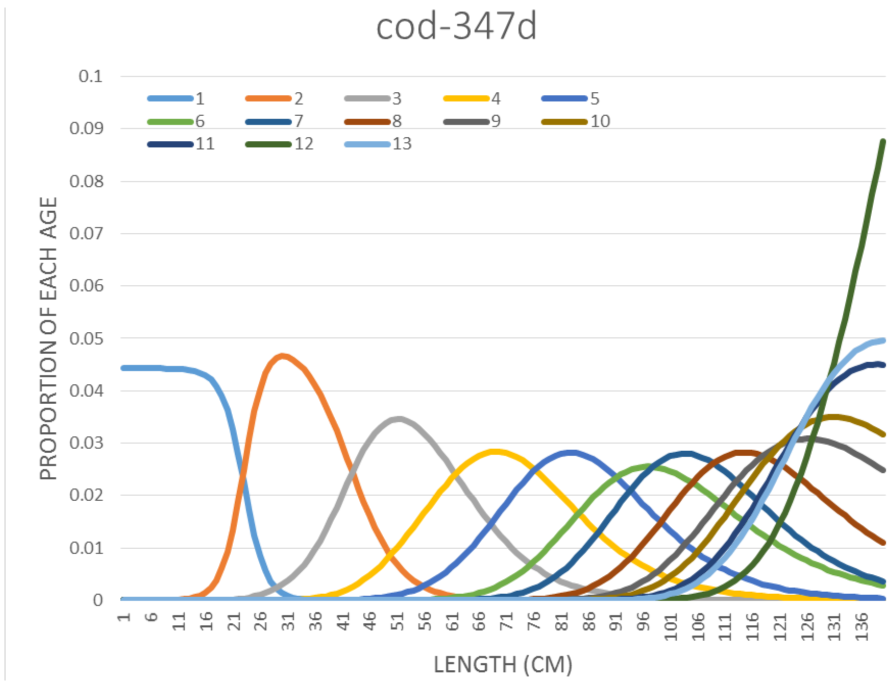

Figure 6.3.1.1.2. Length distributions of cod for each age simulated from the GAM analyses.

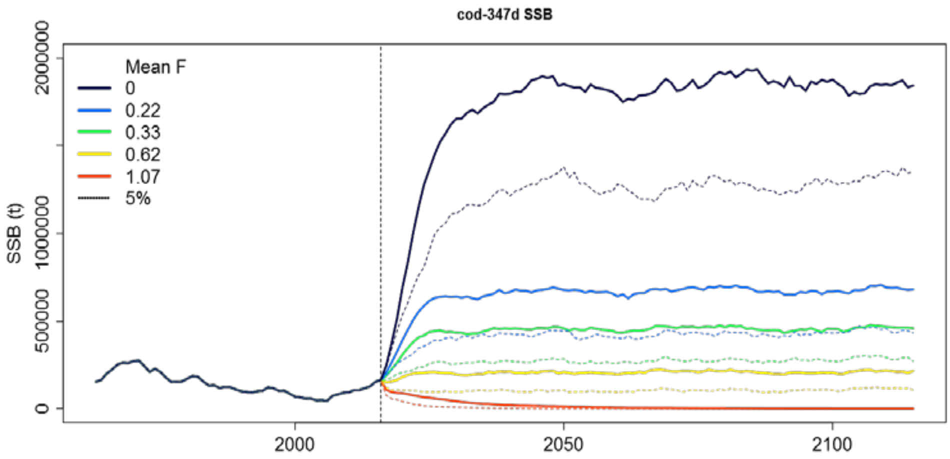

Figure 6.3.1.1.3. Development of stock size (SSB) of cod for the five F values simulated. Median values (solid lines) and lower 5th percentiles (dashed lines).

6.3.1.2 Cod-347d SBIs

The results below are a selection of some length frequency results from the catch. More detailed simulation results for cod-347d, including population length frequency SBIs, are included in Annex 4.

Since 2000 all three SBIs have increased as the stock recovers from very low SSB. In the simulated long-term period of about 100 years, the median values and lower 5^{th} percentiles of the SBIs in the cod catch all show a wide range of constant median values (Figure 6.3.1.1.4). The lower the F, the longer it takes to reach this equilibrium level. Fishing at F_{MSY} (F=0.33) or lower leads to increases in all SBIs from the current estimates.

Figure 6.3.1.1.5 shows the expected range (95%) and the expected variation in two example iterations for each SBI when fishing at F_{MSY}. In all cases, the lower 5^{th}-percentile of the expected range is approximately at the current observed level. All SBI fluctuate naturally over the simulated period, though L_{95} fluctuates more gradually and with less variation relative to the historical range of values when compared to P_{mat} and P_{mega}.

Fishing at F_{MSY} with the current selectivity implies that only 30% of the catch would be greater than the length-at-first-maturity and only a small proportion (<15%) of the catch would be megaspawners. Even with zero fishing, the maximum proportion of megaspawners in the population is estimated to fluctuate around 15-20%, and the proportion above length-at-first-maturity fluctuates around 30%. Note these population length frequencies include recruits, which are highly abundant and immature.

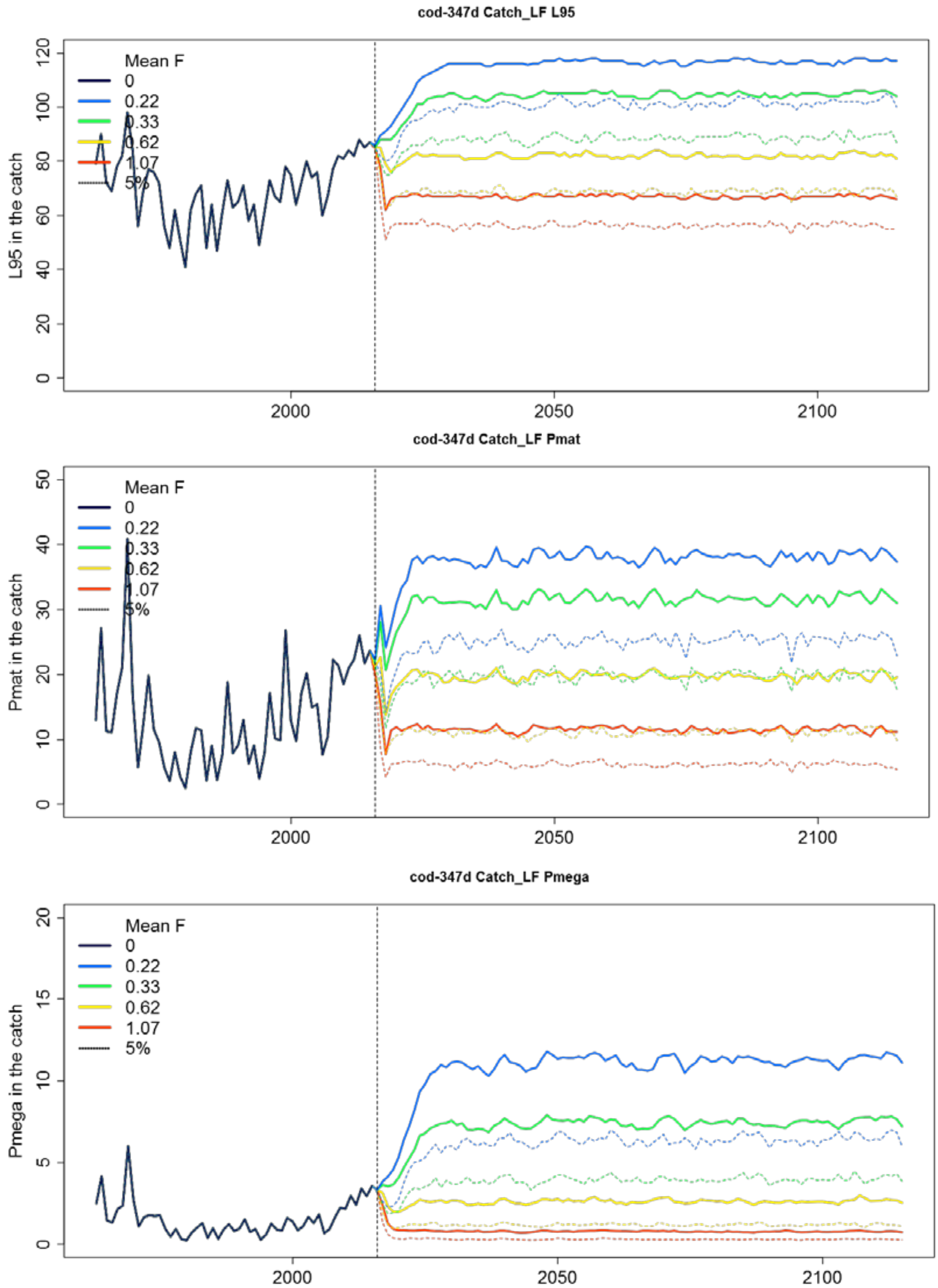

Figure 6.3.1.1.4. Size-based indicators in the simulated catch. L95 (top), Pmat (middle) and Pmega (bottom) size based indicators from length frequencies in the catch of cod for the four non-zero F values simulated (no catch length distributions are obtained from F=0). Median values (solid lines) and lower 5th percentiles (dashed lines) are plotted, both in one colour for each value of F.

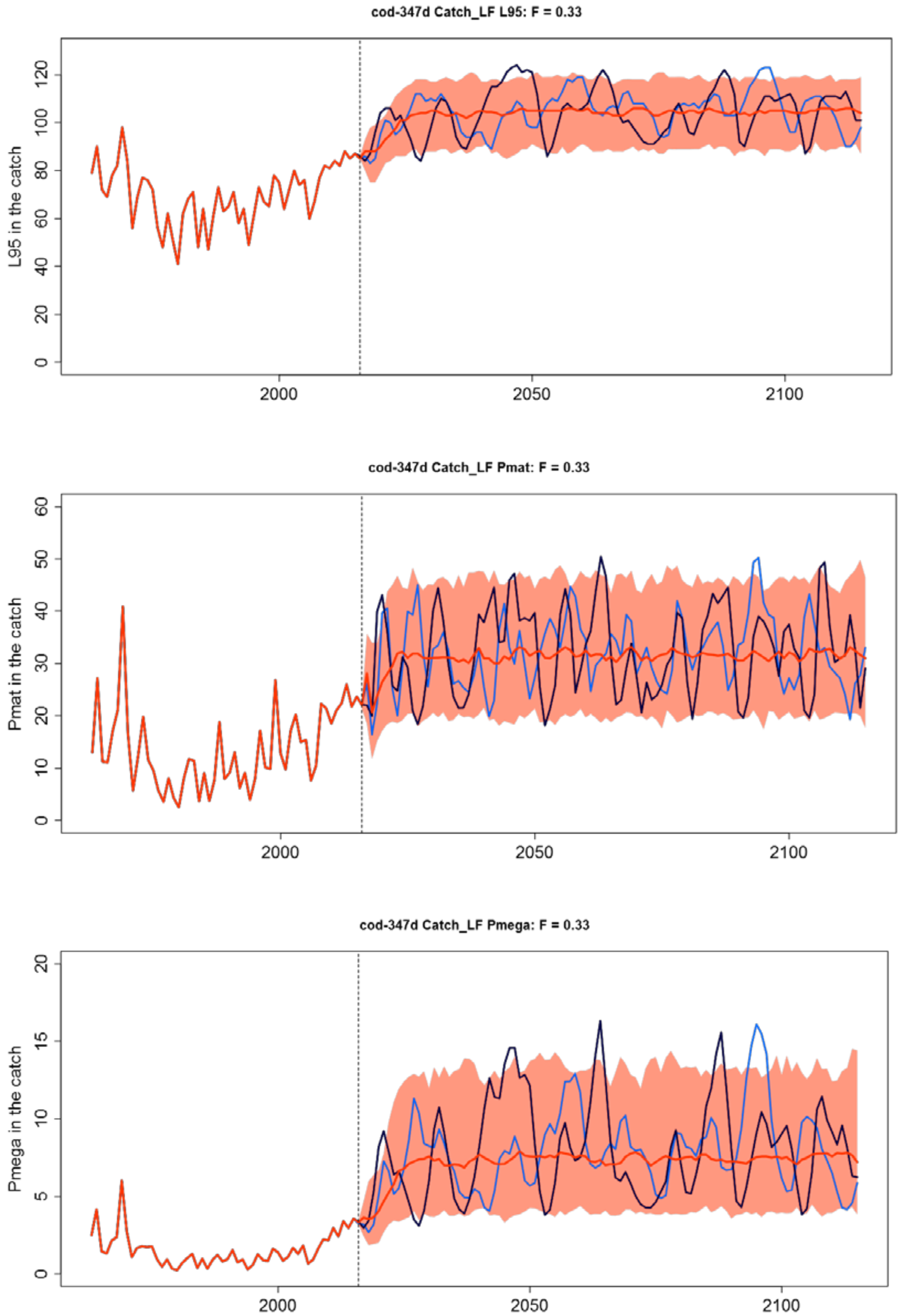

Figure 6.3.1.1.5. Size based indicators from length-frequencies in the catch of cod when fishing at F=FMSY=0.33 . L95 (top), Pmat (middle), and Pmega (bottom) are shown, with median values (solid lines), 95% ranges (shaded area) and two example iterations (black and blue lines).

6.3.2 North Sea plaice (ple-nsea)

6.3.2.1 Selectivity, ALKs and simulated SSB development

Details of the simulated recruitment are shown in Annex 4, Figure A.4.5. Recruitment varies around the historically observed level with the upper 95th-percentile slightly higher than the historical maximum observed (since the stock is expected to grow larger than observed in the past). Autocorrelation is significant (AR1=0.45), but lower than for cod.

The resampled selectivity curves in the simulations for plaice are shown in Figure 6.3.2.1.1. Due to differences in the underlying assumptions of the assessment model, plaice selectivity is estimated to have varied more when compared to cod selectivity. This is also in part due to a higher number of years being resampled. The selectivity for plaice is fairly dome-shaped with the maximum assessed age (age 10) being among the lowest selected ages in most years.

Figure 6.3.2.1.2 shows the resultant ALKs from the GAM analyses. It is clear that the maximum attainable length has not been sampled in the IBTS data. Hence for ages 7 and up, a high proportion of the numbers-at-age will be assigned the maximum length of 65 cm. The ALKs are fairly similar for ages 7 and up. The poorer sampling of the larger sizes also affects the quality of the ALKs for older ages, with age 13 having a lower proportion of larger fish than ages 7-12.

Figure 6.3.2.1.3 shows the development of SSB under the different F scenarios. Similar to cod, the model implies that significant stock growth is possible under a scenario of zero fishing, though whether such stock sizes could truly be supported by the ecosystem is unknown. Some stock growth is also modelled under F_{MSY} management and F_{MSY_lower}. As with cod, F has been decreasing since 2000 in this stock from near the highest level observed to approximately F_{MSY} (see Annex 4, Figure A.4.3). However, in comparison with cod, the SSB of plaice has been above B_{lim} for several years, reaching highest observed levels in 2016.

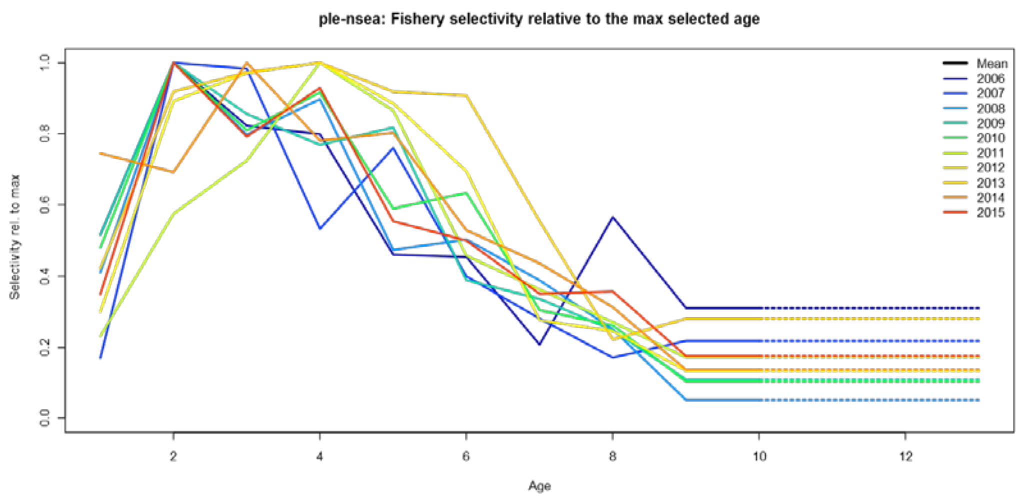

Figure 6.3.2.1.1. The assessment estimated selectivity curves of the plaice fishery (solid lines; relative to the maximum selected age) for the years resampled in the simulations. Values from age 11 onwards (dashed lines) are assumed to be equal to the estimated plus group selectivity.

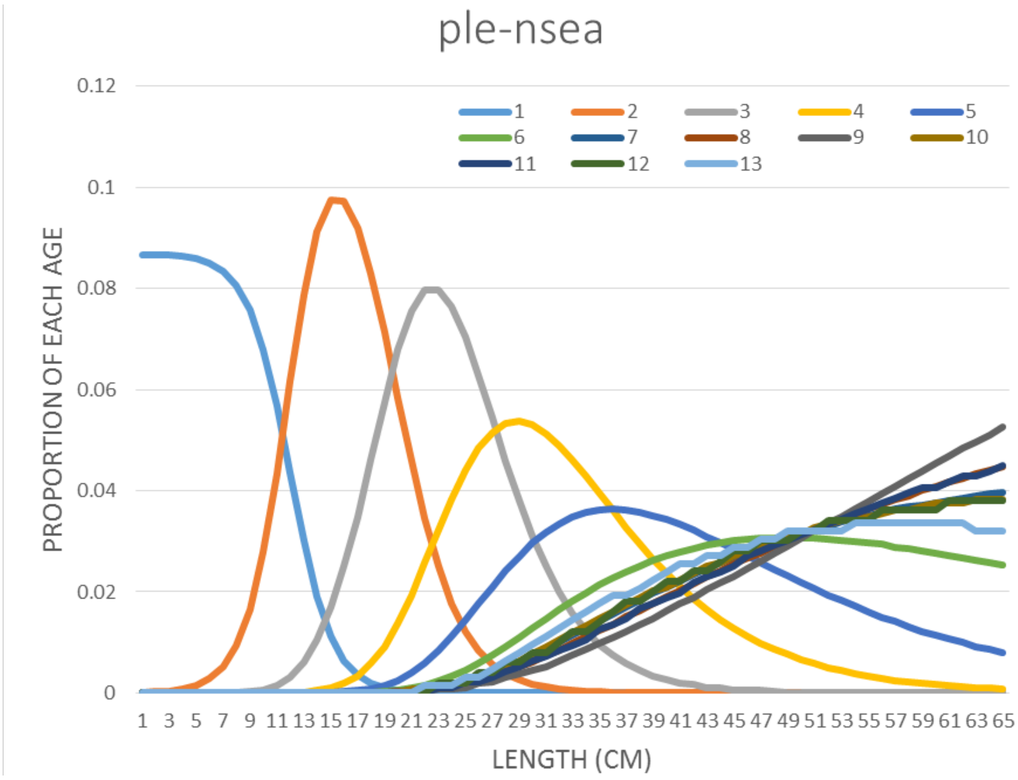

Figure 6.3.2.1.2. Length distributions of plaice for each age simulated from the GAM analyses.

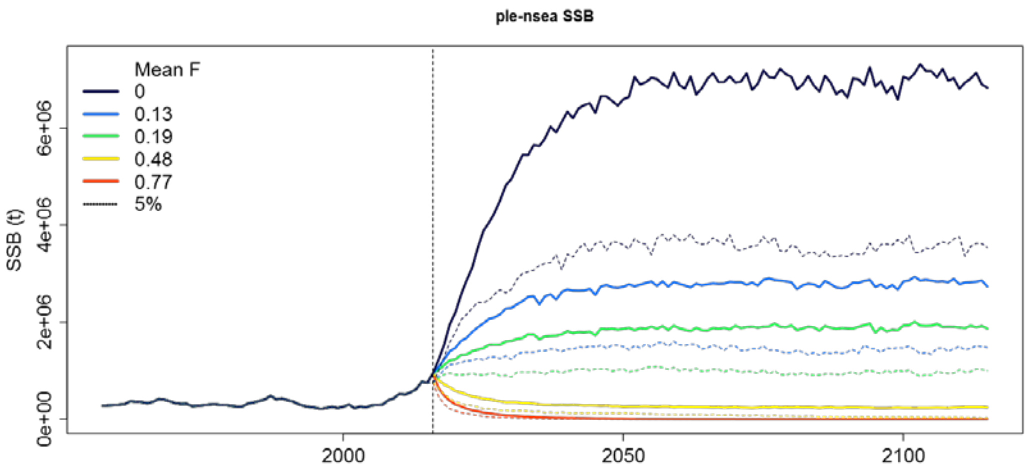

Figure 6.3.2.1.3. Development of stock size (SSB) of plaice for the five F values simulated. Median values (solid lines) and lower 5th-percentiles (dashed lines).

6.3.2.2 Ple-nsea SBI

The results below are a selection of some length frequency results from the catch. More detailed simulation results for ple-nsea, including population length frequency SBIs, are included in Annex 4.

Since 2000, all three SBIs have increased as the stock has increased to record high SSB (Figure 6.3.2.2.1). In the simulated long-term, the median values and lower 5th-percentiles of the SBIs in the plaice catch all show a wide range of median values. There is only a small difference between the L_{95}-values expected when fishing at F_{MSY} or F_{MSY_lower}, and in both cases there is limited increase in L_{95} compared to current values. It is likely that this is a result of the maximum observed length from the IBTS samples for the ages examined (65 cm), which imposes a limit on how high L_{95} can get (i.e. no fish greater than 65 cm are created using the ALKs). This is a modelling artefact rather than a biological barrier to growth and therefor these results should be treated with caution. However, it is clear that at higher F, a reduction in the SBI values would be expected.

Figure 6.3.2.2.2 shows the expected range (95%) and the expected variation in two example iterations for each SBI when fishing at F_{MSY} (F=0.19). Again, L_{95} seems to hit a model imposed maximum at just above 60 cm, leaving a very narrow expected range with the lower 5^{th} percentile around current values. For both P_{mat} and P_{mega} the forecast range is wide, whilst some increase in the median values is expected from the current level. Only few modelled values have been below the lower 5^{th}-percentile that would be expected when fishing at F_{MSY}.

Fishing at F_{MSY} with the current selectivity implies that on average half of the catch would be greater than the length-at-first-maturity and only a small proportion (10-25%) of the catch would be mega spawners. With zero fishing, the maximum proportion of megaspawners in the population is estimated to fluctuate around 40-50%, and the proportion above length-at-first maturity fluctuates around 80%.

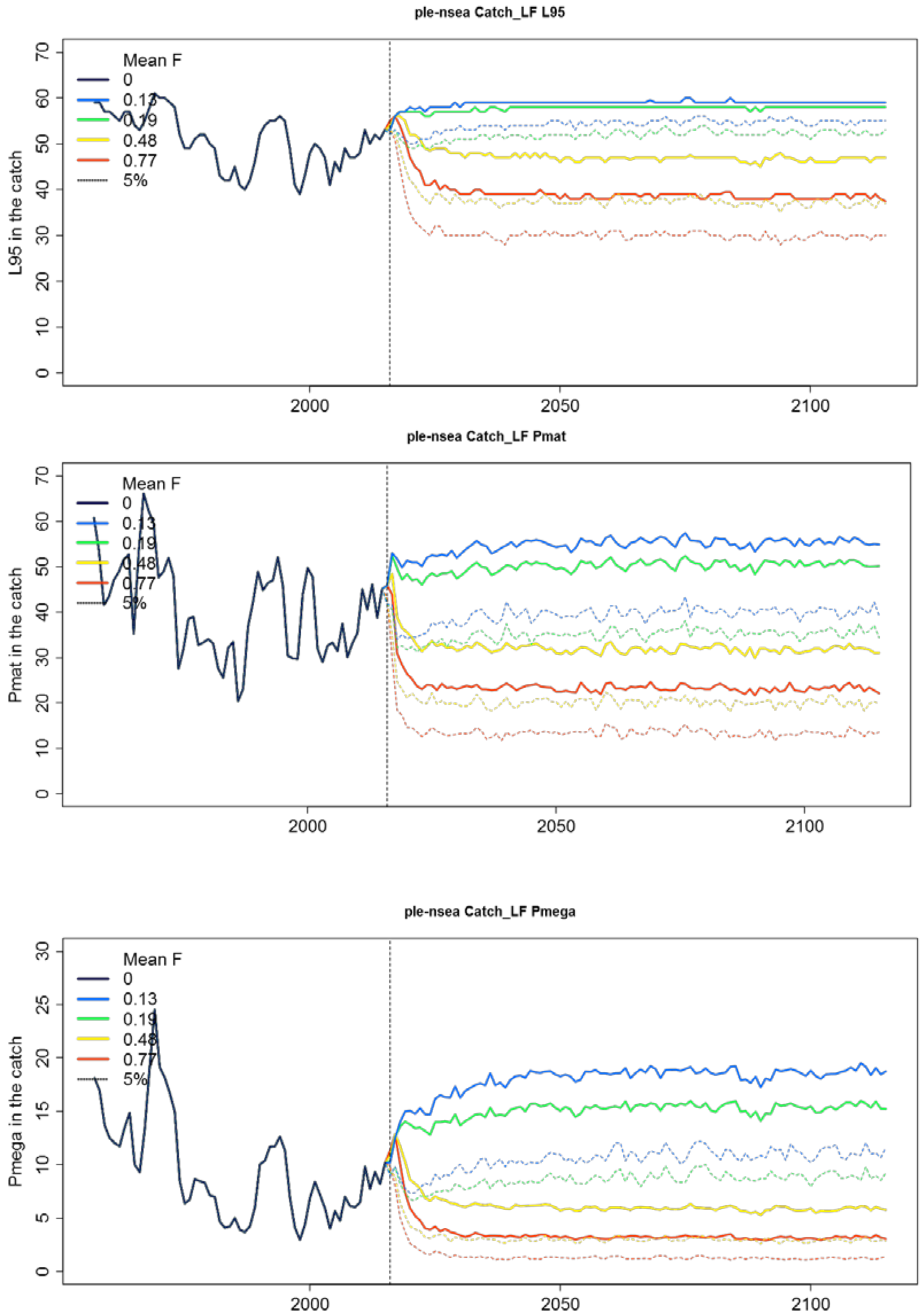

Figure 6.3.2.2.1. Size-based indicators from the simulated catch. L95 (top), Pmat (middle) and Pmega (bottom) size based indicators from length frequencies in the catch of plaice for the four non-zero F values simulated (no catch length distributions are obtained from F=0). Median values (solid lines) and lower 5th-percentiles (dashed lines) are plotted, both in one colour for each value of F.

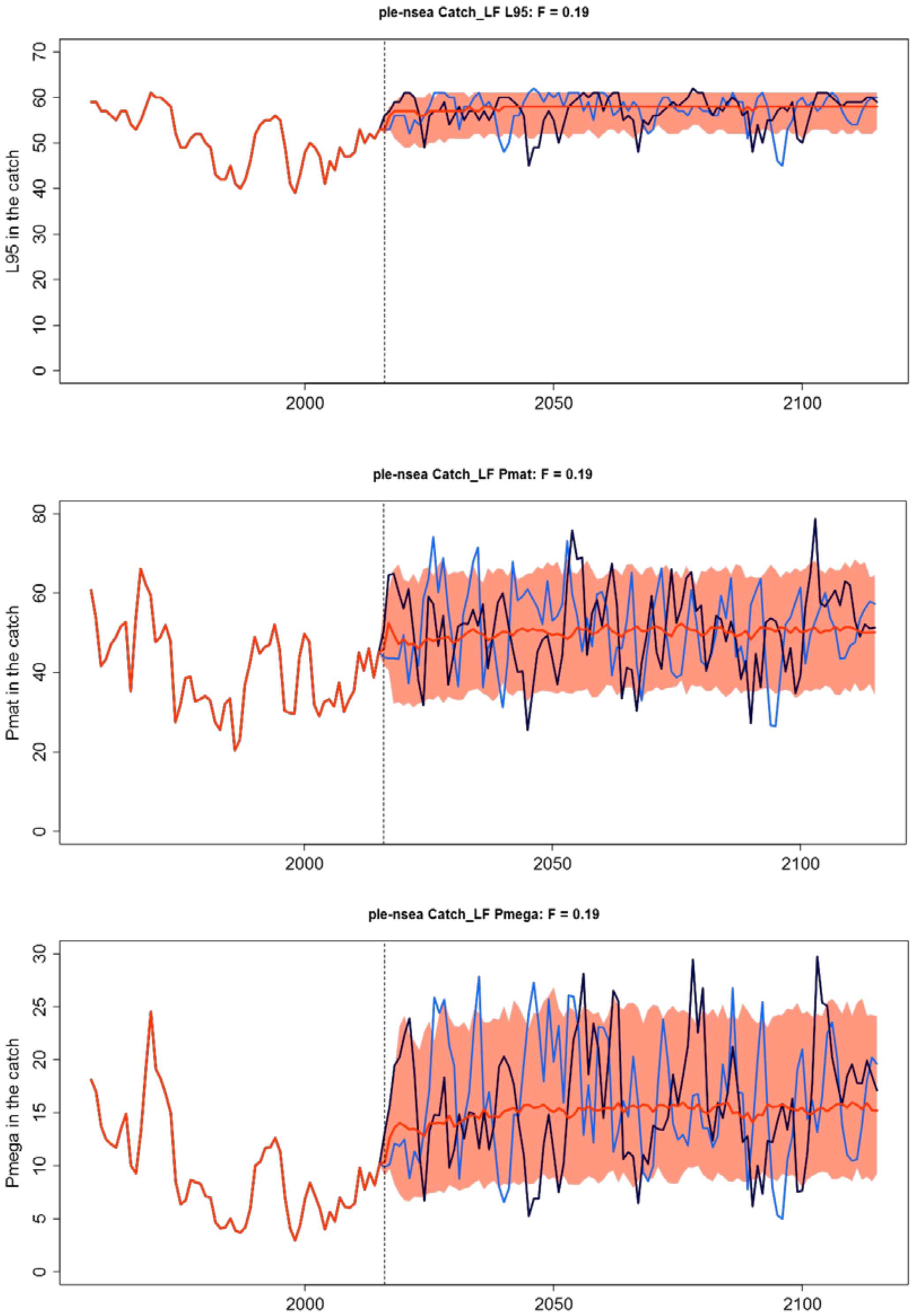

Figure 6.3.2.2.2. Size based indicators from length frequencies in the catch of plaice when fishing at F=FMSY=0.19. L95 (top), Pmat (middle), and Pmega (bottom) are shown, with median values (solid lines), 95% ranges (shaded area) and two example iterations (black and blue lines).

6.3.3 North Sea autumn spawning herring (her-47d3)

6.3.3.1 Selectivity, ALKs and simulated SSB development

Details of the simulated recruitment are shown in Annex 4, Figure A.4.6. Recruitment varies around a lower level than historically observed (following the assumption of reduced productivity), with a high degree of auto-correlation (AR1=0.70).

The selectivity curves resampled in the simulations for herring are shown in Figure 6.3.3.1.1. Selectivity is estimated to have varied over the resampled years, with the maximum selected age moving between ages 5-7. Selectivity does not appear to be dome-shaped, increasing with age in most years.

Figure 6.3.3.1.2 shows the resultant ALKs from the GAM analyses. For most ages (except age 12 and 15), the maximum length seems to have been sampled in the IBTS data. The ALKs are fairly similar for ages 10 and higher, with a lot of overlap in the length distributions at each age. Poorer sampling of the larger sizes also affects the quality of the ALKs for older ages. Few large fish have been sampled for age 14, while a large number of fish have been sampled for age 12, giving this age class a higher proportion of larger fish than ages 13 and 14.

Figure 6.3.3.1.3 shows the development of SSB under the different F scenarios. While stock growth is possible under a scenario of zero fishing, the simulated low productivity recruitment means that projected SSB does not rise above the previously observed maximum (prior to the stock collapse in the 1970s). Under all other F scenarios, SSB will decrease in comparison to the current level. Since 2000, F has been fluctuating slightly below F_{MSY} (see Annex 4, Figure A.4.3), so in most F scenarios an increase in F is simulated.

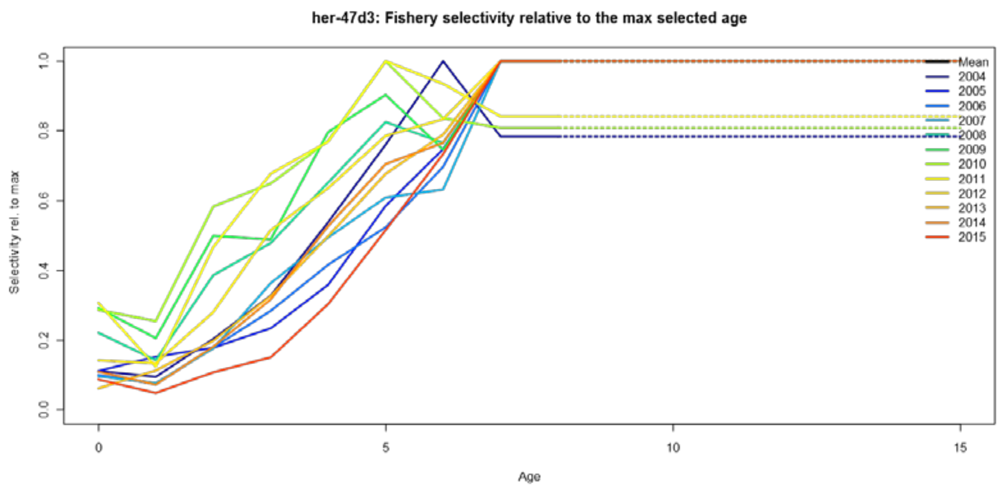

Figure 6.3.3.1.1. The assessment estimated selectivity curves of the herring fishery (solid lines; relative to the maximum selected age) for the years resampled in the simulations. Values from age 9 onwards (dashed lines) are assumed to be equal to the estimated plusgroup selectivity.

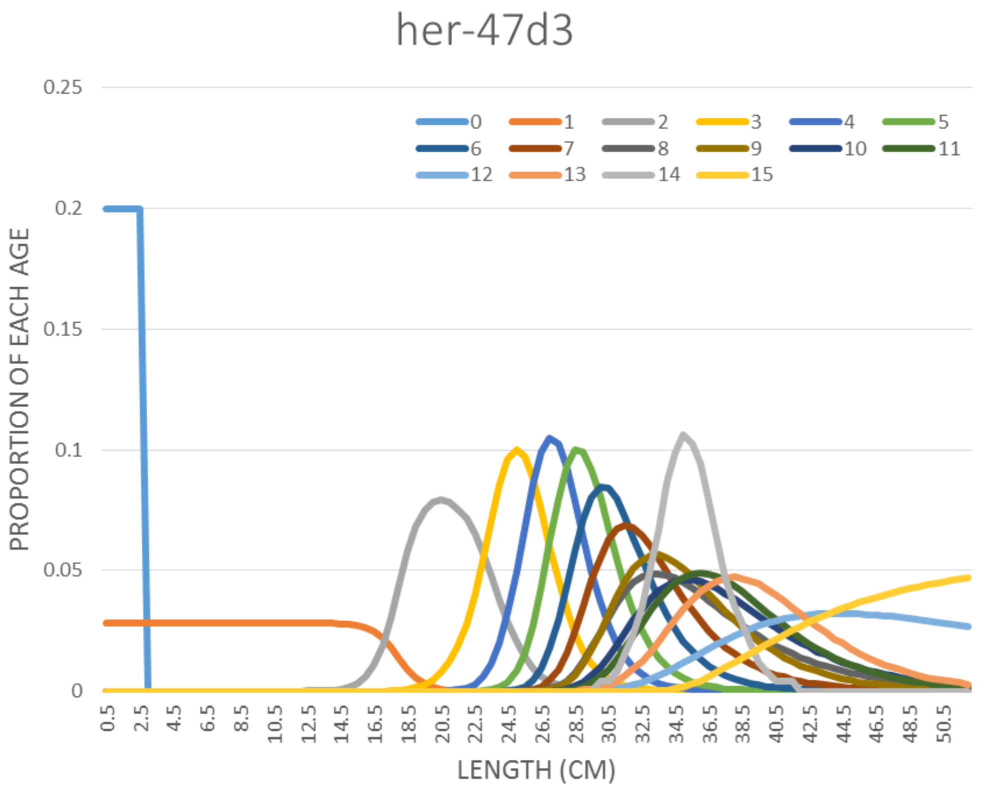

Figure 6.3.3.1.2. Length distributions of herring for each age simulated from the GAM analyses.

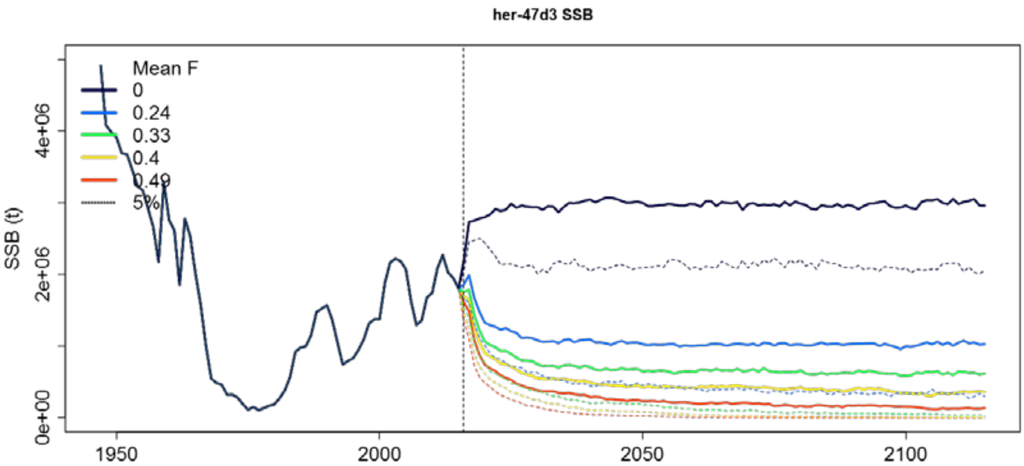

Figure 6.3.1.1.3. Development of stock size (SSB) of herring for the five F values simulated. Median values (solid lines) and lower 5th percentiles (dashed lines), both in one colour for each value of F.

6.3.3.2 Her-47d3 SBI

The results below are a selection of some length-frequency results from the catch. More detailed simulation results for her-47d3, including population length frequency SBIs, are included in Annex 4.

Since 2000 all three SBI have increased as the stock has increased in size with fishing at a relatively low F (Figure 6.3.3.2.1). In the simulated long term, the median values and lower 5^{th}-percentiles of the SBI all show a narrower range of median values than modelled for cod and plaice. L_{95} values are particularly close, with limited differences in the expected median values over the range of F values examined. This is likely due to the fast initial growth followed by slow growth at selected sizes, leaving only small gains in length as fish are allowed to get older with lower F. SSB decreased from current levels under all scenarios of fishing, and likewise all SBIs are expected to decrease from current levels.

Figure 6.3.3.2.2 shows the expected range (95%) and the expected variation in two example iterations for each SBI when fishing at F_{MSY} (F=0.33). L_{95} shows a very limited range slightly below current levels. For both P_{mat} and P_{mega}, a decrease in the median values is expected form the current level, with a wide forecast range similar to the observed range from 2000 to present. The observed values during the recovery period after the stock collapse in the 1970s tend to be below the lower 5th-percentile of what would be expected fishing at F_{MSY}.

Fishing at F_{MSY} with the current selectivity still implies on average 40% of the catch would be greater than the length at first maturity (ranging from ~25-50%) and just less than 20% of the catch would be megaspawners (ranging from ~10-30%). Even with zero fishing, the maximum proportion of mega spawners in the population is estimated to fluctuate just above 15%, and the proportion above length at first maturity fluctuates just below 30%. Note these population length frequencies include recruits, which are highly abundant and immature.

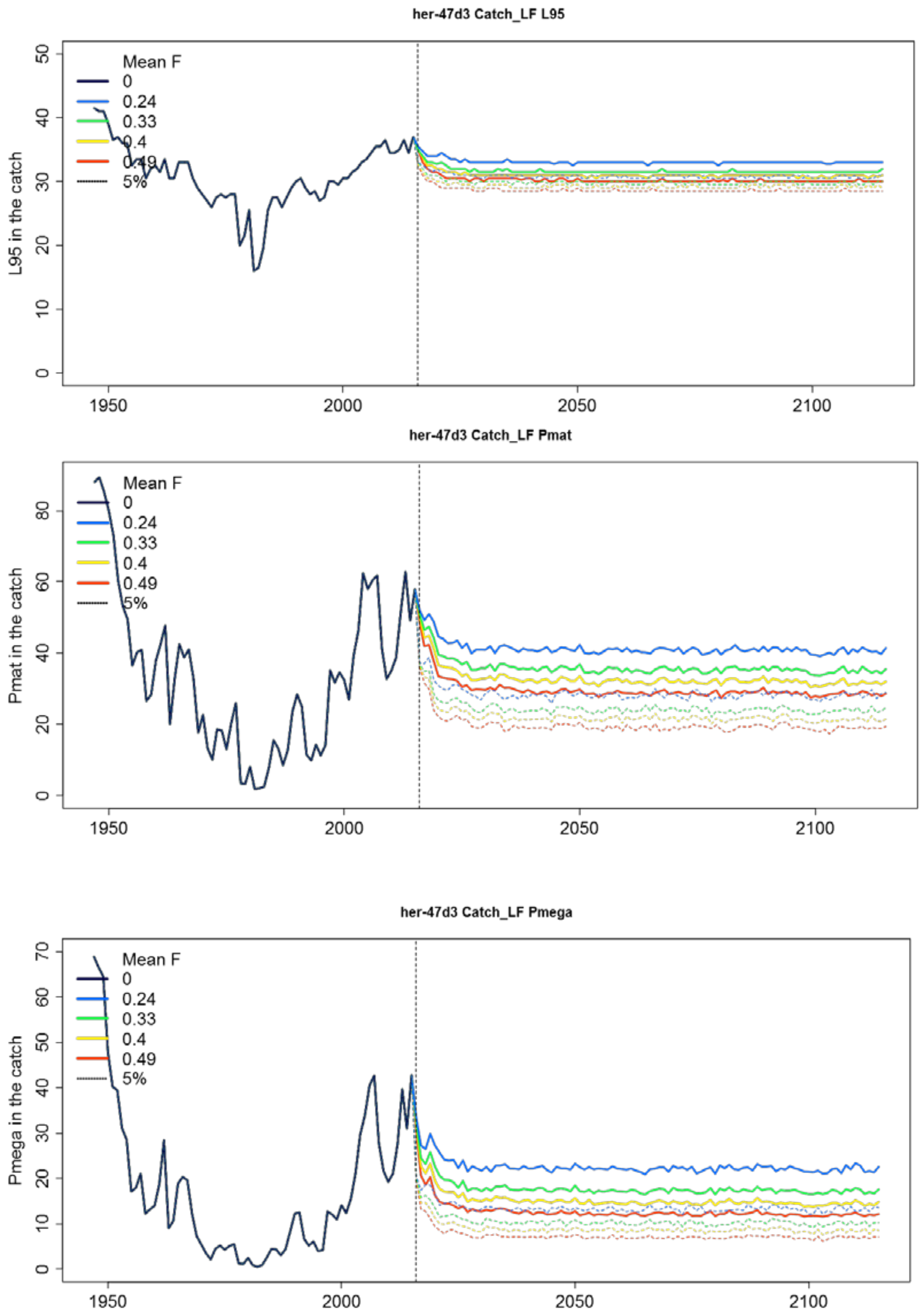

Figure 6.3.3.2.1. Size-based indicators from the simulated catch. L95 (top), Pmat (middle) and Pmega (bottom) size based indicators from length frequencies in the catch of herring for the four non-zero F values simulated (no catch length distributions are obtained from F=0). Median values (solid lines) and lower 5th percentiles (dashed lines) are plotted, both in one colour for each value of F.

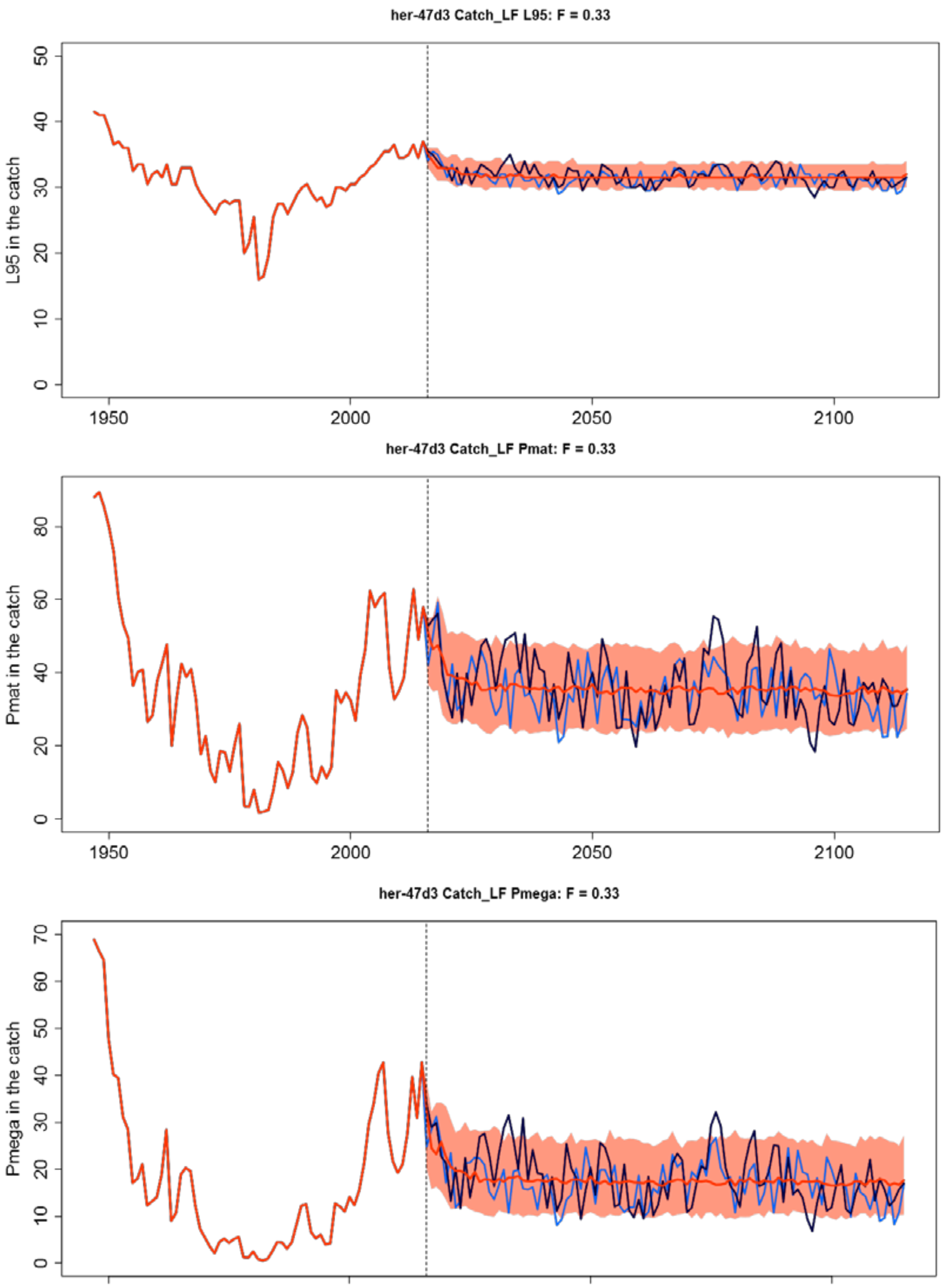

Figure 6.3.3.2.2. Size-based indicators from length frequencies in the catch of herring when fishing at F=FMSY=0.33. L95 (top), Pmat (middle), and Pmega (bottom) are shown, with median values (solid lines), 95% ranges (shaded area) and two example iterations (black and blue lines).

6.4 Discussion

The here presented analyses are a first to simulate future SBI values using the EQSIM software. A number of data and technical issues remain, but some initial conclusions can be drawn on likely values and ranges for these SBIs under F_{MSY} management.

6.4.1 Forecast results

Improvements (increases) in SBIs were seen in L_{95}, P_{mat}, and P_{mega} for North Sea cod (cod-347d). Whilst F has recently reduced to near F_{MSY}, the stock is still at a low level and can be expected to grow more if the stock is fished at F_{MSY} in future. So whilst the stock could currently be classified as being fished sustainably with regards to F and SSB, the current size structure of the population indicates that the stock has not yet recovered to a 'healthy' state.

Improvements in SBI was not as clear for North Sea plaice (ple-nsea) and herring (her-47d3), stocks that both have already recovered safe biological limits for some years. Additionally, issues with the application of the ALKs implying a fixed maximum length for these two stocks imposed unrealistic limits to L_{95}-values. Nevertheless, P_{mega} for plaice indicates that some further improvements could be expected for the ple-nsea stock, and the 95th-percentile of the future distribution (roughly at the same level as the current SBI values) could represent realistic limit reference points.

In the herring simulations, the productivity (recruitment) fed into the simulations seemed low compared to what would be needed for the reference points of SSB. Therefore SSB reduced in all fishing scenarios (except zero fishing), and so too did all SBI values. However, the SBI in all simulated scenarios had 5th-percentiles that were above the SBI-values observed during the collapse and recovery of the stock, indicating that these could be considered as potential limit reference points.

For the purposes of EU mixed fishery management plans, ICES has estimated F_{MSY} ranges for all F-values, which are considered precautionary (annual $P(SSB<B_{lim})$ <5% in the long term i.e. $F_{MSY\_upper} < F_{P0.05}$). All of these F-values lead to long term yields of at least 95% of MSY. However, there are other trade-offs beside yield and precautionarity that will be experienced across these ranges. For all stocks simulated here, the SBI results showed trade-offs in age-structure that should be considered when using potential F_{MSY} ranges. In all cases, the SBI medians and lower 5th-percentiles were higher when fishing at $F=F_{MSY\_lower}$ compared to fishing at $F=F_{MSY}$. Conversely, in all cases when fishing at $F=F_{P0.05}$ (the highest precautionary F), all SBI medians and 5th-percentiles decreased from current values, even for the still recovering cod stock.

6.4.2 Performance of SBI

Of the three SBIs examined, P_{mat} seems to be the least operational. Despite theoretical and calculation concerns raised by WKIND33i (ICES, 2016), the future simulated ranges of this SBI were large compared to the those from L_{95} and P_{mega}, with a large overlap with historic values observed when the stocks were not considered to be fished sustainably or to be at 'healthy' levels. Contrary, both L_{95} and P_{mega} indicated improvements in the range of expected SBI-values and allowed a meaningful comparison between the F_{MSY}-scenario and the past, particular for the cod stock.

Three alternative means of calculating L_{95} were examined (see Annexes 6.A-C, Figures 6.A-C.3). L_{95_mat} is prone to the same issues of P_{mat} (i.e. changing L_{mat} would lead to changes in SBI values not directly linked to changes in the management of the stock), while L_{95_mls} could also be subject to step-changes should regulation change (or disappear). With no clear performance difference in the simulations assuming fixed L_{mat} and MLS, it seems L_{95} for the entire catch length frequency could be the most appropriate version to use. The only changes in values of this SBI would arise from change in stock length structure or changes in selectivity of the fishery.

6.4.3 Reference points

This simulation approach of modelling future reference points (thresholds) for SBIs could be useful since in many cases no obvious biological reference points exist, such as L_{95} or proportion of mature individuals in catch/surveys. The fishery and surveys will in many cases have dome-shaped selectivity (as seen for cod and plaice), but in other cases may be asymptotic of constantly increasing/decreasing. Therefore, SBI derived from fishery or survey catches can only be used as relative indicators of change over time for each stock. Defining universal reference levels that are generally applicable is likely inappropriate given the data being used to calculate them.

The expected future range of SBI values in these simulations is largely driven by the variability in incoming recruitment and the variability in applied F (due to assessment uncertainty). The lower 5th (or 10th etc.) percentile of future ranges could be considered as a reference level, as being below this would likely indicate an unfavourable stock condition relative to what would be expected. Choosing the median value as a reference level would imply being below it 50% of the time, even when following fisheries advice based on fishing at F_{MSY}.

F_{MSY} management, as applied by ICES, is by design supposed to be sustainable. But while 'healthy' may imply 'sustainable', 'sustainable' does not necessarily imply a 'healthy' age-structure. Optimising SSB and F without considering changes to selectivity (as is done at present in ICES reference point calculations) accounts for recruitment overfishing, but ignores potential growth overfishing. Therefore it is entirely possible that SSB and F may indicate MSY compatible fisheries management following the current definition of F_{MSY}, while SBI may still indicate a sub-optimal health of the stock (e.g. as for cod, which is above B_{lim} with F near F_{MSY} but SBI indicate improvements are still possible). The D3.3 indicator should focus on reducing growth overfishing, an important element of fishery productivity. In other words, SSB and F indicators concern mainly the quantity of fishing, while SBI within D3C3 suggest that more focus is required assess the quality of fishing.

To set reference points for SBI that account for growth overfishing, simulations would have to be conducted differently to how they have been done here. Assuming older fish are indeed healthier for the stock and contribute disproportionally more to recruitment success, the current approach of generating future recruitment based simply on SSB is inadequate. Simulating future recruitment accounting for the age structure in the SSB would be more appropriate. Likewise, the current analysis (and the current ICES approach to MSY) works on the assumption of 'constant' selectivity similar to what is currently observed (i.e. most recent *x* years). Running simulations with optimised selectivity patterns that account for growth overfishing (e.g. using an optimal length at first capture Lc_opt; Froese *et al.*, 2016) could provide estimates of future ranges of SBI that are more appropriate as targets/limits for managers.

6.4.4 Conclusions

The simulations by WKIND3.3ii represent initial examinations for the potential to define reference points, and as such the specific results are not recommended for operational use at present. While the procedure used generally shows some promise, there remain a number of technical shortcomings in the procedures used here, including:

1. The results are indicative of what could be expected should current conditions continue into the future (i.e. maturity, growth, selectivity, recruitment

productivity), but any future changes in the environment or fishing selectivity (which could be likely under a fully implemented landings obligation) would impact the applicability of results.

2. The assumption that R=f(SSB) ignores the underlying principle of SBI that states that older fish are more important for reproduction. Additionally, single data points may influence the fits of candidate stock-recruit models and have an impact on the weighting of different functions in the simulations.
3. Plusgroups in assessment models become important at low F (include more year classes in higher abundance). At present many ICES stock assessments have age ranges appropriate for heavily fished stocks, meaning that it is uncertain about what happens to older ages at low F. Selectivity of commercial gears on older ages will have a big impact on length frequency distributions in the catch used to calculate SBI.
4. No research survey selectivity estimates were easily available for the stock simulated. Simulating survey length frequencies would require good estimates of survey selectivity for each stock.
5. Only a limited number of candidate SBIs were examined. E.g. $CPUE_{mega}$ was not simulated.
6. The way the ALKs were implemented was sub-optimal. i.e. by apply them as matrices a maximum achievable length was imposed based on the maximum sampled size. While in all cases this was greater than L_{inf} for each stock, more appropriate use of the smoothed GAM curves, whilst accounting for biological maxima, may be more appropriate. In addition, there were also the occasional oddities, particularly at the older, poorer sampled ages (e.g. for herring age 14 included fewer larger fish than some younger ages and age 12 included larger fish than age 13 and 14)

A number of these issues can be addressed in future, and additional avenues could be explored. In particular:

1. Examine the performance of the fishery (yield) and stock (stock size and recruitment) testing the assumption that large fish do indeed contribute more to recruitment.
2. Simulate optimal selectivity to better estimate biological appropriate reference points for the stock, rather than only reference points for the stock given the current fishery.
3. Simulate survey selectivity e.g. by using survey CPUEs and assessment results to estimate the selectivity at length from the surveys.
4. Look at 3yr or 6yr averages of SBI (to match evaluation time frame and account for interannual variability). These should show more limited and practical ranges of simulated SBI.
5. Ideally, catch should be simulated by fishing métier. This would allow an examination of how changes between fishing gear types would impact on SBI. Questions such as ‘What if plaice was only caught by 80mm TBB or 120mm OTB?’ or ‘ What combination of metiers executing the fishery would allow for healthier stocks?’ could be addressed.
6. Consider the applicability of SBI for short-lived species and elasmobranchs.

7 References

Andersen, T., Carstensen, J., Hernandez-Garcia, E., and Duarte, C. M. 2009. Ecological thresholds and regime shifts: approaches to identification. Trends Ecol Evol, 24: 49-57.

Berg, C. W., and Kristensen, K. 2012. Spatial age-length key modelling using continuation ratio logits. Fisheries Research, 129-130: 119-126.

Beverton, R. J. H., and Holt, S. 1957. On the dynamics of exploited fish populations, Ministry of Agriculture, Fisheries and Food, London.

Bolster, W. J., Alexander, K. E., and Leavenworth, W. B. 2011. The historic abundance of cod on the Nova Scotian shelf. *In* Shifting baselines. Ed. by J. B. C. Jackson, K. H. Alexander, and E. Sala. Island Press, Washington DC.

Cope, J. M., and Punt, A. E. 2009. Length-based reference points for data-limited situations: Applications and restrictions. Marine and Coastal Fisheries, 1: 169-186.

Crawley, M. J. 2005. Statistics - An introduction using R, John Wiley & Sons, Chichester.

Crawley, M. J. 2007. The R book, John Wiley & sons, Chichester. 942 pp.

Engelhard, G. H., and Heino, M. 2004. Maturity changes in Norwegian spring-spawning herring before, during, and after a major population collapse. Fisheries Research, 66: 299-310.

Fauconnet, L., and Rochet, M.-J. 2016. Fishing selectivity as an instrument to reach management objectives in an ecosystem approach to fisheries. Marine Policy, 64: 46-54.

Fewster, R. M., Buckland, S. T., Siriwardena, G. M., Baillie, S. R., and Wilson, J. D. 2000. Analysis of population trends for farmland birds using generalised additive models. Ecology, 81: 1970-1984.

Fock, H. O., Kloppmann, M. H. F., and Probst, W. N. 2014. An early footprint of fisheries: Changes for a demersal fish assemblage in the German Bight from 1902–1932 to 1991–2009. Journal of Sea Research, 85: 225-335.

Froese, R. 2004. Keep it simple: three indicators to deal with overfishing. Fish & Fisheries, 5: 86-91.

Froese, R., Winker, H., Gascuel, D., Somalia, U. R., and Pauly, D. 2016. Minimizing the impact of fishing. Fish and Fisheries: n/a-n/a.

Greenstreet, S. P. R., Rossberg, A. G., Fox, C., Le Quesne, W. J. F., Blasdale, P., Boulcott, P., Mitchell, I., et al. 2012. Demersal fish biodiversity: species-level indicators and trends-based targets for the marine strategy framework directive. ICES Journal of Marine Science, 69: 1789-1801.

Gröger, J. P., Missong, M., and Rountree, R. A. 2011. Analyses of interventions and structural breaks in marine and fisheries time series: Detection of shifts using iterative methods. Ecological Indicators, 11: 1084-1092.

HELCOM. 2012. Indicator based assessment of coastal fish community status in the Baltic Sea 2005-2009. 131.

ICES. 2015. Report of the working group on biodiversity science (WGBIODIV). 04. 308 pp.

ICES. 2016. Report of the workshop on guidance on development of operational methods for the evaluatoin of the MSFD Criterion D3.3 (WKINDD3.3i). 97 pp.

Lindegren, M., Dakos, V., Gröger, J., Gardmark, A., Kornilovs, G., Otto, S. A., and Möllmann, C. 2012. Early detection of ecosystem regime shifts: A multiple method evaluation for management application. PLoS ONE, 7: 1-9.

Mesnil, B., and Petitgas, P. 2009. Detection of changes in time-series of indicators using CUSUM control charts. Aquatic Living Resources, 22: 187-192.

Pazhayamadom, D. G., Kelly, C. J., Rogan, E., and Codling, E. A. 2013. Self-starting CUSUM approach for monitoring data poor fisheries. Fisheries Research, 145: 114-127.

Probst, W. N., Kloppmann, M., and Kraus, G. 2013a. Indicator-based assessment of commercial fish species in the North Sea according to the EU Marine Strategy Framework Directive (MSFD). ICES Journal of Marine Science, 70: 694-706.

Probst, W. N., and Stelzenmüller, V. 2015. A benchmarking and assessment framework to operationalise ecological indicator based on time series analysis. Ecological Indicators, 55: 94-106.

Probst, W. N., Stelzenmüller, V., and Fock, H. O. 2012. Using cross-correlations to assess the relationship between time-lagged pressure and state indicators – an exemplary analysis of North Sea fish population indicators ICES Journal of Marine Science, 69: 670-681.

Probst, W. N., Stelzenmüller, V., and Kraus, G. 2013b. A simulation-approach to assess the size structure of commercially exploited fish populations within the European Marine Strategy Framework Directive. Ecological Indicators, 24: 621-632.

Rochet, M.-J., and Rice, J. C. 2005. Do explicit criteria help in selecting indicators for ecosystem-based fisheries management? ICES Journal of Marine Science, 62: 528-539.

Rochet, M.-J., Trenkel, V. M., Carpentier, A., Coppin, F., De Sola, L. G., Léauté, J.-P., Mahé, J.-C., et al. 2010. Do changes in environmental and fishing pressures impact marine communities? An empirical assessment. Journal of Applied Ecology, 47: 741-750.

Shephard, S., Rindorf, A., Dickey-Collas, M., Hintzen, N. T., Farnsworth, K. D., and Reid, D. 2014. Assessing the state of pelagic fish communities within an ecosystem approach and the European Marine Strategy Framework Directive. ICES Journal of Marine Science, 71: 1572-1585.

Stelzenmüller, V., Fock, H. O., Gimpel, A., Rambo, H., Diekmann, R., Probst, W. N., Callies, U., et al. 2015. Quantitative environmental risk assessments in the context of marine spatial management: Current approaches and some perspectives. ICES Journal of Marine Science, 72: 1022-1042.

Thurstan, R. H., Brockington, S., and Roberts, C. M. 2010. The effects of 118 years of industrial fishing on UK bottom trawl fisheries. Nature Communications, 1.

Trenkel, V. M., and Rochet, M.-J. 2009. Intersection–union tests for characterising recent changes in smoothed indicator time series. Ecological Indicators, 9: 732-739.

Trenkel, V. M., and Rochet, M.-J. 2010. Combining time trends in multiple metrics for identifying persistent changes in population processes or environmental stressors. Journal of Applied Ecology, 47: 751-758.

Trenkel, V. M., Rochet, M.-J., and Mesnil, B. 2007. From model-based prescriptive advice to indicator-based interactive advice. ICES Journal of Marine Science, 64: 768-774.

Annex 1: List of participants

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Annex 2: Applications of relative SBI

Details of assessed stocks

Legends for subsequent graphs:

Legend for upper graph:

The two panels in this graph show length frequencies for first and last year in CPUE-by-length-by-area surveys for the North Sea (NS-IBTS) and the Baltic (IBITS). *Lc.com* is the length at which 50% of the specimen are retained by the commercial gears, derived from commercial LF or from 90% of minimum landing sizes. *Lm50* is the length where 50% of the larger sex have reached maturity. L*opt* is the theoretical length where cohort biomass reaches a maximum in the unexploited stock. The dotted vertical line at 1.1 *Lopt* indicates the length above which specimens are considered to be mega-spawners. *Linf* is the asymptotic length. The green lines indicate the weighted 95^{th} percentile of lengths, with the dotted line using all length classes in the sample, the dashed line using lengths above *Lm50*, and the solid line using lengths above half of *Linf*.

Legend for lower left graph:

Maturity ogive, i.e., the proportion of mature individuals by length class for the indicated sex. The red circles indicate the lengths at 10%, 50% and 90% maturity, respectively. *Lc.com* indicates the length where 50% of the specimens are retained by the commercial gears.

Legend for lower right graph:

The upper panel of the lower right graph shows the weighted 95% percentile of length in the survey relative to *Linf* (green curves). The dotted green curve uses all length classes in the sample, the dashed line uses lengths above *Lm50*, and the solid line uses lengths above half of *Linf*. The solid red line indicates *Lopt*/*Linf* and the dotted red line indicates the length above which specimens are considered to be mega-spawners. The solid green curve in the lower panel shows the proportion of mature individuals in the LF sample (*Nmat* / *N*). The dashed green curve shows the proportion of mega-spawners (>= 1.1 *Lopt*) among spawners (*Nmega* / *Nmat*).

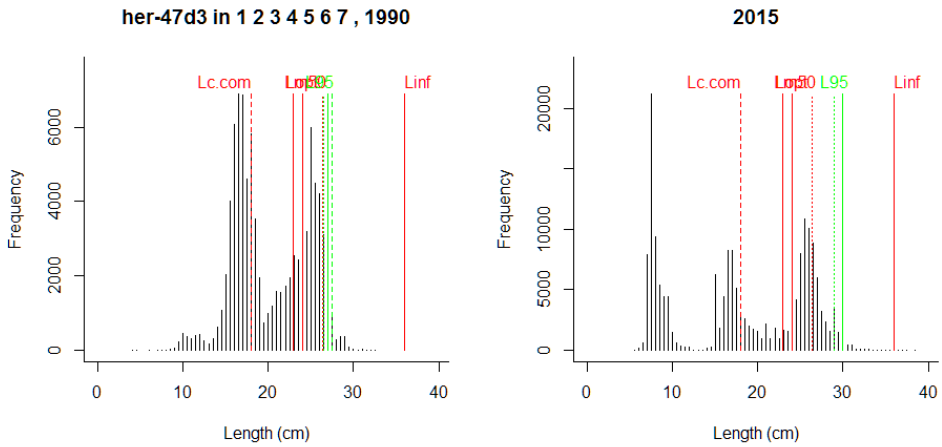
North Sea herring

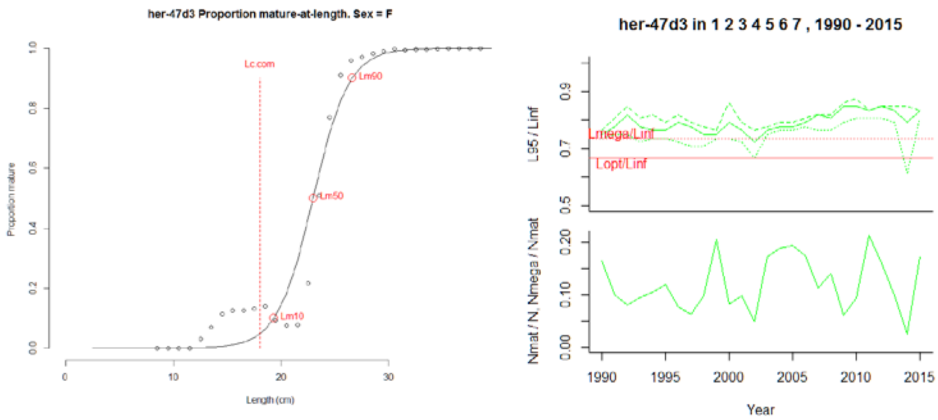
```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 13:41:00 2016
---------------------------------------------
SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-
11-02 16_43_26.csv
Survey     = NS-IBTS
Species    = Clupea harengus Stock = her-47d3
Sex SMALK  = F
Years      = 1991  - 2015
Quarter    = 3
Areas      = 1 2 3 4 5 6 7
Lc.com     = 18 cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
27  outliers (beyond 4 SD) were removed.
Number of remaining observations = 15035
Length range = 8  - 37.5 cm
Weight range = 3  - 477 g
log10(a) = -2.45 , SE = 0.00652
Geometric mean a = 0.00352 , 95% CL = 0.00342 - 0.00362
b = 3.28 , 95% CL = 3.28 - 3.29
Standard deviation of estimated log10(W) = 0.0568
Coefficient of determination (r2) = 0.975
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 1 2 4 3
Number of observations            = 24147
Largest immature                  = 33.5 cm
Smallest mature                   = 7.5 cm
Ogive length at 50% maturity      = 23 cm
Ogive length at 10% and 90% maturity 19.3  - 26.6 cm
------------------------------------------------
Estimation of Linf
------------------------------------------------
Observed maximum length SMALK      = 37.5 cm
Median of annual maximum lengths   = 35.5 cm
Whetherall Linf based on SMALK     = 34 cm
Observed maximum length CPUE       = 55 cm
Median annual maximum lengths CPUE = 36.5 cm
Chosen Linf                        = 36 cm
Length at max cohort biomass Lopt  = 24 cm (assuming b~3 and M/K~1.5)


      Stock Year Lmax.obs        N   N.mat N.mega pp.mat pp.mega  L95 L95mat L95.5 L95Linf
L95matLinf L95.5Linf
1  her-47d3 1990     32.5  291050  47763  14815 0.1641   0.310 26.5   27.5  27.0   0.736
0.764    0.750
```

2	her-47d3	1991	37.0	1511577	150408	NA	0.0995	NA	27.0	29.0	28.0	0.750	0.806	0.778
3	her-47d3	1992	36.5	1753652	141578	61544	0.0807	0.435	27.0	30.5	29.5	0.750	0.847	0.819
4	her-47d3	1993	36.0	1100725	104594	33872	0.0950	0.324	26.0	29.0	28.0	0.722	0.806	0.778
5	her-47d3	1994	37.0	1969634	208131	63655	0.1057	0.306	26.5	29.5	27.5	0.736	0.819	0.764
6	her-47d3	1995	44.0	2060301	245892	NA	0.1193	NA	26.5	28.5	27.5	0.736	0.792	0.764
7	her-47d3	1996	37.0	922631	71980	26043	0.0780	0.362	26.0	29.5	28.5	0.722	0.819	0.792
8	her-47d3	1997	36.0	1293342	81533	32812	0.0630	0.402	25.5	28.5	28.0	0.708	0.792	0.778
9	her-47d3	1998	34.5	349653	34353	9198	0.0982	0.268	25.5	28.0	27.0	0.708	0.778	0.750
10	her-47d3	1999	33.0	264700	54048	13228	0.2042	0.245	26.5	27.5	27.0	0.736	0.764	0.750
11	her-47d3	2000	55.0	901697	74426	36020	0.0825	0.484	26.5	31.0	28.5	0.736	0.861	0.792
12	her-47d3	2001	36.0	859147	84910	26711	0.0988	0.315	26.0	28.5	27.5	0.722	0.792	0.764
13	her-47d3	2002	52.0	560681	27902	NA	0.0498	NA	24.0	27.5	26.0	0.667	0.764	0.722
14	her-47d3	2003	36.5	948747	163181	70286	0.1720	0.431	27.0	28.0	27.5	0.750	0.778	0.764
15	her-47d3	2004	36.0	1010089	189707	83932	0.1878	0.442	27.5	28.5	28.0	0.764	0.792	0.778
16	her-47d3	2005	36.5	648400	125169	84029	0.1930	0.671	27.5	28.5	28.0	0.764	0.792	0.778
17	her-47d3	2006	37.5	733063	127336	92259	0.1737	0.725	28.0	29.0	28.5	0.778	0.806	0.792
18	her-47d3	2007	35.0	555420	63039	44264	0.1135	0.702	27.5	29.5	29.5	0.764	0.819	0.819
19	her-47d3	2008	38.0	618777	87205	48241	0.1409	0.553	27.5	29.5	29.0	0.764	0.819	0.806
20	her-47d3	2009	36.5	511849	31814	31805	0.0622	1.000	28.5	31.0	30.5	0.792	0.861	0.847
21	her-47d3	2010	37.0	576799	53701	38436	0.0931	0.716	29.0	31.5	30.5	0.806	0.875	0.847
22	her-47d3	2011	36.0	1220441	259526	NA	0.2126	NA	29.0	30.0	30.0	0.806	0.833	0.833
23	her-47d3	2012	35.5	359404	57283	43490	0.1594	0.759	29.0	30.5	30.5	0.806	0.847	0.847
24	her-47d3	2013	36.5	1313563	130126	100063	0.0991	0.769	28.5	30.5	30.0	0.792	0.847	0.833
25	her-47d3	2014	34.5	558242	14617	4644	0.0262	0.318	22.0	30.5	28.5	0.611	0.847	0.792
26	her-47d3	2015	38.5	489985	84619	59879	0.1727	0.708	29.0	30.0	30.0	0.806	0.833	0.833

Comment: 90% of minimum landing size used as proxy for Lc.com. It seems like larger specimens are not retained by the gear.





Comment: Indicators seem to be working okay. It needs to be checked whether large individuals are missing from the population or are not retained by the gear.

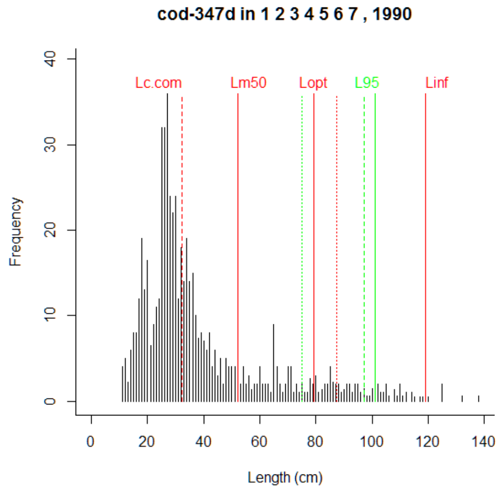
North Sea cod

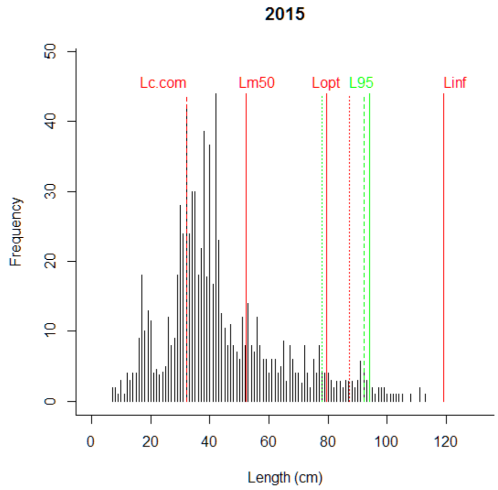
```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 13:44:16 2016
---------------------------------------------
SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv
Survey     = NS-IBTS
Species    = Gadus morhua Stock = cod-347d
Sex SMALK  = F
Years      = 1990  - 2015
Quarter    = 1
Areas      = 1 2 3 4 5 6 7
Lc.com     = 32.2 cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
23  outliers (beyond 4 SD) were removed.
Number of remaining observations = 6069
Length range = 9.3  - 133 cm
Weight range = 6  - 25000 g
log10(a) = -2.25 , SE = 0.00492
Geometric mean a = 0.00563 , 95% CL = 0.00551 - 0.00576
b = 3.15 , 95% CL = 3.15 - 3.16
Standard deviation of estimated log10(W) = 0.0581
Coefficient of determination (r2) = 0.995
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 1 2 4 3
Number of observations            = 13373
Largest immature                  = 88 cm
Smallest mature                   = 9 cm
Ogive length at 50% maturity      = 52.2 cm
Ogive length at 10% and 90% maturity 29.6  - 74.7 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 133 cm
Median of annual maximum lengths   = 119 cm
Whetherall Linf based on SMALK     = 117 cm
Observed maximum length CPUE       = 140 cm
Median annual maximum lengths CPUE = 120 cm
Chosen Linf                        = 119 cm
Length at max cohort biomass Lopt  = 79.3 cm (assuming b~3 and M/K~1.5)
```

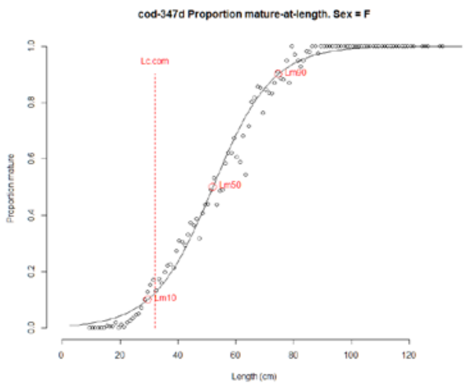
	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	cod-347d	1990	138	3444	865	138.7	0.2511	0.1604	75	97.0	101.0	0.630	0.815	0.849
2	cod-347d	1991	138	23231	2684	223.0	0.1155	0.0831	55	94.0	98.9	0.462	0.790	0.831

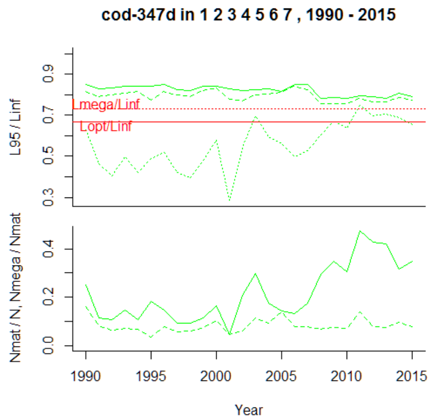
3	cod-347d	1992	125	34024	3700	236.2	0.1087	0.0638	48	95.0	99.3	0.403	0.798	0.834
4	cod-347d	1993	131	21043	3079	224.0	0.1463	0.0727	59	96.0	100.0	0.496	0.807	0.840
5	cod-347d	1994	120	28528	3136	215.1	0.1099	0.0686	50	97.0	100.0	0.420	0.815	0.840
6	cod-347d	1995	125	23407	4304	163.1	0.1839	0.0379	58	92.0	100.0	0.487	0.773	0.840
7	cod-347d	1996	140	16481	2460	198.5	0.1493	0.0807	62	97.0	101.0	0.521	0.815	0.849
8	cod-347d	1997	115	26900	2554	149.2	0.0949	0.0584	50	95.0	98.1	0.420	0.798	0.824
9	cod-347d	1998	121	19750	1854	111.8	0.0939	0.0603	47	94.0	97.9	0.395	0.790	0.823
10	cod-347d	1999	140	10595	1216	93.5	0.1148	0.0769	57	97.9	100.0	0.479	0.823	0.840
11	cod-347d	2000	121	5970	997	104.5	0.1671	0.1048	69	99.0	100.0	0.580	0.832	0.840
12	cod-347d	2001	114	28023	1288	60.9	0.0460	0.0473	34	92.7	98.7	0.286	0.779	0.829
13	cod-347d	2002	117	4015	839	51.6	0.2090	0.0615	65	91.7	97.7	0.546	0.771	0.821
14	cod-347d	2003	119	2516	748	86.6	0.2973	0.1157	83	95.0	98.0	0.697	0.798	0.824
15	cod-347d	2004	133	3510	621	59.4	0.1770	0.0956	71	95.9	98.9	0.597	0.806	0.832
16	cod-347d	2005	115	3085	448	62.5	0.1453	0.1394	67	96.6	97.0	0.563	0.812	0.815
17	cod-347d	2006	118	4235	559	45.4	0.1319	0.0813	59	100.0	101.0	0.496	0.840	0.849
18	cod-347d	2007	113	4795	838	65.4	0.1747	0.0780	63	98.2	101.5	0.529	0.826	0.853
19	cod-347d	2008	130	3794	1112	76.2	0.2932	0.0685	72	90.0	93.0	0.605	0.756	0.782
20	cod-347d	2009	123	2463	858	65.3	0.3482	0.0761	80	90.0	93.4	0.672	0.756	0.785
21	cod-347d	2010	114	3725	1139	82.7	0.3058	0.0726	76	90.0	93.0	0.639	0.756	0.782
22	cod-347d	2011	120	5038	2387	339.0	0.4738	0.1420	89	93.0	94.5	0.748	0.782	0.794
23	cod-347d	2012	109	3688	1569	125.7	0.4254	0.0801	83	91.0	94.0	0.697	0.765	0.790
24	cod-347d	2013	126	3209	1349	101.5	0.4202	0.0753	84	91.0	93.0	0.706	0.765	0.782
25	cod-347d	2014	114	4123	1307	129.3	0.3170	0.0990	82	93.6	96.1	0.689	0.787	0.808
26	cod-347d	2015	113	5210	1819	142.3	0.3492	0.0782	78	92.0	94.0	0.655	0.773	0.790

Comment: Lc.com from analysis of commercial catch









Comment: L95 based on whole survey (dotted green line in the upper panel of the lower right graph) is sensitive to recruitment (e.g. in 2001), but reflects the initial lack of large individuals and the slight recovery better than L95 above 0.5 Linf (solid line) or above Lm50 (dashed green line). A 3-years moving average could correct the sensitivity to fluctuations in recruitment. Proportion of spawners and proportion of mega spawners work well as indicators of a stock where Lc/Lmat=32.2/52.2=0.62 is low and the size structure is clearly truncated.

North Sea haddock

Results of SMALK and CPUE analysis, Fri Nov 04 13:48:56 2016

SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv

Survey = NS-IBTS

Species = Melanogrammus aeglefinus Stock = had-346a

Sex SMALK = F

Years = 1990 - 2015

Quarter = 1

Areas = 1 2 3 4 6 7 5

Lc.com = 27 cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

25 outliers (beyond 4 SD) were removed.

Number of remaining observations = 14072

Length range = 10 - 81 cm

Weight range = 10 - 4935 g

log10(a) = -2.25 , SE = 0.00478

Geometric mean a = 0.00556 , 95% CL = 0.00544 - 0.00568

b = 3.15 , 95% CL = 3.15 - 3.16

Standard deviation of estimated log10(W) = 0.0553

Coefficient of determination (r2) = 0.987

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 1 2 4 3

Number of observations = 26327

Largest immature = 47 cm

Smallest mature = 10 cm

Ogive length at 50% maturity = 26 cm

Ogive length at 10% and 90% maturity 20.7 - 31.4 cm

Estimation of Linf

Observed maximum length SMALK = 81 cm

Median of annual maximum lengths = 67.5 cm

Whetherall Linf based on SMALK = NA cm

Observed maximum length CPUE = 87 cm

Median annual maximum lengths CPUE = 69.5 cm

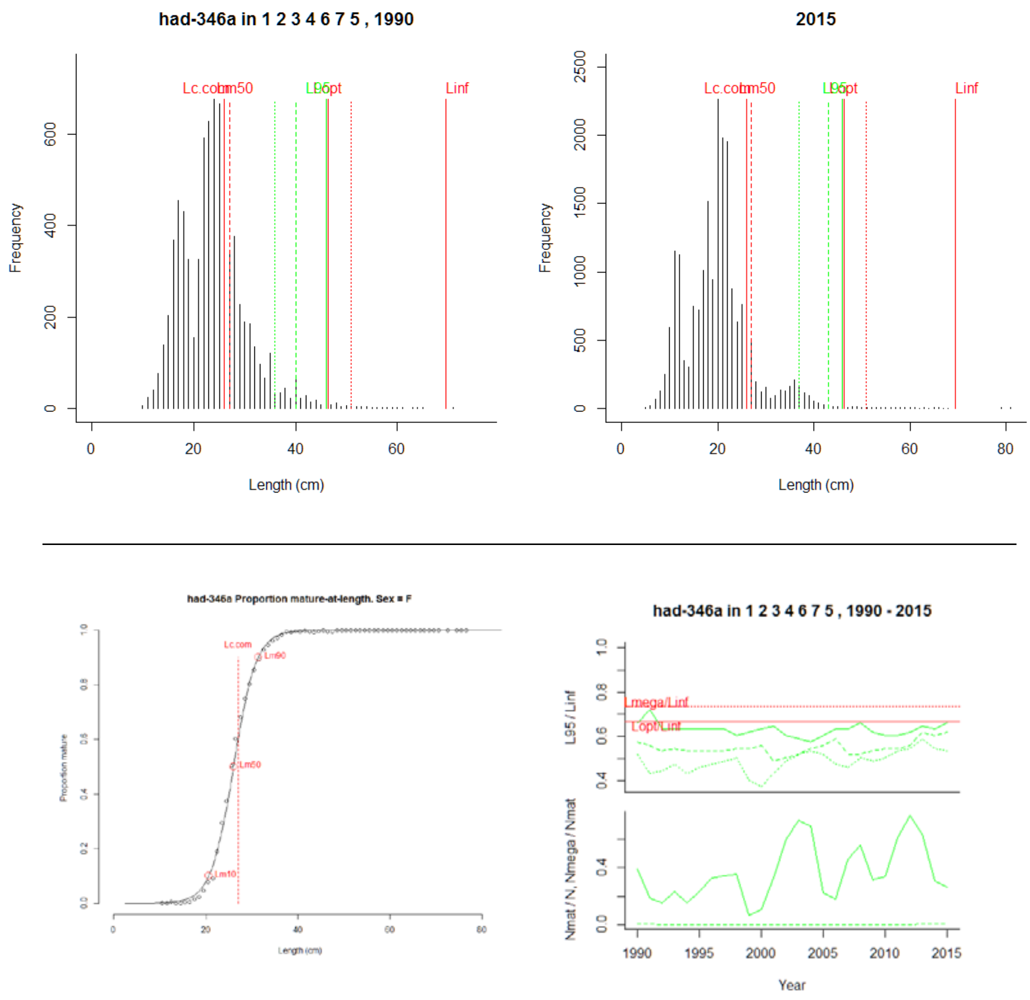
Chosen Linf = 69.5 cm

Length at max cohort biomass Lopt = 46.3 cm (assuming b~3 and M/K~1.5)

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	had-346a	1990	71	49000	19089	96.1	0.3896	0.005033	36	40	46	0.518	0.576	0.662
2	had-346a	1991	82	425741	79844	439.9	0.1875	0.005509	30	39	50	0.432	0.561	0.719

3	had-346a	1992	70	1000579	153609	296.0	0.1535	0.001927	31	37	44	0.446	0.532	0.633
4	had-346a	1993	76	654777	155029	290.3	0.2368	0.001873	33	38	44	0.475	0.547	0.633
5	had-346a	1994	87	789447	120559	225.7	0.1527	0.001872	30	37	44	0.432	0.532	0.633
6	had-346a	1995	72	832794	193448	256.8	0.2323	0.001328	32	37	44	0.460	0.532	0.633
7	had-346a	1996	68	496324	162645	221.7	0.3277	0.001363	33	37	44	0.475	0.532	0.633
8	had-346a	1997	72	396030	135348	125.3	0.3418	0.000926	34	37	44	0.489	0.532	0.633
9	had-346a	1998	67	197435	70302	96.2	0.3561	0.001368	35	38	42	0.504	0.547	0.604
10	had-346a	1999	67	871381	57424	109.7	0.0659	0.001910	28	38	43	0.403	0.547	0.619
11	had-346a	2000	70	822391	85621	84.2	0.1041	0.000983	26	39	44	0.374	0.561	0.633
12	had-346a	2001	68	513140	170058	98.1	0.3314	0.000577	30	34	45	0.432	0.489	0.647
13	had-346a	2002	70	314935	189743	95.2	0.6025	0.000502	34	35	42	0.489	0.504	0.604
14	had-346a	2003	67	210497	154524	139.8	0.7341	0.000905	36	36	41	0.518	0.518	0.590
15	had-346a	2004	74	140169	97159	126.1	0.6932	0.001298	37	38	40	0.532	0.547	0.576
16	had-346a	2005	67	197740	43536	136.8	0.2202	0.003143	36	39	42	0.518	0.561	0.604
17	had-346a	2006	69	219043	40375	120.0	0.1843	0.002972	33	41	44	0.475	0.590	0.633
18	had-346a	2007	67	200529	92757	88.9	0.4626	0.000959	32	36	44	0.460	0.518	0.633
19	had-346a	2008	67	98625	55127	168.1	0.5590	0.003049	35	36	46	0.504	0.518	0.662
20	had-346a	2009	68	173576	54514	76.7	0.3141	0.001408	34	37	43	0.489	0.532	0.619
21	had-346a	2010	68	200130	67174	93.8	0.3357	0.001396	35	38	42	0.504	0.547	0.604
22	had-346a	2011	68	183013	111502	126.5	0.6093	0.001135	37	38	42	0.532	0.547	0.604
23	had-346a	2012	67	95067	73054	137.8	0.7684	0.001887	38	39	43	0.547	0.561	0.619
24	had-346a	2013	72	53800	34061	310.3	0.6331	0.009109	41	43	45	0.590	0.619	0.647
25	had-346a	2014	70	159766	49410	304.8	0.3093	0.006169	38	42	44	0.547	0.604	0.633
26	had-346a	2015	81	130483	34157	234.5	0.2618	0.006866	37	43	46	0.532	0.619	0.662

Comment: No mega-spawners; 90% of minimum landing size assumed as proxy for Lc.com



Comment: Severely truncated size structure and absence of mega-spawners. L95 across all sizes works better than L95 restricted to larger sizes, suggesting slight improvement in size structure at very low level. This is also visible in number of spawners.

North Sea whiting

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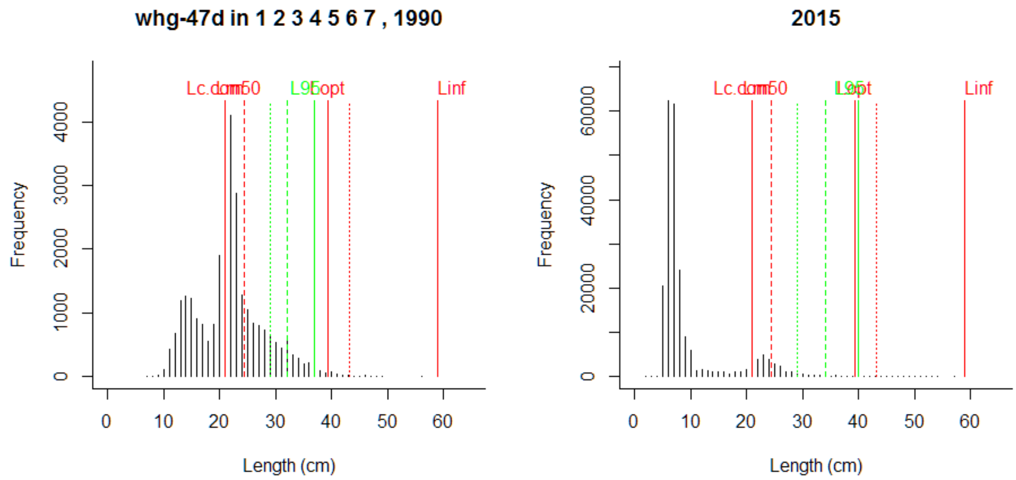
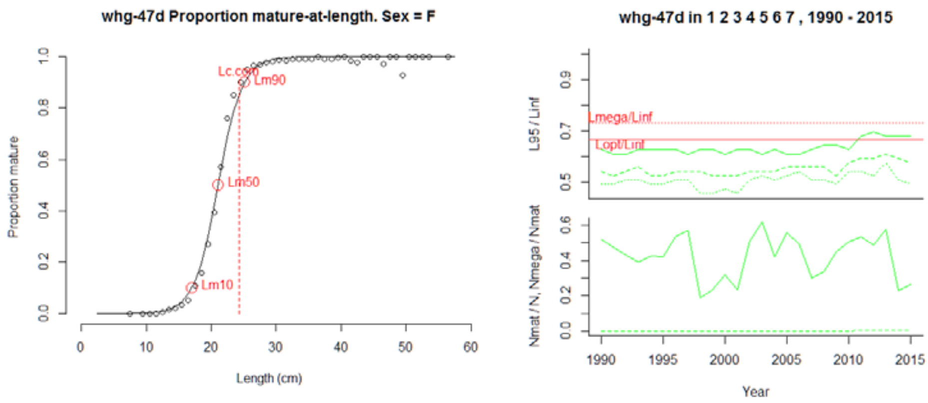
----------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 13:30:08 2016
----------------------------------------------
SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv
Survey     = NS-IBTS
Species    = Merlangius merlangus Stock = whg-47d
Sex SMALK  = F
Years      = 1990  - 2015
Quarter    = 1
Areas      = 1 2 3 4 5 6 7
Lc.com     = 24.3 cm (length where 50% are retained by commercial gear)
----------------------------------------------
Summary stats of weighted F  W~L regression
----------------------------------------------
53  outliers (beyond 4 SD) were removed.
Number of remaining observations = 19431
Length range = 7  - 57.8 cm
Weight range = 2  - 1966 g
log10(a) = -2.36 , SE = 0.00353
Geometric mean a = 0.00432 , 95% CL = 0.00426 - 0.00439
b = 3.19 , 95% CL = 3.19 - 3.2
Standard deviation of estimated log10(W) = 0.0565
Coefficient of determination (r2) = 0.989
--------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
--------------------------------------------------------------
Available maturity codes          = 1 2 3 4
Number of observations            = 32380
Largest immature                  = 49 cm
Smallest mature                   = 7 cm
Ogive length at 50% maturity      = 21.1 cm
Ogive length at 10% and 90% maturity 17  - 25.1 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 57.8 cm
Median of annual maximum lengths   = 51.5 cm
Whetherall Linf based on SMALK     = 58.9 cm
Observed maximum length CPUE       = 69 cm
Median annual maximum lengths CPUE = 56 cm
Chosen Linf                        = 58.9 cm
Length at max cohort biomass Lopt  = 39.3 cm (assuming b~3 and M/K~1.5)
```

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	whg-47d	1990	56	239879	124637	82.8	0.520	0.000665	29	32	37	0.492	0.543	0.628
2	whg-47d	1991	54	1063441	504150	164.6	0.474	0.000326	29	31	36	0.492	0.526	0.611

3	whg-47d	1992	50	1186150	510939	177.4	0.431	0.000347	30	32	36	0.509	0.543 0.611
4	whg-47d	1993	54	1040973	406856	538.5	0.391	0.001324	30	33	37	0.509	0.560 0.628
5	whg-47d	1994	52	986085	418401	233.9	0.424	0.000559	29	31	37	0.492	0.526 0.628
6	whg-47d	1995	57	1174044	492876	291.2	0.420	0.000591	29	31	37	0.492	0.526 0.628
7	whg-47d	1996	56	636144	340117	194.4	0.535	0.000572	30	32	37	0.509	0.543 0.628
8	whg-47d	1997	48	231331	132070	71.7	0.571	0.000543	30	32	36	0.509	0.543 0.611
9	whg-47d	1998	56	554787	105297	78.0	0.190	0.000741	27	32	37	0.458	0.543 0.628
10	whg-47d	1999	59	705237	166565	74.7	0.236	0.000448	27	31	37	0.458	0.526 0.628
11	whg-47d	2000	59	697651	221355	71.8	0.317	0.000325	28	31	36	0.475	0.526 0.611
12	whg-47d	2001	54	891597	210879	81.2	0.237	0.000385	27	31	37	0.458	0.526 0.628
13	whg-47d	2002	54	372549	190310	85.3	0.511	0.000448	30	32	37	0.509	0.543 0.628
14	whg-47d	2003	69	315561	195005	117.2	0.618	0.000601	31	32	36	0.526	0.543 0.611
15	whg-47d	2004	55	258664	109461	74.0	0.423	0.000676	30	32	37	0.509	0.543 0.628
16	whg-47d	2005	53	134110	74586	74.2	0.556	0.000995	31	33	36	0.526	0.560 0.611
17	whg-47d	2006	59	134772	66197	84.6	0.491	0.001279	32	33	36	0.543	0.560 0.611
18	whg-47d	2007	65	230301	68990	110.8	0.300	0.001605	30	33	37	0.509	0.560 0.628
19	whg-47d	2008	60	291796	98459	125.0	0.337	0.001269	30	33	38	0.509	0.560 0.645
20	whg-47d	2009	54	341310	153868	159.1	0.451	0.001034	29	31	38	0.492	0.526 0.645
21	whg-47d	2010	56	263072	133448	248.8	0.507	0.001864	32	34	37	0.543	0.577 0.628
22	whg-47d	2011	58	270043	144451	628.3	0.535	0.004349	32	35	40	0.543	0.594 0.679
23	whg-47d	2012	61	286154	138729	686.3	0.485	0.004947	31	35	41	0.526	0.594 0.696
24	whg-47d	2013	56	179738	103730	665.9	0.577	0.006420	34	36	40	0.577	0.611 0.679
25	whg-47d	2014	58	494809	114288	804.7	0.231	0.007041	30	35	40	0.509	0.594 0.679
26	whg-47d	2015	57	542136	142413	538.2	0.263	0.003779	29	34	40	0.492	0.577 0.679

Comment: No mega-spawners; 90% of minimum landing size assumed as proxy for Lc.com, but may be too high





Comment: L95 indicators show similar trends, but L95 above half of Linf seems too high. No mega-spawners; truncated age structure consistent with past F >> Fmsy in assessment. Lc.com assumed as 90% MLS, may still be too high (= above Lm50).

Norway pout in the North Sea

Results of SMALK and CPUE analysis, Fri Nov 04 13:53:43 2016

SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv

Survey = NS-IBTS

Species = Trisopterus esmarkii Stock = nop-34

Sex SMALK = F

Years = 1990 - 2015

Quarter = 1

Areas = 1 2 3 4 7 6 5

Lc.com = 13 cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

14 outliers (beyond 4 SD) were removed.

Number of remaining observations = 4487

Length range = 8 - 25.2 cm

Weight range = 3 - 126 g

log10(a) = -2.28 , SE = 0.0122

Geometric mean a = 0.00524 , 95% CL = 0.00496 - 0.00554

b = 3.11 , 95% CL = 3.09 - 3.14

Standard deviation of estimated log10(W) = 0.0667

Coefficient of determination (r2) = 0.962

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 1 2 3 4

Number of observations = 6417

Largest immature = 21 cm

Smallest mature = 8 cm

Ogive length at 50% maturity = 13.5 cm

Ogive length at 10% and 90% maturity 11.2 - 15.8 cm

Estimation of Linf

Observed maximum length SMALK = 25.2 cm

Median of annual maximum lengths = 23 cm

Whetherall Linf based on SMALK = 25.6 cm

Observed maximum length CPUE = 30 cm

Median annual maximum lengths CPUE = 24 cm

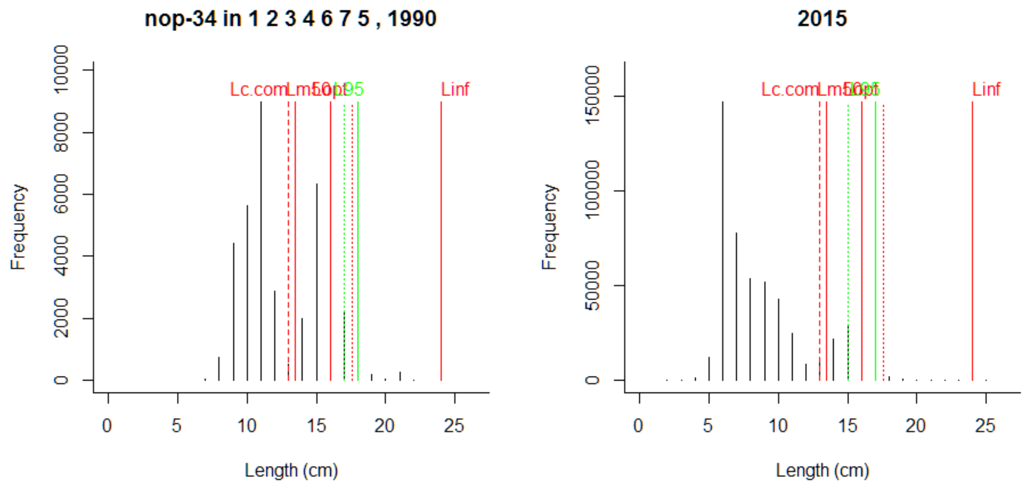
Chosen Linf = 24 cm

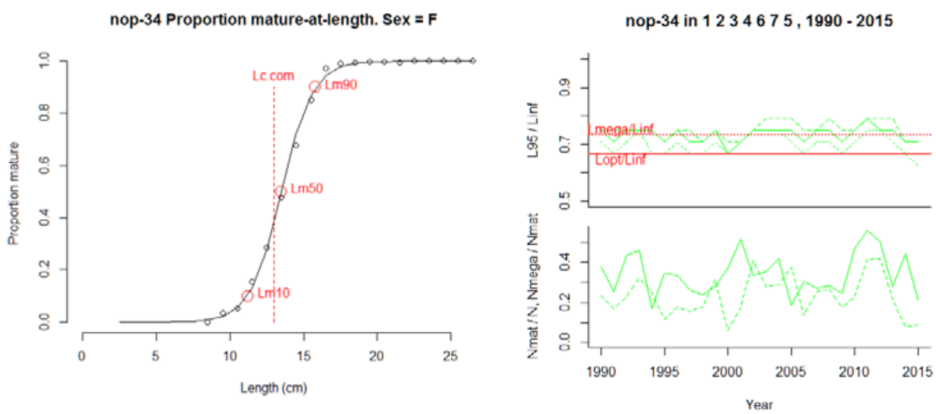
Length at max cohort biomass Lopt = 16 cm (assuming b~3 and M/K~1.5)

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	nop-34	1990	22	189588	71419	16783	0.377	0.2350	17	18	18	0.708	0.750	0.750
2	nop-34	1991	26	1427520	362045	61737	0.254	0.1705	16	18	17	0.667	0.750	0.708

3	nop-34	1992	30	2985659	1302296	296701	0.436	0.2278	17	18	18	0.708	0.750	0.750
4	nop-34	1993	23	1458936	670781	216538	0.460	0.3228	18	18	18	0.750	0.750	0.750
5	nop-34	1994	25	2638033	447301	111937	0.170	0.2503	16	18	18	0.667	0.750	0.750
6	nop-34	1995	27	2276154	790526	92196	0.347	0.1166	16	17	17	0.667	0.708	0.708
7	nop-34	1996	25	1336447	449513	80306	0.336	0.1787	17	18	18	0.708	0.750	0.750
8	nop-34	1997	24	2385631	622020	98899	0.261	0.1590	16	18	17	0.667	0.750	0.708
9	nop-34	1998	22	440974	104109	18586	0.236	0.1785	16	17	17	0.667	0.708	0.708
10	nop-34	1999	23	451560	125338	39008	0.278	0.3112	17	18	18	0.708	0.750	0.750
11	nop-34	2000	23	1838486	686347	41235	0.373	0.0601	16	17	16	0.667	0.708	0.667
12	nop-34	2001	23	775308	399647	69879	0.515	0.1749	17	17	17	0.708	0.708	0.708
13	nop-34	2002	27	743542	250053	102863	0.336	0.4114	18	18	18	0.750	0.750	0.750
14	nop-34	2003	29	499442	177076	49134	0.355	0.2775	18	19	18	0.750	0.792	0.750
15	nop-34	2004	24	277548	116417	33691	0.419	0.2894	18	19	18	0.750	0.792	0.750
16	nop-34	2005	22	388954	73032	27582	0.188	0.3777	17	19	18	0.708	0.792	0.750
17	nop-34	2006	24	660720	202347	27750	0.306	0.1371	16	18	17	0.667	0.750	0.708
18	nop-34	2007	22	764738	207337	52405	0.271	0.2528	17	18	18	0.708	0.750	0.750
19	nop-34	2008	23	803780	227689	61095	0.283	0.2683	17	19	18	0.708	0.792	0.750
20	nop-34	2009	24	1644811	407414	70474	0.248	0.1730	16	18	17	0.667	0.750	0.708
21	nop-34	2010	25	1335967	627237	142342	0.470	0.2269	17	18	18	0.708	0.750	0.750
22	nop-34	2011	28	689120	384732	159619	0.558	0.4149	18	19	19	0.750	0.792	0.792
23	nop-34	2012	24	229532	115431	48481	0.503	0.4200	18	19	18	0.750	0.792	0.750
24	nop-34	2013	23	966295	269577	58575	0.279	0.2173	17	19	18	0.708	0.792	0.750
25	nop-34	2014	22	582291	258679	20356	0.444	0.0787	16	17	17	0.667	0.708	0.708
26	nop-34	2015	25	1907314	405913	36289	0.213	0.0894	15	17	17	0.625	0.708	0.708

Comment: Indicators seem to work reasonably well; but Lc.com was just guessed





Comment: Recruitment variability introduces noise in all indicators; this could be reduced e.g. by a 3-years moving average. This is a small species that grows relatively much throughout the year, so ratio of indicators to fixed reference points depends on season. But on average indicators seem to be working well.

Saithe in the North Sea

Results of SMALK and CPUE analysis, Fri Nov 04 14:02:38 2016

SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv

Survey = NS-IBTS

Species = Pollachius virens Stock = sai-3a46

Sex SMALK = F

Years = 1990 - 2015

Quarter = 1

Areas = 2 3

Lc.com = 31.5 cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

0 outliers (beyond 4 SD) were removed.

Number of remaining observations = 114

Length range = 13 - 103 cm

Weight range = 16 - 11380 g

log10(a) = -2.37 , SE = 0.0345

Geometric mean a = 0.00426 , 95% CL = 0.00364 - 0.00499

b = 3.2 , 95% CL = 3.16 - 3.25

Standard deviation of estimated log10(W) = 0.0501

Coefficient of determination (r2) = 0.995

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 62 61 63 64

Number of observations = 103

Largest immature = 50 cm

Smallest mature = 39 cm

Ogive length at 50% maturity = 46.2 cm

Ogive length at 10% and 90% maturity 39.6 - 52.8 cm

Estimation of Linf

Observed maximum length SMALK = 103 cm

Median of annual maximum lengths = 72.5 cm

Whetherall Linf based on SMALK = 102 cm

Observed maximum length CPUE = 118 cm

Median annual maximum lengths CPUE = 100 cm

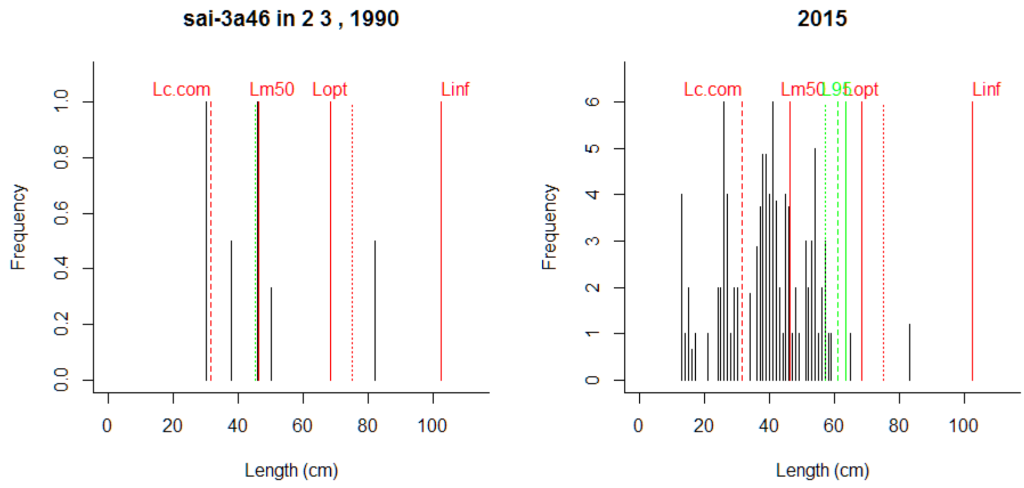
Chosen Linf = 102 cm

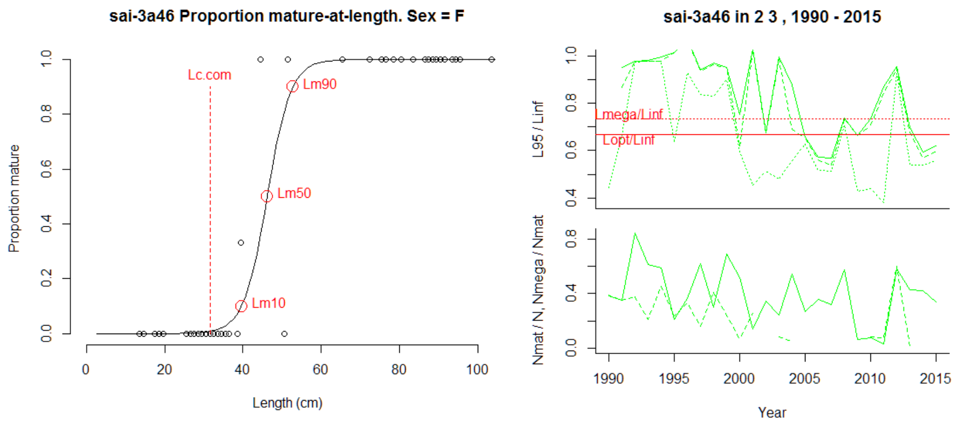
Length at max cohort biomass Lopt = 68.3 cm (assuming b~3 and M/K~1.5)

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	sai-3a46	1990	82	3.33	1.28	0.50	0.3833	0.3914	45.2	NA	NA	0.441	NA	NA
2	sai-3a46	1991	118	120.84	42.56	15.00	0.3522	0.3524	68.5	88.7	97.5	0.669	0.867	0.952

3	sai-3a46	1992	110	109.00	91.79	34.50	0.8421	0.3759	99.9	100.0	100.0	0.976	0.977	0.977
4	sai-3a46	1993	110	176.33	107.76	22.83	0.6111	0.2119	99.9	100.0	100.3	0.976	0.977	0.980
5	sai-3a46	1994	112	65.67	38.37	17.33	0.5844	0.4517	100.0	100.0	101.8	0.977	0.977	0.994
6	sai-3a46	1995	113	318.33	67.78	16.00	0.2129	0.2360	65.0	104.0	104.0	0.635	1.016	1.016
7	sai-3a46	1996	110	89.92	32.72	10.92	0.3638	0.3337	95.0	110.0	110.0	0.928	1.074	1.074
8	sai-3a46	1997	103	56.00	34.62	5.67	0.6182	0.1637	85.6	95.9	96.4	0.836	0.937	0.942
9	sai-3a46	1998	103	21.67	6.54	2.67	0.3020	0.4076	85.0	98.5	99.2	0.830	0.962	0.969
10	sai-3a46	1999	101	6.00	4.13	1.00	0.6886	0.2421	92.2	97.5	97.5	0.901	0.952	0.952
11	sai-3a46	2000	100	64.67	33.61	2.33	0.5198	0.0694	61.0	63.2	77.0	0.596	0.617	0.752
12	sai-3a46	2001	108	247.25	35.26	9.00	0.1426	0.2553	46.5	105.0	105.2	0.455	1.026	1.028
13	sai-3a46	2002	70	52.17	17.90	NA	0.3432	NA	52.5	69.0	69.0	0.513	0.674	0.674
14	sai-3a46	2003	103	340.00	82.78	7.00	0.2435	0.0846	49.0	101.0	102.0	0.479	0.986	0.996
15	sai-3a46	2004	112	34.20	18.51	1.00	0.5413	0.0540	57.0	70.8	90.0	0.557	0.691	0.879
16	sai-3a46	2005	68	35.00	9.49	NA	0.2712	NA	64.3	66.9	67.4	0.628	0.654	0.658
17	sai-3a46	2006	59	58.37	20.91	NA	0.3583	NA	52.8	57.5	58.6	0.516	0.562	0.572
18	sai-3a46	2007	61	112.50	36.13	NA	0.3212	NA	52.4	55.0	58.3	0.512	0.537	0.569
19	sai-3a46	2008	78	24.00	13.76	1.00	0.5733	0.0727	72.5	75.0	75.5	0.709	0.733	0.737
20	sai-3a46	2009	68	16.67	1.04	NA	0.0625	NA	44.0	68.0	68.0	0.430	0.664	0.664
21	sai-3a46	2010	76	153.33	11.54	1.00	0.0753	0.0867	45.2	72.0	75.2	0.441	0.703	0.734
22	sai-3a46	2011	95	726.84	25.38	2.00	0.0349	0.0788	39.0	86.0	89.0	0.381	0.840	0.869
23	sai-3a46	2012	103	107.00	61.82	37.00	0.5777	0.5986	94.8	96.7	98.0	0.925	0.944	0.957
24	sai-3a46	2013	81	109.09	46.60	1.00	0.4272	0.0215	55.0	69.0	71.4	0.537	0.674	0.697
25	sai-3a46	2014	63	31.12	13.03	NA	0.4187	NA	55.1	58.1	60.8	0.538	0.567	0.594
26	sai-3a46	2015	83	139.70	47.00	1.20	0.3364	0.0255	57.0	60.8	63.5	0.557	0.594	0.620

Comment: High variability because of few data; 90% of MLS assumed as Lc.com





Comment: Few data (catches only in round fish areas 2 and 3) cause variability, but indicators correctly suggest that size structure is getting more truncated. Again, a 3-year moving average could reduce variability and strengthen the average signal.

Plaice in the North Sea

Results of SMALK and CPUE analysis, Fri Nov 04 19:07:24 2016

SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv

Survey = NS-IBTS

Species = Pleuronectes platessa Stock = ple-nsea

Sex SMALK = F

Years = 1992 - 2015

Quarter = 1

Areas = 4 5 6 7 2 3 1

Lc.com = 20.5 cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

20 outliers (beyond 4 SD) were removed.

Number of remaining observations = 7107

Length range = 7.6 - 55 cm

Weight range = 4 - 1784 g

log10(a) = -2 , SE = 0.0063

Geometric mean a = 0.00995 , 95% CL = 0.00967 - 0.0102

b = 2.98 , 95% CL = 2.97 - 2.99

Standard deviation of estimated log10(W) = 0.052

Coefficient of determination (r2) = 0.986

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 62 61 63 64

Number of observations = 4609

Largest immature = 41 cm

Smallest mature = 10 cm

Ogive length at 50% maturity = 22.6 cm

Ogive length at 10% and 90% maturity 14.8 - 30.4 cm

Estimation of Linf

Observed maximum length SMALK = 55 cm

Median of annual maximum lengths = 50.7 cm

Whetherall Linf based on SMALK = 59.7 cm

Observed maximum length CPUE = 67 cm

Median annual maximum lengths CPUE = 56 cm

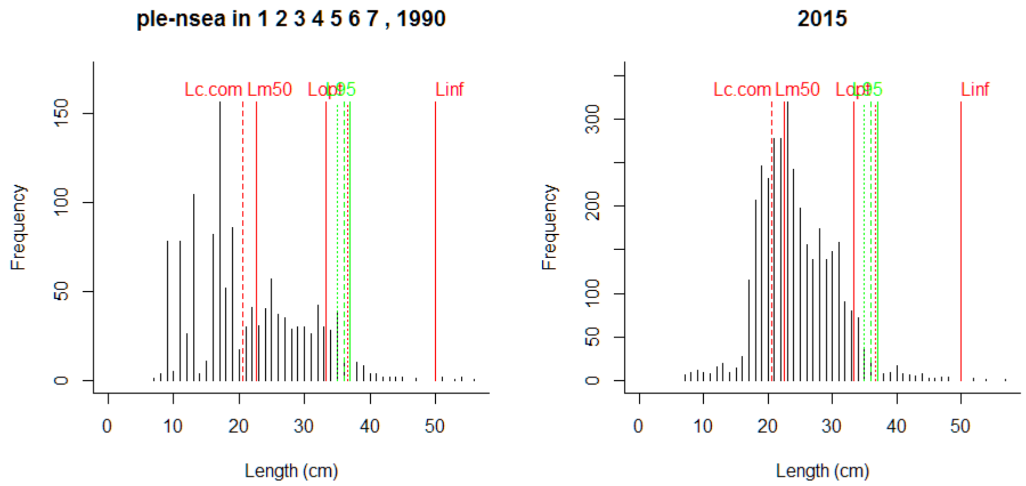
Chosen Linf = 50 cm

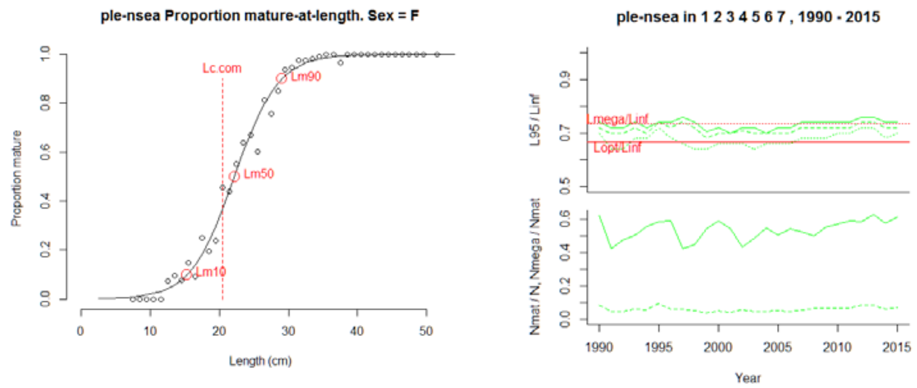
Length at max cohort biomass Lopt = 33.3 cm (assuming b~3 and M/K~1.5)

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	ple-nsea	1990	56	5183	3222	272	0.622	0.0845	35	36.0	37.0	0.70	0.720	0.740
2	ple-nsea	1991	62	34098	14362	716	0.421	0.0498	32	35.0	36.0	0.64	0.700	0.720

3	ple-nsea	1992	57	26439	12516	627	0.473	0.0501	32	35.0	36.0	0.64	0.700	0.720
4	ple-nsea	1993	61	13174	6629	411	0.503	0.0619	34	36.0	37.0	0.68	0.720	0.740
5	ple-nsea	1994	60	10490	5848	344	0.558	0.0588	34	35.0	36.0	0.68	0.700	0.720
6	ple-nsea	1995	55	7819	4564	439	0.584	0.0962	36	37.0	37.0	0.72	0.740	0.740
7	ple-nsea	1996	56	10283	6042	385	0.588	0.0636	34	36.0	37.0	0.68	0.720	0.740
8	ple-nsea	1997	56	14564	6169	385	0.424	0.0624	33	37.0	38.0	0.66	0.740	0.760
9	ple-nsea	1998	54	10973	4887	267	0.445	0.0546	32	36.0	37.0	0.64	0.720	0.740
10	ple-nsea	1999	54	9323	5025	202	0.539	0.0402	32	34.0	35.3	0.64	0.680	0.706
11	ple-nsea	2000	63	6024	3534	185	0.587	0.0524	33	35.0	36.0	0.66	0.700	0.720
12	ple-nsea	2001	57	7677	4157	188	0.542	0.0451	33	35.0	35.0	0.66	0.700	0.700
13	ple-nsea	2002	54	8834	3808	213	0.431	0.0560	33	35.3	36.0	0.66	0.707	0.720
14	ple-nsea	2003	54	10167	4919	232	0.484	0.0472	32	35.0	36.0	0.64	0.700	0.720
15	ple-nsea	2004	49	6588	3594	179	0.546	0.0498	33	35.0	35.0	0.66	0.700	0.700
16	ple-nsea	2005	53	8199	4106	211	0.501	0.0513	33	35.0	36.0	0.66	0.700	0.720
17	ple-nsea	2006	52	9502	5137	258	0.541	0.0502	33	35.0	36.0	0.66	0.700	0.720
18	ple-nsea	2007	55	14370	7470	431	0.520	0.0576	34	36.0	37.0	0.68	0.720	0.740
19	ple-nsea	2008	56	20173	10072	682	0.499	0.0678	34	36.0	37.0	0.68	0.720	0.740
20	ple-nsea	2009	67	19075	10535	699	0.552	0.0663	34	36.0	37.0	0.68	0.720	0.740
21	ple-nsea	2010	56	21411	12171	834	0.568	0.0685	35	36.0	37.0	0.70	0.720	0.740
22	ple-nsea	2011	56	27118	15954	1073	0.588	0.0672	35	36.0	37.0	0.70	0.720	0.740
23	ple-nsea	2012	57	30458	17833	1553	0.585	0.0871	36	37.0	38.0	0.72	0.740	0.760
24	ple-nsea	2013	56	21950	13754	1174	0.627	0.0853	36	37.0	38.0	0.72	0.740	0.760
25	ple-nsea	2014	58	27972	16096	1021	0.575	0.0634	34	36.0	37.0	0.68	0.720	0.740
26	ple-nsea	2015	57	29175	17885	1298	0.613	0.0726	35	36.0	37.0	0.70	0.720	0.740

Comment: Large individuals are apparently not retained by the gear





Comment: The SG was of the opinion that large flatfish are not sampled representatively by the survey gear, as correctly shown by the indicators. Thus, commercial data should be used instead.

Mackerel in the Northeast Atlantic (here: North Sea)

Results of SMALK and CPUE analysis, Fri Nov 04 15:46:51 2016

SMALK_File = SMALK_NS-IBTS_2016-10-31.csv CPUE_File = NSCPUE per length per subarea_2016-11-02 16_43_26.csv

Survey = NS-IBTS

Species = Scomber scombrus Stock = mac-nea

Sex SMALK = F

Years = 1996 - 2015

Quarter = 1

Areas = 1 2 3 7 4 6 5

Lc.com = 27 cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

1 outliers (beyond 4 SD) were removed.

Number of remaining observations = 1818

Length range = 14 - 44 cm

Weight range = 19 - 743 g

log10(a) = -2.56 , SE = 0.0174

Geometric mean a = 0.00274 , 95% CL = 0.00253 - 0.00297

b = 3.3 , 95% CL = 3.28 - 3.33

Standard deviation of estimated log10(W) = 0.0472

Coefficient of determination (r2) = 0.978

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 1 2 3 4

Number of observations = 2410

Largest immature = 30 cm

Smallest mature = 14 cm

Ogive length at 50% maturity = 25.6 cm

Ogive length at 10% and 90% maturity 22.7 - 28.5 cm

Estimation of Linf

Observed maximum length SMALK = 44 cm

Median of annual maximum lengths = 39 cm

Whetherall Linf based on SMALK = 40.6 cm

Observed maximum length CPUE = 56 cm

Median annual maximum lengths CPUE = 44 cm

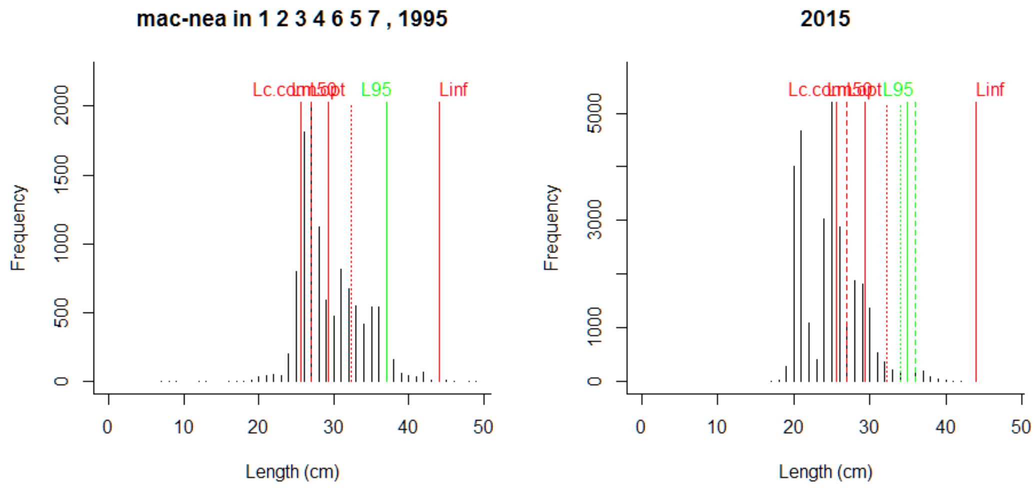
Chosen Linf = 44 cm

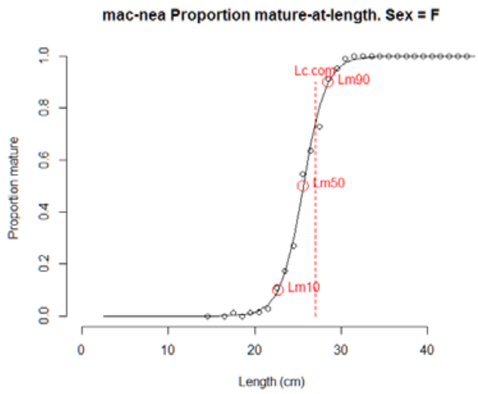
Length at max cohort biomass Lopt = 29.3 cm (assuming b~3 and M/K~1.5)

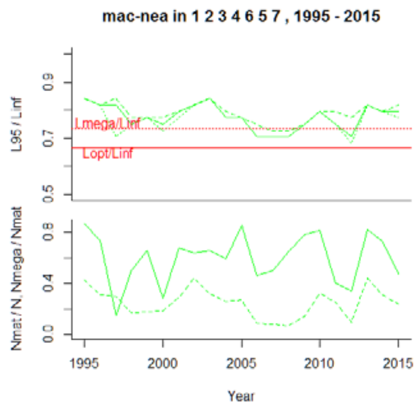
	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	mac-nea	1995	49	46059	40042	17096	0.869	0.4270	37	37	37	0.841	0.841	0.841
2	mac-nea	1996	50	28124	20652	6432	0.734	0.3115	36	36	36	0.818	0.818	0.818

3	mac-nea	1997	48	136028	19658	5786	0.145	0.2944	31	37	36	0.705	0.841	0.818
4	mac-nea	1998	44	44228	22304	3779	0.504	0.1695	33	34	33	0.750	0.773	0.750
5	mac-nea	1999	48	30703	20213	3668	0.658	0.1815	34	34	34	0.773	0.773	0.773
6	mac-nea	2000	44	75354	21268	3889	0.282	0.1829	32	34	33	0.727	0.773	0.750
7	mac-nea	2001	56	24515	16604	4792	0.677	0.2886	34	35	35	0.773	0.795	0.795
8	mac-nea	2002	45	33327	21258	9445	0.638	0.4443	36	36	36	0.818	0.818	0.818
9	mac-nea	2003	44	17624	11644	3706	0.661	0.3183	37	37	37	0.841	0.841	0.841
10	mac-nea	2004	43	25764	15288	3971	0.593	0.2598	34	35	34	0.773	0.795	0.773
11	mac-nea	2005	49	17508	14953	4008	0.854	0.2681	34	34	34	0.773	0.773	0.773
12	mac-nea	2006	41	84313	39058	3400	0.463	0.0870	31	33	31	0.705	0.750	0.705
13	mac-nea	2007	43	88638	44347	3591	0.500	0.0810	31	32	31	0.705	0.727	0.705
14	mac-nea	2008	43	97981	63825	4316	0.651	0.0676	31	32	31	0.705	0.727	0.705
15	mac-nea	2009	42	36072	28349	3976	0.786	0.1402	33	33	33	0.750	0.750	0.750
16	mac-nea	2010	48	40102	32606	10536	0.813	0.3231	35	35	35	0.795	0.795	0.795
17	mac-nea	2011	43	73327	29335	7421	0.400	0.2530	33	35	33	0.750	0.795	0.750
18	mac-nea	2012	46	111502	38636	3528	0.347	0.0913	30	34	31	0.682	0.773	0.705
19	mac-nea	2013	44	33324	27451	12080	0.824	0.4401	36	36	36	0.818	0.818	0.818
20	mac-nea	2014	43	32393	23587	7289	0.728	0.3090	35	35	35	0.795	0.795	0.795
21	mac-nea	2015	44	83504	39913	9497	0.478	0.2379	34	36	35	0.773	0.818	0.795

Comment: Assuming 90% of minimum landing size for Lc.com







Comment: Species seems to be well represented by the gear and indicators seem to work well. High proportion of mature individuals is confirmed by reasonably high biomass. High variability in proportion of mature individuals (solid green line in lower right graph and panel) is caused by closeness of Lc.com and Lm50 (see maturity ogive). This could be reduced by a 3-year moving average.

Western Baltic cod

Results of SMALK and CPUE analysis, Fri Nov 04 15:59:58 2016

SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-11-01 15_32_54.csv

Survey = BITS

Species = Gadus morhua Stock = cod-2224

Sex SMALK = F

Years = 1994 - 2015

Quarter = 1

Areas = 22 24 23

Lc.com = 32 cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

43 outliers (beyond 4 SD) were removed.

Number of remaining observations = 17649

Length range = 8 - 119 cm

Weight range = 5 - 25220 g

log10(a) = -2.18 , SE = 0.00339

Geometric mean a = 0.0066 , 95% CL = 0.0065 - 0.0067

b = 3.11 , 95% CL = 3.11 - 3.11

Standard deviation of estimated log10(W) = 0.0533

Coefficient of determination (r2) = 0.993

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 1 2 3 4

Number of observations = 7787

Largest immature = 78 cm

Smallest mature = 9 cm

Ogive length at 50% maturity = 34 cm

Ogive length at 10% and 90% maturity 23.7 - 44.2 cm

Estimation of Linf

Observed maximum length SMALK = 119 cm

Median of annual maximum lengths = 99.5 cm

Whetherall Linf based on SMALK = NA cm

Observed maximum length CPUE = 119 cm

Median annual maximum lengths CPUE = 102 cm

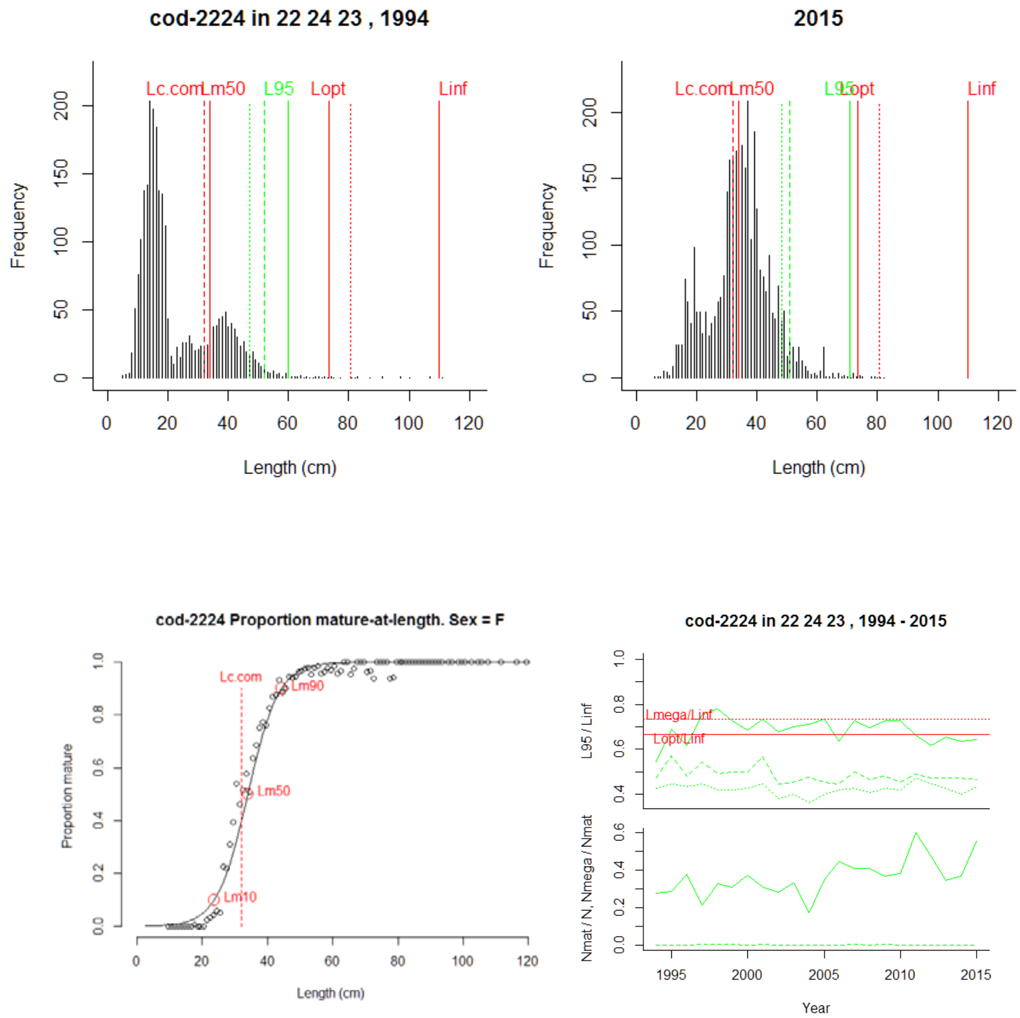
Chosen Linf = 110 cm

Length at max cohort biomass Lopt = 73.3 cm (assuming b~3 and M/K~1.5)

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	cod-2224	1994	111	6296	1763	2.53	0.280	0.001437	47	52.0	60.0	0.427	0.473	0.545
2	cod-2224	1995	96	22991	6570	14.80	0.286	0.002253	49	63.0	76.0	0.445	0.573	0.691

3	cod-2224	1996	103	8087	3048	5.83	0.377	0.001914	48	53.0	68.0	0.436	0.482	0.618
4	cod-2224	1997	99	16022	3410	25.43	0.213	0.007456	49	60.0	83.0	0.445	0.545	0.755
5	cod-2224	1998	107	10294	3396	20.47	0.330	0.006029	46	54.0	86.0	0.418	0.491	0.782
6	cod-2224	1999	100	7965	2479	9.76	0.311	0.003936	46	55.0	80.0	0.418	0.500	0.727
7	cod-2224	2000	116	6020	2234	2.10	0.371	0.000940	47	55.0	75.3	0.427	0.500	0.685
8	cod-2224	2001	111	8377	2585	19.81	0.309	0.007663	49	62.7	81.0	0.445	0.570	0.736
9	cod-2224	2002	99	7987	2250	3.28	0.282	0.001458	42	49.0	74.5	0.382	0.445	0.677
10	cod-2224	2003	101	8736	2908	1.68	0.333	0.000577	44	50.0	77.0	0.400	0.455	0.700
11	cod-2224	2004	104	13918	2428	4.39	0.174	0.001809	40	52.5	78.2	0.364	0.478	0.711
12	cod-2224	2005	105	13633	4761	11.28	0.349	0.002369	44	50.0	81.0	0.400	0.455	0.736
13	cod-2224	2006	102	6278	2795	2.05	0.445	0.000733	46	49.0	70.0	0.418	0.445	0.636
14	cod-2224	2007	101	6791	2783	12.60	0.410	0.004529	47	54.8	80.0	0.427	0.498	0.727
15	cod-2224	2008	119	9146	3748	12.31	0.410	0.003284	45	51.0	76.4	0.409	0.464	0.695
16	cod-2224	2009	108	5064	1861	11.94	0.367	0.006416	47	53.0	80.0	0.427	0.482	0.727
17	cod-2224	2010	104	9192	3531	8.43	0.384	0.002388	46	50.0	80.0	0.418	0.455	0.727
18	cod-2224	2011	92	12255	7354	6.37	0.600	0.000867	52	54.0	73.0	0.473	0.491	0.664
19	cod-2224	2012	88	6441	3045	4.05	0.473	0.001331	49	52.0	68.0	0.445	0.473	0.618
20	cod-2224	2013	89	6568	2263	1.88	0.345	0.000829	47	52.0	72.0	0.427	0.473	0.655
21	cod-2224	2014	98	8167	3000	1.29	0.367	0.000430	44	52.0	70.0	0.400	0.473	0.636
22	cod-2224	2015	82	8555	4732	1.44	0.553	0.000304	48	51.0	70.6	0.436	0.464	0.642

Comment: L95 falls outside of area of mega-spawners, which could be a potential threshold



Comment: Age structure in stock is severely truncated with close to zero mega-spawners. L95 for lengths above ½ Lopt misses that. Other indicators work well.

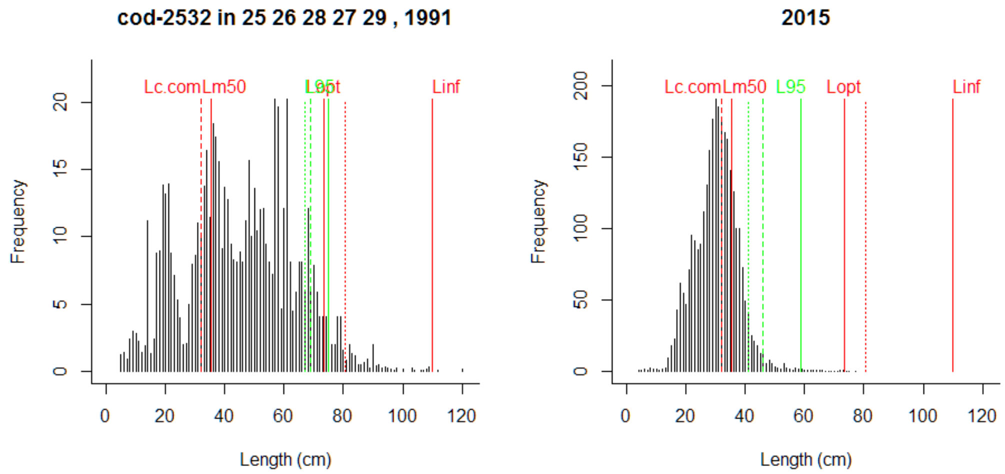
Eastern Baltic cod

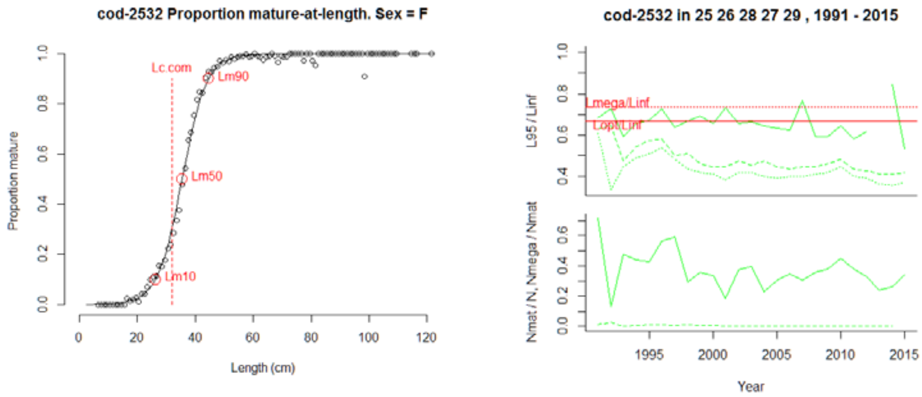
```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 16:12:07 2016
---------------------------------------------
SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-
11-01 15_32_54.csv
Survey     = BITS
Species    = Gadus morhua Stock = cod-2532
Sex SMALK  = F
Years      = 1991  - 2015
Quarter    = 1
Areas      = 26 28 25 27
Lc.com     = 32 cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
162  outliers (beyond 4 SD) were removed.
Number of remaining observations = 46015
Length range = 6  - 127 cm
Weight range = 2  - 20400 g
log10(a) = -2.15 , SE = 0.00228
Geometric mean a = 0.0071 , 95% CL = 0.00703 - 0.00717
b = 3.08 , 95% CL = 3.08 - 3.08
Standard deviation of estimated log10(W) = 0.0577
Coefficient of determination (r2) = 0.991
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 2 3 1 4
Number of observations            = 23369
Largest immature                  = 98 cm
Smallest mature                   = 6 cm
Ogive length at 50% maturity      = 35.4 cm
Ogive length at 10% and 90% maturity 26.2  - 44.6 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 127 cm
Median of annual maximum lengths   = 106 cm
Whetherall Linf based on SMALK     = 135 cm
Observed maximum length CPUE       = 136 cm
Median annual maximum lengths CPUE = 113 cm
Chosen Linf                        = 110 cm
Length at max cohort biomass Lopt  = 73.3 cm (assuming b~3 and M/K~1.5)

      Stock Year Lmax.obs      N N.mat N.mega pp.mat   pp.mega   L95 L95mat L95.5 L95Linf
L95matLinf L95.5Linf
1  cod-2532 1991       120   2641   1890   25.57   0.716 0.013530 66.9    69.0  75.0    0.608
0.627     0.682
2  cod-2532 1992       109   5963    780   23.18   0.131 0.029719 37.0    71.4  80.0    0.336
0.649     0.727
```

3	cod-2532	1993	127	11667	5545	21.89	0.475	0.003948	49.0	52.0	65.4	0.445	0.473	0.595
4	cod-2532	1994	127	8510	3744	16.37	0.440	0.004372	53.8	60.0	72.0	0.489	0.545	0.655
5	cod-2532	1995	110	7755	3318	34.14	0.428	0.010290	56.0	63.0	74.0	0.509	0.573	0.673
6	cod-2532	1996	136	5264	2956	38.67	0.562	0.013080	59.0	64.0	80.0	0.536	0.582	0.727
7	cod-2532	1997	105	3211	1895	11.48	0.590	0.006059	53.0	55.0	70.0	0.482	0.500	0.636
8	cod-2532	1998	121	6022	1755	18.55	0.291	0.010566	48.0	56.0	73.4	0.436	0.509	0.667
9	cod-2532	1999	113	6207	2234	11.99	0.360	0.005368	46.0	51.0	76.0	0.418	0.464	0.691
10	cod-2532	2000	118	7625	2574	12.19	0.338	0.004735	45.0	49.0	72.0	0.409	0.445	0.655
11	cod-2532	2001	104	11076	2040	6.38	0.184	0.003129	42.0	49.0	80.4	0.382	0.445	0.731
12	cod-2532	2002	118	13668	5111	7.43	0.374	0.001454	46.0	52.0	72.3	0.418	0.473	0.657
13	cod-2532	2003	121	6413	2544	8.61	0.397	0.003385	46.0	50.0	73.2	0.418	0.455	0.665
14	cod-2532	2004	110	10719	2472	6.32	0.231	0.002555	44.0	52.0	71.0	0.400	0.473	0.645
15	cod-2532	2005	115	12095	3659	8.32	0.303	0.002274	43.0	49.0	69.7	0.391	0.445	0.634
16	cod-2532	2006	118	9981	3477	7.91	0.348	0.002275	44.0	48.0	68.6	0.400	0.436	0.624
17	cod-2532	2007	102	14295	4386	13.41	0.307	0.003057	44.0	49.0	84.2	0.400	0.445	0.766
18	cod-2532	2008	116	19204	6870	16.49	0.358	0.002401	45.0	49.0	65.0	0.409	0.445	0.591
19	cod-2532	2009	113	18411	7018	18.18	0.381	0.002591	46.0	51.0	65.0	0.418	0.464	0.591
20	cod-2532	2010	113	24482	11052	27.85	0.451	0.002520	49.0	53.0	71.0	0.445	0.482	0.645
21	cod-2532	2011	110	15307	5850	7.76	0.382	0.001326	44.0	48.0	64.0	0.400	0.436	0.582
22	cod-2532	2012	97	23153	7685	5.23	0.332	0.000680	43.0	47.0	68.0	0.391	0.427	0.618
23	cod-2532	2013	91	21176	5111	1.74	0.241	0.000341	40.0	45.0	NA	0.364	0.409	NA
24	cod-2532	2014	98	17230	4486	1.37	0.260	0.000305	39.0	45.0	93.1	0.355	0.409	0.846
25	cod-2532	2015	77	16075	5459	NA	0.340	NA	41.0	46.0	58.7	0.373	0.418	0.534

Comment: L95 falls outside of area of mega-spawners and even below Lopt; missing of mega-spawners confirmed in commercial data.





Comment: Size structure has become severely truncated in recent years, mega-spawners are absent. All indicators pick that up, but L95 above ½ Lopt is too high.

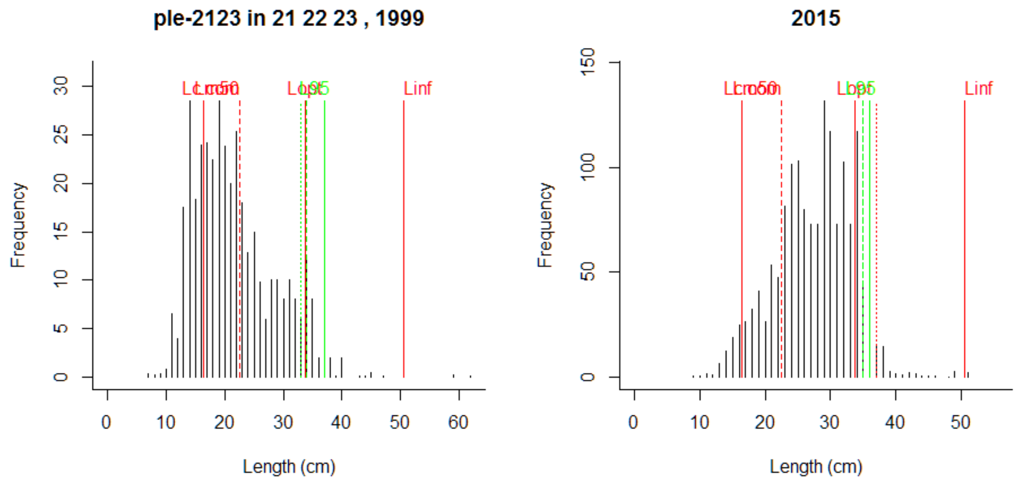
Western Baltic plaice

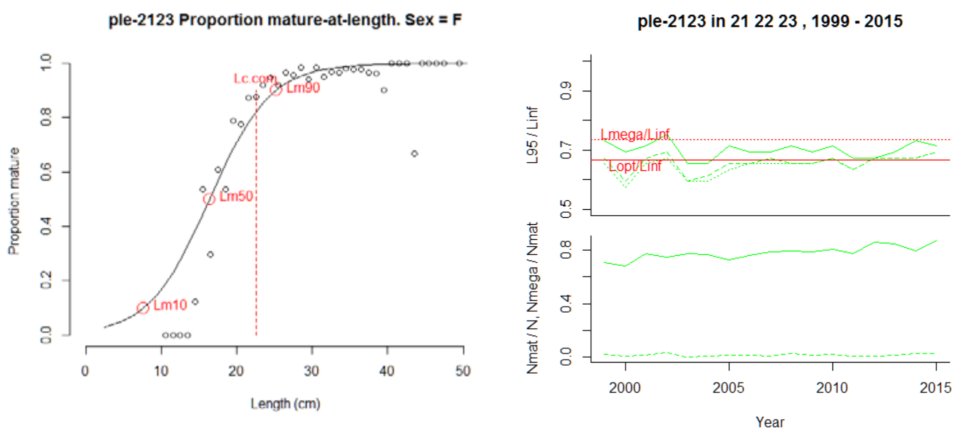
```
----------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 16:27:04 2016
----------------------------------------------
SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-
11-01 15_32_54.csv
Survey     = BITS
Species    = Pleuronectes platessa Stock = ple-2123
Sex SMALK  = F
Years      = 1999  - 2015
Quarter    = 1
Areas      = 21 22 23
Lc.com     = 22.5 cm (length where 50% are retained by commercial gear)
----------------------------------------------
Summary stats of weighted F  W~L regression
----------------------------------------------
5  outliers (beyond 4 SD) were removed.
Number of remaining observations = 5972
Length range = 7  - 53 cm
Weight range = 4  - 2130 g
log10(a) = -2.03 , SE = 0.00989
Geometric mean a = 0.00942 , 95% CL = 0.00901 - 0.00985
b = 3.04 , 95% CL = 3.02 - 3.05
Standard deviation of estimated log10(W) = 0.0655
Coefficient of determination (r2) = 0.974
--------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
--------------------------------------------------------------
Available maturity codes          = 61 62 64 63
Number of observations            = 1274
Largest immature                  = 43 cm
Smallest mature                   = 14 cm
Ogive length at 50% maturity      = 16.4 cm
Ogive length at 10% and 90% maturity 7.57  - 25.2 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 53 cm
Median of annual maximum lengths   = 47 cm
Whetherall Linf based on SMALK     = 50.5 cm
Observed maximum length CPUE       = 62 cm
Median annual maximum lengths CPUE = 48 cm
Chosen Linf                        = 50.5 cm
Length at max cohort biomass Lopt  = 33.7 cm (assuming b~3 and M/K~1.5)

      Stock Year Lmax.obs    N N.mat N.mega pp.mat pp.mega L95 L95mat L95.5 L95Linf L95mat-
Linf L95.5Linf
1  ple-2123 1999       62 1037   734  13.77  0.708 0.01876  33     34  37.0   0.653      0.673
0.732
2  ple-2123 2000       48 1998  1363  15.82  0.682 0.01160  29     30  35.0   0.574      0.594
0.693
```

3	ple-2123	2001	53	3232	2511	43.46	0.777	0.01730	33	34	36.0	0.653	0.673	0.713
4	ple-2123	2002	62	916	686	23.74	0.749	0.03462	34	35	38.0	0.673	0.693	0.752
5	ple-2123	2003	45	2457	1902	9.11	0.774	0.00479	30	30	33.0	0.594	0.594	0.653
6	ple-2123	2004	42	2700	2078	11.87	0.770	0.00571	30	31	33.0	0.594	0.614	0.653
7	ple-2123	2005	56	2013	1464	21.51	0.727	0.01469	32	33	36.0	0.633	0.653	0.713
8	ple-2123	2006	48	2245	1708	30.47	0.761	0.01784	33	33	35.0	0.653	0.653	0.693
9	ple-2123	2007	47	2520	1984	19.81	0.787	0.00998	33	34	35.0	0.653	0.673	0.693
10	ple-2123	2008	48	2402	1910	49.47	0.795	0.02591	33	33	36.1	0.653	0.653	0.714
11	ple-2123	2009	47	1621	1280	20.46	0.789	0.01599	33	33	35.0	0.653	0.653	0.693
12	ple-2123	2010	49	1742	1409	32.21	0.809	0.02285	34	34	36.0	0.673	0.673	0.713
13	ple-2123	2011	48	5560	4309	27.47	0.775	0.00638	32	32	34.0	0.633	0.633	0.673
14	ple-2123	2012	47	3912	3362	30.79	0.859	0.00916	34	34	34.0	0.673	0.673	0.673
15	ple-2123	2013	47	4979	4214	68.68	0.846	0.01630	34	34	35.0	0.673	0.673	0.693
16	ple-2123	2014	49	5296	4224	128.01	0.798	0.03030	34	34	37.0	0.673	0.673	0.732
17	ple-2123	2015	51	3959	3462	87.58	0.874	0.02530	35	35	36.0	0.693	0.693	0.713

Comment: 90% of minimum landing size assumed for Lc.com. Missing of large plaice could be real or gear effect





Comment: Plaice has recovered in recent years, with high numbers of mature individuals, and thus one would expect more large individuals; abrupt decline in large individuals is strange, these may not be caught by the survey gear, same as in the North Sea. A comparison with commercial data is needed.

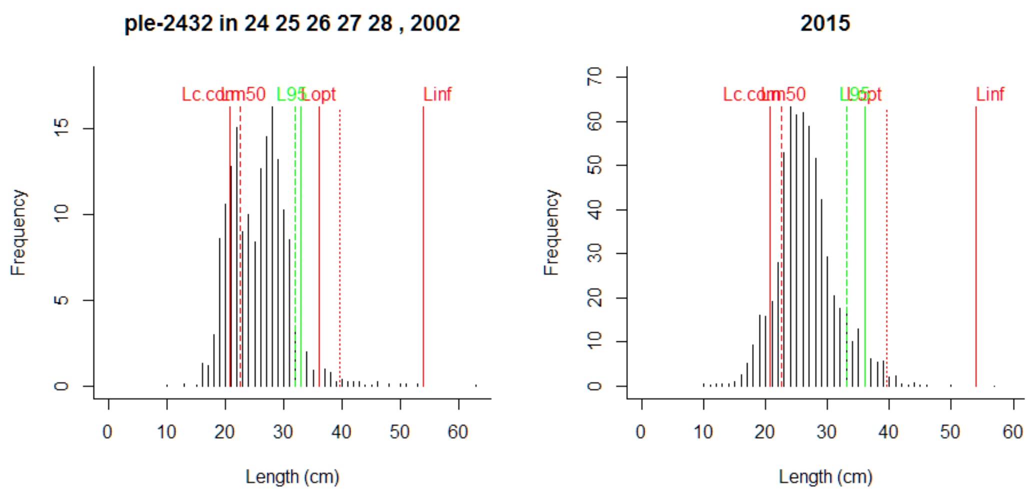
Plaice in the central and eastern Baltic

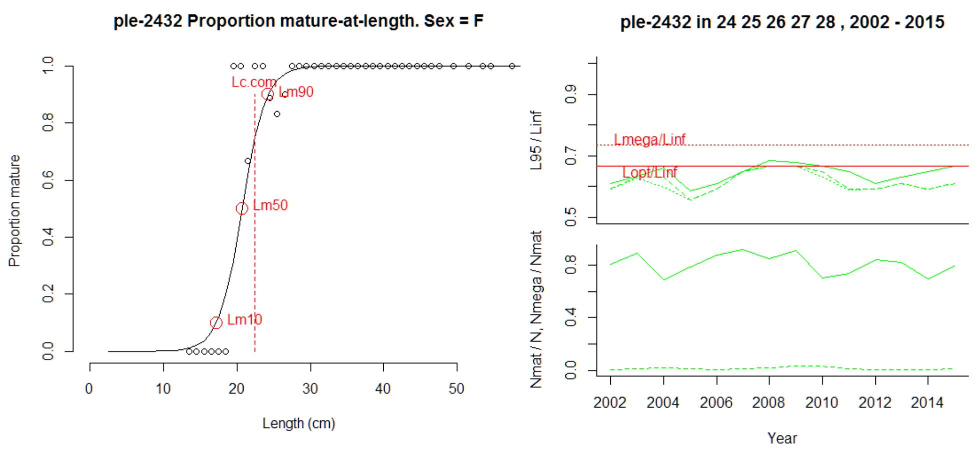
```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 16:35:27 2016
---------------------------------------------
SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-11-01 15_32_54.csv
Survey     = BITS
Species    = Pleuronectes platessa Stock = ple-2432
Sex SMALK  = F
Years      = 2002  - 2015
Quarter    = 1
Areas      = 24 25 26
Lc.com     = 22.5 cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
5  outliers (beyond 4 SD) were removed.
Number of remaining observations = 4401
Length range = 10  - 57 cm
Weight range = 11  - 2590 g
log10(a) = -1.85 , SE = 0.0124
Geometric mean a = 0.0142 , 95% CL = 0.0135 - 0.0151
b = 2.9 , 95% CL = 2.88 - 2.91
Standard deviation of estimated log10(W) = 0.131
Coefficient of determination (r2) = 0.968
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 1 3 2 4
Number of observations            = 627
Largest immature                  = 26 cm
Smallest mature                   = 13 cm
Ogive length at 50% maturity      = 20.7 cm
Ogive length at 10% and 90% maturity 17.2  - 24.2 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 57 cm
Median of annual maximum lengths   = 49 cm
Whetherall Linf based on SMALK     = 59.4 cm
Observed maximum length CPUE       = 63 cm
Median annual maximum lengths CPUE = 52.5 cm
Chosen Linf                        = 54 cm
Length at max cohort biomass Lopt  = 36 cm (assuming b~3 and M/K~1.5)
```

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	ple-2432	2002	63	556	449	5.25	0.808	0.01171	32.0	32	33.0	0.593	0.593	0.611
2	ple-2432	2003	57	269	238	4.59	0.885	0.01925	33.9	34	34.2	0.629	0.630	0.634

3	ple-2432	2004	57	290	199	5.20	0.688	0.02613	32.3	34	35.6	0.599	0.630	0.659
4	ple-2432	2005	51	460	361	5.25	0.786	0.01453	30.0	30	31.6	0.556	0.556	0.586
5	ple-2432	2006	49	533	465	5.17	0.872	0.01113	32.0	32	33.0	0.593	0.593	0.611
6	ple-2432	2007	53	494	453	6.38	0.916	0.01410	35.0	35	35.0	0.648	0.648	0.648
7	ple-2432	2008	47	639	541	13.36	0.846	0.02471	36.0	36	37.0	0.667	0.667	0.685
8	ple-2432	2009	52	757	685	22.86	0.905	0.03337	36.0	36	36.7	0.667	0.667	0.680
9	ple-2432	2010	59	946	660	22.76	0.698	0.03449	34.0	35	36.0	0.630	0.648	0.667
10	ple-2432	2011	54	1095	807	13.70	0.737	0.01698	31.8	32	35.0	0.589	0.593	0.648
11	ple-2432	2012	51	1113	936	8.09	0.841	0.00865	32.0	32	33.0	0.593	0.593	0.611
12	ple-2432	2013	51	1003	818	9.66	0.816	0.01181	33.0	33	34.0	0.611	0.611	0.630
13	ple-2432	2014	50	1891	1314	10.87	0.695	0.00827	32.0	32	35.0	0.593	0.593	0.648
14	ple-2432	2015	57	1699	1341	18.76	0.789	0.01399	33.0	33	36.0	0.611	0.611	0.667

Comment: 90% of minimum landing size assumed for Lc.com. Missing mega spawners could be a gear problem.





Comment: The plaice stocks have recovered in recent years. One would expect this to be reflected in more large individuals. Maybe these are missed by the gear, same as in North Sea. Comparison with commercial data is needed.

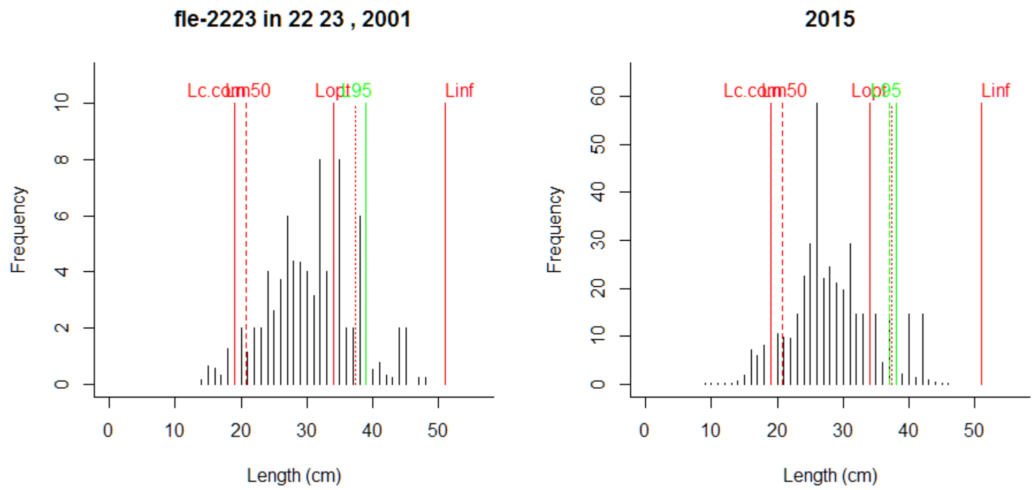
Flounder in Sound and Belt Sea

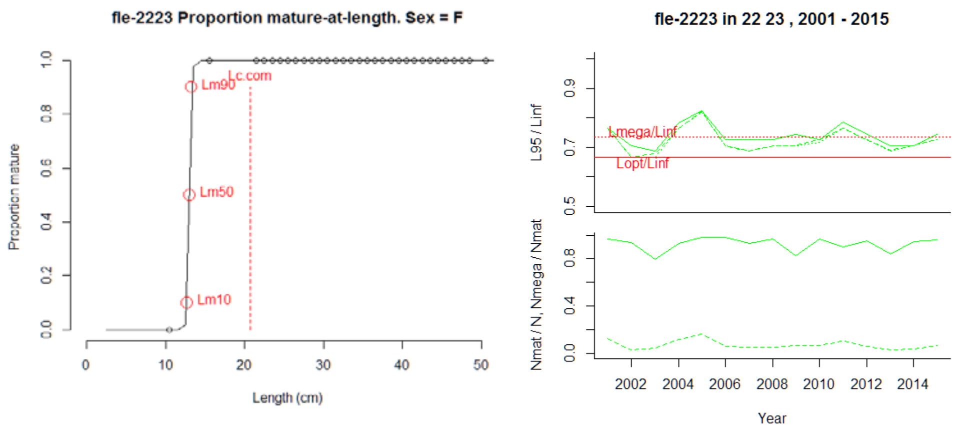
```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 16:45:37 2016
---------------------------------------------
SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-
11-01 15_32_54.csv
Survey     = BITS
Species    = Platichthys flesus Stock = fle-2223
Sex SMALK  = F
Years      = 2002  - 2015
Quarter    = 1
Areas      = 22
Lc.com     = 20.7 cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
4  outliers (beyond 4 SD) were removed.
Number of remaining observations = 1447
Length range = 10  - 51 cm
Weight range = 13  - 2114 g
log10(a) = -2.23 , SE = 0.0263
Geometric mean a = 0.00595 , 95% CL = 0.00528 - 0.0067
b = 3.23 , 95% CL = 3.2 - 3.27
Standard deviation of estimated log10(W) = 0.0555
Coefficient of determination (r2) = 0.967
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 2 3 4 1
Number of observations            = 475
Largest immature                  = 10 cm
Smallest mature                   = 10 cm
Ogive length at 50% maturity      = 13 cm
Ogive length at 10% and 90% maturity 12.7  - 13.3 cm
Chosen length at 50% maturity Lm50 = 19 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 51 cm
Median of annual maximum lengths   = 48 cm
Whetherall Linf based on SMALK     = NA cm
Observed maximum length CPUE       = 51 cm
Median annual maximum lengths CPUE = 50 cm
Chosen Linf                        = 51 cm
Length at max cohort biomass Lopt  = 34 cm (assuming b~3 and M/K~1.5)


      Stock  Year  Lmax.obs      N  N.mat  N.mega  pp.mat  pp.mega   L95  L95mat  L95.5  L95Linf
L95matLinf L95.5Linf
1  fle-2223 2001        48   215    208    27.1   0.968   0.1305 39.0    39.0   39.0    0.765
0.765     0.765
```

2	fle-2223	2002	47	384	360	12.6	0.937	0.0349	34.0	34.0	36.0	0.667	0.667	0.706
3	fle-2223	2003	51	327	262	12.6	0.800	0.0480	34.0	34.5	35.0	0.667	0.677	0.686
4	fle-2223	2004	51	268	249	30.6	0.927	0.1232	39.0	39.0	39.9	0.765	0.765	0.783
5	fle-2223	2005	51	255	251	41.5	0.982	0.1653	41.8	41.8	42.0	0.819	0.821	0.824
6	fle-2223	2006	49	475	465	29.4	0.979	0.0633	36.0	36.0	37.0	0.706	0.706	0.725
7	fle-2223	2007	50	595	551	30.1	0.927	0.0547	35.0	35.0	37.0	0.686	0.686	0.725
8	fle-2223	2008	50	1060	1024	57.9	0.966	0.0566	36.0	36.0	37.0	0.706	0.706	0.725
9	fle-2223	2009	49	533	440	29.6	0.826	0.0674	36.0	36.0	38.0	0.706	0.706	0.745
10	fle-2223	2010	51	670	648	45.6	0.967	0.0704	36.6	37.0	37.0	0.718	0.725	0.725
11	fle-2223	2011	50	1016	913	98.8	0.898	0.1082	39.0	39.0	40.0	0.765	0.765	0.784
12	fle-2223	2012	48	1673	1594	100.6	0.953	0.0631	37.0	37.0	38.0	0.725	0.725	0.745
13	fle-2223	2013	50	1220	1022	33.3	0.838	0.0326	35.0	35.1	36.0	0.686	0.689	0.706
14	fle-2223	2014	47	1589	1497	56.5	0.942	0.0377	36.0	36.0	36.0	0.706	0.706	0.706
15	fle-2223	2015	46	1152	1104	79.7	0.958	0.0722	37.0	37.0	38.0	0.725	0.725	0.745

Comment: Maturity ogive too few data; Lm50 from fle-2425; Lc.com assumed as 90% of minimum landing size





Comment: Size structure of flounder looks more or less okay, but large individuals are missing, probably not retained by the gear, as with the other flatfish. Comparison with commercial data is needed. Also, there are too few maturity data to fit an ogive.

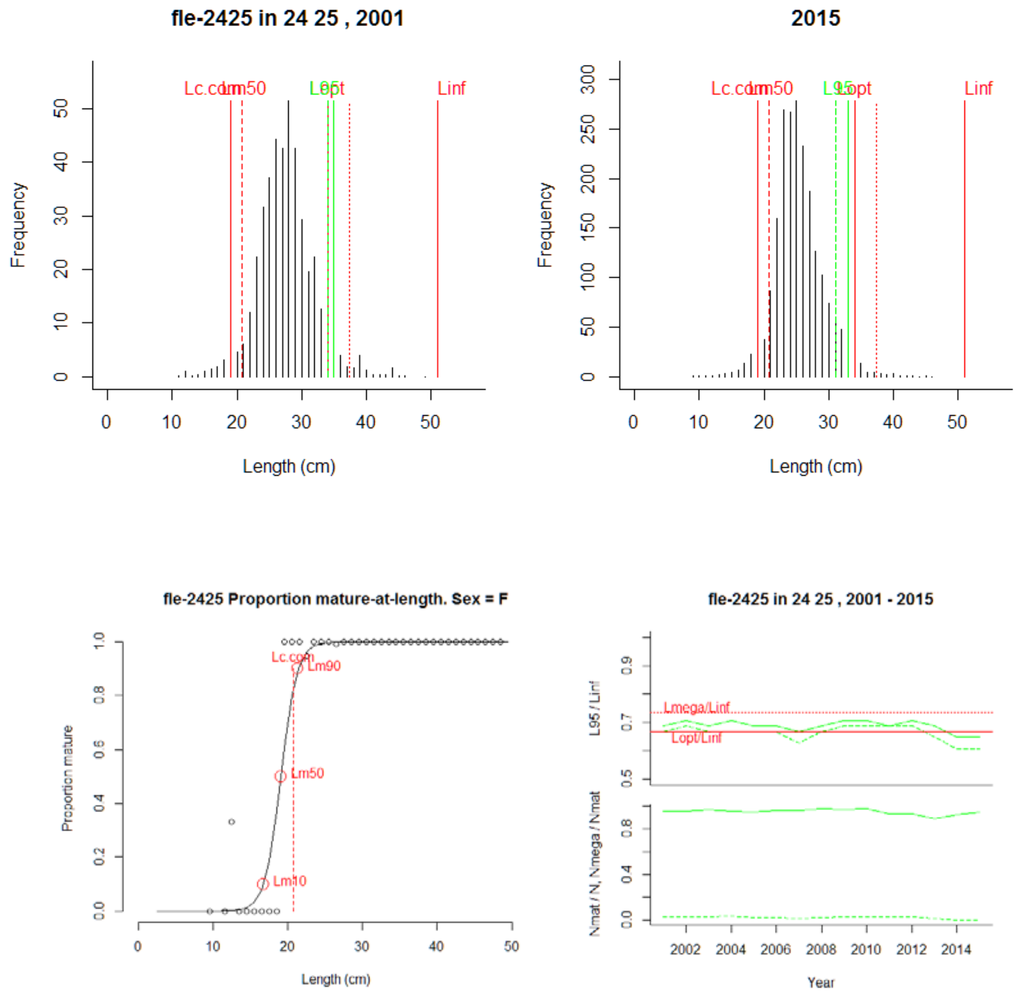
Flounder in the central Baltic

```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 16:58:57 2016
---------------------------------------------
SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-
11-01 15_32_54.csv
Survey     = BITS
Species    = Platichthys flesus Stock = fle-2425
Sex SMALK  = F
Years      = 2001  - 2015
Quarter    = 1
Areas      = 24 25
Lc.com     = 20.7 cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
20  outliers (beyond 4 SD) were removed.
Number of remaining observations = 8517
Length range = 9  - 53 cm
Weight range = 7  - 1860 g
log10(a) = -2.06 , SE = 0.00823
Geometric mean a = 0.00877 , 95% CL = 0.00845 - 0.0091
b = 3.1 , 95% CL = 3.09 - 3.12
Standard deviation of estimated log10(W) = 0.059
Coefficient of determination (r2) = 0.976
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 1 2 3 4
Number of observations            = 2473
Largest immature                  = 26 cm
Smallest mature                   = 9 cm
Ogive length at 50% maturity      = 19.1 cm
Ogive length at 10% and 90% maturity 16.7  - 21.4 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 53 cm
Median of annual maximum lengths   = 46 cm
Whetherall Linf based on SMALK     = 48.1 cm
Observed maximum length CPUE       = 60 cm
Median annual maximum lengths CPUE = 48 cm
Chosen Linf                        = 51 cm
Length at max cohort biomass Lopt  = 34 cm (assuming b~3 and M/K~1.5)


      Stock Year Lmax.obs    N N.mat N.mega pp.mat pp.mega L95 L95mat L95.5 L95Linf L95mat-
Linf L95.5Linf
1  fle-2425 2001      49 1075  1033   34.5  0.961 0.03340  34     34    35   0.667      0.667
0.686
2  fle-2425 2002      49 2535  2425   85.6  0.956 0.03529  35     35    36   0.686      0.686
0.706
```

3	fle-2425	2003	48	1784	1732	49.6	0.971	0.02863	34	34	35	0.667	0.667	0.686
4	fle-2425	2004	47	1390	1335	50.9	0.960	0.03812	34	34	36	0.667	0.667	0.706
5	fle-2425	2005	48	2073	1965	50.1	0.948	0.02548	34	34	35	0.667	0.667	0.686
6	fle-2425	2006	46	2245	2175	45.2	0.969	0.02079	34	34	35	0.667	0.667	0.686
7	fle-2425	2007	51	1845	1782	28.5	0.966	0.01597	32	32	34	0.627	0.627	0.667
8	fle-2425	2008	60	5053	4956	109.7	0.981	0.02214	34	34	35	0.667	0.667	0.686
9	fle-2425	2009	53	2853	2785	87.3	0.976	0.03134	35	35	36	0.686	0.686	0.706
10	fle-2425	2010	46	3545	3476	106.9	0.980	0.03077	35	35	36	0.686	0.686	0.706
11	fle-2425	2011	49	2186	2053	62.1	0.939	0.03026	35	35	35	0.686	0.686	0.686
12	fle-2425	2012	52	4189	3932	125.9	0.939	0.03203	35	35	36	0.686	0.686	0.706
13	fle-2425	2013	47	5277	4686	92.3	0.888	0.01969	33	33	35	0.647	0.647	0.686
14	fle-2425	2014	47	5864	5439	29.7	0.928	0.00546	31	31	33	0.608	0.608	0.647
15	fle-2425	2015	46	7314	6950	38.1	0.950	0.00549	31	31	33	0.608	0.608	0.647

Comment: Missing of mega spawners is probably a gear effect



Comment: Large individuals are missing.

Western Baltic herring

```
---------------------------------------------

Results of SMALK and CPUE analysis, Fri Nov 04 17:06:36 2016

---------------------------------------------

SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-11-01 15_32_54.csv

Survey     = BITS

Species    = Clupea harengus Stock = her-3a22

Sex SMALK  = F

Years      = 1993  - 2012

Quarter    = 1

Areas      = 24 23

Lc.com     = NA cm (length where 50% are retained by commercial gear)

---------------------------------------------

Summary stats of weighted F  W~L regression

---------------------------------------------

1  outliers (beyond 4 SD) were removed.

Number of remaining observations = 310

Length range = 11  - 31 cm

Weight range = 7  - 250 g

log10(a) = -2.67 , SE = 0.035

Geometric mean a = 0.00214 , 95% CL = 0.00182 - 0.0025

b = 3.36 , 95% CL = 3.31 - 3.41

Standard deviation of estimated log10(W) = 0.0446

Coefficient of determination (r2) = 0.982

-------------------------------------------------------------

Maturity analysis from proportion-mature-at-length data

-------------------------------------------------------------

Available maturity codes          = 2 1 3 4

Number of observations            = 485

Largest immature                  = 28 cm

Smallest mature                   = 11 cm

Ogive length at 50% maturity      = 20 cm

Ogive length at 10% and 90% maturity 15.6  - 24.4 cm

-------------------------------------------------

Estimation of Linf

-------------------------------------------------

Observed maximum length SMALK      = 31 cm

Median of annual maximum lengths   = 29.2 cm

Whetherall Linf based on SMALK     = 29.5 cm

Observed maximum length CPUE       = 46 cm

Median annual maximum lengths CPUE = 32.5 cm

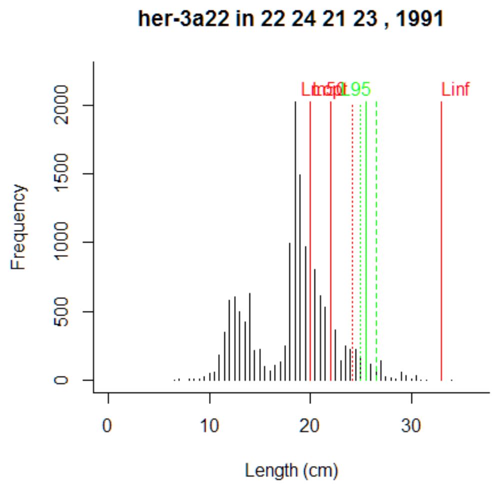
Chosen Linf                        = 33 cm

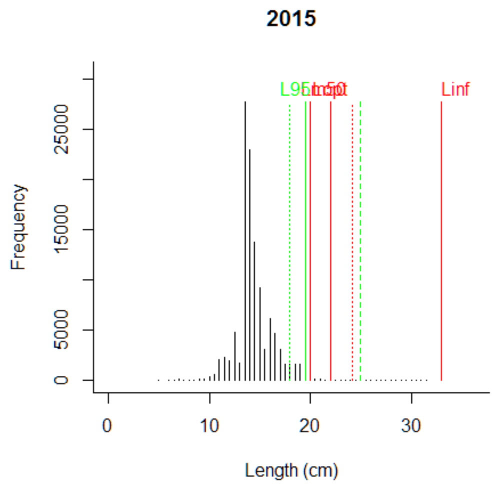
Length at max cohort biomass Lopt  = 22 cm (assuming b~3 and M/K~1.5)
```

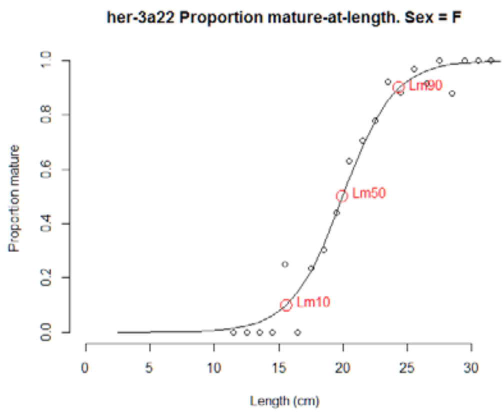
	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	her-3a22	1991	34.0	27881	5508	NA	0.1976	NA	25.0	26.5	25.5	0.758	0.803	0.773
2	her-3a22	1992	32.5	92776	27621	16381.8	0.2977	0.5931	26.5	27.0	27.0	0.803	0.818	0.818

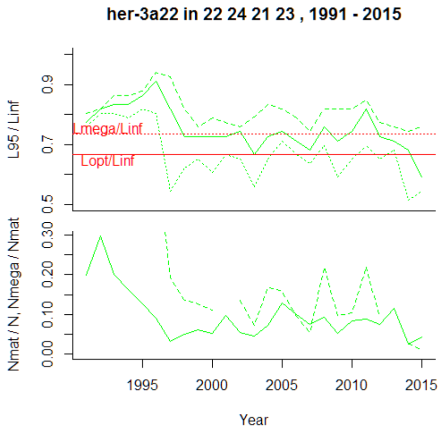
3	her-3a22	1993	32.0	74578	14932	7131.9	0.2002	0.4776	26.5	28.5	27.5	0.803	0.864	0.833
4	her-3a22	1994	33.0	30201	4925	1813.2	0.1631	0.3682	26.0	28.5	27.5	0.788	0.864	0.833
5	her-3a22	1995	34.0	27461	3484	NA	0.1269	NA	27.0	29.0	28.5	0.818	0.879	0.864
6	her-3a22	1996	37.0	22498	2051	1070.3	0.0911	0.5219	26.5	31.0	30.0	0.803	0.939	0.909
7	her-3a22	1997	34.0	82674	2747	527.2	0.0332	0.1919	18.0	30.5	27.0	0.545	0.924	0.818
8	her-3a22	1998	34.5	63831	3174	430.6	0.0497	0.1357	20.5	27.0	24.0	0.621	0.818	0.727
9	her-3a22	1999	34.0	80154	4925	626.6	0.0614	0.1272	21.5	25.0	24.0	0.652	0.758	0.727
10	her-3a22	2000	31.5	94379	4902	542.0	0.0519	0.1106	20.0	26.0	24.0	0.606	0.788	0.727
11	her-3a22	2001	31.0	85287	8380	NA	0.0983	NA	22.0	25.5	24.0	0.667	0.773	0.727
12	her-3a22	2002	30.0	80207	4453	605.5	0.0555	0.1360	21.5	25.0	24.5	0.652	0.758	0.742
13	her-3a22	2003	32.0	62172	2902	207.6	0.0467	0.0715	18.5	26.1	22.0	0.561	0.790	0.667
14	her-3a22	2004	31.5	27273	1972	329.1	0.0723	0.1668	21.5	27.5	24.0	0.652	0.833	0.727
15	her-3a22	2005	31.5	23490	3040	478.7	0.1294	0.1575	23.5	27.0	24.5	0.712	0.818	0.742
16	her-3a22	2006	32.5	17033	1682	158.2	0.0987	0.0940	22.0	26.0	23.5	0.667	0.788	0.712
17	her-3a22	2007	32.5	32833	2491	137.0	0.0759	0.0550	21.0	24.5	22.5	0.636	0.742	0.682
18	her-3a22	2008	32.5	28122	2600	567.4	0.0925	0.2182	23.0	27.0	25.0	0.697	0.818	0.758
19	her-3a22	2009	33.0	35543	1850	181.3	0.0521	0.0980	19.5	27.0	23.5	0.591	0.818	0.712
20	her-3a22	2010	32.5	45529	3772	393.1	0.0829	0.1042	21.5	27.0	24.5	0.652	0.818	0.742
21	her-3a22	2011	33.5	27338	2416	527.8	0.0884	0.2184	23.0	28.0	27.0	0.697	0.848	0.818
22	her-3a22	2012	39.0	48528	3681	344.1	0.0759	0.0935	21.5	25.5	24.0	0.652	0.773	0.727
23	her-3a22	2013	46.0	40696	4721	NA	0.1160	NA	22.5	25.0	23.5	0.682	0.758	0.712
24	her-3a22	2014	34.5	134683	3538	98.5	0.0263	0.0278	17.0	24.5	22.5	0.515	0.742	0.682
25	her-3a22	2015	31.5	143732	6097	68.0	0.0424	0.0112	18.0	25.0	19.5	0.545	0.758	0.591

Comment: Proportion of mega-spawners works ok; L95 shows the decline. No Lc.com or MCRL available.









Comment: This stock has been overfished. The decline in size structure is reflected in the indicators. The very low proportion of mature fish is alarming. L95 for lengths above Lm50 is too optimistic, due to high Lm50/Linf ratio in small pelagics. Variability in all indicators due to recruitment could be reduced by moving average.

Herring in the Central Baltic

Results of SMALK and CPUE analysis, Fri Nov 04 17:16:57 2016

SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-11-01 15_32_54.csv

Survey = BITS

Species = Clupea harengus Stock = her-2532-gor

Sex SMALK = F

Years = 1993 - 2015

Quarter = 1

Areas = 25 26 28

Lc.com = NA cm (length where 50% are retained by commercial gear)

Summary stats of weighted F W~L regression

----

16 outliers (beyond 4 SD) were removed.

Number of remaining observations = 11805

Length range = 8 - 35 cm

Weight range = 3 - 278 g

log10(a) = -2.45 , SE = 0.00718

Geometric mean a = 0.00354 , 95% CL = 0.00342 - 0.00365

b = 3.19 , 95% CL = 3.18 - 3.2

Standard deviation of estimated log10(W) = 0.0599

Coefficient of determination (r2) = 0.971

Maturity analysis from proportion-mature-at-length data

Available maturity codes = 2 1 3 4

Number of observations = 9891

Largest immature = 27.5 cm

Smallest mature = 2 cm

Ogive length at 50% maturity = 14 cm

Ogive length at 10% and 90% maturity 9.46 - 18.5 cm

Chosen length at 50% maturity Lm50 = 15 cm

Estimation of Linf

Observed maximum length SMALK = 35 cm

Median of annual maximum lengths = 31.5 cm

Whetherall Linf based on SMALK = 33.9 cm

Observed maximum length CPUE = 40 cm

Median annual maximum lengths CPUE = 33 cm

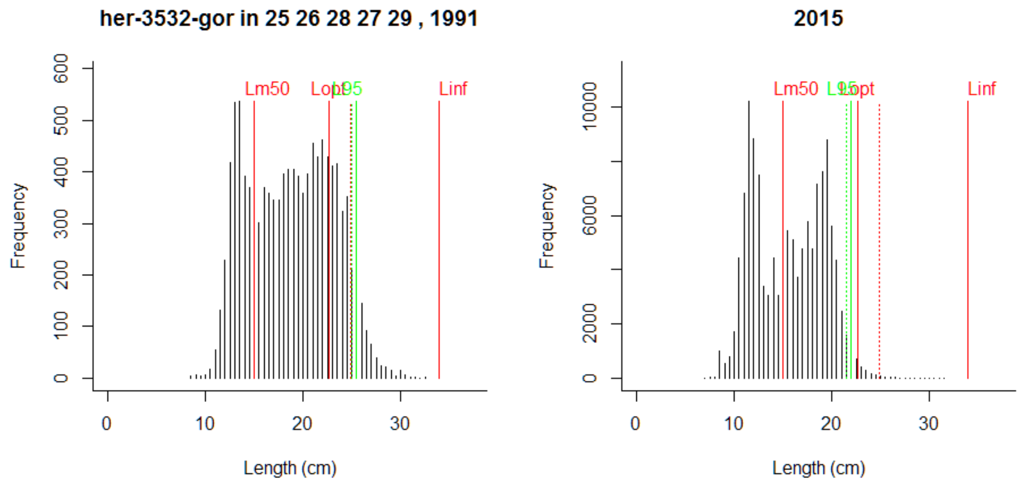
Chosen Linf = 33.9 cm

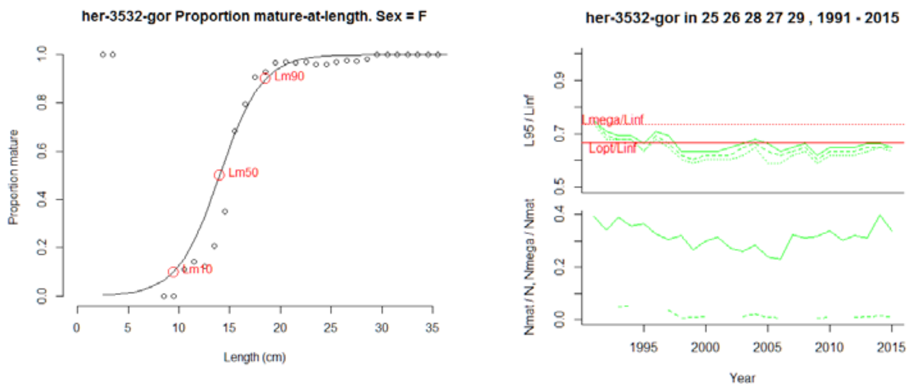
Length at max cohort biomass Lopt = 22.6 cm (assuming b~3 and M/K~1.5)

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	her-3532-gor	1991	32.5	48905	19178	3223	0.392	0.16808	25.0	25.5	25.5	0.736	0.751	0.751
2	her-3532-gor	1992	33.0	336065	114769	NA	0.342	NA	23.0	23.5	24.0	0.678	0.692	0.707
3	her-3532-gor	1993	37.5	360874	139980	6919	0.388	0.04943	23.0	23.0	23.5	0.678	0.678	0.692
4	her-3532-gor	1994	32.5	62095	22093	1195	0.356	0.05408	23.0	23.0	23.5	0.678	0.678	0.692

5	her-3532-gor	1995	40.0	138349	50566	NA	0.365	NA	21.5	21.5	22.5	0.633	0.633	0.663
6	her-3532-gor	1996	35.0	37470	12226	NA	0.326	NA	23.0	23.5	24.0	0.678	0.692	0.707
7	her-3532-gor	1997	33.5	28923	8828	329	0.305	0.03730	22.0	22.5	23.5	0.648	0.663	0.692
8	her-3532-gor	1998	38.0	414559	132899	723	0.321	0.00544	20.5	21.0	21.5	0.604	0.619	0.633
9	her-3532-gor	1999	36.5	226351	60309	530	0.266	0.00879	20.0	20.5	21.5	0.589	0.604	0.633
10	her-3532-gor	2000	33.0	195449	58601	730	0.300	0.01246	20.5	21.0	21.5	0.604	0.619	0.633
11	her-3532-gor	2001	32.0	216343	68096	NA	0.315	NA	20.5	21.0	21.5	0.604	0.619	0.633
12	her-3532-gor	2002	35.0	408684	110698	NA	0.271	NA	20.5	21.0	22.0	0.604	0.619	0.648
13	her-3532-gor	2003	33.0	266569	69449	905	0.261	0.01302	21.0	22.0	22.5	0.619	0.648	0.663
14	her-3532-gor	2004	36.0	260865	74052	1636	0.284	0.02210	22.0	22.5	23.0	0.648	0.663	0.678
15	her-3532-gor	2005	32.5	506593	120466	1222	0.238	0.01014	20.0	21.5	22.5	0.589	0.633	0.663
16	her-3532-gor	2006	32.5	747451	172103	1214	0.230	0.00705	20.0	21.0	21.5	0.589	0.619	0.633
17	her-3532-gor	2007	32.0	297864	95928	NA	0.322	NA	21.0	21.5	22.0	0.619	0.633	0.648
18	her-3532-gor	2008	34.0	334585	103678	NA	0.310	NA	21.5	22.0	22.5	0.633	0.648	0.663
19	her-3532-gor	2009	34.5	545231	172196	1078	0.316	0.00626	20.0	20.5	21.0	0.589	0.604	0.619
20	her-3532-gor	2010	32.5	559528	189631	1946	0.339	0.01026	21.0	21.5	22.0	0.619	0.633	0.648
21	her-3532-gor	2011	32.0	516019	156471	NA	0.303	NA	21.0	21.5	22.0	0.619	0.633	0.648
22	her-3532-gor	2012	32.5	487939	156087	1496	0.320	0.00958	21.0	21.5	22.0	0.619	0.633	0.648
23	her-3532-gor	2013	34.5	506052	157753	2155	0.312	0.01366	21.5	22.0	22.5	0.633	0.648	0.663
24	her-3532-gor	2014	35.5	234082	93266	1528	0.398	0.01638	22.0	22.0	22.5	0.648	0.648	0.663
25	her-3532-gor	2015	31.5	413257	139315	1708	0.337	0.01226	21.5	22.0	22.0	0.633	0.648	0.648

Comment: Proportion of mega-spawners works ok; L95 shows the decline





Comment: Large individuals are missing, but decline looks smooth, could be real. Needs to be checked against commercial LF data. No Lc.com or MCRS is available.

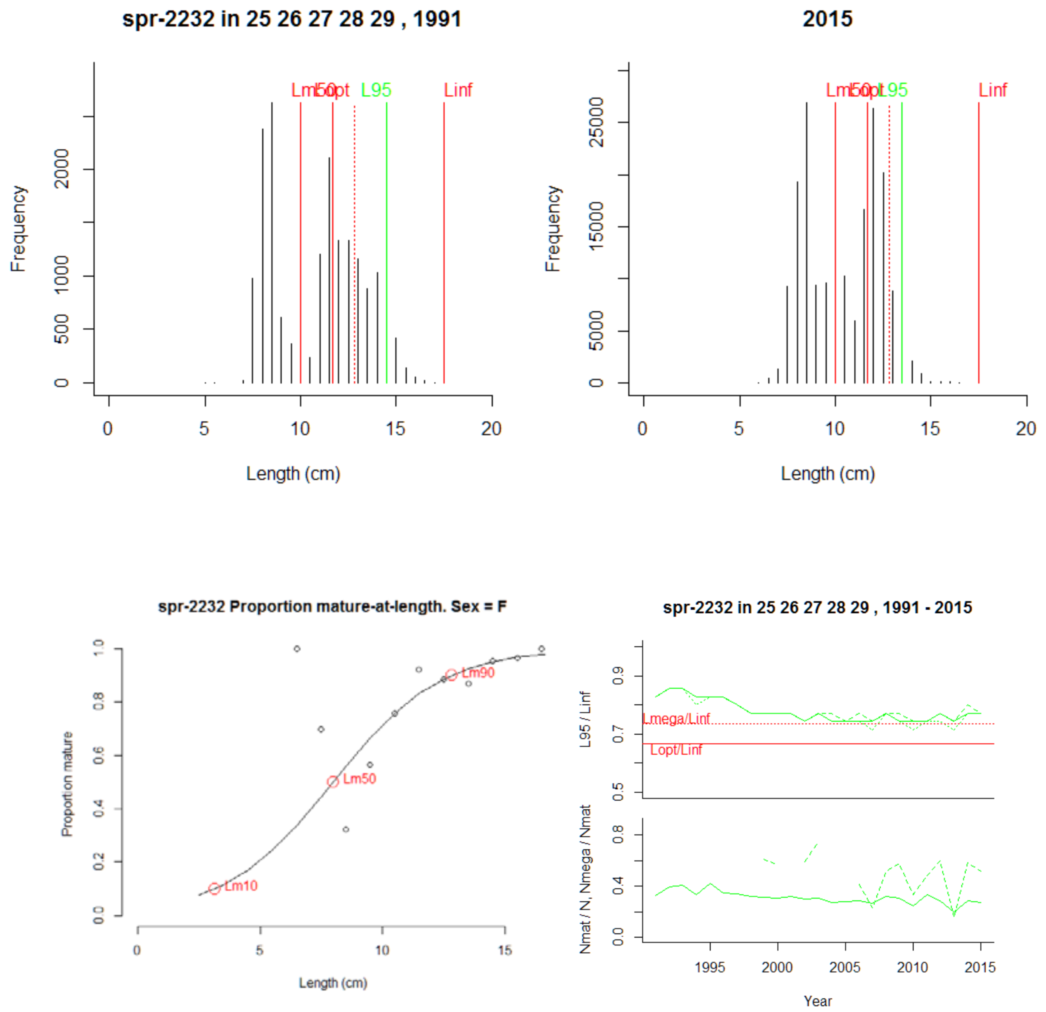
Baltic sprat

```
---------------------------------------------
Results of SMALK and CPUE analysis, Fri Nov 04 17:31:41 2016
---------------------------------------------
SMALK_File = SMALK_BITS_2016-10-31.csv CPUE_File = BalticCPUE per length per subarea_2016-11-01 15_32_54.csv
Survey     = BITS
Species    = Sprattus sprattus Stock = spr-2232
Sex SMALK  = F
Years      = 1999  - 2015
Quarter    = 1
Areas      = 25 26
Lc.com     = NA cm (length where 50% are retained by commercial gear)
---------------------------------------------
Summary stats of weighted F  W~L regression
---------------------------------------------
17  outliers (beyond 4 SD) were removed.
Number of remaining observations = 3504
Length range = 5.5  - 16 cm
Weight range = 1  - 26 g
log10(a) = -2.32 , SE = 0.015
Geometric mean a = 0.00478 , 95% CL = 0.00447 - 0.00512
b = 3.1 , 95% CL = 3.07 - 3.12
Standard deviation of estimated log10(W) = 0.11
Coefficient of determination (r2) = 0.955
-------------------------------------------------------------
Maturity analysis from proportion-mature-at-length data
-------------------------------------------------------------
Available maturity codes          = 2 3 1 4
Number of observations            = 1112
Largest immature                  = 14.5 cm
Smallest mature                   = 5.5 cm
Ogive length at 50% maturity      = 7.99 cm
Ogive length at 10% and 90% maturity 3.15  - 12.8 cm
Chosen length at 50% maturity Lm50 = 10 cm
-------------------------------------------------
Estimation of Linf
-------------------------------------------------
Observed maximum length SMALK      = 16 cm
Median of annual maximum lengths   = 15.5 cm
Whetherall Linf based on SMALK     = 14.5 cm
Observed maximum length CPUE       = 18.5 cm
Median annual maximum lengths CPUE = 16.5 cm
Chosen Linf                        = 17.5 cm
Length at max cohort biomass Lopt  = 11.7 cm (assuming b~3 and M/K~1.5)
```

	Stock	Year	Lmax.obs	N	N.mat	N.mega	pp.mat	pp.mega	L95	L95mat	L95.5	L95Linf	L95matLinf	L95.5Linf
1	spr-2232	1991	17.0	34721	11274	8785	0.325	0.779	14.5	14.5	14.5	0.829	0.829	0.829

2	spr-2232	1992	17.0	241229	94460	NA	0.392	NA	15.0	15.0	15.0	0.857	0.857	0.857
3	spr-2232	1993	17.0	59318	24171	NA	0.407	NA	15.0	15.0	15.0	0.857	0.857	0.857
4	spr-2232	1994	17.0	27499	9213	NA	0.335	NA	14.0	14.5	14.5	0.800	0.829	0.829
5	spr-2232	1995	16.5	93199	39510	35401	0.424	0.896	14.5	14.5	14.5	0.829	0.829	0.829
6	spr-2232	1996	17.0	101181	35125	NA	0.347	NA	14.5	14.5	14.5	0.829	0.829	0.829
7	spr-2232	1997	16.5	77809	26268	13691	0.338	0.521	14.0	14.0	14.0	0.800	0.800	0.800
8	spr-2232	1998	16.0	851247	271024	NA	0.318	NA	13.5	13.5	13.5	0.771	0.771	0.771
9	spr-2232	1999	17.5	489174	152464	93208	0.312	0.611	13.5	13.5	13.5	0.771	0.771	0.771
10	spr-2232	2000	17.5	398821	121358	68393	0.304	0.564	13.5	13.5	13.5	0.771	0.771	0.771
11	spr-2232	2001	17.0	393079	125267	NA	0.319	NA	13.5	13.5	13.5	0.771	0.771	0.771
12	spr-2232	2002	16.5	1126170	335475	197624	0.298	0.589	13.0	13.0	13.0	0.743	0.743	0.743
13	spr-2232	2003	17.5	457247	138722	103308	0.303	0.745	13.5	13.5	13.5	0.771	0.771	0.771
14	spr-2232	2004	16.0	520774	140453	NA	0.270	NA	13.0	13.5	13.0	0.743	0.771	0.743
15	spr-2232	2005	16.0	949775	267208	NA	0.281	NA	13.0	13.0	13.0	0.743	0.743	0.743
16	spr-2232	2006	16.5	1165944	331752	137843	0.285	0.416	13.0	13.5	13.0	0.743	0.771	0.743
17	spr-2232	2007	17.5	517559	137299	31427	0.265	0.229	12.5	13.0	13.0	0.714	0.743	0.743
18	spr-2232	2008	16.0	533112	170200	88329	0.319	0.519	13.5	13.5	13.5	0.771	0.771	0.771
19	spr-2232	2009	18.5	587545	179080	103034	0.305	0.575	13.0	13.5	13.0	0.743	0.771	0.743
20	spr-2232	2010	16.5	689673	168072	56431	0.244	0.336	12.5	13.0	13.0	0.714	0.743	0.743
21	spr-2232	2011	16.0	639644	213639	102527	0.334	0.480	13.0	13.0	13.0	0.743	0.743	0.743
22	spr-2232	2012	16.0	591248	170978	102191	0.289	0.598	13.0	13.5	13.5	0.743	0.771	0.771
23	spr-2232	2013	16.0	1435943	283771	45295	0.198	0.160	12.5	13.0	13.0	0.714	0.743	0.743
24	spr-2232	2014	15.5	322747	93297	54478	0.289	0.584	13.5	14.0	13.5	0.771	0.800	0.771
25	spr-2232	2015	16.5	634957	172973	89263	0.272	0.516	13.5	13.5	13.5	0.771	0.771	0.771

Comment: Concept of mega-spawners may not apply to sprat.



Comment: More maturity data are needed. Bottom trawl may not adequately reflect length distribution of this species. Commercial data or data from control catches in acoustic surveys are needed for comparison.

Annex 3: GAM results for relationships between stock indicators and SBI

Summary of the GAM-output for L_{95}

```
Family: gaussian
Link function: identity
Formula:
L95.smooth ~ s(ssb.rel, k = 3, by = FishStock) + s(f.rel, k = 3
,
    by = FishStock) + s(r.rel, k = 3, by = FishStock)
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.909719   0.006873   132.4   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Approximate significance of smooth terms:
                               edf Ref.df      F p-value
s(ssb.rel):FishStockcod-347d 1.288  1.493  3.000 0.06848 .
s(ssb.rel):FishStockple-2123 1.000  1.000  0.952 0.33186
s(ssb.rel):FishStockple-nsea 1.594  1.835  0.646 0.51385
s(ssb.rel):FishStockwhg-47d  1.000  1.000  0.618 0.43401
s(f.rel):FishStockcod-347d   1.000  1.000 47.647 4.4e-10 ***
s(f.rel):FishStockple-2123   1.000  1.000  2.013 0.15956
s(f.rel):FishStockple-nsea   1.000  1.000  0.584 0.44672
s(f.rel):FishStockwhg-47d    1.120  1.226  2.447 0.11145
s(r.rel):FishStockcod-347d   1.587  1.828  0.738 0.46058
s(r.rel):FishStockple-2123   1.000  1.000  1.492 0.22532
s(r.rel):FishStockple-nsea   1.000  1.000  0.796 0.37476
s(r.rel):FishStockwhg-47d    1.518  1.767  5.663 0.00732 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.506   Deviance explained = 57.6%
GCV score = 0.0016955  Scale est. = 0.0014394  n = 100
GCV score = 0.0016955  Scale est. = 0.0014394  n = 100
```

Summary of the GAM-output for SSB_{mega}

```
Family: gaussian
Link function: identity
Formula:
ssb.mega.rel ~ s(ssb.rel, k = 3, by = FishStock) + s(f.rel, k =
3,
    by = FishStock) + s(r.rel, k = 3, by = FishStock)
Parametric coefficients:
```

```
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.51522    0.03168   16.26   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Approximate significance of smooth terms:
                                   edf Ref.df      F  p-value
s(ssb.rel):FishStockcod-347d 1.000  1.000 16.918 8.67e-05 ***
s(ssb.rel):FishStockple-2123 1.447  1.646  0.521 0.560511
s(ssb.rel):FishStockple-nsea 1.316  1.532  8.853 0.001262 **
s(ssb.rel):FishStockwhg-47d  1.318  1.534  8.274 0.001814 **
s(f.rel):FishStockcod-347d   1.000  1.000 13.353 0.000437 ***
s(f.rel):FishStockple-2123   1.000  1.000  1.782 0.185421
s(f.rel):FishStockple-nsea   1.000  1.000  0.929 0.337800
s(f.rel):FishStockwhg-47d    1.000  1.000  1.502 0.223679
s(r.rel):FishStockcod-347d   1.000  1.000  0.856 0.357350
s(r.rel):FishStockple-2123   1.429  1.627  1.812 0.168234
s(r.rel):FishStockple-nsea   1.000  1.000  0.061 0.805721
s(r.rel):FishStockwhg-47d    1.000  1.000  6.080 0.015627 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.458   Deviance explained = 53.2%
GCV score = 0.03673  Scale est. = 0.031401  n = 100
```

Summary of the GAM-output for cpue$_{mega}$

```
Family: gaussian
Link function: identity
Formula:
cpue.mega.rel ~ s(ssb.rel, k = 3, by = FishStock) + s(f.rel,
    k = 3, by = FishStock) + s(r.rel, k = 3, by = FishStock)
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.57455    0.03071   18.71   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Approximate significance of smooth terms:
                                   edf Ref.df      F  p-value
s(ssb.rel):FishStockcod-347d 1.000  1.000  0.430 0.513942
s(ssb.rel):FishStockple-2123 1.798  1.959  1.972 0.145681
s(ssb.rel):FishStockple-nsea 1.435  1.680  6.977 0.003250 **
s(ssb.rel):FishStockwhg-47d  1.420  1.662  8.548 0.001135 **
s(f.rel):FishStockcod-347d   1.610  1.846  1.244 0.284503
s(f.rel):FishStockple-2123   1.000  1.000  3.059 0.083950 .
```

```
s(f.rel):FishStockple-nsea   1.000  1.000  0.069 0.794148
s(f.rel):FishStockwhg-47d    1.403  1.642  0.267 0.722315
s(r.rel):FishStockcod-347d   1.382  1.616  4.582 0.019907 *
s(r.rel):FishStockple-2123   1.000  1.000 13.044 0.000512 ***
s(r.rel):FishStockple-nsea   1.000  1.000  0.196 0.658823
s(r.rel):FishStockwhg-47d    1.894  1.988  4.589 0.013012 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
R-sq.(adj) =  0.461   Deviance explained = 54.8%
GCV score = 0.031477  Scale est. = 0.026144  n = 100
```

Summary of the GAM-output for P_{mega}

```
Family: gaussian
Link function: identity
Formula:
p.mega.rel ~ s(ssb.rel, k = 3, by = FishStock) + s(f.rel, k = 3
,
    by = FishStock) + s(r.rel, k = 3, by = FishStock)
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.5102     0.0333   15.32   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Approximate significance of smooth terms:
                               edf Ref.df     F p-value
s(ssb.rel):FishStockcod-347d 1.000  1.000 2.832 0.09598 .
s(ssb.rel):FishStockple-2123 1.000  1.000 0.764 0.38441
s(ssb.rel):FishStockple-nsea 1.000  1.000 2.245 0.13768
s(ssb.rel):FishStockwhg-47d  1.000  1.000 1.144 0.28771
s(f.rel):FishStockcod-347d   1.000  1.000 3.136 0.08008 .
s(f.rel):FishStockple-2123   1.000  1.000 3.609 0.06078 .
s(f.rel):FishStockple-nsea   1.489  1.739 2.342 0.10674
s(f.rel):FishStockwhg-47d    1.000  1.000 0.236 0.62840
s(r.rel):FishStockcod-347d   1.000  1.000 7.632 0.00699 **
s(r.rel):FishStockple-2123   1.597  1.837 0.574 0.55112
s(r.rel):FishStockple-nsea   1.000  1.000 0.000 0.99659
s(r.rel):FishStockwhg-47d    1.393  1.630 4.134 0.02725 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
R-sq.(adj) =  0.227   Deviance explained = 33.2%
GCV score = 0.038509  Scale est. = 0.032934  n = 100
```

Summary of the GAM-output for P_{mat}

```
Family: gaussian
Link function: identity

Formula:
p.mat.rel ~ s(ssb.rel, k = 3, by = FishStock) + s(f.rel, k = 3,
    by = FishStock) + s(r.rel, k = 3, by = FishStock)
Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.67226    0.02741   24.53   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Approximate significance of smooth terms:
                                  edf Ref.df      F  p-value
s(ssb.rel):FishStockcod-347d 1.000  1.000  1.109 0.295325
s(ssb.rel):FishStockple-2123 1.000  1.000  0.064 0.800193
s(ssb.rel):FishStockple-nsea 1.000  1.000  3.176 0.078280 .
s(ssb.rel):FishStockwhg-47d  1.000  1.000  2.487 0.118452
s(f.rel):FishStockcod-347d   1.657  1.881  8.019 0.000920 ***
s(f.rel):FishStockple-2123   1.000  1.000  0.176 0.675851
s(f.rel):FishStockple-nsea   1.529  1.778  0.885 0.394165
s(f.rel):FishStockwhg-47d    1.000  1.000 22.367 8.36e-06 ***
s(r.rel):FishStockcod-347d   1.000  1.000 14.723 0.000235 ***
s(r.rel):FishStockple-2123   1.708  1.914  1.967 0.146342
s(r.rel):FishStockple-nsea   1.056  1.108  0.005 0.957304
s(r.rel):FishStockwhg-47d    1.806  1.962  2.510 0.088035 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
R-sq.(adj) =   0.44   Deviance explained = 52.4%
GCV score = 0.024176  Scale est. = 0.020367  n = 100
```

Annex 4: Stock statuses & simulation results

Stock statuses

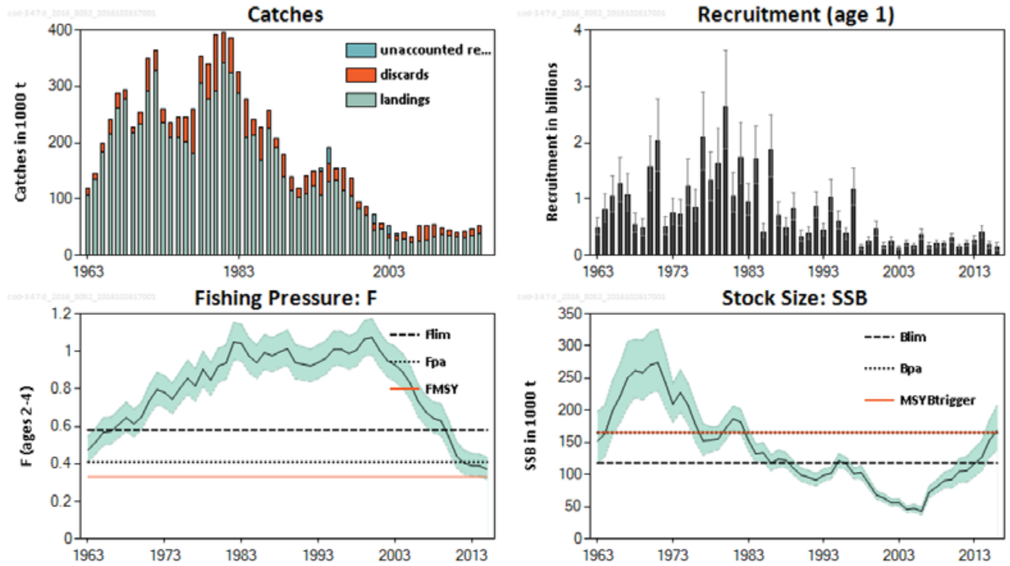


Figure A.4.1. Cod in Subarea 4, Division 7.d and Subdivision 3.a.20. Summary of stock assessment with point-wise 95% confidence intervals. Catch is estimated and adjusted for unaccounted removals (from 1993 to 2005).

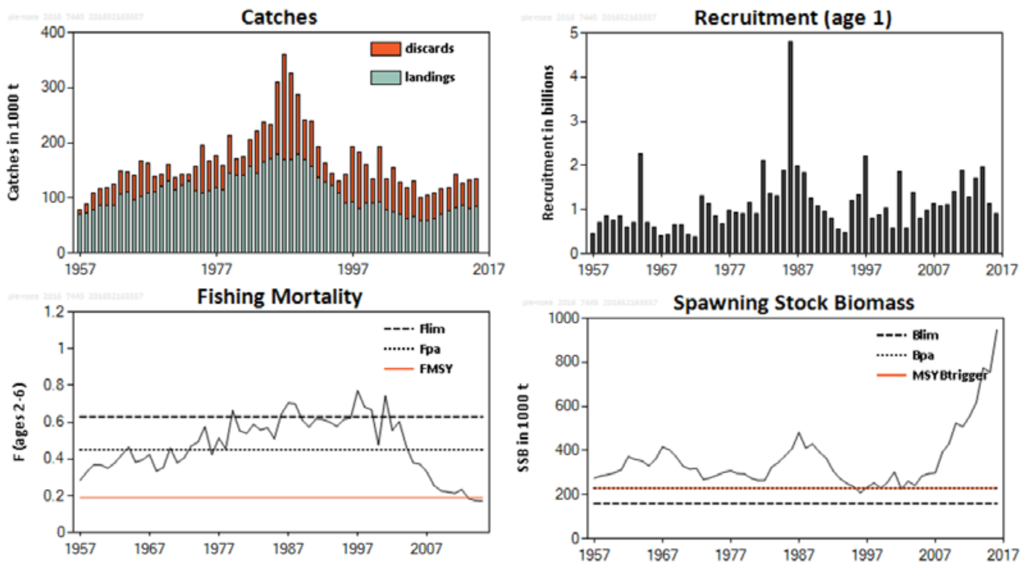


Figure A.4.2. Plaice in Subarea 4 and Subdivision 3.a.20 combined. Summary of stock assessment.

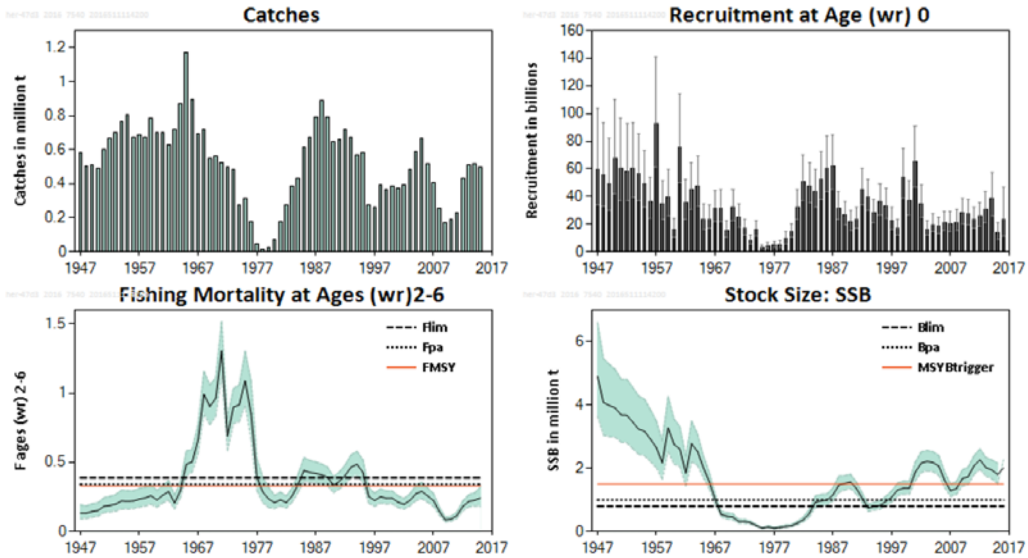


Figure A.4.3. Herring in Subarea 4 and divisions 3.a and 7.d (autumn spawners). Commercial catches (upper left), and from the stock assessment: recruitment, fishing mortality, and spawning-stock biomass.

Recruitment in the assessments and simulations

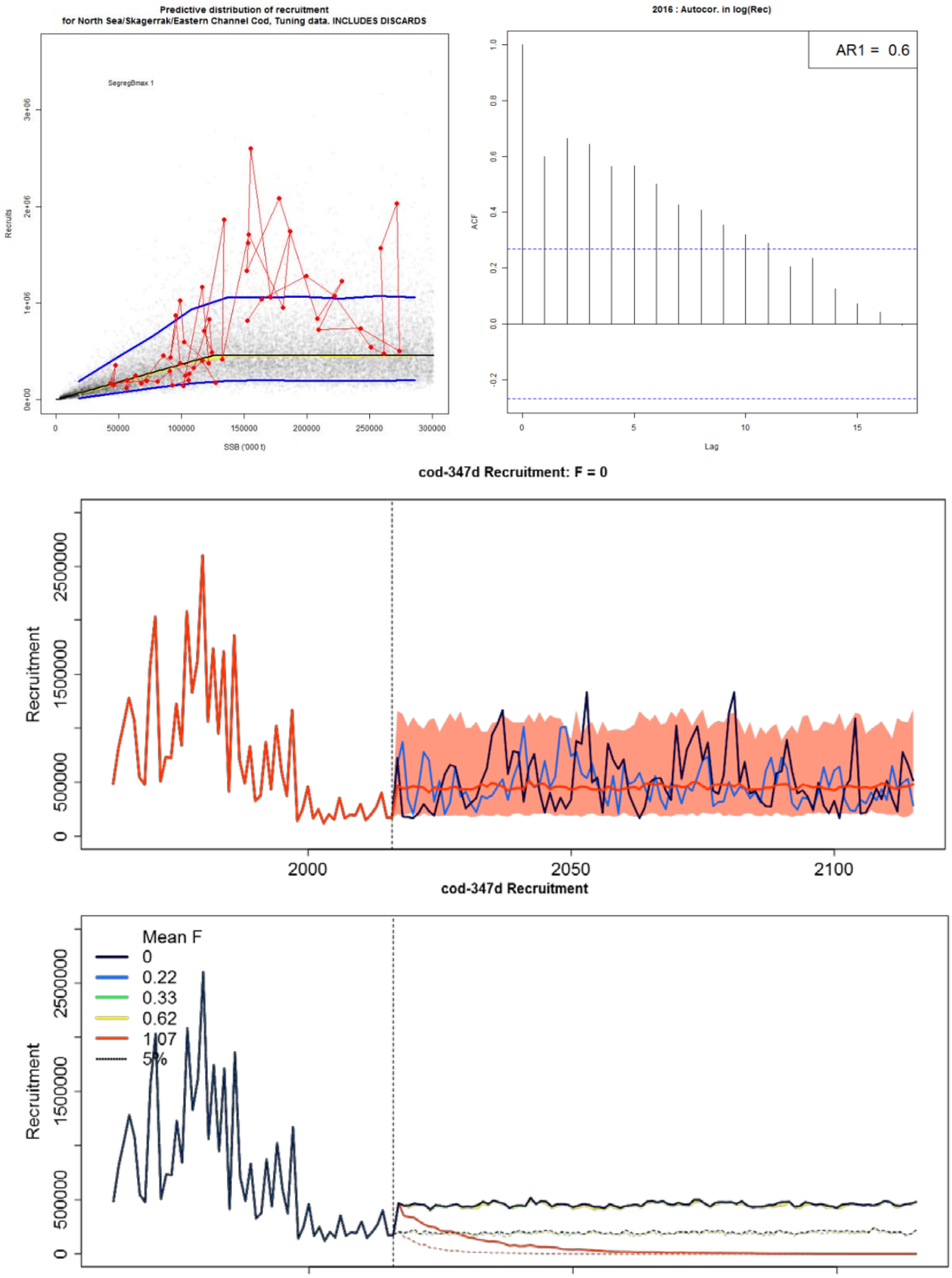


Figure A.4.4 Cod-347d: Stock recruitment relationship used in the simulations (top left), autocorrelation in recruitment (top right), simulated recruitment at F=0 (middle; median, 95% range and two example iterations) and simulated recruitment for each F level (bottom; medians and lower 5th percentiles plotted).

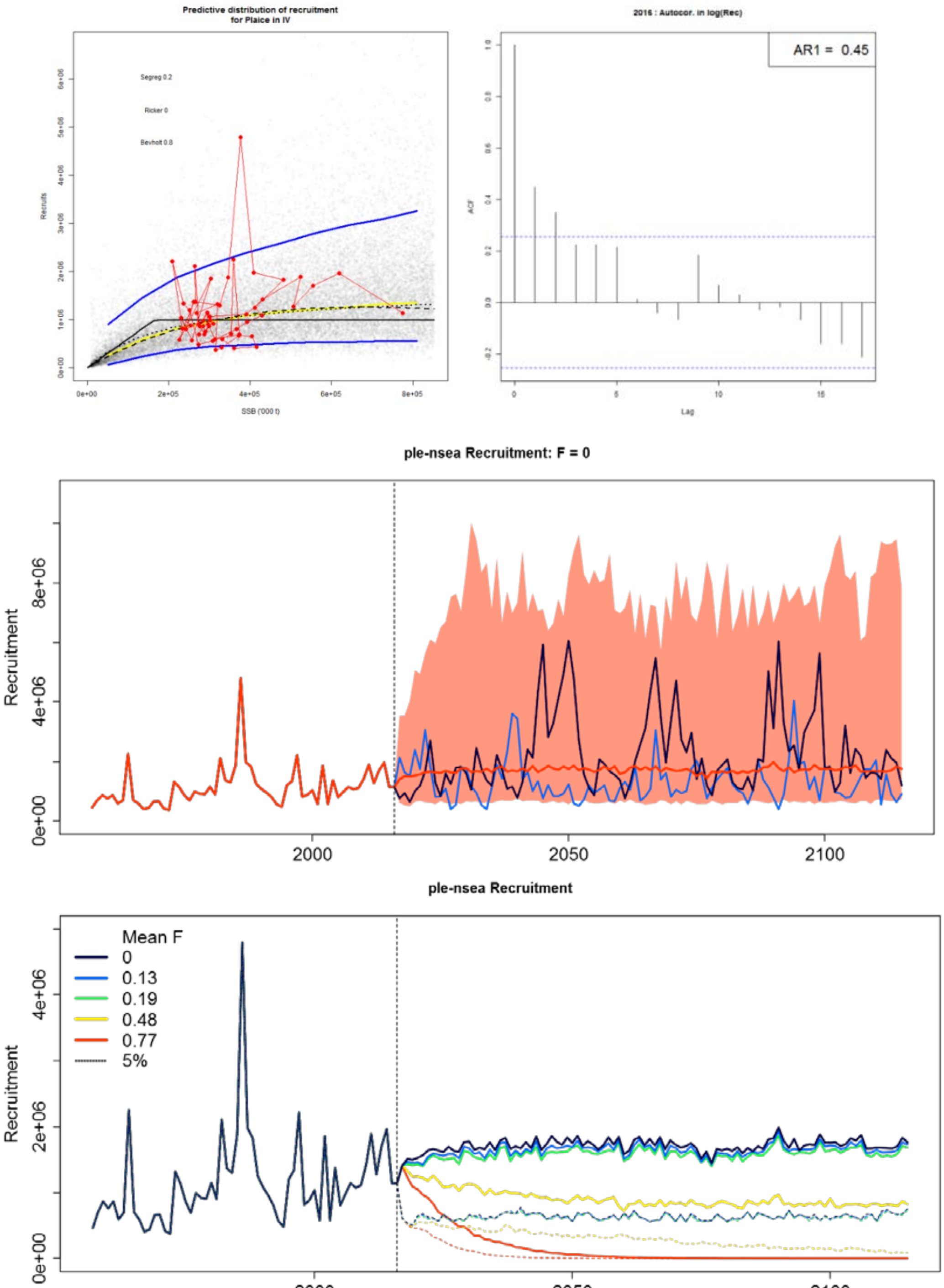


Figure A.4.5. Ple-nsea: Stock recruitment relationship used in the simulations (top left), autocorrelation in recruitment (top right), simulated recruitment at F=0 (middle; median, 95% range and two example iterations) and simulated recruitment for each F level (bottom; medians and lower 5th percentiles plotted).

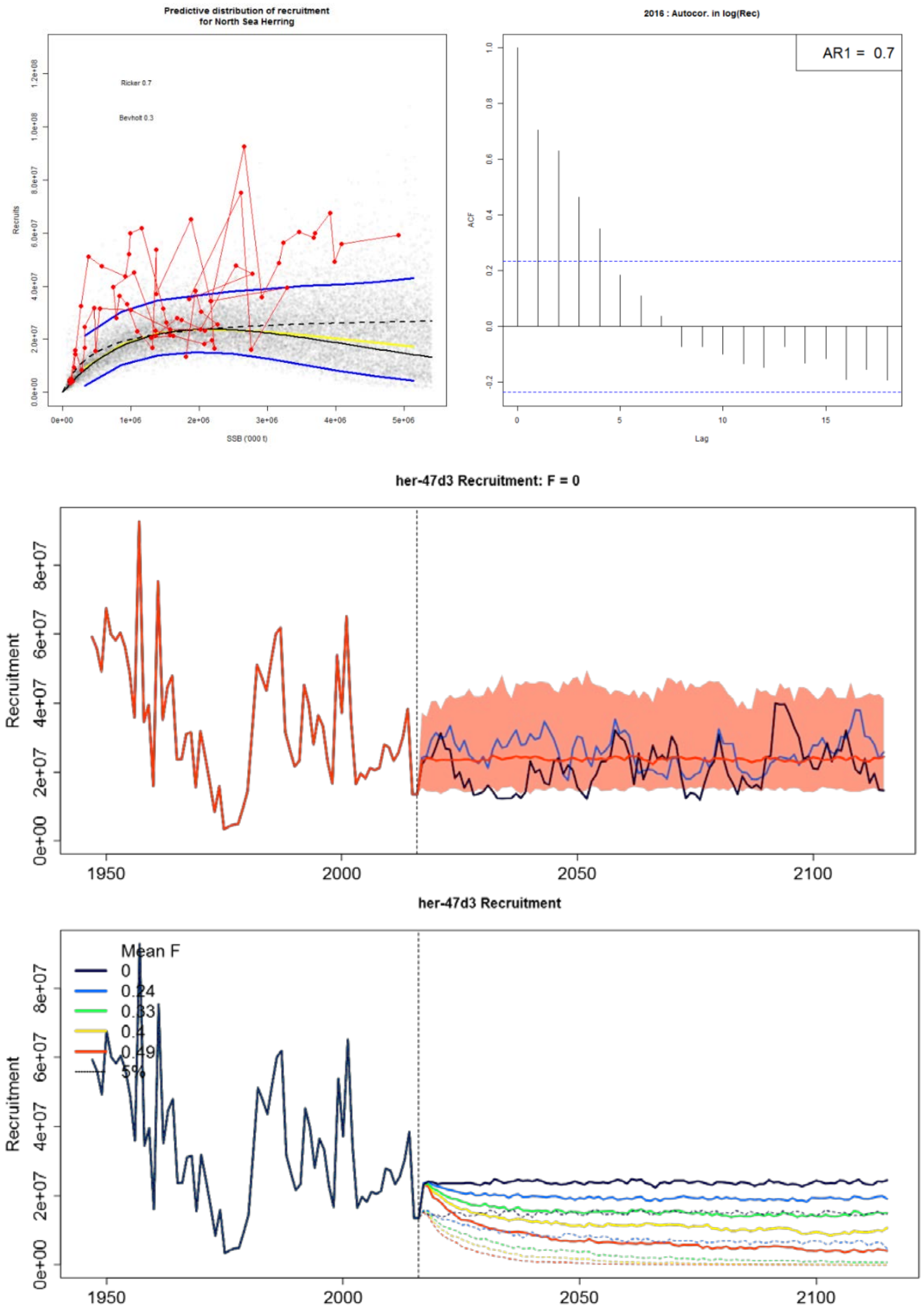


Figure A.4.6. Her-47d3: Stock recruitment relationship used in the simulations (top left), autocorrelation in recruitment (top right), simulated recruitment at F=0 (middle; median, 95% range and two example iterations) and simulated recruitment for each F level (bottom; medians and lower 5th percentiles plotted).

Cod-347d Simulation Results

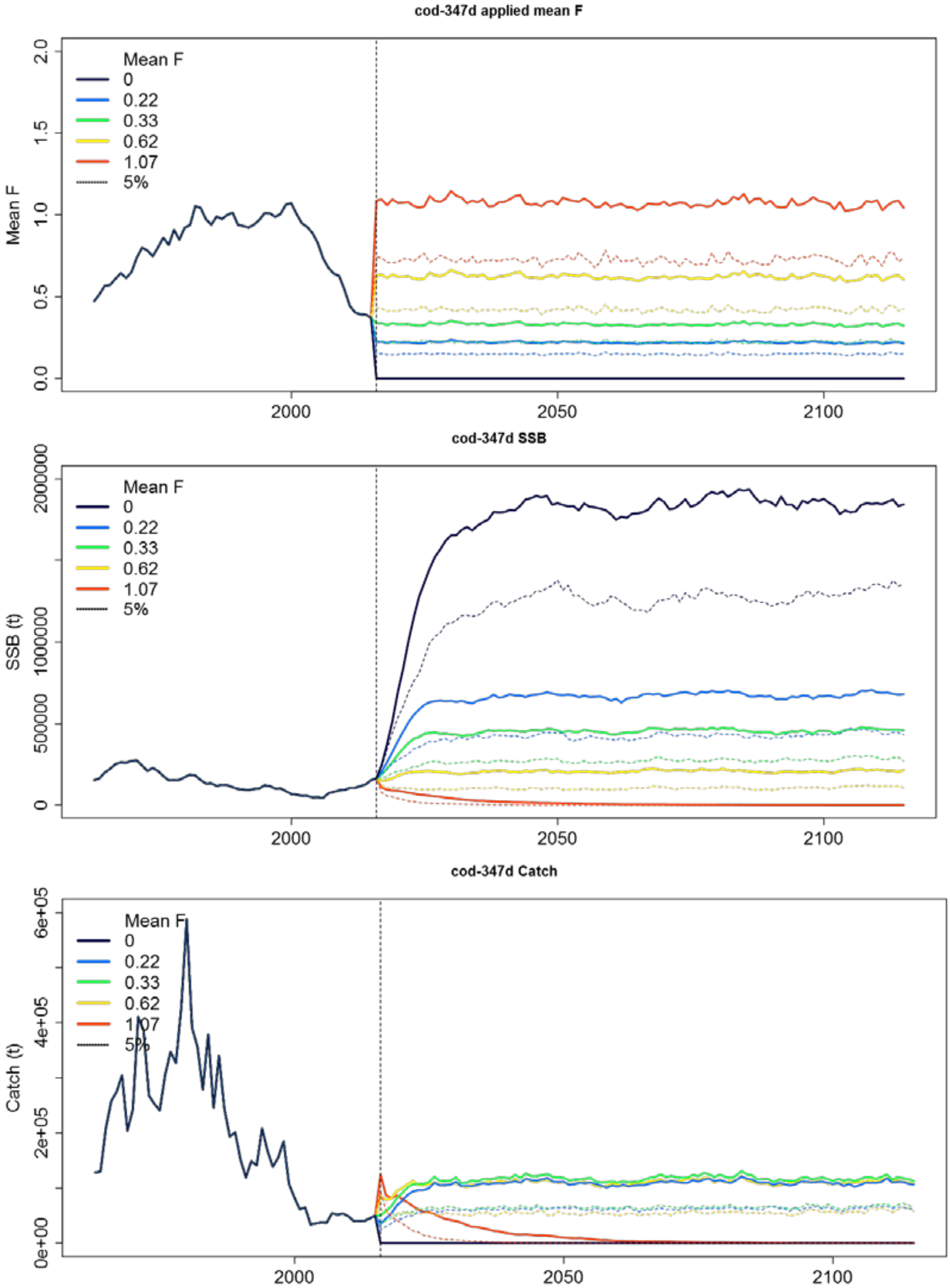


Figure A.4.7. Development of the cod fishery and stock under the five F scenarios simulated. Applied F (top), SSB (middle) and catch (bottom) are shown, with median values (solid lines) and lower 5th percentiles (dashed lines) are plotted.

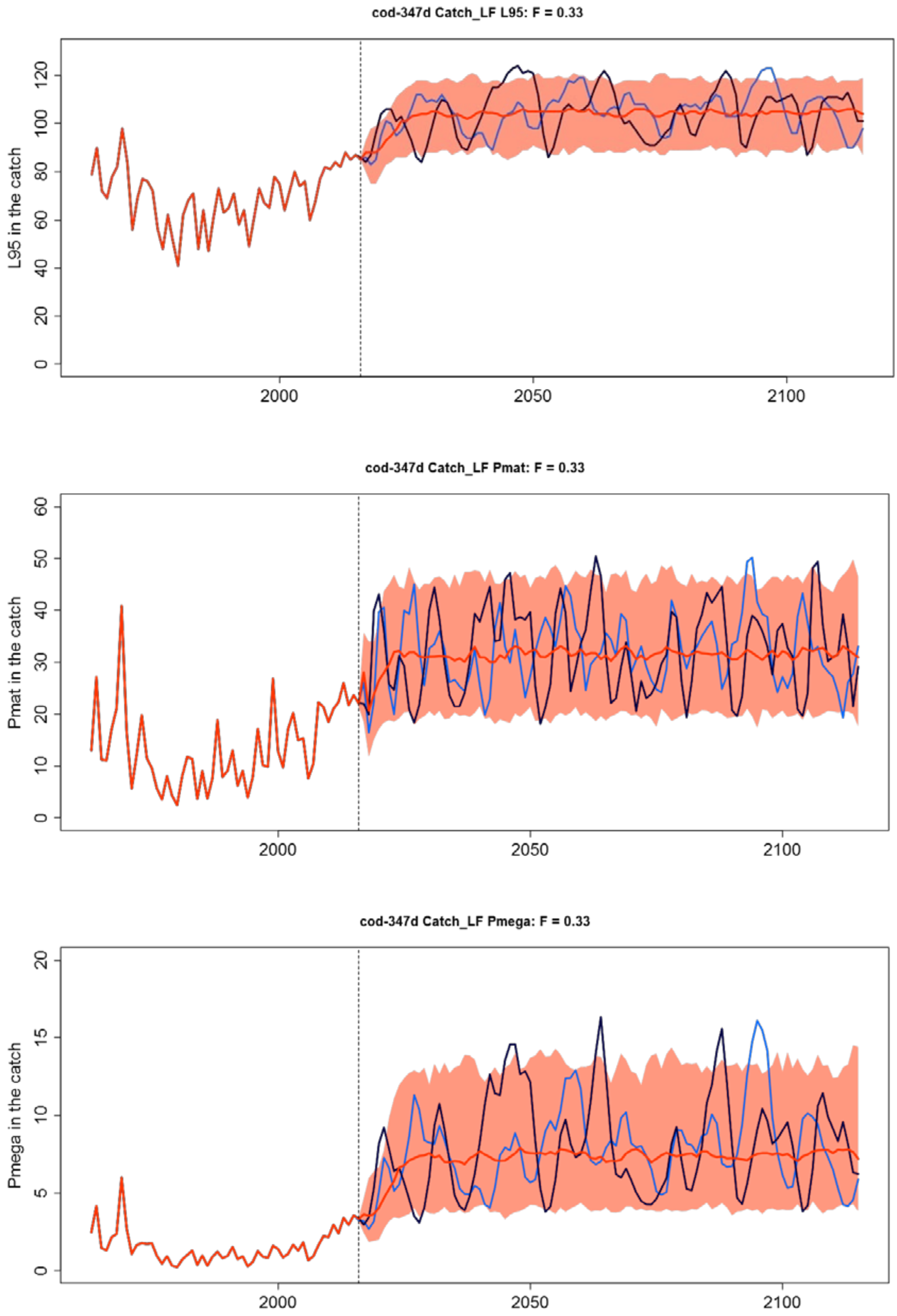


Figure A.4.8 Size based indicators from length frequencies in the catch of cod when fishing at F=FMSY. L95 (top), Pmat (middle), and Pmega (bottom) are shown, with median values (solid lines), 95% ranges (shaded area) and two example iterations (black and blue lines).

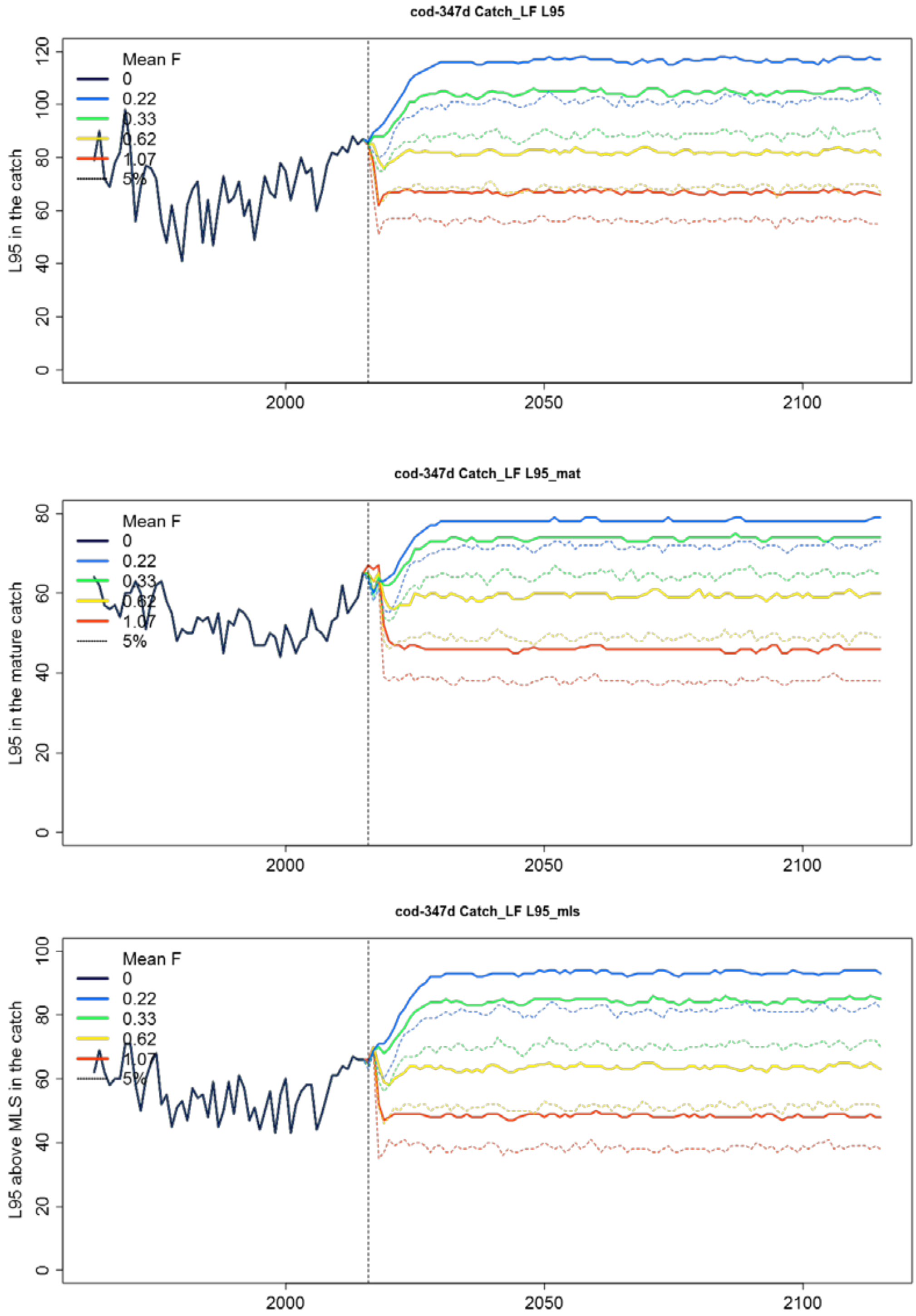


Figure A.4.9. Variations of the L95 size based indicators from length frequencies in the catch of cod for the four non-zero F values simulated (no catch length distributions are obtained from F=0). L95 (top), L95_mat (middle), and L95_mls (bottom) are shown, with median values (solid lines) and lower 5th percentiles (dashed lines).

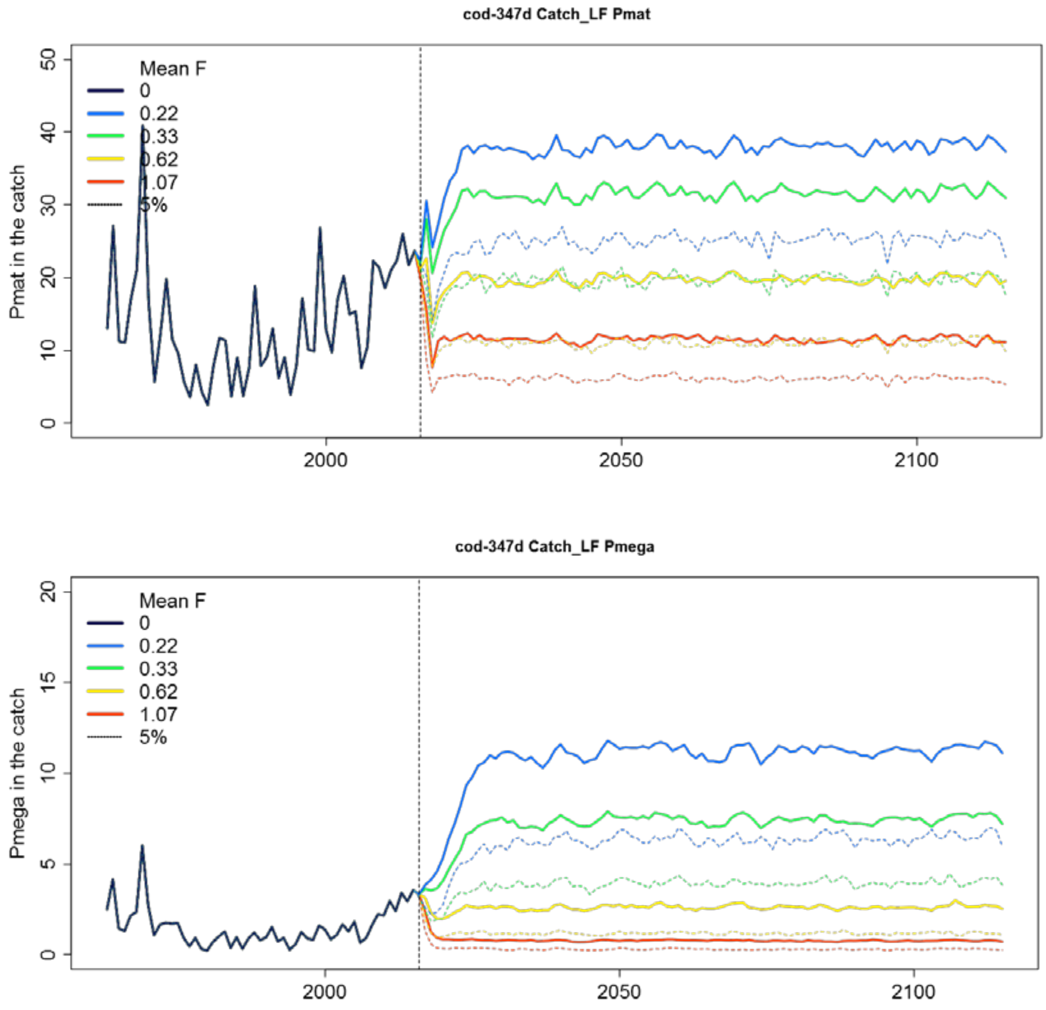


Figure A.4.10. Pmat (top) and Pmega (bottom) size based indicators from length frequencies in the catch of cod for the four non-zero F values simulated (no catch length distributions are obtained from F=0). Median values (solid lines) and lower 5th percentiles (dashed lines).

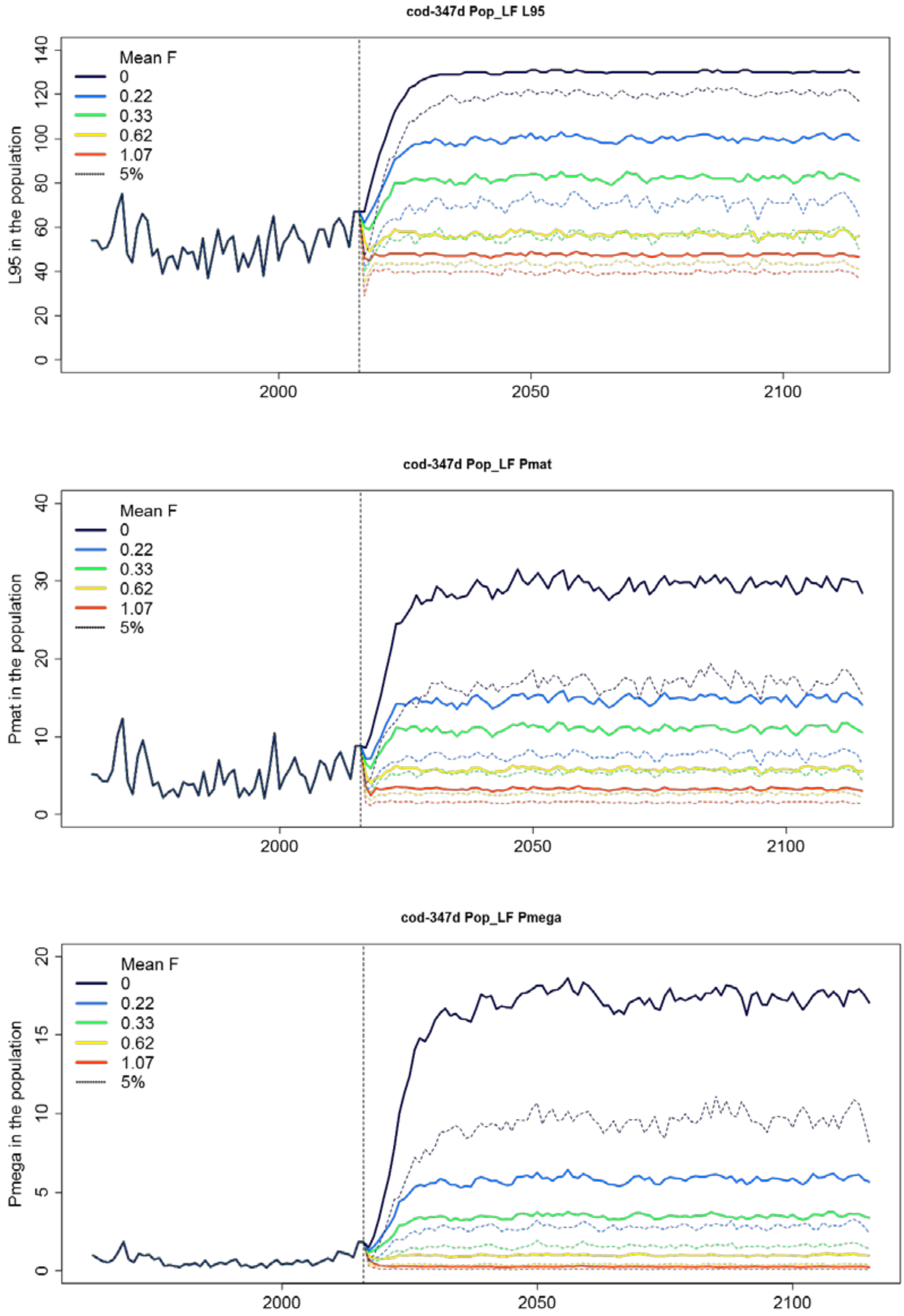


Figure A.4.11. L95 (top), Pmat (middle) and Pmega (bottom) size based indicators from length frequencies in the simulated true population of cod for the five F values simulated. Median values (solid lines) and lower 5th percentiles (dashed lines).

Ple-nsea Simulation Results

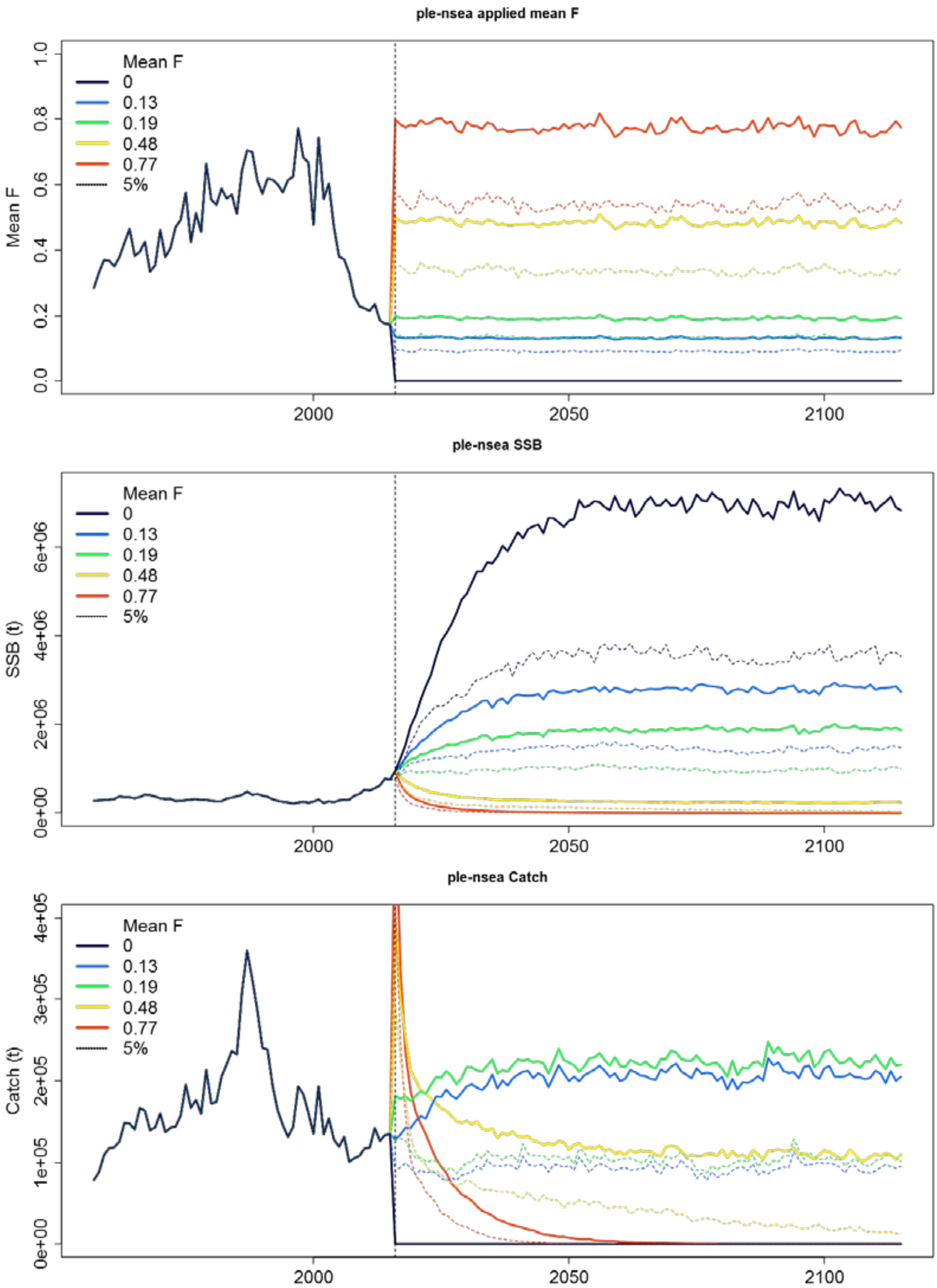


Figure A.4.12. Development of the plaice fishery and stock under the five F scenarios simulated. Applied F (top), SSB (middle) and catch (bottom) are shown, with median values (solid lines) and lower 5th percentiles (dashed lines) are plotted.

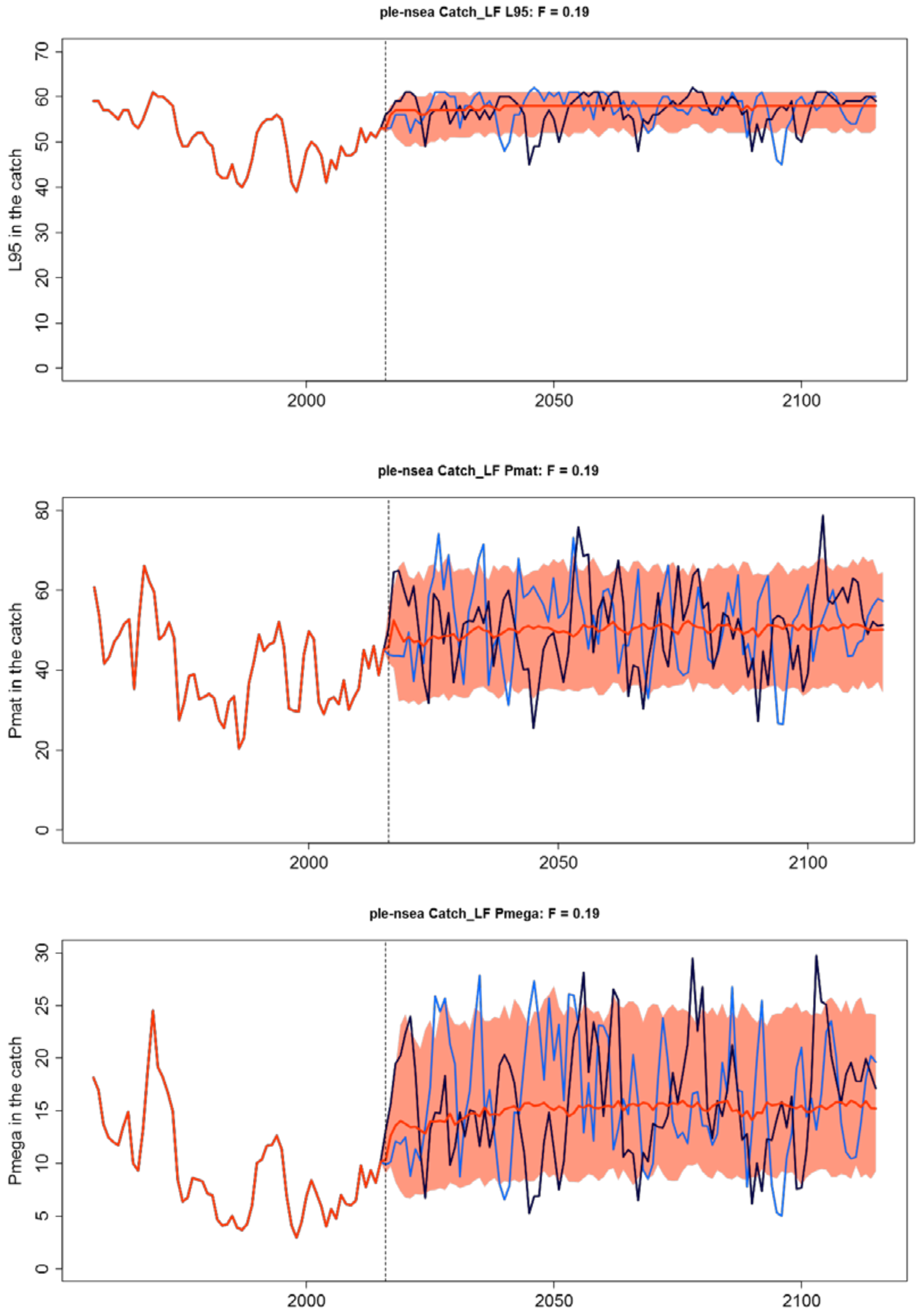


Figure A.4.13. Size based indicators from length frequencies in the catch of plaice when fishing at F=FMSY. L95 (top), Pmat (middle), and Pmega (bottom) are shown, with median values (solid lines), 95% ranges (shaded area) and two example iterations (black and blue lines).

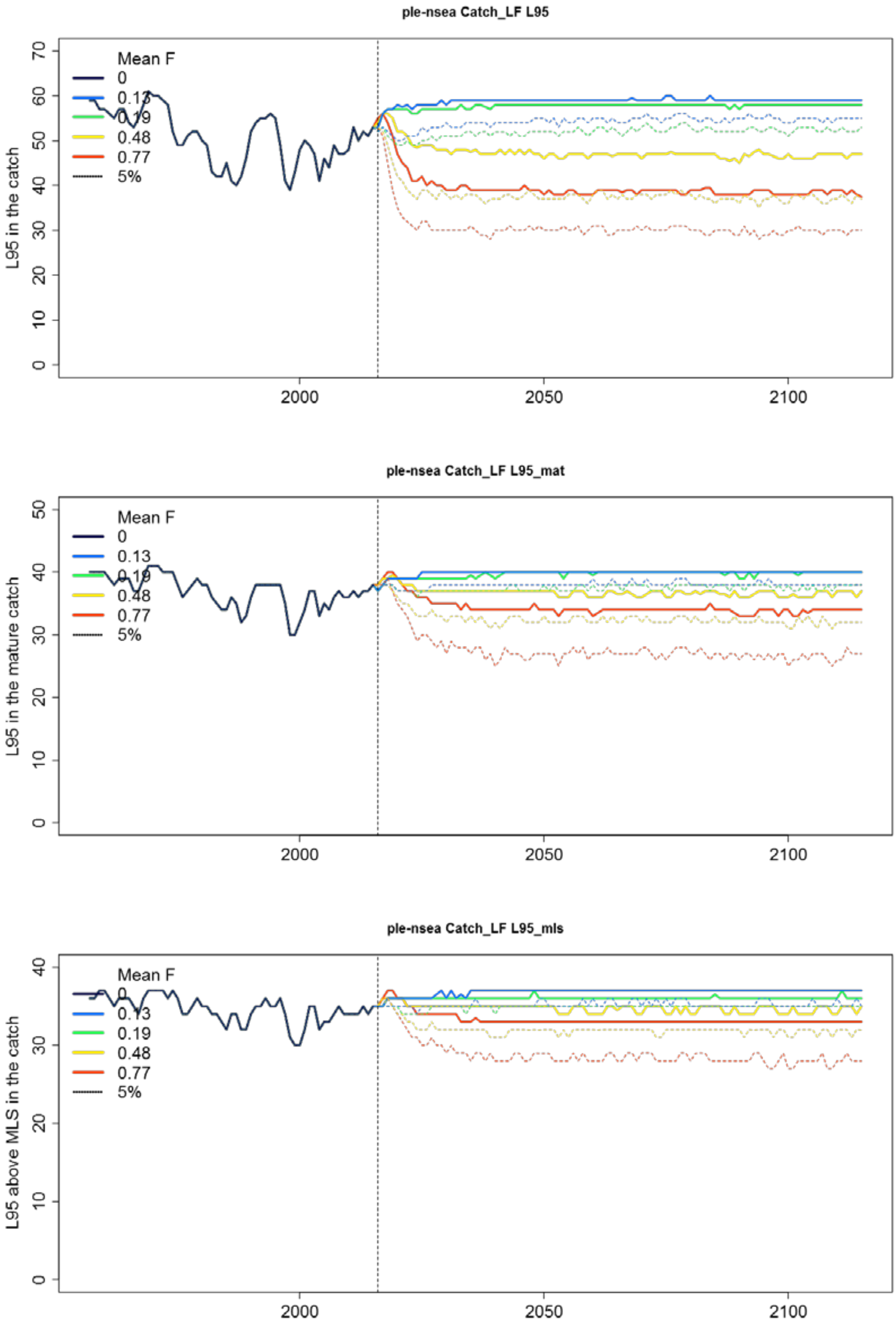


Figure A.4.14. Variations of the L95 size based indicators from length frequencies in the catch of plaice for the four non-zero F values simulated (no catch length distributions are obtained from F=0). L95 (top), L95_mat (middle), and L95_mls (bottom) are shown, with median values (solid lines) and lower 5th percentiles (dashed lines).

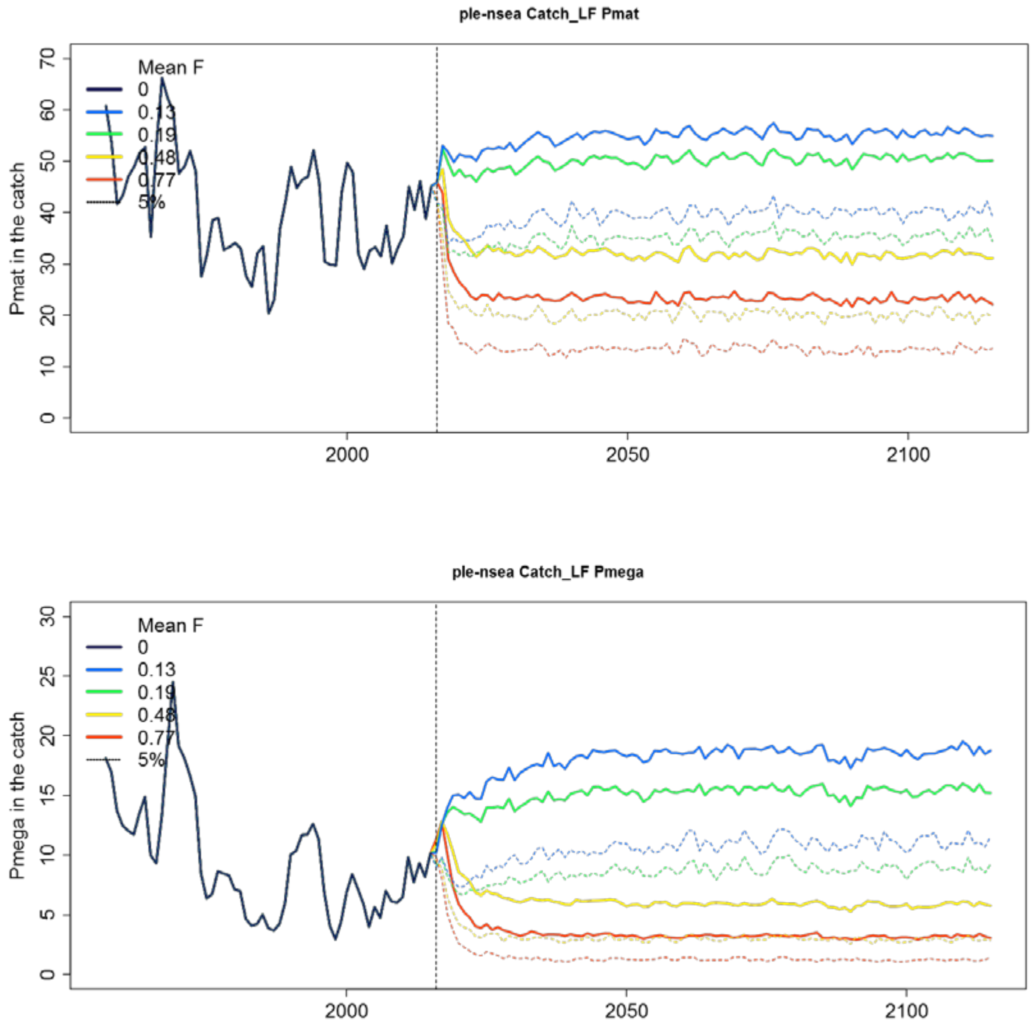


Figure A.4.15. Pmat (top) and Pmega (bottom) size based indicators from length frequencies in the catch of plaice for the four non-zero F values simulated (no catch length distributions are obtained from F=0). Median values (solid lines) and lower 5th percentiles (dashed lines).

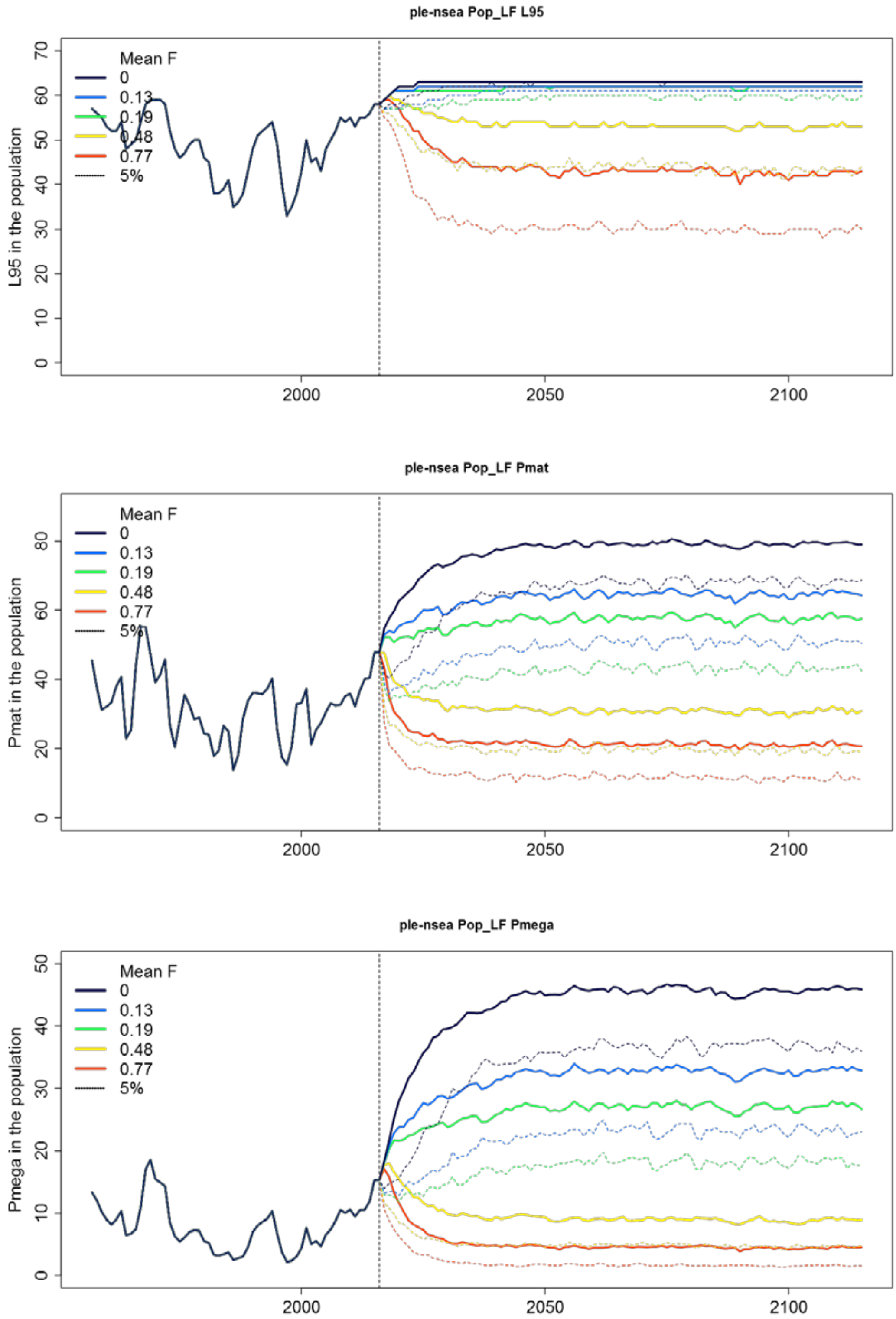


Figure A.4.16. L95 (top), Pmat (middle) and Pmega (bottom) size based indicators from length frequencies in the simulated true population of plaice for the five F values simulated. Median values (solid lines) and lower 5th percentiles (dashed lines).

Her-47d3 Simulation Results

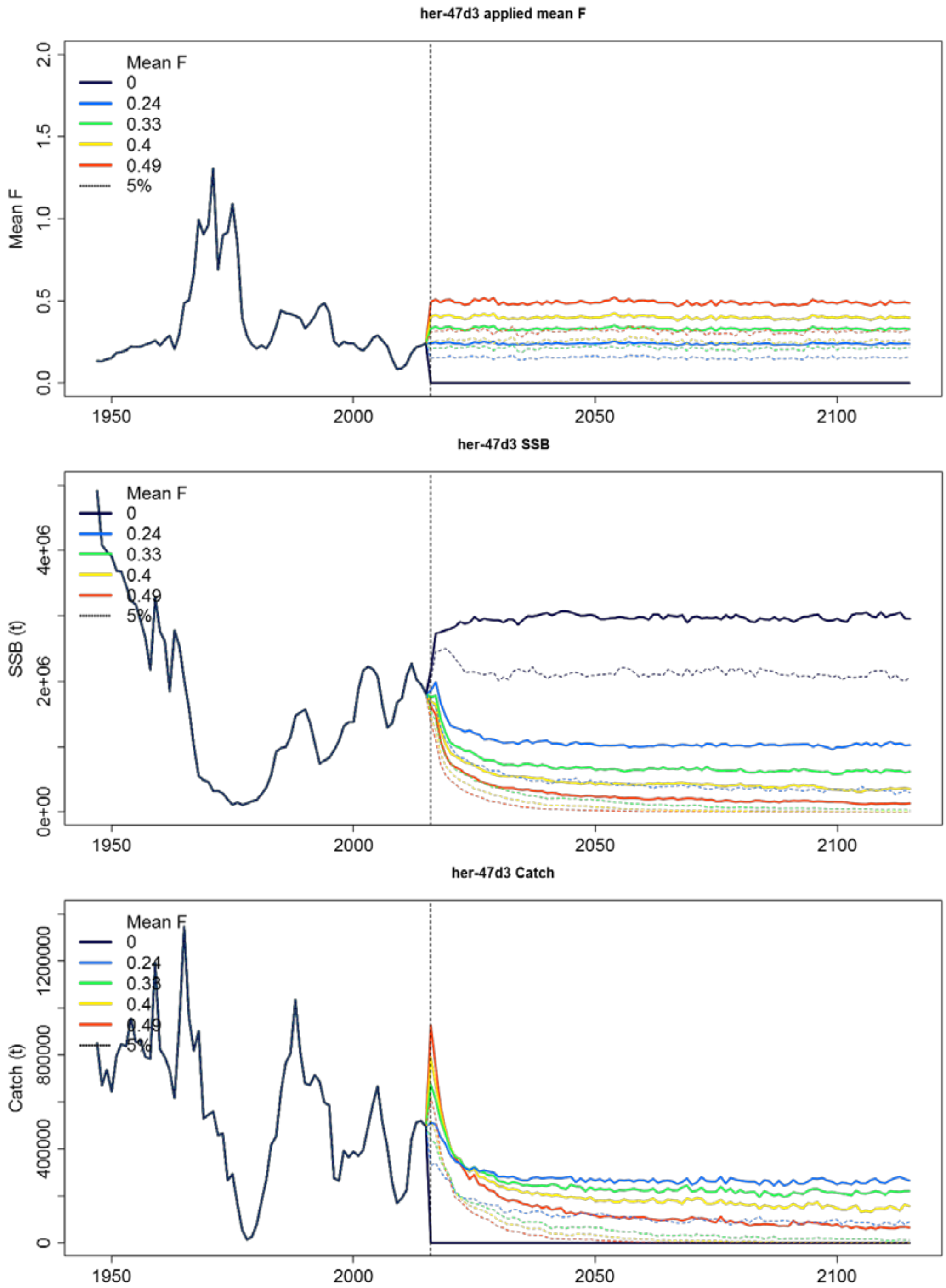


Figure A.4.17. Development of the herring fishery and stock under the five F scenarios simulated. Applied F (top), SSB (middle) and catch (bottom) are shown, with median values (solid lines) and lower 5th percentiles (dashed lines) are plotted.

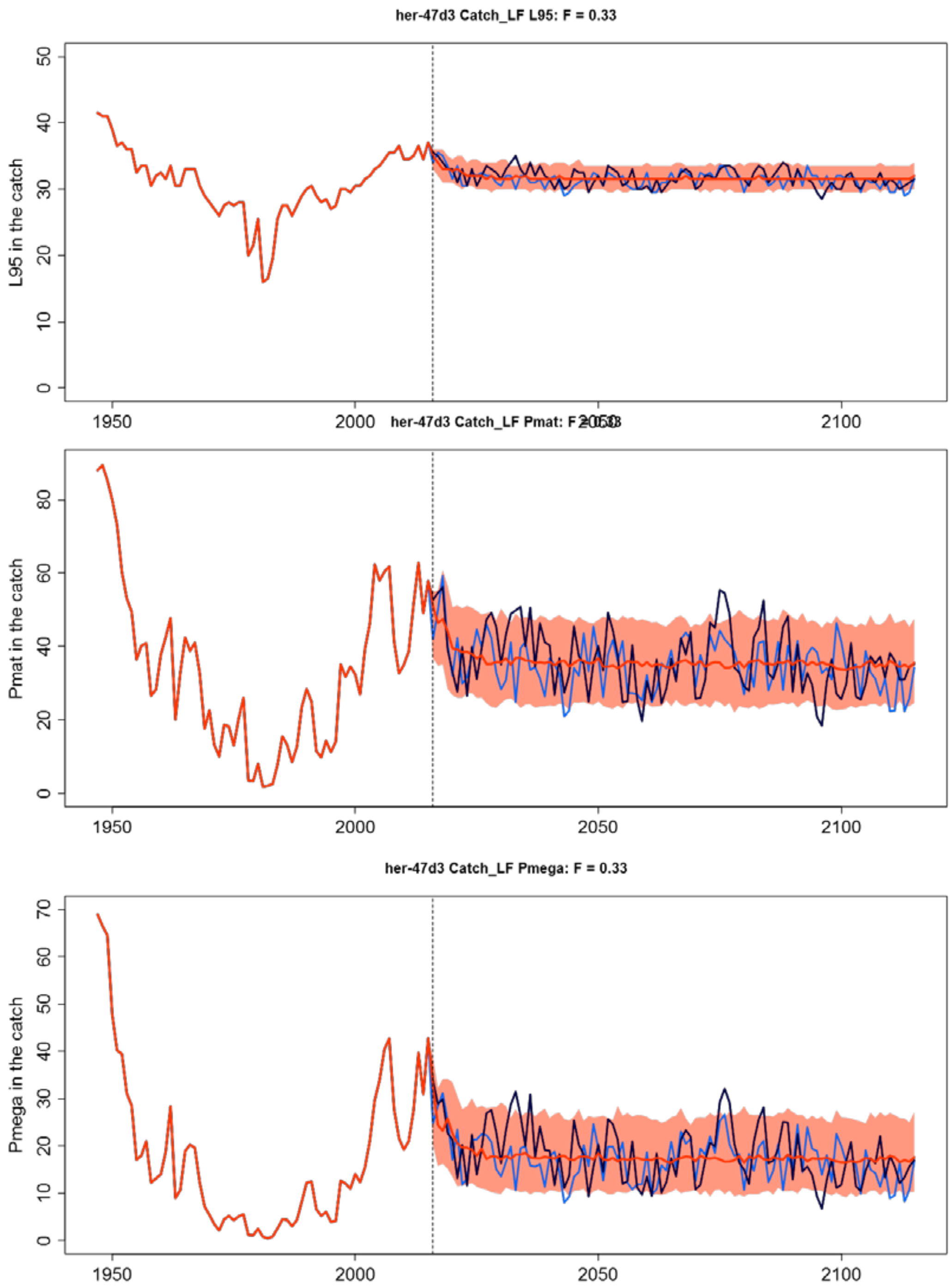


Figure A.4.18. Size based indicators from length frequencies in the catch of herring when fishing at F=FMSY. L95 (top), Pmat (middle), and Pmega (bottom) are shown, with median values (solid lines), 95% ranges (shaded area) and two example iterations (black and blue lines).

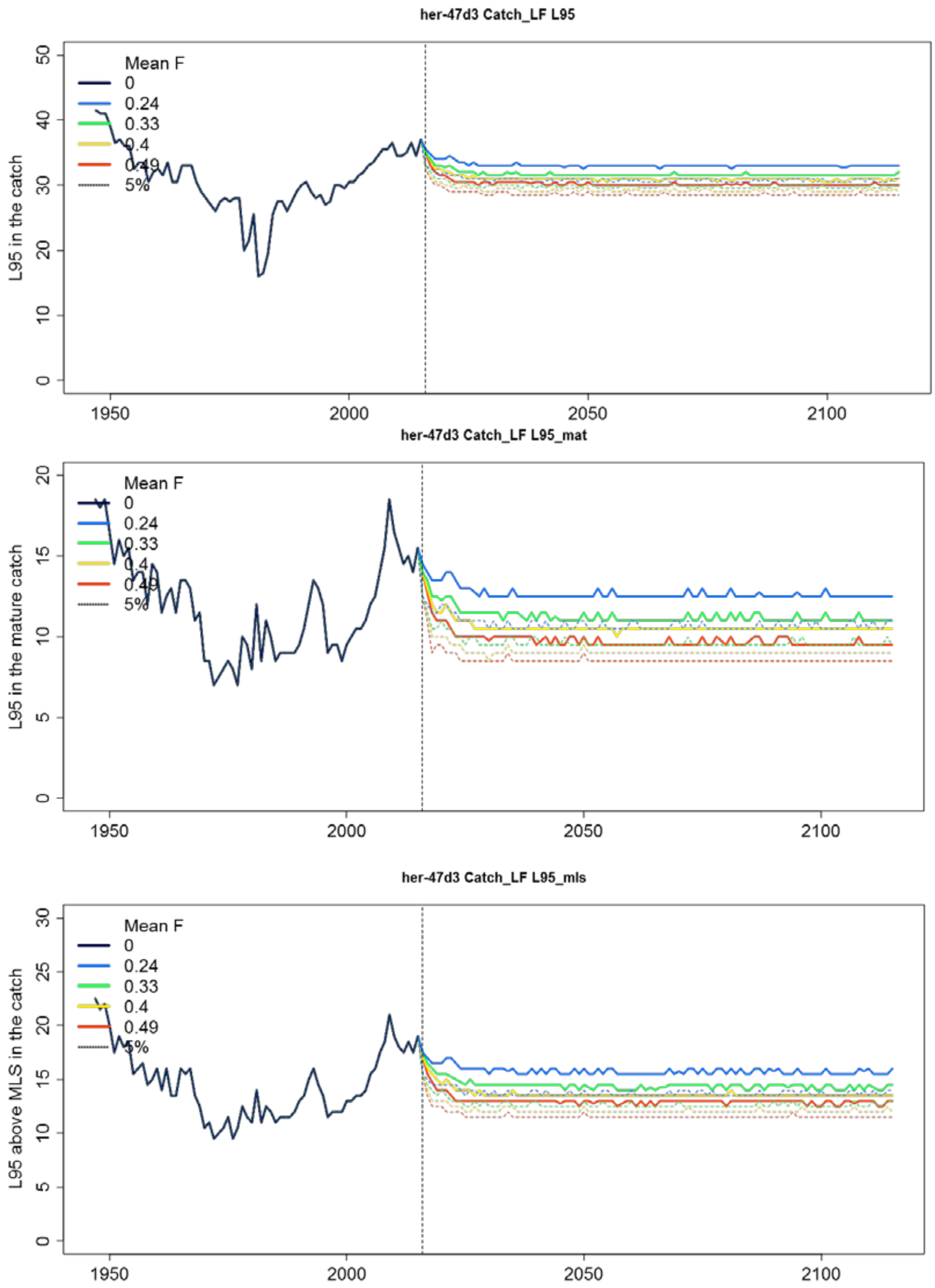
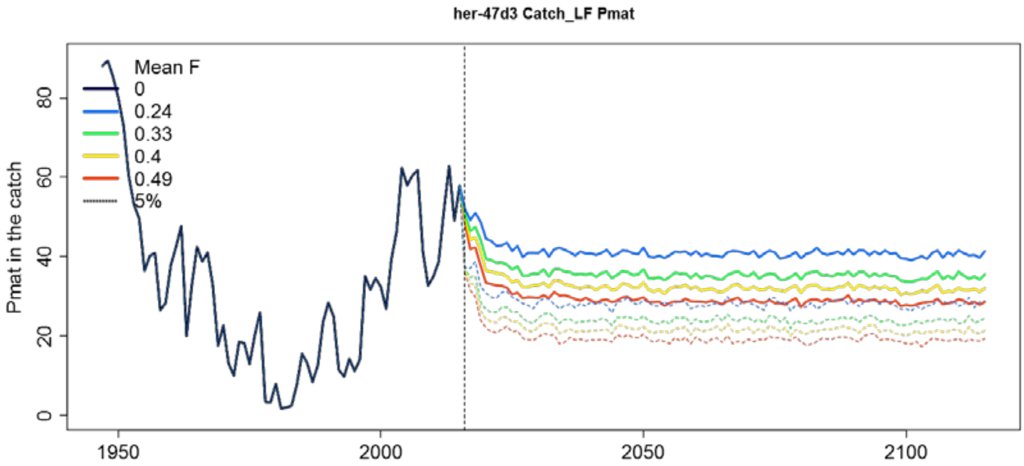


Figure A.4.19. Variations of the L95 size based indicators from length frequencies in the catch of herring for the four non-zero F values simulated (no catch length distributions are obtained from F=0). L95 (top), L95_mat (middle), and L95_mls (bottom) are shown, with median values (solid lines) and lower 5th percentiles (dashed lines).



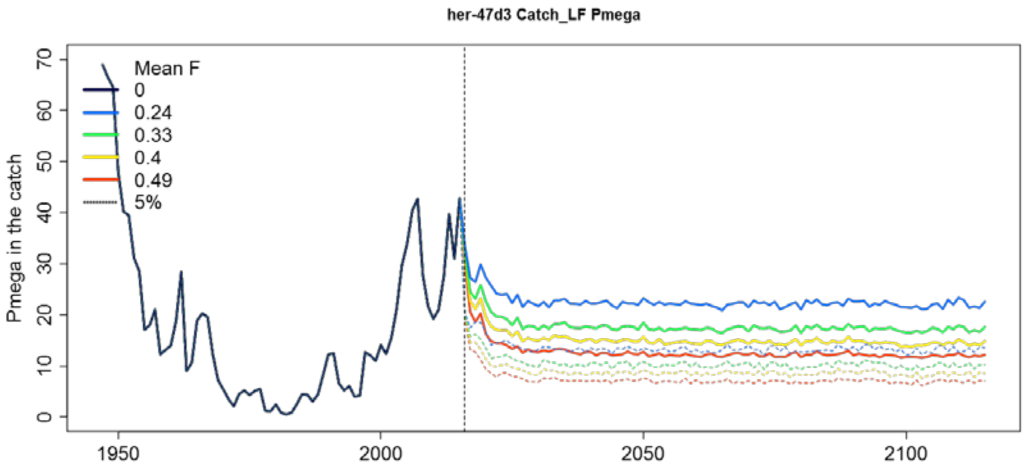


Figure A.4.20. Pmat (top) and Pmega (bottom) size based indicators from length frequencies in the catch of herring for the four non-zero F values simulated (no catch length distributions are obtained from F=0). Median values (solid lines) and lower 5th percentiles (dashed lines).

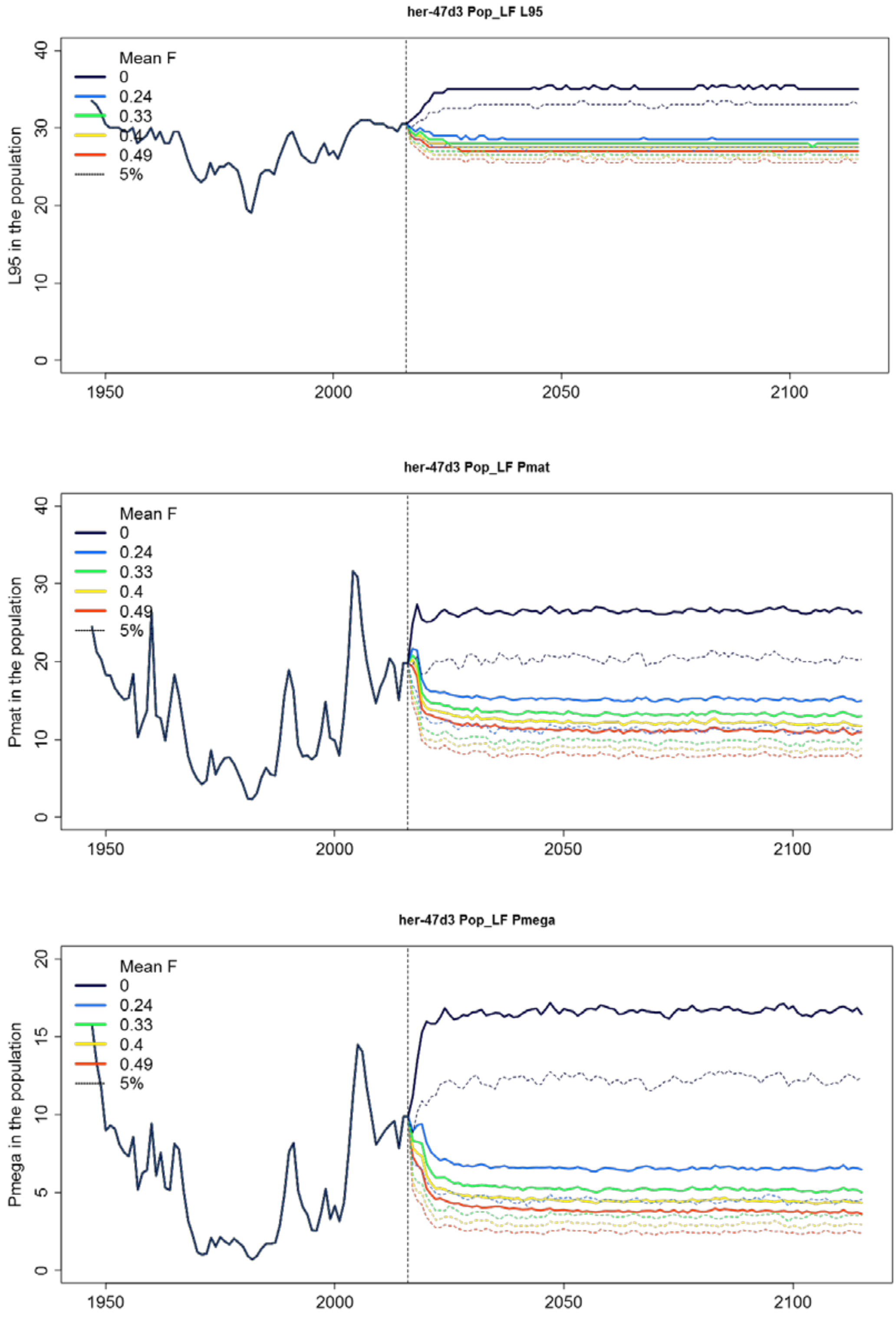


Figure A.4.21. L95 (top), Pmat (middle) and Pmega (bottom) size based indicators from length frequencies in the simulated true population of herring for the five F values simulated. Median values (solid lines) and lower 5th percentiles (dashed lines).

Annex 5: Review of the ICES Report of the Workshop on guidance of operational methods for the evaluation of the MSFD criterion D3.3 (WKIND3.3ii)

RGIND3.3ii

Review of the ICES' report of the Workshop on guidance on development of operational methods for the evaluation of the MSFD criterion D3.3 (WKIND3.3ii), Copenhagen, 1-4 November 2016. ICES CM 2016/ACOM:44, 145pp.

Reviewers: Carl O'Brien (UK, Chair), Peter Wright (UK), Saša Raicevich (Italy)

Secretariat RG: Iñígo Martinez

Review process

The Review Group (RG) conducted its work by correspondence during February 2017, finalizing its technical review in March 2017.

General comments

WKIND3.3ii was held from 1–4 November 2016 at ICES Headquarters in Copenhagen, Denmark. The workshop was the second part of a workshop series hosted by ICES and requested by the EU-Commission to provide guidance on development of operational methods for the evaluation of MSFD criterion D3.3.

The report deals with the guidance on the development of operational methods for the evaluation of the MSFD criterion D3.3 and particularly, focusses on size-based indicators (SBI).

Overall the workshop made progress on this topic, with several simulations in a field that has been little explored so far. The report reads well, but in some cases the description of materials and methods could be improved and more informative. For instance, a table/text providing clear guidance on indicators' definition; i.e. indicators formulae, and their estimation methods; e.g. integration/aggregation methods, would be helpful. In some cases, the name given to some indicators seems to be misleading; e.g. abundance of mega-spawners is a biomass value.

The general approach applied – namely, considering different cut-offs level to explore/control the influence of recruitment on different indicators and reduce variability, exploring different reference points, making comparisons of fishery-dependent and fishery-independent data, using multiple models to explore relationships between SBI and stock indicators, and using modelling to infer the effects of different fishing scenarios on SBI; is robust. However, although results are not always conclusive, **the report provides interesting insights and**, notwithstanding some limitations on data and/or models, **will provide valuable evidence to guide future work**.

The finding that the relative SBI (L_{95}, Pmega and Pmat) seemed to contain additional information to SSB as indicated by non-linear relationships between these SBI and SSB is particularly important to earlier debates questioning the need for D3.3.

The main findings of the workshop were:

- Depending on the considered data sources, the values of size-based indicators will differ. Commercial data may indicate higher abundances of large individuals, whereas survey data may be biased towards higher proportion of small individuals. **Careful consideration of best data sources is necessary, probably stock by stock**.

- **SBI do not show predictable and constant relationships to stock indicators** (SSB, R and F). Further work is required to improve understanding of these relationships. The understanding of relationships between stock indicators and SBI will help to validate and develop new and meaningful reference points.
- Population models (EQSIM) allowed estimating which SBI-values can be expected under prevailing conditions assuming different intensities of fishing. These values indicate that higher SBI-values can be expected for North Sea cod when fishing with F_{MSY}. For North Sea plaice the SBI values are predicted to remain in the current range. For North Sea autumn spawning herring SBI are expected to get lower than the current values.
- **Further work is required to identify if and how GES-thresholds can be derived**.

Currently no relative SBI is fully operational. The major impairment is still the meaningful setting of reference points for the assessment of the size distribution within the stock. The simulations by WKIND3.3ii represent initial examinations for the potential to define reference points, and as such the **specific results are not recommended for operational use at present**.

Revisions to the report could address the following two points.

1. Lack of distinction in the meaning of using SBI based on fishery-dependent versus fishery-independent data. Whilst the first would be related to pressure, the second are related to stock status. This distinction was given/considered within the WKIND3.3i report. However, the two data sources are treated indifferently in the report; i.e. as being fully interchangeable, such as they would convey the same information. Whether, and how, fishery dependent data could provide an accurate assessment for the length-frequency distribution (LFD) of large size individuals, which are often underrepresented in trawl survey, in relation to stock status is another issue that would need careful assessment given the different data typology and sources of variation; e.g. gear, selectivity, spatio-temporal distribution of effort, and market drivers, and should be clearly described.
2. The investigated reference points, though they are mentioned to be preliminary and not fully developed, should be better described/discussed in their biological meaning. While Lopt has a clear definition, mega-spawners are not clearly defined (in biological terms) in the report. Also, the empirical estimate of Lmega=1.1*Lopt may not be appropriate for all species, and also reproductive strategies (multiple/repeated spawners) should be considered; i.e. **the question: *what is a mega spawner?* is not fully addressed in the report and could be a theme for further work**. The implication of using some cut-off level as L50mat that changes over time should be better addressed.

Recommendation

The technical review of the WKIND3.3ii report focused on the scientific aspects of the report's sections. Whilst none of the relative SBI presented and explored is fully operational, the report provides a basis to define future work.

In the request to ICES from DG ENV, ICES had been requested to further develop methods to describe the size distribution of a stock. The exploration should focus on:

a) the data requirements to assess the size distribution of a stock;

b) potential size-based indicators (SBI) that are not redundant to D3C1 and D3C2;

c) methods to describe the trend over time in SBI; and

d) the setting of thresholds and reference levels for any potential methods.

The review group concludes that the **WKIND3.3ii report provides a basis for the ADGIND3.3ii to develop a workplan for ICES to further explore a) through d) and ultimately, to develop a scientific basis for the future assessment of good environmental status (GES) of the MSFD Criterion D3C3**.

Technical comments

EXECUTIVE SUMMARY

COMMENT:

There are some findings that need further clarification/revision.

Data sources. Fishery dependent LFD have several pitfalls, in particular they are subjective to many confounding factors (e.g. fishing effort distribution, fishing gear selectivity, etc.). The report does not provide any hierarchy between trawl-survey data, whilst fishery independent data should be preferred, and under some restricted cases, also fishery dependent data should be used. However, the meaning of SBI indicators when associated to fishery-dependent and fishery independent data could be quite different. FI data relates to stock status, while FD should be use to represent pressure exerted over the stocks. This issue is not properly taken into account and should be mentioned in the executive summary. Indeed the report considers both sources of data as fully complementary.

Problems related to the assessment of Linf, L50m, Lopt and Lmega are not explained.

Cut-off values: please change 'Lm50/Linf' to 'Lm50'. The statement 'Maybe initial reference points may have to be adopted' is unclear and should be better detailed.

SECTION 3: Advances in relative size-based indicators

COMMENTS:

To improve the performance of relative SBI, WKIND3.3ii aimed to test the effect of using various cut-off points in the length-frequency distribution (LFD) to exclude early juveniles from the calculation of SBI. These cut-off points should ensure that mostly the mature fraction of the stock is considered when estimating the 95th-percentile of the length-frequency distribution (L_{95}) or the proportion of megaspawners (Pmega).

WKIND3.3ii decided to compare SBI time series of L_{95} against fisheries population reference points such as Lm50 (length at 50% mature), L_{opt} (the body length where the biomass of a cohort and its fecundity are maximum; Froese *et al.*, 2016) or Linf, in order to identify possible reference points. WKIND3.3ii analysed time series of SBI and compared the LFD with the indicator performances against potential reference points across several stocks from the Baltic and North Sea.

The chapter is interesting, but it lacks clarity in definition of indicators and thresholds adopted; e.g. *what is a mega spawner?* including the validity of the methods to estimate/assess them. The conceptual difference between using fishery dependent and fishery independent SBI indicators (pressure versus status indicators) in missing and should be provided.

The general approach of comparing SBI focussed on mature sized individuals with reference points based on theoretical values of L_{opt} appears reasonable.

Based on the literature, there is biological evidence for the importance of large repeat spawners, due to higher relative fecundity, egg size and longer spawning times but it is not clear how well the megaspawners criteria relate to this.

DETAILED COMMENTS:

3.1 Introduction

The use of various cut-off points in the length-frequency distribution to exclude early juveniles from the calculation of SBI appears sound given that the focus should be on mature fish size without any confounding effects of year-class strength. However, the period used to calculate Lm50 is important as recent averages will reflect an altered state in many exploited stocks. Using periods less than a decade to calculate Lm50 is probably relevant for considering the current mature component but if there has been selection for earlier puberty then this change in trait is ignored unless historic ogives are considered.

3.2 Material and methods

Is there precedence in estimating asymptotic length (Linf) from SMALK data as this method of sampling is not representative of the catch; i.e. size stratified sampling?

It would be useful to relate Lmega (=1.1 L_{opt}) to the reported lengths of repeat spawners to clarify the biological basis of this term.

Page 6, 1st paragraph. LFD aggregation: the aggregation methods (both for commercial and trawl-survey data) should be better specified.

Page 6, 2nd paragraph. The quality/applicability of SMALK data - short description should be provided so that non-ICES readers can have a better understanding.

Given the influence of estimation of Linf on Lopt and Lmega (and associated indicators), is the estimation of Linf as the median of all annual length in DATRAS data a good proxy for Linf? For instance, why not use the maximum length in the time series (or other options)? Still, the Linf would be underestimated. This should be highlighted and discussed somewhere. The reviewers suggest to add a table that summarises the analytical approach (and provides formulas) to calculate both SBI and potential references points. This would facilitate readers to understand the whole process and increase the clarity of the report.

Page 6, last paragraph. For consistency with following graphs and text, introduce Lmega as = 1.1 * Lopt.

Page 7, 2nd paragraph. Please change: 'as the ratio between the number of mature individuals and the number of megaspawners' to 'as the ratio between the number of megaspawners and the number of mature individuals'.

Page 7 line, 2nd paragraph: please change '1.1 Linf' to '1.1 * Lopt'.

Page 7, 3rd paragraph: Insert a short table summarizing the stocks considered, area, data sources, length of the time series, data sources, methods applied to estimate Linf.

3.3 Results

3.3.1 Differences between commercial and survey data

As already mentioned, SBI applied to commercial data explain how the pressure exerted by fishing is affecting the stock in terms of size, thus relates to pressure, while using trawl survey data provide insights on the status of the stock. This item should be duly discussed.

Commercial data is not standardized for gear type unlike research survey catches. The contribution of different fleet métiers with differing gear selectivity has changed over time. More information or thought needs to be given to the temporal consistency of commercial catch data before advocating its use.

Pages 8-10. Figures 3.3.3.1, 3.3.2, 3.3.3. The Unit of measure of frequencies for both commercial and trawl survey data should be provided. Possibly, the term 'frequency' is not the most appropriate but, rather CPUE and Index of abundance. Adding Lmega to the thresholds could provide more coherence with the text and following graphs.

Page 8, last sentence. Observed differences are not surprising. It seems clear that the selectivity of commercial vs. experimental gears differs, as well as the sampling design (e.g. commercial vs. experimental, seasonality -years vs. season, aggregation methods) of data used. Also, the units of measure of frequencies are not comparable themselves. A comment should consider/mention these confounding variables.

Page 9, last sentence. Just a comment- this is true but the sampling design differs between the two data sets.

3.3.2 Use of different cut-off points for L95

Page 11, last paragraph. Making simple correlation analyses among indicators could have better shown what the authors are describing in the last paragraph. In particular, plotting correlations (Y) among specific SBI against the Lm50/Lopt ratio (X) for all considered stocks might better show the point they are making.

3.3.3 Potential SBI reference point

Page 11, 3rd paragraph. The statement is trivial since Lopt is estimated as 2/3 of Linf and Lmega is 1.1 Lopt therefore it is obvious they are always below and above 0.7, respectively.

Page 11, 4th paragraph. The authors should better clarify/justify their decisions/statements.

3.3.4 Applying relative SBI to a variety of stocks

The comment in the table that variability in Pmat could be reduced by the use of a moving average would surely be inappropriate because typically, this is a non-stationary time-series for many stocks.

The reviewers agree that no relative SBI is fully operational. The reference points used for L_{95}-variants may have some advantage but were somewhat insensitive to truncation of large individuals from the stock. Lm50 and Pmega.mat can be sensitive to the years used to estimate Pmat.

3.3.5. Strength and weaknesses

Pages 15-16, table 3.3.5.1. Even for Pmega.mat (as for L95) it should be stated that Lmega estimate as Lopt*1.1 needs further assessment and validation. Possibly this holds true as a comment to be introduced in the weaknesses of L95.mat and L95.5.

3.4. Discussion

3.4.1 Choice of data sources, page 16.

The conceptual difference between using Fishery Independent data (FD, i.e. trawl survey data) and Fishery Dependent data (FD, i.e., commercial catch data should be duly discussed), since they would be quite different. Indeed, FD data relate to stock status, while FI data should be used to represent pressure exerted over the stocks (e.g. pressure vs. state indicators). Moreover FD LFD data have several pitfalls when used to address stock status, in particular they are subjective to many confounding factors (e.g., fishing effort distribution, fishing gear selectivity, etc.) and different aggregation methods are most often used for their estimates. The report does not provide any conceptual distinction and hierarchy between the two kinds. This issue is not duly taken into account, and this should be revised also considering that in WKIND3.3i report (page 7) this distinction was given.

Page 16-17. Since the ToR relates to 'explore data requirement' the text should better address the data requirement also considering data needed to estimate thresholds and indicators themselves. For instance, some assumptions made to estimate Lmega, as well as Linf should be carefully considered, as well as the use of SMALK and other potential sources of data. Even a discussion on data spatial aggregation should be included, in relation to potential differences in the final aggregated LFD.

3.4.2. Within the text, the fact that Lmega =1.1*Lopt should be remarked, along with the fact that this definition/estimate of Lmega is provisional should be better stated.

3.4.3. The average length-of-first-maturity has been demonstrated to be decreasing in many exploited fish stocks (see Engelhard & Heino, 2004, but also report of WKIND3.3i). Hence, the use of Lm50 as a cut-off point could introduce additional bias to the time series of L_{95}.mat. Defining Lm50 as a constant would seem a sensible choice but the way this constant is derived; e.g. as average Lm50 across all years, could be important in producing relevant value.

3.5 Conclusions

The reviewers suggest to atune items 1 and 2 according to the comments above.

The conclusions do not deal with the problem of varying Pmat and this should be made clear.

Whilst the group considers Pmega as the conceptually most sound relative SBI the definition of which size-classes are referred to as megaspawners needs biological evidence based on repeat spawners.

SECTION 4: RELATIONSHIPS BETWEEN STOCK INDICATORS AND SBI

COMMENTS

The chapter deals with assessing the redundancy between SBI and stock indicators (F, R, and SSB) by applying a series of modeling approaches (GAM, lagged GAM etc.). The approach is sound, given the mentioned limitations and the small number of stocks considered. In comparison to Chapter 3, authors explored additional SBI indicators (SSB-mega and Cpue-mega) whilst some indicators previously considered (L95.5, L95.mat) were not assessed. The conclusions are coherent with the outcomes of the analyses.

DETAILED COMMENTS:

4.2 Materials and methods

Sections 4.2.1 and 4.2.2. The description of the calculation of some indicators not previously described (cpue-mega and SSB mega) is a bit unclear and it would benefit from the provision of synthetic formulation of the indicators. Also the aggregation methods, and approach for average estimations should be provided, e.g. was stratification applied? The name associated to SSBmega ('abundance of mega-spawners') is misleading, since it seems the indicator is based on Biomass, so it should be Biomass of mega-spawners or something similar.

Table 4.2.2.1. 5th Column. Lopt/Lmega. According to Chapter 3, Lmega = 1.1*Lopt, so one of the two reference limits should be used (they are not the same). Also, since for some of the stocks considered FISHBASE parameters were used, the authors should discuss somewhere the quality of this source and mention that such parameters would be needed at stock level.

Life-history parameters from Table 4.2.2.1 were used as cut-off points to determine the proportion of megaspawners (L_{opt} for Pmega) or mature individuals (Lmat for Pmat) and the abundance of megaspawners (cpuemega). **Future workshops need to review L_{MAT} for stocks**, as for example in Table 4.2.2.1 the FISHBASE Lmat for haddock is far higher than actually found and Lmat for cod-347d differs by ~ 30 cm depending on population deme (e.g. Wright et al., 2011a,b).

4.3.3 Discussion

Page 37. The first paragraph should also refer to other elements to be considered in data treatment to estimate indicators, such as spatial aggregation (e.g. stratification or other approaches), and lack of some specific parameters).

The results should be treated with great caution and should be considered *only as indicative*.

The finding that the relative SBI (L_{95}, Pmega and Pmat) seemed to contain additional information to SSB as indicated by non-linear relationships between these SBI and SSB is particularly important to earlier debates questioning the need for D3.3.

4.5 Recommendation

The reviewers agree with the recommendation that **further investigation of the usefulness of SBI for the assessment of the status of exploited fish stocks is needed**.

SECTION 5: REVIEW ON TIME SERIES BASED ASSESSMENT METHODS

COMMENTS:

The chapter is a well-organized description of TSBA, providing a structured description of up-to-date techniques. Despite the good description, no conclusive suggestions or guidance are provided; possibly a comparison of methods applied to the same time-series could be beneficial in a future WK.

MINOR ISSUES:

5.2.1. Although not being a time-series analysis *sensu stricto*, the basic non parametric correlations should be mentioned. This is a very basic option to assess correlation among variables (indicator vs. time) without any linear assumption.

5.2.2 A question: what about the Rodionov *et al*. method (STARS, eg, Application of a sequential regime shift detection method to the Bering Sea ecosystem (Sergei Rodionov and James E. Overland, ICES J Mar Sci (2005) 62 (3): 328-332)

SECTION 6: EXPLORING THE INFLUENCE OF FISHING SCENARIOS ON SBI USING POPULATIONS MODELS

COMMENTS:

The chapter is rather interesting, and it presents with a clear approach the rational, methods, results and conclusions of the analyses. The approach is sound, given that all limitations are duly considered/mentioned. The reviewers believe that the discussion (in particular, but not only, on reference points) and conclusions are relevant to guide future work on D3 (but also relevant, in itself, for ICES). Part of the reflections on SBI significance in relation to growth overfishing could be possibly used for the executive summary.

MINOR ISSUES:

6.2.2 Page 47. Bottom line, Berg and Kristensen is repeated twice.

6.4 The discussion presents a number of important results. For North Sea cod, the size structure of the population indicates that the stock has not yet recovered to a 'healthy' state despite being classified as being fished sustainably with regards to F and SSB. **This provides some justification for having D3.3**.

In the herring simulations, the SBI in all simulated scenarios had 5th-percentiles that were above the SBI-values observed during the collapse and recovery of the stock, indicating that these could be considered as potential limit reference points.

The discussion of performance supported the use of L_{95} for the entire catch length frequency but this contradicts earlier evidence that this can be heavily influenced by recruitment (later says 'The expected future range of SBI values in these simulations is largely driven by the variability in incoming recruitment and the variability in applied F').

Figures 6.3.1.1.4-5, 6.3.2.2.1-2, 6.3.3.2.1-2. Where L95 is shown, I suggest to super impose the threshold values for e.g. Lm50, Lopt, Lmega (the same, when appropriate, in Annex 4)

6.4.2 Performance of SBI, Page 64. Annex 6 is mentioned, but the reviewers could not find it in the document, please check/integrate.

6.4.3 The section on reference points is important and provides a useful approach for future D3.3 related work.

Dr CM O'Brien

Chair of RGIND3.3ii

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