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Length at maturation of Eastern Baltic cod based on BITS data

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Introduction

The analyses of maturity focused on defining the parameters necessary as input for Stock Synthesis (SS) model, which is length at first maturation and the slope of the curve representing proportion mature at length. Length at first maturation was defined as the length at which half of the fish have become mature, which is from here on referred to as L50. Thus, the analyses presented here only concern defining the length at which 50% of the stock has reached maturity, i.e. does not account for e.g. skipped spawning in larger cod.

Data from BITS Q1 survey in ICES DATRAS database were used for the analyses, for the years 1991-2018. Data from DEN, LAT, LTU, POL, RUS, SWE were included in the analyses (GFR has very little individual fish data for SD25-32 from BITS survey). The analyses do not distinguish between males and females, these were pooled for the analyses.

Countries upload maturity data in DATRAS using different scales for maturity staging and the scales have also changed over time. Therefore, the data for individual countries were first analysed separately, to identify which stages should be classified as mature or immature.

Proportion of maturity stages in different length-groups

The proportion of maturity stages (as uploaded to DATRAS) were plotted for each length group of cod, by country and year, to identify any peculiarities in the data (See Annex 1 for the figures by country). Based on this, data for some years for some countries were excluded from further analyses. The table below shows the number of individuals included in further analyses of size at maturity, by country and year.

Table 1. Number of individuals used in calculations of L50

Year	DEN	LAT	LTU	POL	RUS	SWE	Total
1991		844		834		402	2080
1992				155		284	439
1993		309		653		402	1364
1994				799		1067	1866
1995		390		736		1097	2223
1996		295		1344		1265	2904
1997	1357			1496		1066	3919
1998	2102			1543		847	4492
1999	2483	419		1022		1117	5041

2000	2248	438		491	1031	4208
2001		184			1030	1214
2002		409			2079	1017
2003	145	287		608	1634	1043
2004	1901	709		441	2139	1017
2005	1954	419		608	2017	967
2006	2094	502		418	661	1188
2007	2729	856		475	507	1024
2008	2760	1059		406	1613	1006
2009	624	629		556	2456	977
2010	1024	378		423	2421	1022
2011	623	191		1321	2533	363
2012	1089	160		510		800
2013	611	165	221	408	2479	872
2014	1062	135	204	550		762
2015	842	505	256	526		828
2016	1357	132	147	449		885
2017	1185	593	60	478		787
2018	799	63	251	436	824	625

Classification of stages to immature or mature

Based on the figures in Annex 1 and consultations with national experts, the stages were classified as mature(spawner) or immature (non-spawner). Classification of maturity stages to mature or immature was relatively straightforward for some countries (e.g. SWE, DEN), where the maturity scale applied allows directly distinguishing between mature and immature. Also, the proportion of stages by length (Appendix 1) did not reveal severe peculiarities in these countries data, showing a clear signal towards an increased proportion mature with length.

For some countries, the “resting” stage (i.e. stage 5, II) was found problematic to interpret, whether these fish should be considered as mature or not. In the SWE and DEN data, there were only a few fish at stage 5 and these were mostly larger individuals, i.e. larger than the length where full maturity had already been reached. In contrast, e.g. POL data contained a lot of fish at stage 5 for all sizes of cod. Further, stage II in POL and LAT data is considered to contain both mature and immature individuals, representing large part of the fish analysed.

Thus, among the countries that have longer time series of maturity data, with larger number of individuals analysed also in later years, SWE and DEN maturity data was most straightforward to interpret. For this reason, two scenarios of L50 were calculated:

- i) Using only SWE and DEN data
- ii) Using data from all countries, with a conservative assumption that the fish classified as resting (stage 5, II) are not part of the spawning stock

Table 2 below describes classification of maturity stages for each country. The analyses only concern defining the length at which 50% of the stock has reached maturity, i.e. does not account for e.g. skipped spawning in larger cod.

Table 2: Classification of maturity stages (as uploaded in DATRAS) to mature and immature, for the purpose of L50 calculation, for the years included in the analyses.

Country	Years	Stages in DATRAS	Interpretation
DEN	1997-2003 2004-2018	1-5 61-66	1: Immature 2-5: Mature 61: Immature 62-66: Mature
LAT	1991-2000, 2004-2007 2001-2003, 2008-2018	1-5 I-VI	1,5: Immature 2-4: Mature I-II: Immature III-VI: Mature
LTU	2013-2015 2016-2018	61-66 II-VII	61: Immature 62-66: Mature II: Immature III, IV, VII: Mature
POL	1991-2000 2004-2018	1-5 I-IX	1,5: Immature 2-4: Mature I-II: Immature III-IX: Mature
RUS	2002-2011 2013,2018	1-5 I-VIII	1: Immature 2-5: Mature I-II: Immature III-VIII: Mature
SWE	1991-2007 2008-2018	1-5 I-IX	1: Immature 2-5: Mature I-II: Immature III-IX: Mature

Maturity at length curves

Based on the classifications described in Table 2, proportion mature at length curves were derived, both for the scenario i) using only SWE and DEN data, ii) using data from all countries. The curves are shown in Annex 2.

From these figures it was apparent that the part of the curve representing larger cod (ca > 50 cm) was often noisy, i.e. not going up to 1 (100% maturity). This is because of the outliers observed in the data as seen in Figures in Annex 1, i.e. fish occasionally classified as immature at large size. Further, in the version with all countries data included, the uncertain “resting “ stage that was not included as part of mature stock, is blurring the maturity curves, as these fish occurred in all sizes in some countries data. Nevertheless, in almost all years, the curve for smaller cod (ca <50cm) was reasonably clear, showing a continuous increase towards 100 % maturation with length. This part of the curve representing smaller cod on their way of reaching maturation is of largest importance for L50 calculation.

To reduce the noise in the data for larger cod, all fish that were otherwise classified as immature but had a length of >50 cm were set as mature. The adjusted proportion mature at length curves are shown in Annex 3, and this adjusted datasets were used in a next step for L50 and slope calculations.

Calculation of L50 and the slope

The L50 and slope values were calculated for two different datasets:

- i) Using only SWE and DEN data
- ii) Using data from all countries

L50 for each year was calculated using glm, with binomial form:

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glm (mature_or_immature ~Length, family=binomial)
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The slope was derived as a coefficient from the model associated with length.

Figure 1 shows the comparison of the results for the two sets of data used.

The long-term dynamics of L50 were generally very similar in the calculations using the two different sets of data (i or ii). Importantly, the substantial decline in the size at maturation is clearly visible in both datasets, indicating maturation at ca 20 cm in length in later years. This result appears to be robust to the uncertainties associated with classification of some maturity stages, as described above. In conclusion, the L50 estimates as input to stock assessment are robust to whether i) only SWE and DEN or ii) all countries data are used in the calculations.

The apparent outlier for 2014 when using only SWE and DEN data is due to unusual distribution of maturity stages in SWE data in that year (see Annex 1).

In Stock Synthesis model, time variations in parameters can be taken into account via using separate values by blocks of years. The years were grouped based on visual judgement of when largest changes in L50 occurred:

Table 3. Average L50 values by periods of year, as input to Stock Synthesis model

Time period	L50, cm
1991-2000	35
2001-2005	32
2006-2014	27
2015-2018	21

The estimations of slope (Figure 2) are more variable, with not as clear trend over time as for L50. The value for slope is generally higher in the version using only SWE and DK data. Differences in slope obtained depending on the dataset used are likely associated with uncertainties regarding the resting stage, which was present in the data for all sizes of cod. An average value obtained from the analyses and over the entire time series (0.23) is suggested as an input for slope in Stock Synthesis model.

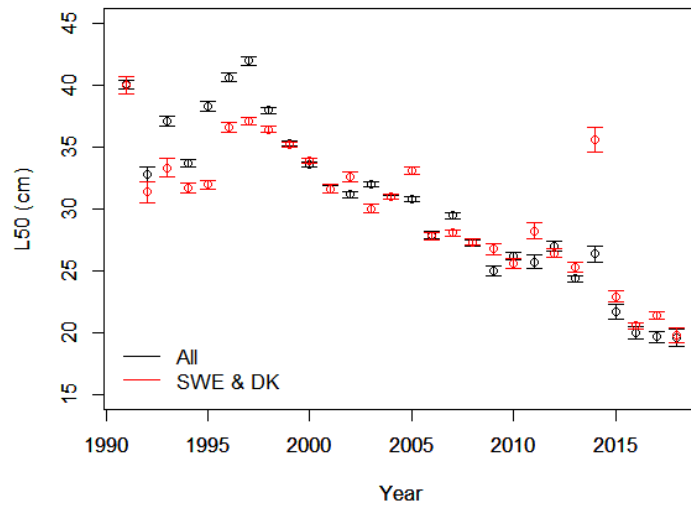


Figure 1. Time series of L50 of EB cod, combined for females and males (incl. error in the estimation of L50), using i) only SWE and DK data, or ii) all countries data.

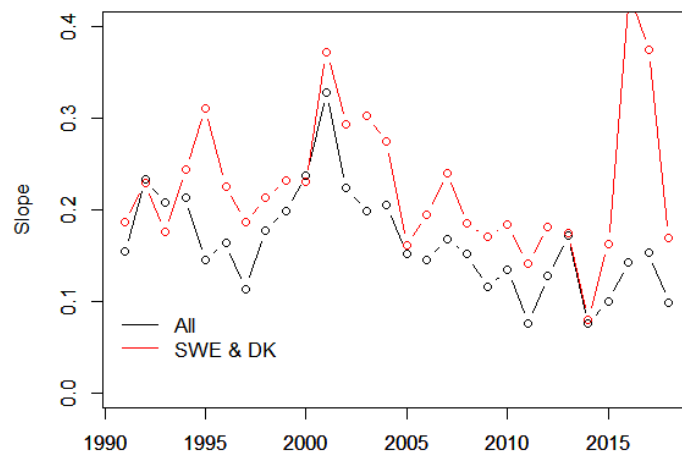
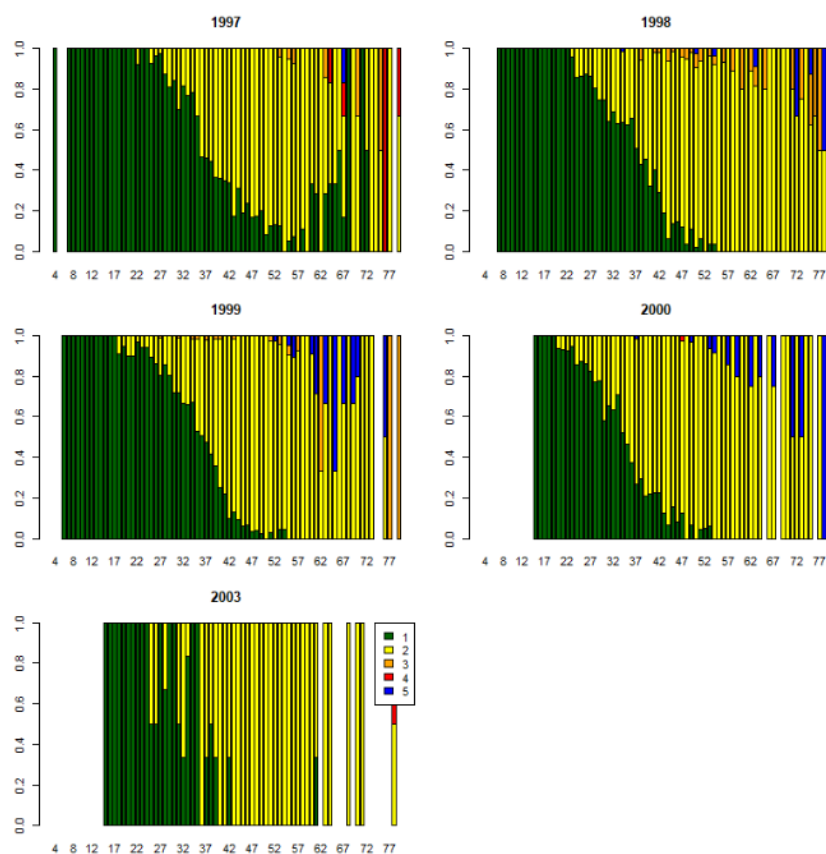


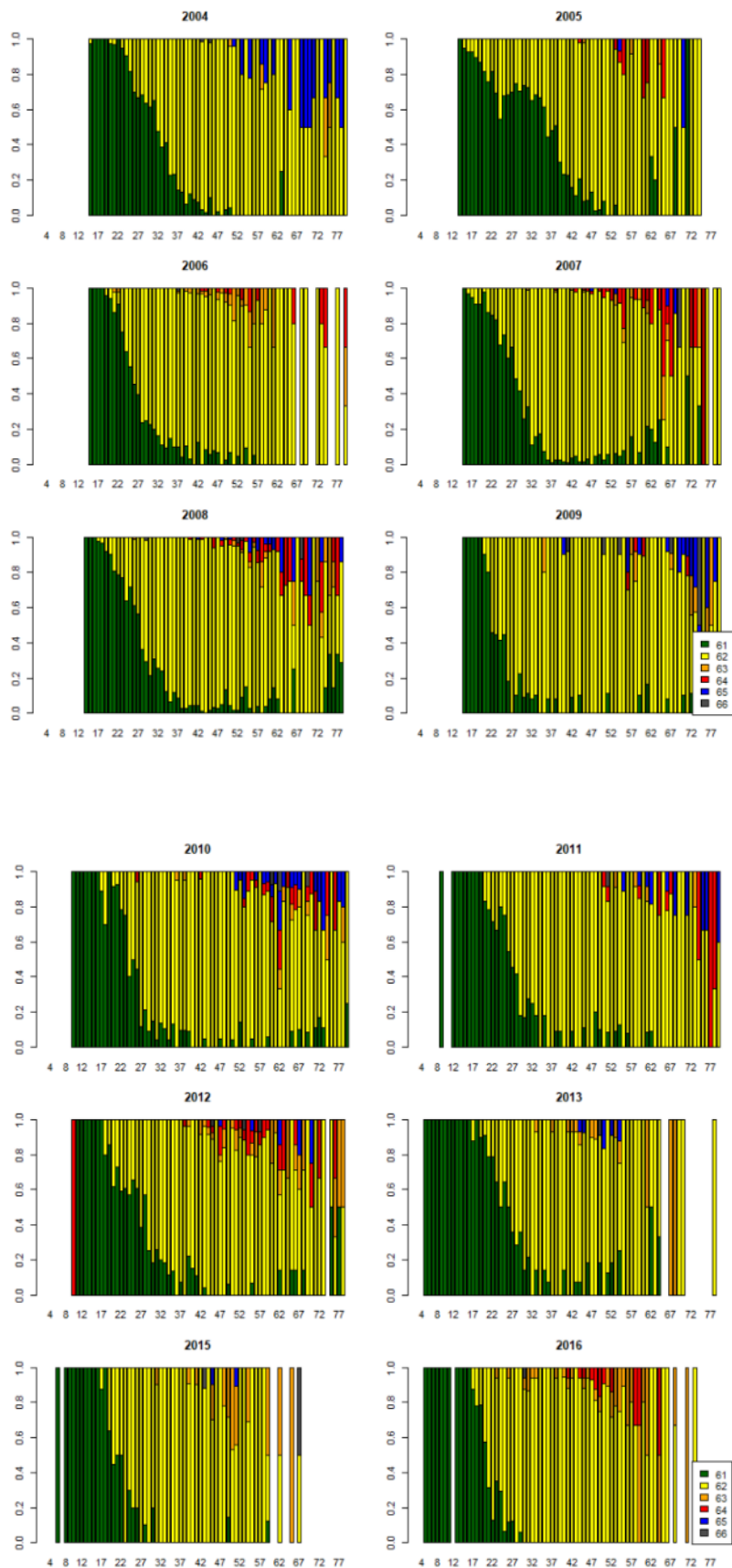
Figure 2. Time series of slope, using i) only SWE and DK data, or ii) all countries data.

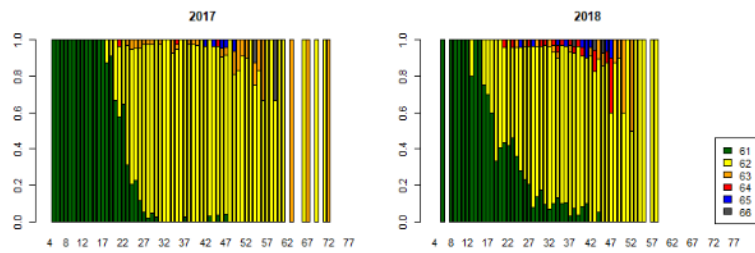
Annex 1. Proportion of maturity stages by cod length, by country and year

The figures show proportion of maturity stages (shown in colors) by cod length (x-axis).

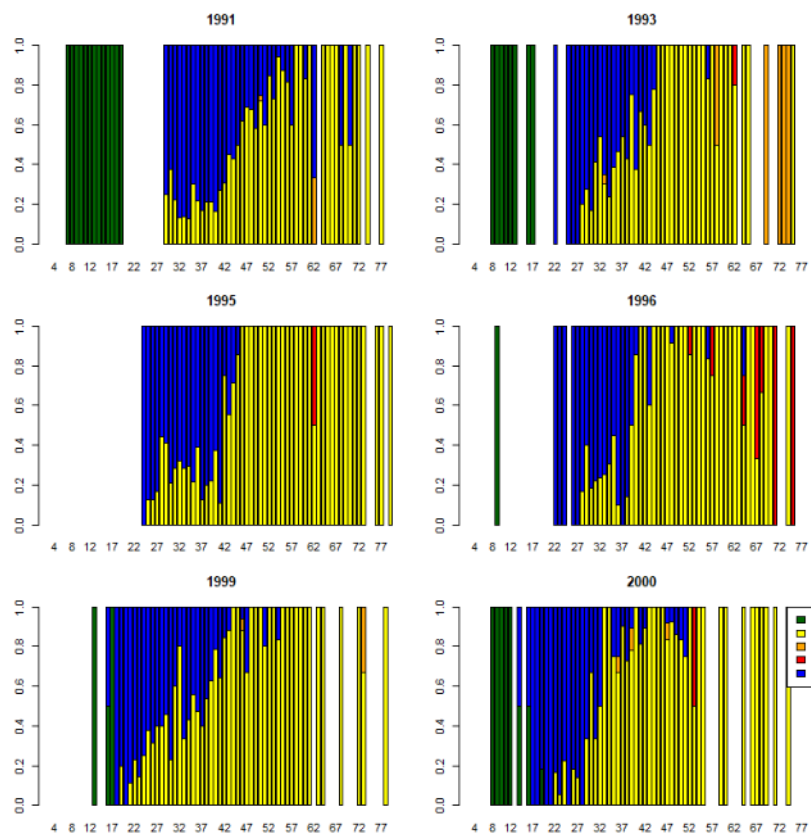
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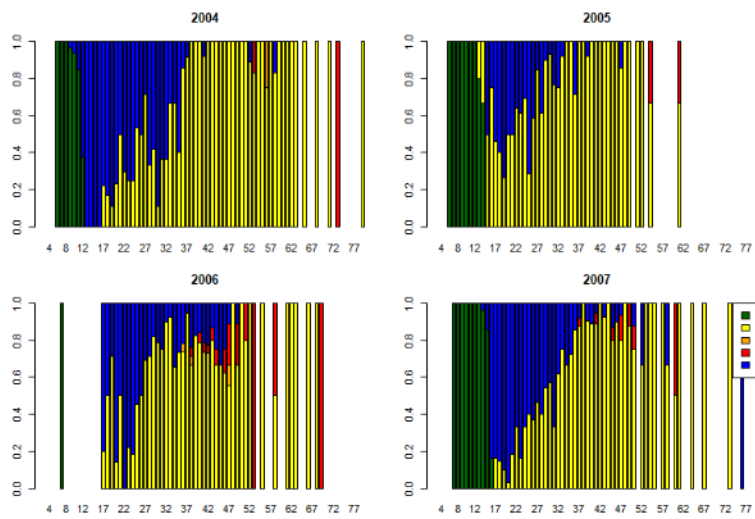
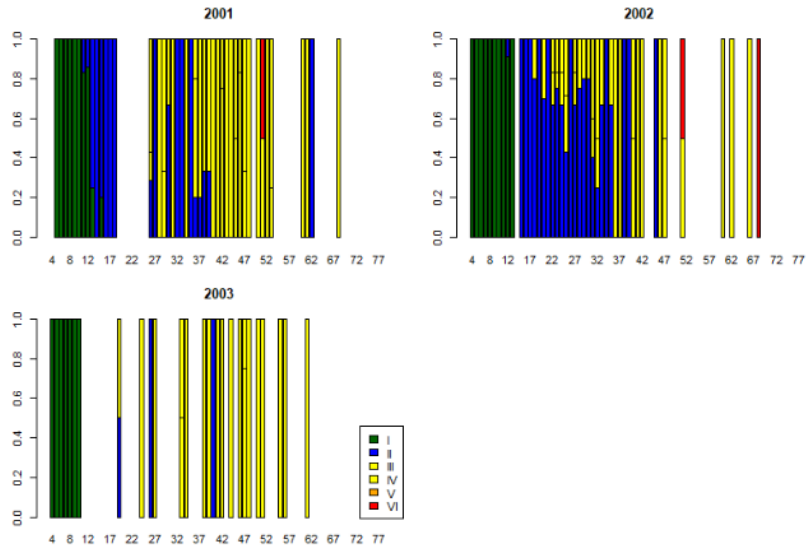


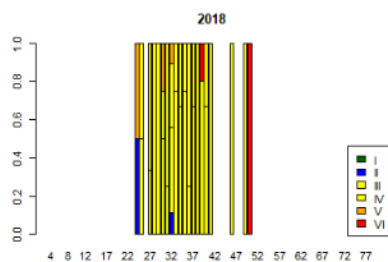
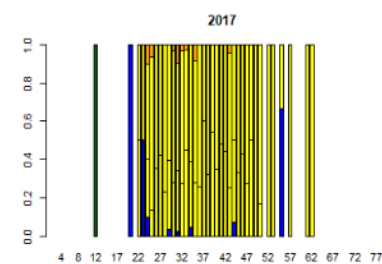
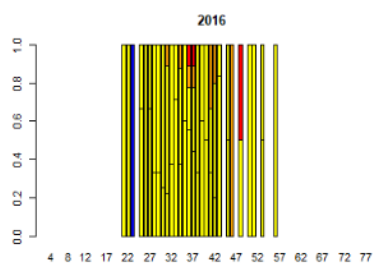
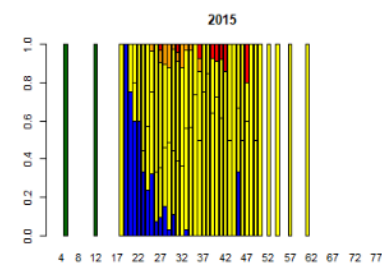
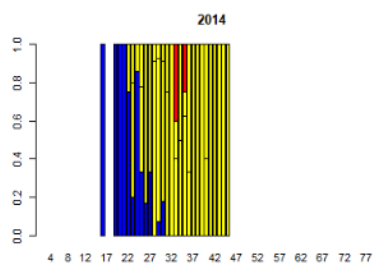
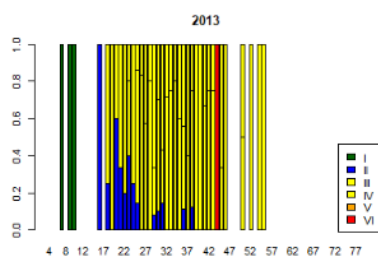
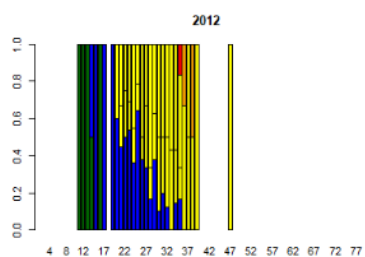
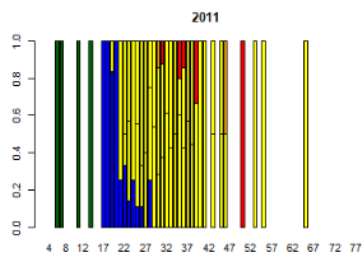
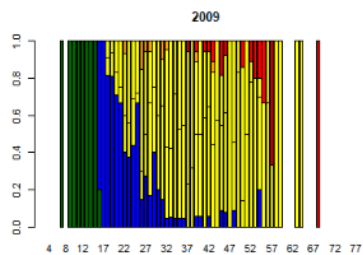
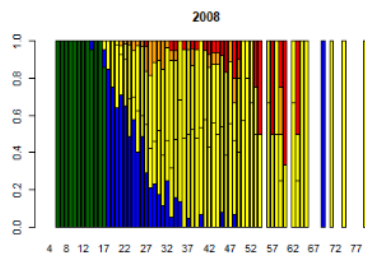




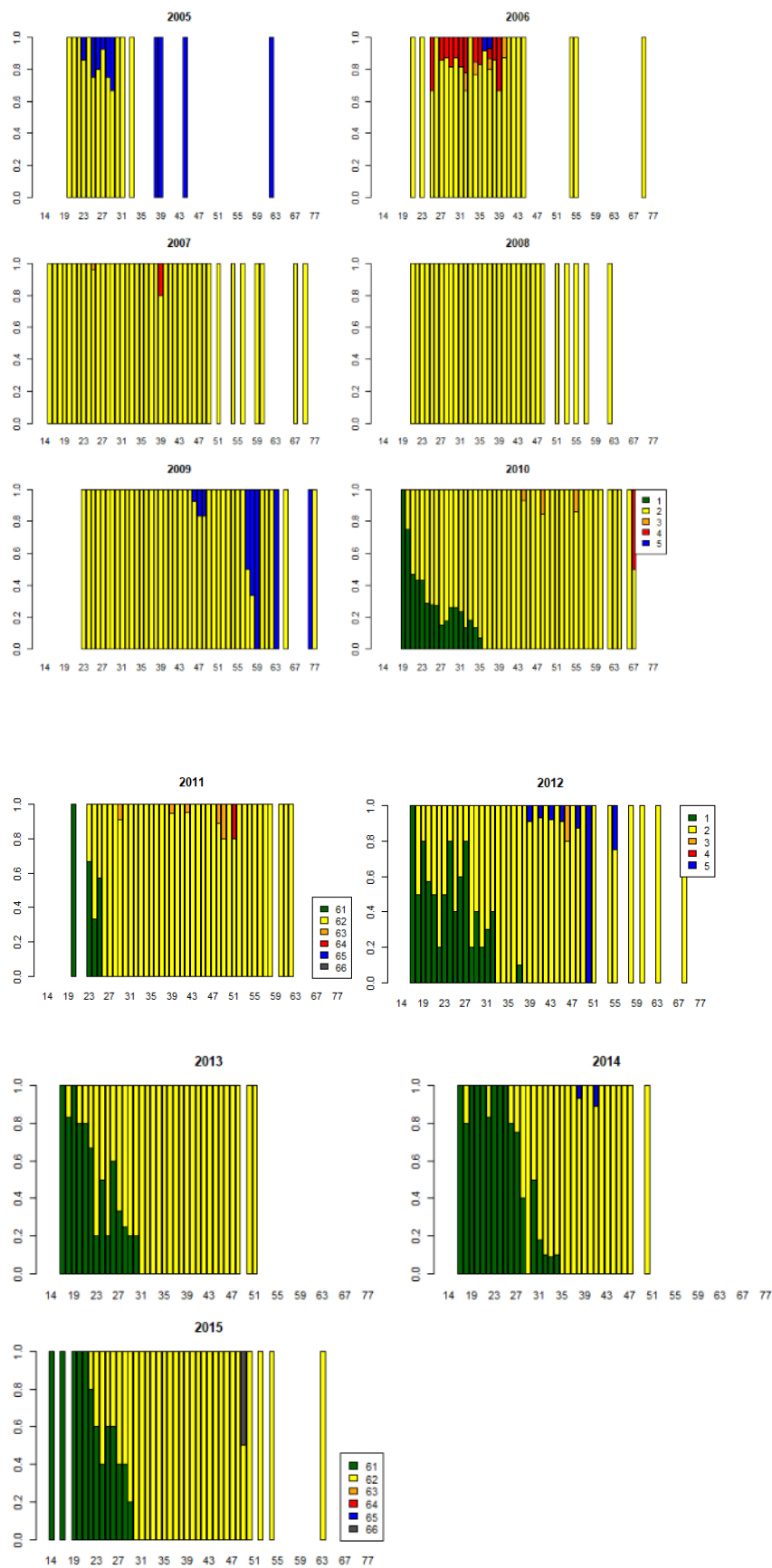
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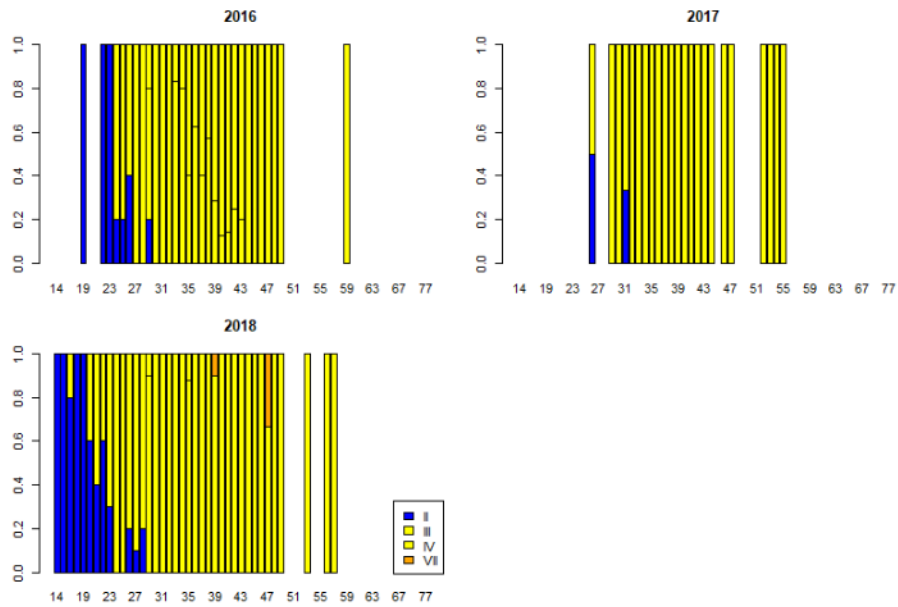




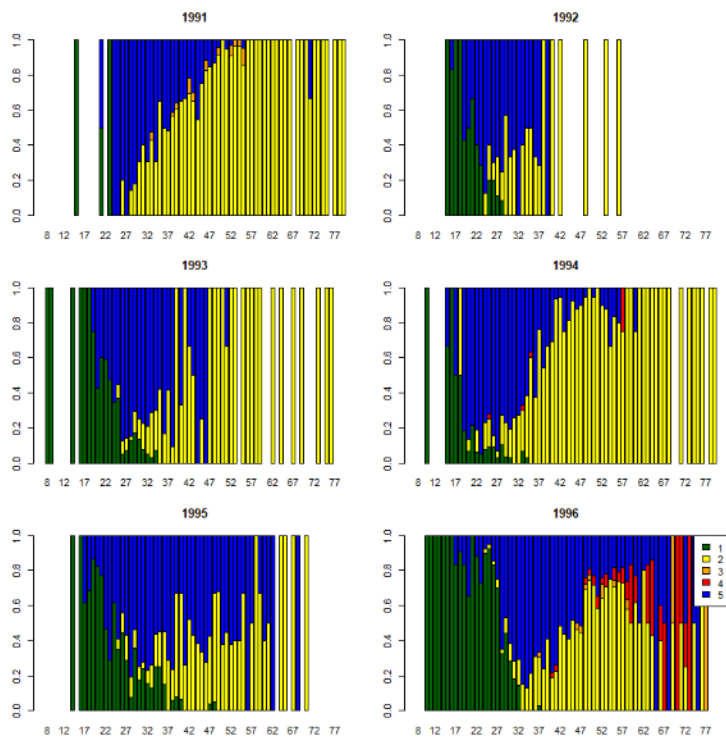


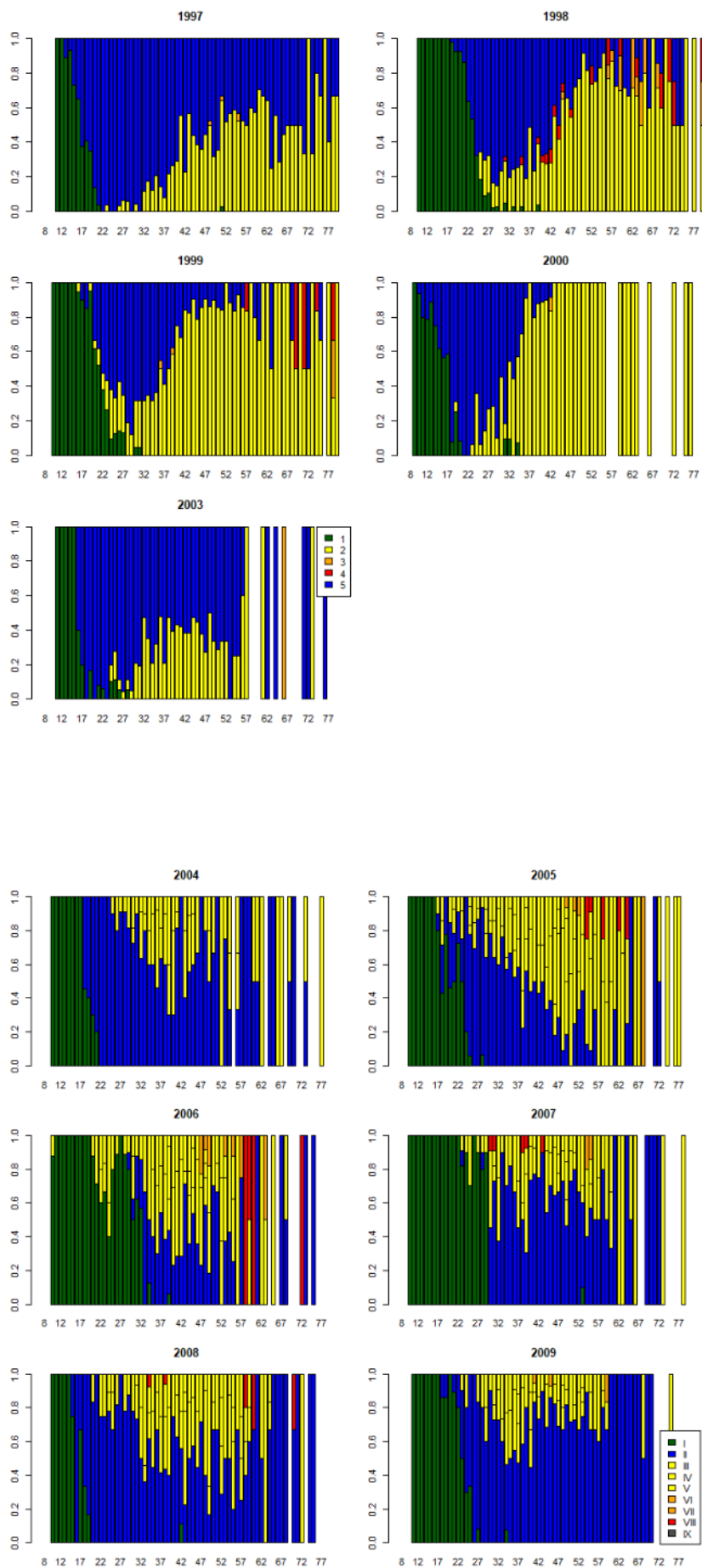
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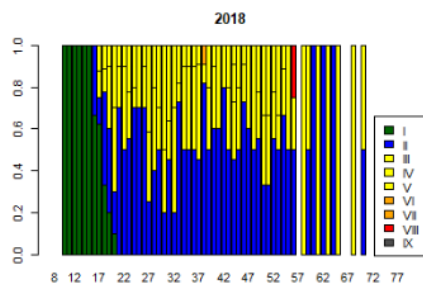
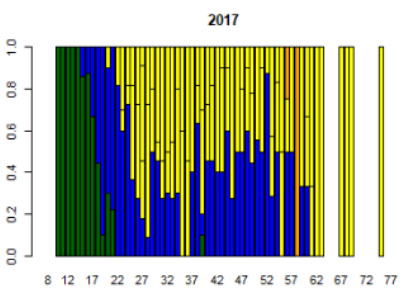
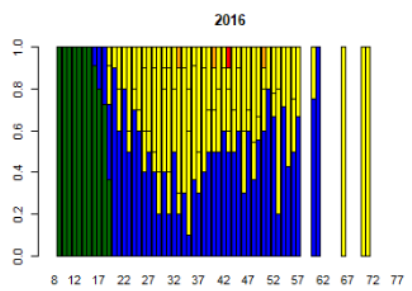
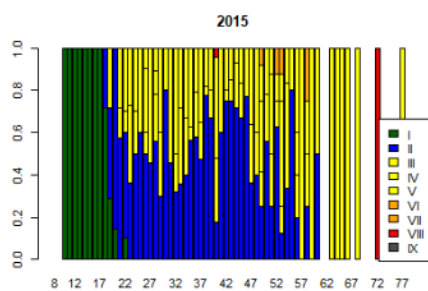
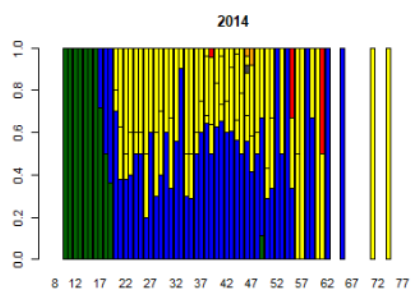
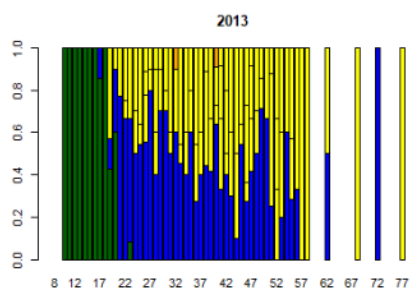
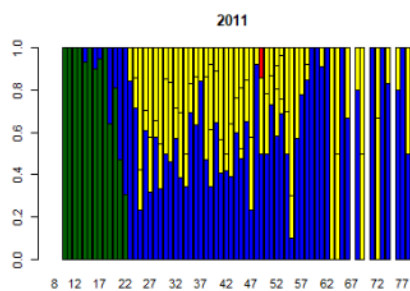
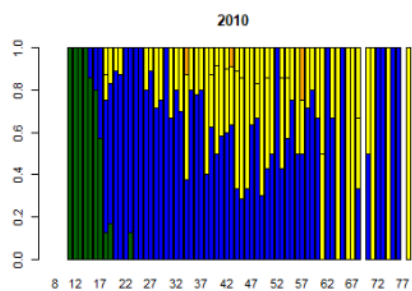




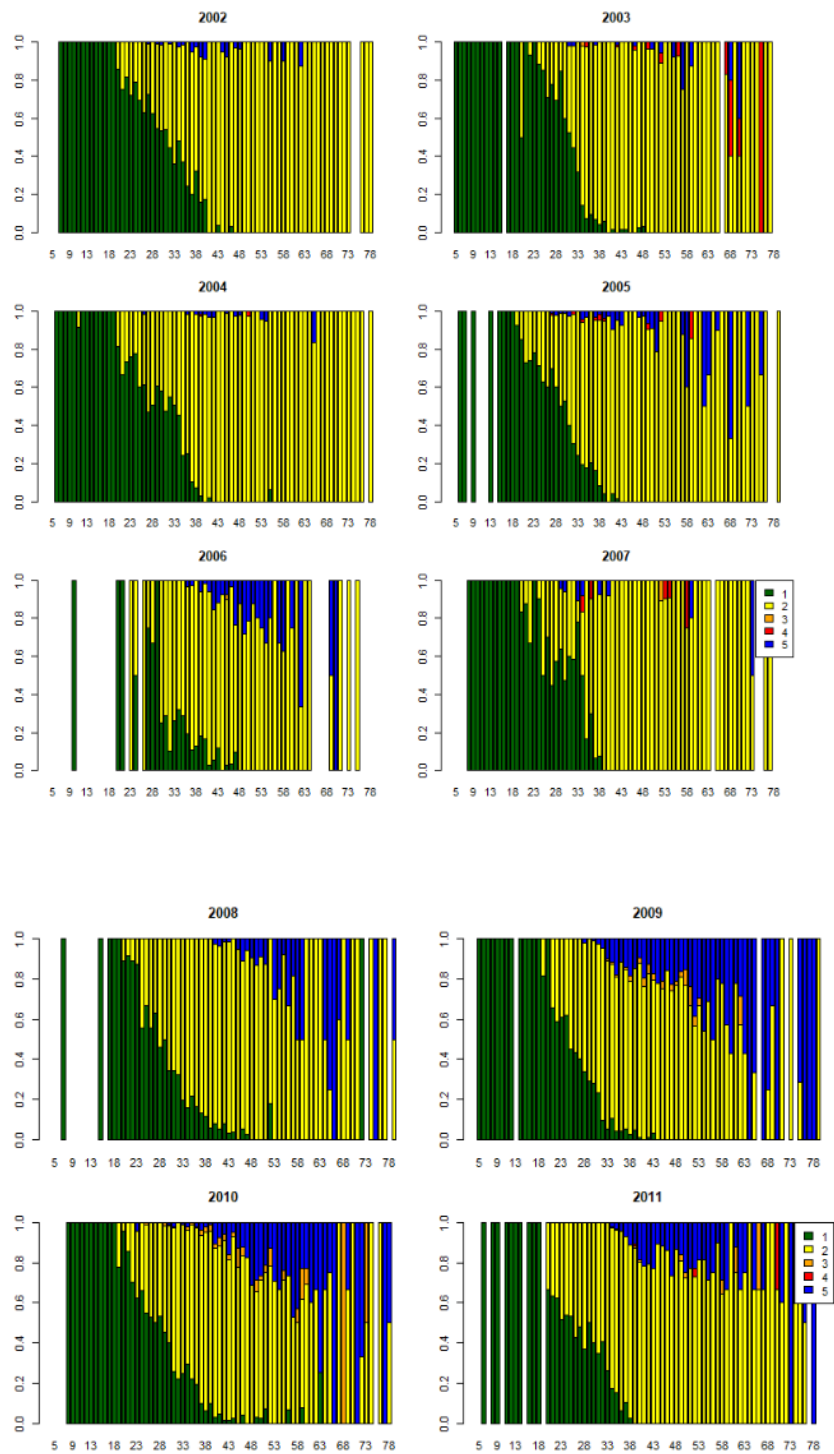
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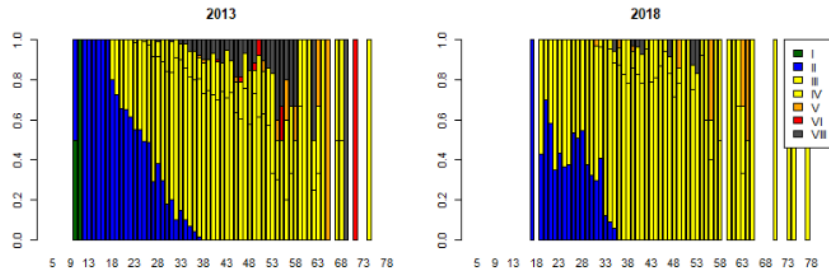




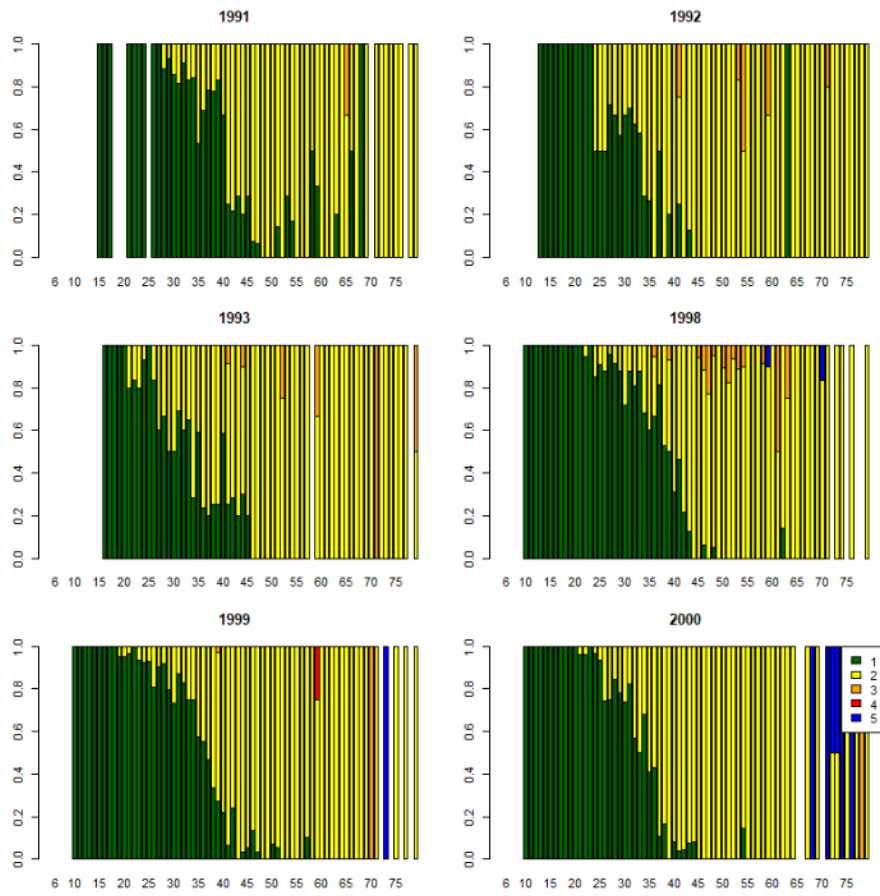


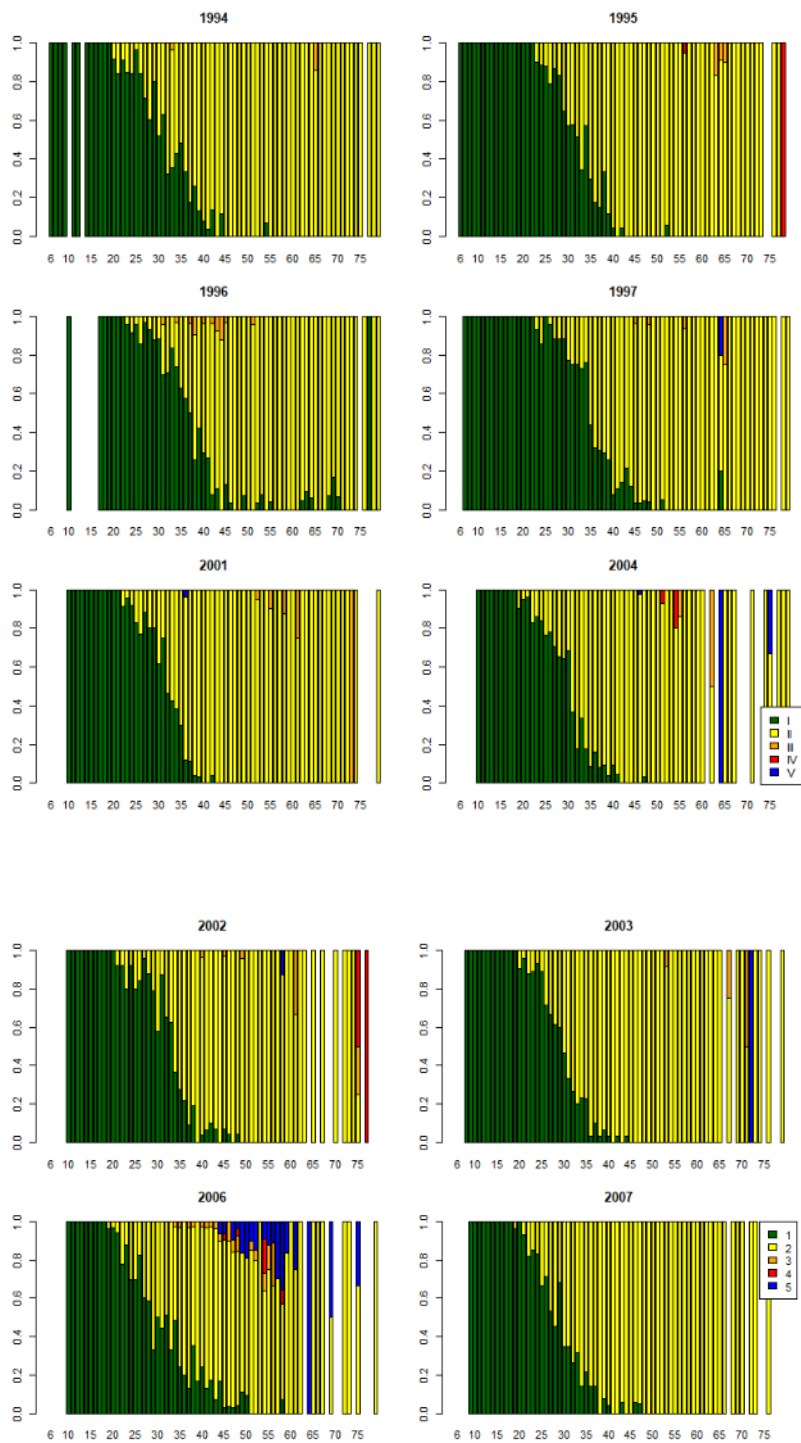
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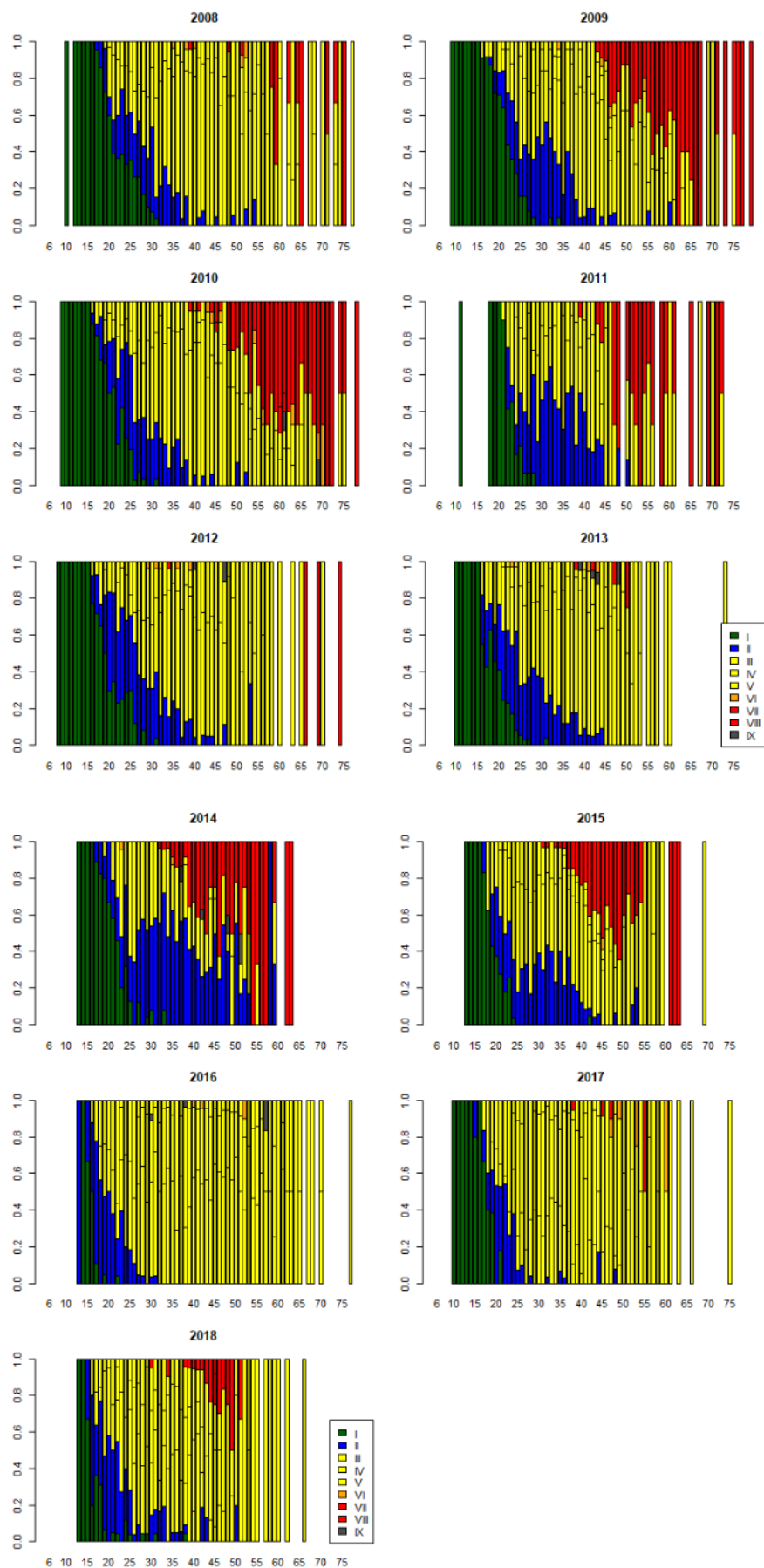




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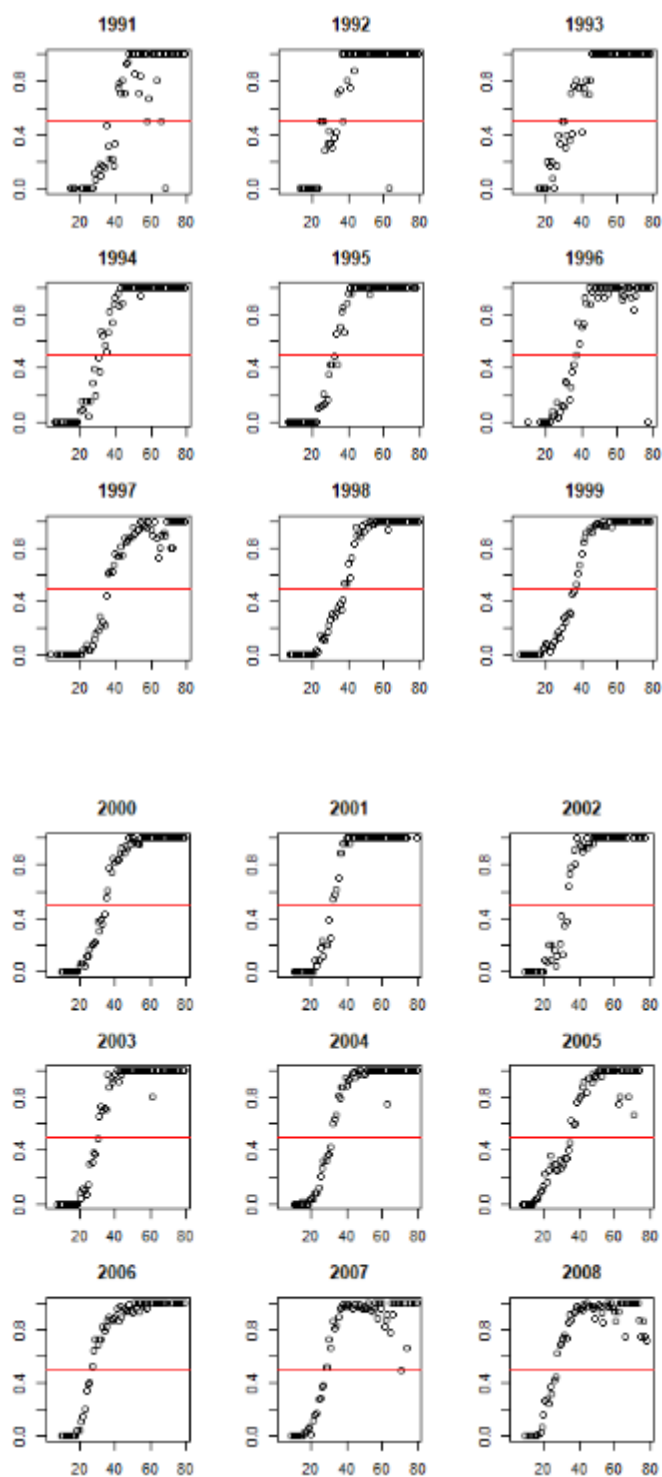


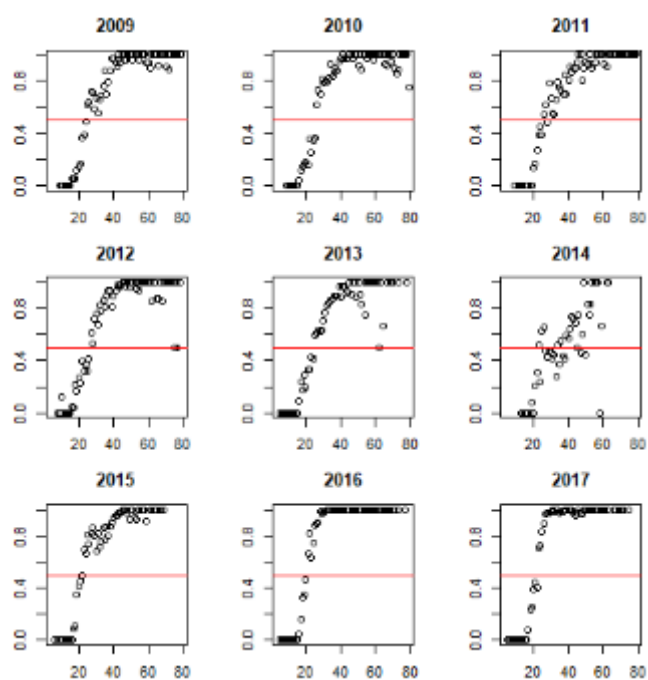




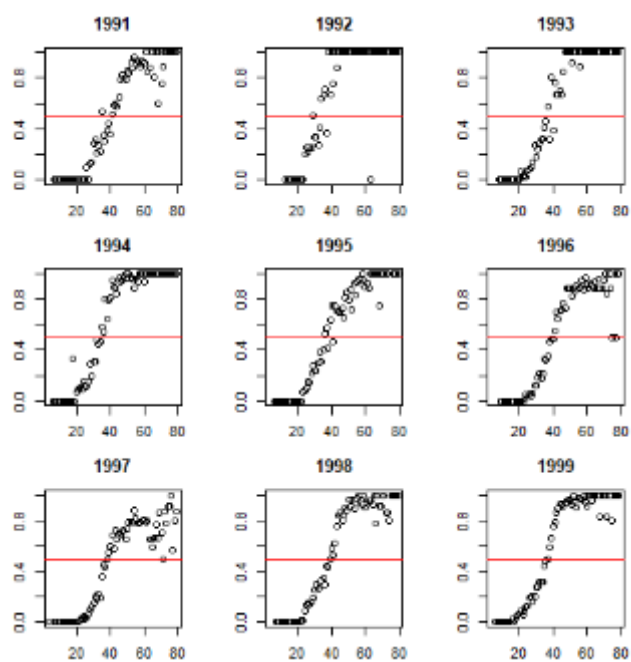
Annex 2 Proportion mature at length curves (original data)

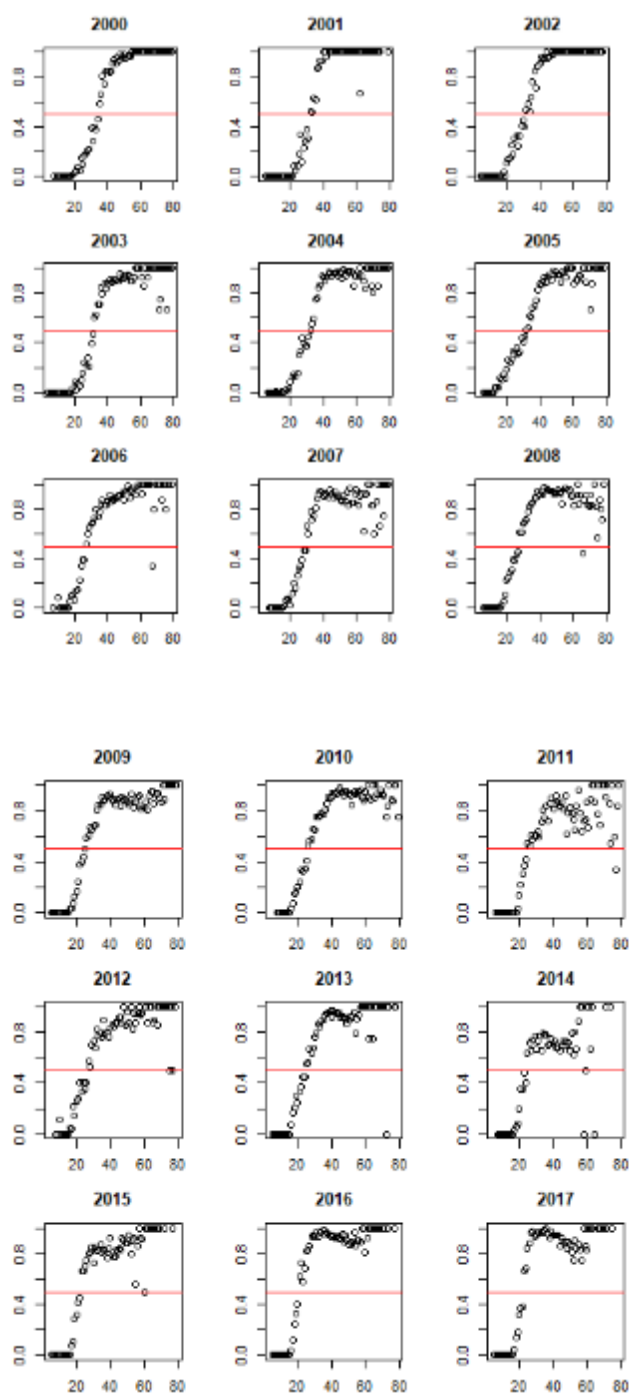
Data from only SWE and DEN:





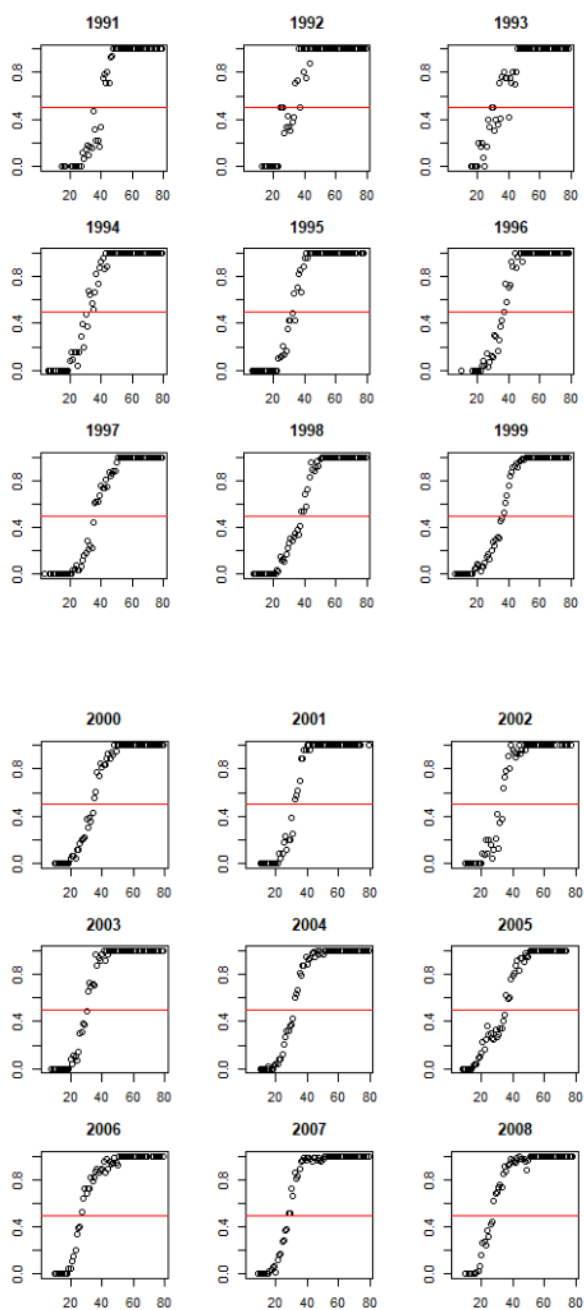
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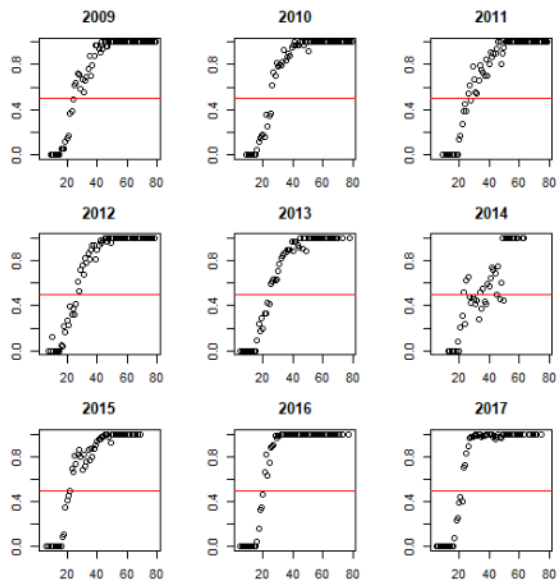




Annex 3. Proportion mature at length curves (adjusted for >50 cm cod)

Data from only SWE and DEN:





Data from all countries:

