8 Icelandic saithe

8.1 Stock description and management units

Description of the stock and management units is provided in the stock annex.

The stock was benchmarked and the management plan evaluated in March 2019 (ICES, 2019a). The result was no change in assessment setup. A minor change in the management plan was introduced as $MGMTB_{trigger}$ was decreased from 65 to 61 thous. tonnes to be in line with ICES MSY $B_{trigger}$. Other reference points were unchanged except HR_{lim} and $HR_{pa.}$ were introduced to replace F_{lim} and F_{pa}.

8.2 Fisheries-dependent data

Landings of saithe in Icelandic waters in 2020 are estimated to have been 50 252 t (Table 8.1 and Figure 8.1). This is considerable reduction from earlier year and not in accordance with the TAC that has been around 80 thous. tonnes for the current and last fishing year. (Figure 8.4)

Of the landings, 43 842 t were caught by trawl, 1794 t by gillnets, and the rest caught by other fishing gear. Most of the catch is taken by bottom trawl (83% in 2010–2017, 90% in 2018–2020, with gillnet and jiggers taking the majority of the rest, 5% each fleet. The share taken by the gillnet fleet was larger in the past, 26% in 1987–1996 compared to 9% in 1998–2020 (Figure 8.1). The reduction in the gillnet fisheries is caused by general reduction in gillnet boats that are mostly targeting cod and increased mesh size in gillnet fisheries targeting cod.

The reduction in the gillnet fleet was driven by boats changing from gillnets (another types of gear) to longlines, a change driven by cod and haddock fisheries. Price of large gillnet cod sold for bacalau reduced compared to "normal size" so it became more economical to operate long-liners that supply fish evenly through the year. Increase in the haddock stock in the early 2000's and progress in automatic baiting were also an important factor.

For saithe fisheries the important factor is that saithe is rarely caught by longliners so the fleet has become much less of saithe fleet than before. The share of longlines has though gradually been increasing from 0.8% before 2000 to 2.2% in 2013–2016 reducing to 1.5% in 2020.

The fleet using demersal trawl can be divided in two parts, those that freeze the catch and those that land it fresh. The trend in last decade has been that the proportion of the trawler fleet that land the catch fresh has increased. Freezing trawlers have taken large proportion of the catch of saithe and redfish but much less of cod and haddock (Figure 16). The main reason for this is relative price of frozen vs fresh fish for each species, but mixed fisheries issues like avoiding redfish when landing fresh fish can be a factor (redfish scratches the bycatch).

Spatial distribution of the saithe fisheries changed much from 2002–2014. (Figures 8.5 and 8.7). Before 2002 most of the saithe was caught south and west of Iceland but since 2012 40–50% of the catch have been taken north west of Iceland. Comparable percentage before 2002 was 3–8%. Similar increase can be seen for golden redfish but redfish and saithe have for a long time been caught by the same vessels, not necessarily in the same hauls, rather as night and day fish. The area where saithe is caught now (Hali Figure 8.7) has since early in the 20th century been the most important cod fishing ground for trawlers.

8.2.1 Logbook data

CPUE from the fleet show increasing trend over time (Figure 8.16 and 8.17). Considerable variability can be seen on top of this trend and all measures of CPUE show substantial reduction since 2018.

The GLM indices shown in 8.17 are compiled by a model of the form .

$$C = T^{\gamma} \times \delta_{year}$$

$$C = T^{\gamma} \times \delta_{year}\delta_{freeze}$$

Where C is catch of saithe, T hours trawled. $\delta_{year}$is an estimated year factor δ_{freeze} a factor indicating if the catch is frozen aboard the vessel. γ is an estimated parameter showing relationship between hours trawled and catch.

Those models give similar trend as the indices compiled directly but the interesting observation of those models is that the models predict inverse relationship between hours trawled and saithe catch ($\gamma = -0.25$) (the models are run on all hauls where saithe is registered).

8.2.2 Landings, advice and TAC

For all Icelandic stocks that are managed by a TAC system the TAC is given for fishing year where fishing year **y/y+1** is from September 1st in the year **y** to August 31st in year **y+1**. Assessment done in the spring of year **y**, is used to give advice for the fishing year starting September 1st the same year. For most stocks the survey conducted in March is the most influential data source and the most recent survey from March in the assessment year is used in the advice.

The management plan and assessment for Icelandic saithe have been identical since 2010 and both advice and TAC based on the 20% harvest control rule. Since 2014/2015 the TAC has not been caught (Figure 8.4) but in the period 1997/1998 to 2013/2014 the TAC was caught in all years except 2007/2008 and 2008/2009. The catch in the fishing year 2019/2020 is estimated to have been 53 thous. tonnes, while the set TAC was 80 000 tonnes.

The Icelandic Fisheries management system allows some transfer between species based on cod-equivalence factors that are supposed to reflect the price of the species compared to cod (see ICES, 2021). Cod is though not included in the system that is quite limited. In recent years saithe has been converted to other species (Figure 8.2) that are probably more economical to catch than saithe. But considerable part of the saithe quota has not been used that might be a signal of over-estimation of the stock or that catching saithe is not economical. As described before, the fleet has been less of a saithe fleet in recent years and historical assessment shows that fishing mortality of Icelandic saithe was never really high (the same applies to other saithe stocks ref).

8.2.3 Landings by age

Compilation of catch in numbers is based on age and length distributions from the catches where the number aged is usually considerably less than number length measured. Discarding is not considered to be a problem in the Icelandic saithe fisheries, with an estimated discard proportion of 0.1% (annual reports by Palsson *et al.*, 2003 and later). Recently, the fleet does also seem to have difficulty in catching the set TAC making discards more unlikely. Since the amount discarded is likely to be small, not taking discards into account in the total catches and catch in numbers is not considered to have major effect on the stock assessment.

Foreign landings that are 194 tonnes are included in the landings above. They are mostly caught by longlines (99 tonnes) and handlines (95 tonnes). All the foreign landings have in recent years been taken by the Faroese fleet.

Catch in numbers are compiled based on 2 fleets, bottom trawl and gillnets, 1 region and 1 season. Bottom trawl accounts for 90% of the landings and other fleets than bottom trawl and gillnet are included with the bottom trawl.

The samples used to derive catch in numbers are both taken by observers at sea and from shore samples. The trawlers that freeze the catch account for majority of sea samples while all shore samples are from fresh fish trawlers. In additions relatively few fishes from sea samples are sampled for otoliths but the age-length keys are most likely similar.

Length distributions from sea and shore samples show some difference in recent years, the shore samples show more of large fish (Figure 8.8). This difference might be reflecting the difference in composition of the catch of the trawlers that freeze the catch and those that land the catch fresh. Excluding sea sampled when compiling catch in number for the year 2020 leads to more of 9 years and older fish but less of other age groups (green and red bars in Figure 8.9).

Length distributions from bottom trawl show tendency to catch smaller fish from 2003–2017 but again larger fish in 2018–2020 (Figure 8.10). In 2020 the +110 cm group is especially abundant.

Numbers sampled in 2018–2020 is shown in Tables 8.2 and 8.3. Sampling effort was low in 2020, mostly due to Covid. In recent years sea samples account on the average for about 77% of the length measured fish that is used in the calculation of the catch in number and 67% of the length samples. On the other hand, 25% of the aged otoliths come from sea samples. These numbers are different in 2020 when no aged fish and 50% of length measured fish come from sea samples.

90% of the length samples are taken from trawl that accounts for ~90% of the catches.

The sampling program has been revised in last decades, the number of age samples reduced and the number of fish per sample has also reduced (Figure 8.3 and stock annex).

Two age-length keys are used to calculate catch at age, one key for the gillnet catch and another key for other gears combined. The same length-weight relationship ($W = 0.02498 * L^{2.75674}$) is applied to length distributions from both fleets.

Catch in numbers by age are listed in Table 8.4 and Figure 8.9 where they are compared to prediction from last year, not fitting too well (red and blue bars).

In recent decade increased proportion of saithe catches has been caught north-west of Iceland (Figure 8.5). This situation could lead to potential problem, if the sampling effort does not follow distribution in the catches. To look at this problem catch in numbers were recompiled using 12 cells, 3 gear (bottom trawl, gillnets and handlines), 2 areas (north and south) and 2 time periods (Jan–May and June–Dec). The resulting catch in numbers are nearly identical (Figure 8.11) and using it in assessment leads to less than 1% difference of reference biomass.

8.2.4 Mean weight and maturity at age

Weights of ages 3–6 have been low in recent years, but older ages are close to average weight (Table 8.5 and Figures 8.12–8.14). The large 2012 year class has the lowest mean weight of all year classes, both in catches and in the survey. This is in line with density dependent growth that has been observed in this stock and can for example be seen for year classes 1984 and 2000 that are both large. Year classes 2013 and 2014 that seem to be above average have higher mean weight at age than the 2012 year class. The long-term trend since 1980 has been a gradual decline in the weight of all ages.

Weight at age in the landings are used to compile the reference biomass (B4+) that is the basis for the catch advice. Catch weights are also used to compile the spawning stock. Catch weights for the assessment year are predicted by applying a linear model using survey weights in the assessment year and the weight of the same year class in catches in the previous year as predictors (Magnusson, 2012 and stock annex).

Maturity at ages 4–9 has decreased in recent years and is currently around average since 1985 (Table 8.6 and Figure 8.11). A model using maturity at age from the Icelandic groundfish spring survey is used to derive smoothed trends in maturity by age and year (see stock annex).

8.3 Scientific surveys

In the benchmarked assessments from 2010 and 2019, only spring survey data are used to calibrate the assessment. Compared to the autumn survey the spring survey has larger number of stations (lower CV) and longer time series. Saithe is among the most difficult demersal fishes to get reliable information from bottom trawl surveys. In the spring survey, which has 500–600 stations, a large proportion of the saithe is caught in relatively few hauls and there seems to be considerable inter-annual variability in the number of these hauls.

The biomass indices from the spring survey (Figure 8.12) fluctuated greatly from 1985–1995 but were consistently low from 1995–2001. Since 1995 the indices have been variable but compared to the period 1985–1995 the variability seems “real” rather than noise. This difference is also seen by the estimated confidence intervals of the indices that are smaller after 1995. In 2018 the indices were the highest in the series and had tripled since 2014. (Table 8.7 and Figure 8.12). Most of the increase was caused by year class 2012 that was strong in the surveys 2015–2018 (Figure 8.14). The biomass index from the March survey shows lower index in 2019 than recent years (Figure 8.12). The reduction since 2018 that was the highest value in the series (the 1986 value is considered an outlier) is around 50%. Similar reduction in survey biomass has been seen before.

Estimated CV from the survey is often relatively high and many relatively low values appear in the survey matrix, both for the youngest and oldest age groups. The youngest age group (age 3–4 and younger) are considered to inhabit waters shallower than the survey covers and the older age groups are reducing in numbers and could also be pelagic.

To take this into account the survey residuals are compiled as $\frac{log(I+\epsilon)}{log(\hat{I}+\epsilon)}$ where ϵ is a number that should avoid giving low values too much weight as they do in log-log fit. Typical value of ϵ is the value that 3–4 otoliths will give, that would be 0.15 for saithe. Higher values are used for saithe 0.3 for the older ages, 0.5 for ages 3–5 and 0.7 for age 2, a value giving age 2 very low weight except the index if very high.

Looking at the CV large part of the high biomass in 2018 was caused by age 6, a value with relatively high CV.

The autumn survey shows similar trend as the spring survey and the index is at high level in 2017 (2004 and 2018 are outliers due to large CV). The values before 2000 might be underestimate due to stations added in 2000 (Figure 8.6) where large schools of saithe are sometimes found. Excluding these stations leads to lower but more stable index.

Catchcurves from the survey indicate that Z ~ 0.5 assuming similar q with age (Figure 8.22).

Indices from the gillnet survey conducted south and west of Iceland since 1996 were high from 2015–2020 but the 2021 value is lower. (Figure 8.13). The gillnet survey is mostly targeting large saithe (mean weight in 2021 was 6.7 kg).

To summarize, survey indices and CPUE from last 2–4 years indicate decreasing stock.

The high index in March 1986 (Figure 8.18) is mostly the result of one large haul that is scaled down to the second largest haul when compiling indices for tuning. The scaling is from 16 tonnes to 1 tonne.

Internal consistency in the March survey measured by the correlation of the indices for the same year class in 2 adjacent surveys is relatively poor, with R^2 close to 0.46 where it is highest (Figure 8.21).

8.4 Assessment method

In accordance with the recommendation from the benchmark (ICES, 2019a), a separable forward-projecting statistical catch-age model Muppet (Björnsson 2019), developed in AD Model Builder, is used to fit commercial catch at age (ages 3–14 from 1980 onwards) and survey indices at age (ages 2–10 from 1985 onwards). The selectivity pattern is constant within each of 3 periods (Figure 8.23). Natural mortality is set at 0.2 for all ages. The survey residuals ($\frac{log(I+\epsilon)}{log(\hat{I}+\epsilon)}$) are modelled as multivariate normal distribution with the correlation estimated (one coefficient).

The assessment model is also used for short term forecast, the Muppet model can't be run without prediction.

The input for the short-term forecast is shown in Tables 8.3, 8.4 and 8.7. Future weights, maturity, and selectivity are assumed to be the same as in the assessment year, as described in the stock annex. Recruitment predictions are based on the segmented stock-recruitment function estimated in the assessment model which is essentially geometric mean when the stock is above estimated break point that is near B_{loss}.

8.5 Reference points and HCR

In April 2013, the Icelandic government adopted a management plan for managing the Icelandic saithe fishery (Ministry of Industries and Innovation, 2013). ICES evaluated this management plan and concluded that it was precautionary and in conformity with ICES MSY framework.

The management plan for the Icelandic saithe fishery, adopted for the first time in 2013 was reevaluated by ICES in March 2019 and found to be precautionary and in conformity with ICES MSY approach (ICES, 2019a).

The TAC set in year *t* is for the upcoming fishing year, from 1 September in year *t*, to 31 August in year *t*+1. The TAC according to the management plan is calculated as follows.

If $SSB_y \geq MGMTB_{trigger}$

$$Tac_{y/y+1} = \frac{Tac_{y-1/y} + 0.2 \times B_{4+,y}}{2}$$

If $SSB_y \leq MGMTB_{trigger}$

$$Tac_{y/y+1} = \alpha \times Tac_{y-1/y} + (1-\alpha) \times \frac{SSB_y}{MGMTB_{trigger}} \times 0.2 \times B_{4+,y}$$

$$\alpha = 0.5 \times \frac{SSB_y}{MGMTB_{trigger}}$$

Where $Tac_{y/y+1}$ is the TAC for the fishing year starting 1 September in year y ending 31 August in year $y+1$. $B_{4+,y}$ the biomass of age 4 and older in the beginning of the assessment year compiled from catch weights. The latter equation shows that the weight of the last years Tac does gradually reduce from 0.5 to 0.0 when estimated SSB changes from $MGMTB_{trigger}$ to 0.

Reference points were also reevaluated at WKICEMSE 2019 (See table below and ICES, 2019a). B_{lim}, B_{pa}, $MSYB_{trigger}$, HR_{MSY} and HR_{Mgt} were unchanged, $MGMTB_{trigger}$ changed from 65 to 61 thous. tonnes and HR_{lim} and HR_{pa} were defined but earlier F_{lim} and F_{pa} had been defined.

Item	B_{lim}	B_{pa}	$MSYB_{trigger}$	$MGTB_{trigger}$	HR_{MSY}	HR_{Mgt}	HR_{lim}	HR_{pa}
Value	44	61	61/65	61	0.2	0.2	0.36	0.26/0.25
Basis	B_{loss}/1.4	B_{loss}	B_{pa}	B_{pa}	Stochastic simulations.			

The recipe to evaluate MSY $B_{trigger}$ and HR_{pa} has changed since 2019 so those reference points were evaluated based on the same simulations as in 2019, leading to MSY $B_{trigger}$ = 65 thousand tonnes and HR_{pa} = 0.25.

8.6 State of the stock

The results of the principal stock quantities (Table 8.8 and Figure 8.24) show that the reference biomass (B4+) has historically ranged from 130 to 410 kt (in 1999 and 1988), but this range has been narrower since 2003, between 220 and 410 kt. The current estimated stock size of $B4+_{2021}$ = 382 kt is among the highest values in the time series. Spawning biomass is estimated as 221 kt, among highest in the timeseries.

The harvest rate peaked around 28% in the mid 1990's but has since 2013 been below HR_{Mgt} target of 20%. The explanations for lower than intended harvest rate since 2013 are that the allocated TAC has not been fished and the stabilizer was reducing the TAC when the stock was increasing. Fishing mortality has been low since 2004 compared to before that. Part of the difference is caused by change in selection pattern (Figure 8.23) that leads to F before and after 2004 not being comparable measures of fishing pressure. SSB has been at a relatively high level during the last ten years.

Recruitment has been relatively stable since year class 2006, above average. Year class 2012 is estimated to be strong and year classes 2013 and 2014 above average. Year class 2015 is estimated as poor but year classes 2016–2018 around geometric mean. Geometric mean is the first guess in the model for each year class. Deviations from the mean are then driven by the survey and catches but survey indices for ages 3 and 4 have been around average in recent years, except for year class 2015 where all survey indices have been low and the year class estimated poor since in the 2018 assessment.

The details of the fishing mortality and stock in numbers are presented in Tables 8.9 and 8.10.

The commercial catch-at-age residuals in 2020 (Figure 8.28) are positive age 9 and older except for age 10. The more or less positive residuals for old fish are not unexpected as unusually much large fish was caught in 2020 (Figure 8.10), and proportion of age 9 and older in 2020 is higher than expected (Figure 8.9). The survey residuals (Figure 8.27) show large positive values in 2018 for ages 4–7, the age groups accounting for most of the biomass, therefore the survey biomass in 2018 exceeds prediction by large margin (Figure 8.26). The 2019–2021 residuals are relatively small with both positive and negative values leading to similar observed and predicted survey biomass.

Assumptions about catch in the assessment year deviate from the stock annex that specifies the catch in the calendar year 2021 as the remaining TAC from the fishing year 2020/2021 at 1 January 2021 plus 1/3 of the catch in the fishing year 2021/2022. 63 thousand tonnes of the catch for the fishing year 2020/2021 were remaining 1 January and the total catch for the year 2021 will be 90 thousand. tonnes following this procedure. Development of landings indicate that the catch for 2021 will not be higher than 70 thousand tonnes so the parameter “remaining TAC” in the model is set to 43 thousand tonnes. The advice for next fishing year is based on biomass in the beginning of the assessment year so assumptions about catch in the assessment year do not affect the advice.

8.7 Uncertainties in assessment and forecast

The assessment of Icelandic saithe is relatively uncertain due to fluctuations in the survey data, poor recruitment estimates and irregular changes in the fleet selectivity. The internal consistency in the spring bottom trawl surveys is low for saithe (Figure 8.21). This is not surprising, considering the nature of the species that is partly pelagic, schooling, and relatively widely migrating. Uncertainties base on the hessian matrix in the assessment model indicate that CV of the biomass 4+ is around 16%, rather high value for this kind of estimate that is usually underestimation of the real uncertainty.

The retrospective pattern (Figure 8.21) reveals some of the assessment uncertainty. The harvest control rule evaluations incorporated uncertainties in assessment as well as other sources of uncertainty (ICES, 2019).

Using retrospective pattern based on the assessment years 2017–2021 Mohns rho is -0.04 for the reference biomass, -0.054 for the Harvest rate, 0.10 for SSB and -0.07 for recruitment (Table 8.11 called Oldsettings) . Those values are mostly generated by the very high 2018 survey biomass.

Looking at metrics from converged assessment (assessment year < 2018, year <= assessment the values are shown in Table 8.12 based on assessment years 2000–2017. Bias is defined as $\overline{log(\frac{B_{y,y}}{B_{y,assY}})}$ and CV as $\sigma^{log(\frac{B_{y,y}}{B_{y,assY}})}$. Mohns rho is really another way to present bias. The selection of years to use is the difference between Tables 8.11 and 8.12, in 8.12 the results are based on the assessment years that are not used when compiling results for Table 8.11.

CV of B4+ from the adopted model is 0.2 and the bias -0.07 compared to Mohns rho of 0.043 based on the 5 years peel (5 last assessments). The 2018 assessment has here large effect but the pattern since 2000 has been periods of over and underestimation.

Alternative settings of the Muppet model and one SAM run were tested (Figure 8.30) compared to the results. The result show very low estimated biomass when the survey data are downweighted, the same result is obtained with the leaveout run in SAM, both indicating that catch in numbers indicate smaller stock compared to survey indices. Winchorised survey results lead to less noise and more weight on the survey in the assessment. The Adapt model used is just the Muppet model, using N of the oldest fish from the forward running model. The backwards running model is selected by changing one number in the main input file. A major advantage with the adapt approach that CV of survey can be estimated independently for each age group , if attempted in a catch at age model the survey CV of one age will be set to zero. The table below show $B4+_{2021}$, the number that matters for the advice. The values are in thousand tonnes.

Std settings	Winchorised survey	Adapt	LessWeight On survey	2020 Std settings	SAM
382	424	339	277	377	347

If all the models would be taken as equally plausible configurations (which they are not) the average B4+2020 is 357 and CV 0.15.

The SAM settings are correlated random walk, 3 observation variance blocks for the catches and 4 for the survey.

One problem in the assessment is the fact that the TAC has not been fished in some recent years (Figure 8.4). The assessment models indicate substantial reduction of fishing mortality and harvest rate in last 4 years (Figure 8.24), mostly because the TAC has not been fished. The selection pattern observed since 2004 (Figure 8.15) indicates that the fisheries are targeting younger fish than before, something that could be interpreted as lack of large fish. This trend is even greater than observed in the figure as mean weight at age of ages 4–5 have been low in recent years (Figure 8.12). The gillnet survey that is an indicator of the amount of large saithe has shown sharp decrease from a high level in 2019 (Figure 8.19) and the autumn survey shows decreasing trend.

The problem seen in recent years is not new and the fact that fishing mortality of saithe was never high, indicates that it is difficult to catch saithe. One reason is that most of the gear is demersal while saithe is partly pelagic. Change of fleet and fishing practice in recent 20 years might also have effects. But the summary of the investigations in earlier section, reduction in CPUE, TAC not caught, gillnet survey showing decrease is that the TAC is too high and the biomass most likely overestimated.

The effect of too high TAC is increased catch of some other species through the transfer system, something that could change with higher price of saithe. Overestimation of the saithe stock leads to overestimation of the predation on capelin by saithe, leading to more precautionary capelin advice.

8.8 Ecosystem considerations

Changes in the distribution of large pelagic stocks (blue whiting, mackerel, Norwegian spring-spawning herring, Icelandic summer-spawning herring) may affect the tendency of saithe to migrate off shelf and between management units. Saithe is a migrating species and makes both vertical and long-distance feeding and spawning migrations (Armannsson *et al.*, 2007, Armannsson and Jonsson, 2012, i Homrum *et al.*, 2013). The evidence from tagging experiments (ICES, 2008) show some migrations along the Faroe-Iceland Ridge, as well as onto the East Greenland shelf.

Saithe is an important predator of capelin and is included in the predation model used to compile advice for Icelandic capelin.

8.9 Possible changes in assessment setup.

Earlier this winter the assessment of Icelandic cod was benchmarked and a number of changes done in the model formulation that lead to substantial downward revision of the biomass (ICES 2021). All the changes had to do with treatment of survey indices in the model.

1. With lower fishing effort the abundance of old age groups increased. For some of those age groups (10+) the number caught had been so low that sampling error related to few otoliths had been the most important uncertainty. Ages 11 and older in the surveys were earlier not used in the tuning as they were minor part of the stock (1–2%). Not including them in the survey lead to "ghostfish" i.e dome shaped selection pattern of the fleet, not an impossible pattern but not acceptable without some proofs, especially when the older fish becomes larger part of the stock.
2. For ages 6–9 abundance increased, and nonlinear relationships started to show up, that was not apparent when range of values was smaller.

3. The relationship between abundance indices of ages 1–3 and older fish changed. The change can either be related to increased mortality or changed behaviour or less coastal spatial distribution.
4. The VPA version of Muppet was run and CV in the survey estimated for each age group using a VPA model. That pattern was then used in the separable model with one estimated multiplier.

Looking at saithe only factor 4 was relevant. Estimating power curves turned out to lead to no improvement of fit and the power coefficients were not far from 1 and quite variable in retrospective runs. Age composition of saithe has not been changing dramatically in recent years but old saithe has always been common compared to old cod. Looking at all aged fish since 1980 number of cod otoliths is 3.5 times the number of saithe otoliths but for all ages > 12 years the number of saithe is larger than number of cod. Changes in spatial distribution of recruits could be relevant for saithe but the recruitment indices are of too low quality to easily detect changes. The common perception about saithe is that the nursery areas are close to shore while the nursery areas of cod are both close to shore and in deeper waters.

What was then left was to re estimate the survey CV pattern with age (like redefining observation error blocks in SAM) and increase the number of age groups in the tuning fleet. In addition, a version of the model that uses the estimated survey CV was run.

To revise the pattern of survey CV with age the VPA model is used, estimating CV in the survey for each age group. The VPA model used is just the Muppet model, first the model is run in the forward model but then the number of fish in the oldest age group is used for VPA. If large changes in the CV pattern are observed the procedure might be reiterated.

To look again at the value of ϵ in survey residuals in ($\frac{log(I+\epsilon)}{log(\hat{I}+\epsilon)}$) the number of aged saithe in the survey is 900 and the average total index around 20. 4 otoliths do therefore correspond to $\epsilon = 0.15$ which would be the suggested value to use for all age groups based only on this consideration. Other factors like poor spatial coverage of recruits might be used to justify higher values. In some of the alternative tested, age 2 was not included in the tuning fleet.

When doing the reweighting scheme, the pattern of ϵ must be exactly the same in the linked separable and VPA model. In principle the objective function for models using the same pattern of ϵ can be compared but if ϵ is different the comparison might be quest

When compiling the survey indices, relative standard error in the estimation of the indices is also compiled $CV_{s,y,a} = \frac{\sigma_{I_{y,a}}}{I_{y,a}}$ where $\sigma_{I_{y,a}}$ is standard error in the indices. High value indicates that few stations are responsible for large part of the index, it is the part of the uncertainty that can be improved by increasing the number of stations. There are other uncertainties that cannot be reduced by increasing the number of stations in the same area, like the proportion of fish that is pelagic or closer to coast that the survey covers. The model setup is to use $CV_{s,y,a}$ but add to that an estimated CV by age called $CV_{2,a}$ $CV_{s,y,a} = \frac{\sigma_{I_{y,a}}}{I_{y,a}}$. $CV_{tot,y,a} = \sqrt{\left(CV_{s,y,a}^2 + CV_{2,a}^2\right)}$.

$CV_{2,a}$ can here be estimated for each age group as $CV_{tot,y,a}$ is never going to be 0.

Using this approach the variance-covariance matrix (approximately 9x9) must be recalculated and inverted at every timestep, not a difficult task for today's computers.

In Figures 8.29 and 8.31 and the Tables 8.11 and 8.12 the results of 5 settings are compared. All the settings are based on the same data except the number of age groups in the survey varies.

1. Oldsettings. The adopted model from the benchmark 2019.
2. Sameepsreweight. Same pattern of ϵ but CV pattern be age re estimated.
3. eps01reweight. $\epsilon = 0.1$ for all age groups. Age 2 not included.

4. surveyCV. Model uses estimated $CV_{y,a}$in survey as described above.
5. SurAge314eps01. ϵ = 0.1 for all age groups. Survey indices age 3–14.

Models 1 and 2 tuned with ages 2–10, 3 and 5 with ages 3–10 and 5 with 3–14. Models 1–4 are based on constant q by age for ages 7 and older but model 5 with constant q for ages 10 and older. Assumptions about age above which q does not change is an important factor in the settings.

Looking at Mohns rho, model 4 performs best, not unexpected as the "overestimation in 2018" was caused by survey value with high CV something easily taken care of by that model. Looking over assessment years 2001–2017 model 4 performs best but the metrics for models 1 and 3 are similar.

Comparing models 1 and 2 B4+2021 is 381 vs 311 thousand tonnes, and the objective function -752.7 vs -821.9. Model 2 fits the data much better (it is reweighted in 2021) and indicates much smaller stock. Retrospective performance of model 2 is on the other hand worse than of model 1 but here the inference might be different if the end value of model 2 was different.

In summary model 3 seems to be most feasible alternative if a new model was adopted today. The table below shows the estimated B4+ in 2021 by the different models.

Oldsettings	Sameepsreweight	eps01reweight	surveyCV	SurAge314eps01
381.8	310.6	318.2	328.3	383

An interesting factor to look at in the models is estimated q from the surveys (Figure 8.32). Model 5 uses all ages and q in constrained to be identical for ages 9 and older but ages 7 and older for the other models that use age groups until 10. This assumption when does q become constant has considerable effect on stock size, reducing q by age as in model 5 leads to larger stock.

Estimated selection (since 2004) in the model is also somewhat different (Figure 8.33). Models 1 and 5 have different selection pattern for older fish and do therefore not converge to exactly the same biomass in the period after 2003.

8.10 References

Armannsson, H. and S.T. Jonsson. 2012. Vertical migrations of saithe (*Pollachius virens*) in Icelandic waters as observed with data storage tags. ICES J. Mar. Sci. 69:1372-1381.

Armannsson, H., S.T. Jonsson, J.D. Neilson, and G. Marteinsdottir. 2007. Distribution and migration of saithe (*Pollachius virens*) around Iceland inferred from mark-recapture studies. ICES J. Mar. Sci. 64:1006-1016.

Björnsson, Höskuldur, Einar Hjörleifsson and Bjarki Þór Elvarsson, 2019. Muppet: Program for Simulating Harvest Control Rules. Reykjavík: Marinc and Fresh water Institute. http://www.github.com/hoski/Muppet-HCR.

Gudmundsson, G. 2013. Fish stock assessment by time series analysis. ICES NWWG WD29.

i Homrum, E., B. Hansen, S.T. Jonsson, K. Michalsen, J. Burgos, D. Righton, P. Steingrund, T. Jakobsen, R. Mouritsen, H. Hatun, H. Armannsson, and J.S. Joensen. 2013. Migration of saithe (*Pollachius virens*) in the Northeast Atlantic. ICES J. Mar. Sci. 70:782-792.

ICES. 2008. Report of the North-Western Working Group (NWWG). ICES CM 2008/ACOM:03.

ICES. 2010. Report of the Benchmark Workshop on Roundfish (WKROUND). ICES CM 2010/ACOM:36.

ICES. 2013. Report of the evaluation of the Icelandic saithe management plan. ICES CM 2013/ACOM:60.

ICES. 2019. North Western Working Group (NWWG). ICES Scientific Reports. 1:14. 826 pp. http://doi.org/10.17895/ices.pub.5298

ICES. 2019a. Workshop on the benchmark assessment and management plan evaluation for Icelandic haddock and saithe (WKICEMSE). ICES Scientific Reports. 1:10. 107 pp. http://doi.org/10.17895/ices.pub.5091

ICES. 2019b. Saithe (*Pollachius virens*) in Division 5.a (Iceland grounds). *In* Report of the ICES Advisory Committee, 2019, pok.27.5a, https://doi.org/10.17895/ices.advice.4731

ICES. 2021. Workshop on the re-evaluation of management plan for the Icelandic cod stock (WKICECOD). ICES Scientific Reports. 3:30. 85 pp. https://doi.org/10.17895/ices.pub.7987

Magnusson, A. 2012. Icelandic saithe: New model to predict current weight at age. ICES NWWG WD30.

Magnusson, A. 2013. Mathematical properties of the Icelandic saithe HCR. ICES NWWG WD 31.

Ministry of Industries and Innovation. 2013. Adoption of management plan for Icelandic saithe. Letter to ICES, dated 22 Apr 2013.

Palsson, O.K., G. Karlsson, A. Arason, G.R. Gislason, G. Johannesson, and S. Adalsteinsson. 2003. Discards in demersal Icelandic fisheries 2002. Mar. Res. Inst. Rep. 94.

Table 8.1. Saithe in Division 5.a. Nominal catch (t) by countries, as officially reported to ICES.

	belgium	faroes	france	germany	iceland	norway	uk (e/w/ni)	uk (scot)	uk	total
1980	980	4930			52 436	1				58 347
1981	532	3545			54 921	3				59 001
1982	201	3582	23		65 124	1				68 931
1983	224	2138			55 904					58 266
1984	269	2044			60 406					62 719
1985	158	1778			55 135	1	29			57 101
1986	218	2291			63 867					66 376
1987	217	2139			78 175					80 531
1988	268	2596			74 383					77 247
1989	369	2246			79 796					82 411
1990	190	2905			95 032					98 127
1991	236	2690			99 811					102 737
1992	195	1570			77 832					79 597
1993	104	1562			69 982					71 648
1994	30	975		1	63 333					64 339
1995		1161		1	47 466	1				48 629
1996		803		1	39 297					40 101
1997		716			36 548					37 264
1998		997		3	30 531					31 531
1999		700		2	30 583	6	1	1		31 293
2000		228		1	32 914	1	2			33 146
2001		128		14	31 854	44	23			32 063
2002		366		6	41 687	3	7	2		42 071
2003		143		56	51 857	164			35	52 255
2004		214		157	62 614	1	105			63 091
2005		322		224	67 283	2			312	68 143
2006		415		33	75 197	2			16	75 663
2007		392			64 008	3			30	64 433
2008		196			69 992	2				70 190
2009		269			61 391	3				61 663
2010		499			53 772	1				54 272
2011		735			50 386	2				51 123
2012		940			50 843					51 783
2013		925			57 077					58 002
2014		746			45 733	4				46 483
2015		499			47 973	3				48 473
2016		287			48 920	5				49 212
2017		261			48 786	4			4	49 057
2018		270			65 090					65 360

	belgium	faroes	france	germany	iceland	norway	uk (e/w/ni)	uk (scot)	uk	total
2019		237			64 295					64 532
2020		194			50 058					50 253

Table 8.2. Saithe in Division 5.a. Samping from catches 2018–2020

Year	Fleet	Landings (t)	No. of otolith samples	No. of otoliths aged	No. of length samples	No. of length measurements	No. of sea length samples
2018	Long lines	787	0	0	1	1	1
2018	Gillnets	1715	3	75	5	464	1
2018	Jiggers	1250	1	25	5	598	0
2018	Danish seine	969	3	75	5	461	2
2018	Bottom trawl	60975	62	1604	143	25486	96
2018	Other gear	553	0	0	0	0	0
2018	Total	66248	69	1779	159	27010	100
2019	Long lines	966	0	0	5	19	5
2019	Gillnets	1405	0	0	0	0	0
2019	Jiggers	1843	4	100	8	467	2
2019	Danish seine	1451	8	198	11	901	3
2019	Bottom trawl	58339	51	1269	159	28296	118
2019	Other gear	528	0	0	0	0	0
2019	Total	64532	63	1567	183	29683	128
2020	Long lines	745	0	0	1	8	1
2020	Gillnets	2573	3	75	9	630	6
2020	Jiggers	1794	4	87	8	365	0
2020	Danish seine	980	3	75	4	410	1
2020	Bottom trawl	43842	31	775	57	8181	26
2020	Other gear	319	0	0	0	0	0
2020	Total	50252	41	1012	79	9594	34

Table 8.3. Saithe in Division 5.a. Sampling from catches 2020. No age samples were taken at sea.

Gear	Length sea-samples	Length shore-samples	Age shore-samples
Bottom trawl	26	31	31
Demersal seine	2	3	3
Gillnets	6	3	3
Handlines	0	8	4

Table 8.4. Saithe in Division 5.a. Commercial catch at age (thousands).

Year	3	4	5	6	7	8	9	10	11	12+
1980	275	2540	5214	2596	2169	1341	387	262	155	209
1981	203	1325	3503	5404	1457	1415	578	242	61	417
1982	508	1092	2804	4845	4293	1215	975	306	59	129
1983	107	1750	1065	2455	4454	2311	501	251	38	18
1984	53	657	800	1825	2184	3610	844	376	291	546
1985	376	4014	3366	1958	1536	1172	747	479	74	166
1986	3108	1400	4170	2665	1550	1116	628	1549	216	95
1987	956	5135	4428	5409	2915	1348	661	496	498	133
1988	1318	5067	6619	3678	2859	1775	845	226	270	132
1989	315	4313	8471	7309	1794	1928	848	270	191	221
1990	143	1692	5471	10112	6174	1816	1087	380	151	168
1991	198	874	3613	6844	10772	3223	858	838	228	51
1992	242	2928	3844	4355	3884	4046	1290	350	196	125
1993	657	1083	2841	2252	2247	2314	3671	830	223	281
1994	702	2955	1770	2603	1377	1243	1263	2009	454	428
1995	1573	1853	2661	1807	2370	905	574	482	521	154
1996	1102	2608	1868	1649	835	1233	385	267	210	447
1997	603	2960	2766	1651	1178	599	454	125	95	234
1998	183	1289	1767	1545	1114	658	351	265	120	251
1999	989	732	1564	2176	1934	669	324	140	72	75
2000	850	2383	896	1511	1612	1806	335	173	57	57
2001	1223	2619	2184	591	977	943	819	186	94	69
2002	1187	4190	3147	2970	519	820	570	309	101	53
2003	2284	4363	6031	2472	1942	285	438	289	196	72
2004	952	7841	7195	5363	1563	1057	211	224	157	124
2005	2607	3089	7333	6876	3592	978	642	119	149	147
2006	1380	10051	2616	5840	4514	1989	667	485	118	229
2007	1244	6552	8751	2124	2935	1817	964	395	190	99
2008	1432	3602	5874	6706	1155	1894	1248	803	262	307
2009	2820	5166	2084	2734	2883	777	1101	847	555	373
2010	2146	6284	3058	997	1644	1571	514	656	522	409
2011	2004	4850	4006	1502	677	1065	1145	323	433	469
2012	1183	4816	3514	2417	903	432	883	1015	354	549
2013	1163	5538	6366	2963	1610	664	375	537	460	320
2014	668	3499	4867	2805	1276	725	347	241	312	401
2015	781	2712	6461	2917	1509	694	589	249	133	347
2016	1588	6230	2653	2838	1648	1059	526	337	148	131
2017	750	3333	7542	1806	1449	813	648	229	127	237
2018	689	6681	4267	7908	1446	962	455	258	192	175

Year	3	4	5	6	7	8	9	10	11	12+
2019	1292	1585	6325	2752	4543	693	675	339	242	231
2020	1333	2310	1496	3228	1334	1700	710	351	379	666

Table 8.5. Saithe in Division 5.a. Mean weight at age (g) in the catches and in the spawning stock, with predictions in gray.

Year	3	4	5	6	7	8	9	10	11	12+
1980	1428	1983	2667	3689	5409	6321	7213	8565	9147	9979
1981	1585	2037	2696	3525	4541	6247	6991	8202	9537	9523
1982	1547	2194	3015	3183	5114	6202	7256	7922	8924	10021
1983	1530	2221	3171	4270	4107	5984	7565	8673	8801	9445
1984	1653	2432	3330	4681	5466	4973	7407	8179	8770	10520
1985	1609	2172	3169	3922	4697	6411	6492	8346	9401	10767
1986	1450	2190	2959	4402	5488	6406	7570	6487	9616	11080
1987	1516	1715	2670	3839	5081	6185	7330	8025	7974	10886
1988	1261	2017	2513	3476	4719	5932	7523	8439	8748	9823
1989	1403	2021	2194	3047	4505	5889	7172	8852	10170	11194
1990	1647	1983	2566	3021	4077	5744	7038	7564	8854	11284
1991	1224	1939	2432	3160	3634	4967	6629	7704	9061	9547
1992	1269	1909	2578	3288	4150	4865	6168	7926	8349	10181
1993	1381	2143	2742	3636	4398	5421	5319	7006	8070	9842
1994	1444	1836	2649	3512	4906	5539	6818	6374	8341	10388
1995	1370	1977	2769	3722	4621	5854	6416	7356	6815	8799
1996	1229	1755	2670	3802	4902	5681	7182	7734	9256	9601
1997	1325	1936	2409	3906	5032	6171	7202	7883	8856	9865
1998	1347	1972	2943	3419	4850	5962	6933	7781	8695	10043
1999	1279	2106	2752	3497	3831	5819	7072	8078	8865	10872
2000	1367	1929	2751	3274	4171	4447	6790	8216	9369	10443
2001	1280	1882	2599	3697	4420	5538	5639	7985	9059	10419
2002	1308	1946	2569	3266	4872	5365	6830	7067	9240	10190
2003	1310	1908	2545	3336	4069	5792	7156	8131	8051	10825
2004	1467	1847	2181	2918	4017	5135	7125	7732	8420	9547
2005	1287	1888	2307	2619	3516	5080	6060	8052	8292	8569
2006	1164	1722	2369	2808	3235	4361	6007	7166	8459	9583
2007	1140	1578	2122	2719	3495	4114	5402	6995	7792	9848
2008	1306	1805	2295	2749	3515	4530	5132	6394	7694	9589
2009	1412	1862	2561	3023	3676	4596	5651	6074	7356	9237
2010	1287	1787	2579	3469	4135	4850	5558	6289	6750	8785
2011	1175	1801	2526	3680	4613	5367	5685	6466	6851	7739
2012	1160	1668	2369	3347	4430	5486	6161	6448	7220	8236
2013	1056	1675	2219	3244	4529	5628	6397	7055	7378	8342

Year	3	4	5	6	7	8	9	10	11	12+
2014	1211	1575	2229	2983	4378	5598	6773	8023	7875	9020
2015	1072	1639	2141	3122	4262	5555	6633	7697	8269	8773
2016	1105	1468	2260	3071	4127	5272	6379	7247	8566	8969
2017	1282	1674	2199	3255	4314	5718	6361	7630	8590	9238
2018	1346	1724	2335	3005	4178	5319	6544	7773	8530	9324
2019	1485	2054	2449	3128	4104	5694	6483	7750	8563	9488
2020	1285	2015	2386	3131	4065	5059	6284	7025	8285	9175
2021	1372	1802	2708	3299	4149	5340	6202	7516	8459	9344
2022	1372	1802	2708	3299	4149	5340	6202	7516	8459	9344

Table 8.6. Saithe in Division 5.a. Maturity at age, with predictions in gray.

Year	3	4	5	6	7	8	9	10	11	12
1980	0	0.083	0.189	0.374	0.606	0.798	0.91	1	1	1
1981	0	0.083	0.189	0.374	0.606	0.798	0.91	1	1	1
1982	0	0.083	0.189	0.374	0.606	0.798	0.91	1	1	1
1983	0	0.083	0.189	0.374	0.606	0.798	0.91	1	1	1
1984	0	0.083	0.189	0.374	0.606	0.798	0.91	1	1	1
1985	0	0.083	0.189	0.374	0.606	0.798	0.91	1	1	1
1986	0	0.075	0.173	0.349	0.579	0.779	0.901	1	1	1
1987	0	0.068	0.158	0.325	0.553	0.76	0.891	1	1	1
1988	0	0.062	0.146	0.305	0.529	0.743	0.881	1	1	1
1989	0	0.058	0.136	0.288	0.51	0.727	0.873	1	1	1
1990	0	0.055	0.129	0.276	0.495	0.716	0.866	1	1	1
1991	0	0.053	0.126	0.27	0.487	0.709	0.862	1	1	1
1992	0	0.053	0.126	0.27	0.487	0.709	0.862	1	1	1
1993	0	0.055	0.13	0.277	0.496	0.716	0.866	1	1	1
1994	0	0.059	0.139	0.293	0.515	0.732	0.875	1	1	1
1995	0	0.066	0.154	0.319	0.546	0.755	0.888	1	1	1
1996	0	0.078	0.177	0.356	0.587	0.785	0.904	1	1	1
1997	0	0.093	0.208	0.403	0.634	0.816	0.919	1	1	1
1998	0	0.111	0.243	0.452	0.679	0.845	0.933	1	1	1
1999	0	0.131	0.278	0.498	0.718	0.867	0.944	1	1	1
2000	0	0.148	0.308	0.533	0.745	0.883	0.951	1	1	1
2001	0	0.158	0.325	0.553	0.76	0.891	0.954	1	1	1
2002	0	0.162	0.331	0.56	0.766	0.893	0.956	1	1	1
2003	0	0.16	0.329	0.557	0.764	0.892	0.955	1	1	1
2004	0	0.155	0.321	0.548	0.757	0.889	0.954	1	1	1
2005	0	0.149	0.31	0.535	0.747	0.884	0.951	1	1	1
2006	0	0.142	0.299	0.522	0.737	0.878	0.949	1	1	1
2007	0	0.137	0.29	0.512	0.729	0.873	0.947	1	1	1

Year	3	4	5	6	7	8	9	10	11	12
2008	0	0.133	0.282	0.502	0.722	0.869	0.945	1	1	1
2009	0	0.129	0.275	0.494	0.715	0.865	0.943	1	1	1
2010	0	0.125	0.268	0.484	0.707	0.861	0.941	1	1	1
2011	0	0.12	0.258	0.472	0.697	0.855	0.938	1	1	1
2012	0	0.113	0.247	0.457	0.684	0.847	0.934	1	1	1
2013	0	0.107	0.234	0.44	0.669	0.838	0.93	1	1	1
2014	0	0.1	0.222	0.423	0.653	0.829	0.925	1	1	1
2015	0	0.095	0.212	0.408	0.639	0.82	0.921	1	1	1
2016	0	0.091	0.204	0.396	0.628	0.812	0.917	1	1	1
2017	0	0.088	0.199	0.389	0.621	0.808	0.915	1	1	1
2018	0	0.087	0.197	0.386	0.618	0.806	0.914	1	1	1
2019	0	0.087	0.197	0.386	0.618	0.806	0.914	1	1	1
2020	0	0.088	0.198	0.388	0.62	0.807	0.915	1	1	1
2021	0	0.089	0.2	0.391	0.623	0.809	0.916	1	1	1
2022	0	0.089	0.2	0.391	0.623	0.809	0.916	1	1	1

Table 8.7. Saithe in Division 5.a. Survey indices by age.

Year	2	3	4	5	6	7	8	9	10
1985	0.59	0.57	3.1	5.32	1.81	1.1	0.52	1.43	0.16
1986	2.34	2.46	2.15	2.21	1.5	0.65	0.3	0.19	0.32
1987	0.38	11.84	13.22	6.61	4.09	3.19	0.82	0.37	0.27
1988	0.31	0.47	2.74	2.86	1.76	0.98	0.42	0.07	0.08
1989	1.42	4.01	5.08	6.68	2.65	1.74	0.89	0.37	0.01
1990	0.73	1.32	4.96	6.42	12.53	3.38	1.23	0.65	0.12
1991	0.22	1.38	1.7	2.18	1.12	2.49	0.31	0.02	0.04
1992	0.14	0.91	5.91	5.67	2.84	2.69	1.93	0.28	0.06
1993	1.27	11	1.93	6.61	2.33	2.2	1.02	3.92	0.66
1994	0.83	0.72	1.96	1.79	2.07	0.72	1.13	1.2	2.77
1995	0.49	1.98	1.12	0.52	0.29	0.34	0.1	0.15	0.15
1996	0.13	0.49	3.78	1.16	1.03	0.59	0.98	0.06	0.09
1997	0.32	0.91	4.73	3.98	0.95	0.4	0.16	0.1	0.05
1998	0.13	1.66	2.36	2.55	1.27	0.72	0.3	0.09	0.07
1999	0.73	3.74	0.94	1.27	1.7	0.59	0.16	0.02	0.02
2000	0.38	2.01	2.55	0.61	0.86	0.54	0.45	0.08	0.03
2001	0.92	2.06	2.73	1.68	0.22	0.23	0.4	0.14	0.07
2002	1.02	2.23	3.01	3.11	2.19	0.42	0.47	0.32	0.22
2003	0.05	9.79	5.14	2.98	1.37	0.78	0.21	0.05	0.1
2004	0.9	1.39	9.6	6.27	4.52	1.52	0.84	0.17	0.17
2005	0.25	4.29	2.41	7.5	4.73	2.36	0.88	0.45	0.13
2006	0	2.19	6.77	1.98	8.86	3.5	1.21	0.29	0.25
2007	0.06	0.31	1.75	3.27	0.82	1.64	0.71	0.29	0.16
2008	0.08	2.26	1.81	2.88	4.05	0.62	0.79	0.34	0.15
2009	0.21	2.45	1.85	0.69	0.91	0.84	0.12	0.26	0.15
2010	0.07	1.24	5.07	2.55	0.64	0.61	0.47	0.07	0.12
2011	0.15	3.84	4.24	3.1	1.17	0.41	0.39	0.44	0.17
2012	0.02	1.77	12.01	6.75	2.76	0.63	0.17	0.38	0.5
2013	0.11	4.28	7.57	6.85	4.67	2.58	1.12	0.3	0.43
2014	0.03	0.39	3.89	3.74	2.02	0.87	0.42	0.15	0.11
2015	0.04	1.08	1.93	3.22	1.73	0.82	0.72	0.66	0.43
2016	0.05	3.17	16.21	2.75	2.27	1.08	0.53	0.44	0.28
2017	0.02	1.48	6.67	14.64	3.03	1.68	0.87	0.45	0.3
2018	0.03	0.5	17.92	10.51	15.28	1.51	0.84	0.43	0.32
2019	0.08	3.75	1.22	3.46	2.61	4.07	0.82	0.61	0.14
2020	0.09	1.89	2.57	0.7	2.14	1.19	2.36	0.35	0.18
2021	0.36	2.55	4.53	3.42	1.06	2.69	0.67	1.17	0.23

Table 8.8. Saithe in Division 5.a. Main population estimates.

Year	B4+	SSB	N3	Yield	f4–9	HR
1980	313	114	28	58	0.29	0.18
1981	306	121	20	58	0.26	0.21
1982	296	138	22	68	0.3	0.2
1983	271	138	32	57	0.24	0.22
1984	288	141	42	60	0.23	0.19
1985	300	139	35	54	0.24	0.2
1986	319	137	67	65	0.28	0.24
1987	336	129	91	80	0.35	0.23
1988	416	126	51	77	0.32	0.19
1989	398	129	32	82	0.31	0.23
1990	378	136	21	98	0.35	0.27
1991	337	146	29	102	0.37	0.26
1992	289	138	15	80	0.37	0.26
1993	232	114	20	72	0.4	0.29
1994	188	95	18	64	0.45	0.28
1995	154	71	30	48	0.46	0.27
1996	151	62	26	39	0.4	0.25
1997	158	64	17	37	0.36	0.21
1998	157	70	9	31	0.29	0.2
1999	135	75	31	31	0.3	0.24
2000	147	77	32	33	0.32	0.22
2001	168	83	55	32	0.26	0.23
2002	226	100	64	42	0.29	0.22
2003	289	124	73	52	0.28	0.21
2004	330	144	26	65	0.25	0.2
2005	296	156	73	69	0.27	0.25
2006	321	164	42	75	0.3	0.21
2007	292	161	19	64	0.27	0.23
2008	261	159	26	69	0.32	0.24
2009	234	147	38	60	0.3	0.24
2010	232	135	37	54	0.28	0.22
2011	235	126	44	51	0.26	0.22
2012	240	121	41	51	0.26	0.23
2013	246	120	42	58	0.29	0.2
2014	243	119	30	46	0.22	0.2
2015	244	124	93	48	0.21	0.2
2016	313	135	43	49	0.2	0.16
2017	347	156	58	49	0.16	0.17
2018	389	181	17	66	0.2	0.16

Year	B4+	SSB	N3	Yield	f4–9	HR
2019	370	203	38	63	0.19	0.15
2020	356	206	48	50	0.16	0.18
2021	382	221	43			
Average	276	130	39	59	0.29	0.22

Table 8.9. Saithe in Division 5.a. Stock in numbers. Shaded area is input to prediction.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1980	32.2	24.7	28.2	46.9	31	10.3	8.2	3.7	1.3	0.7	0.7	0.5	0.3	0.1
1981	48	26.4	20.2	22.7	35.3	21.3	6.3	4.7	2	0.7	0.4	0.4	0.3	0.2
1982	62.5	39.3	21.6	16.3	17.2	24.7	13.4	3.7	2.6	1.1	0.4	0.2	0.2	0.2
1983	52.7	51.2	32.2	17.4	12.2	11.8	14.9	7.5	2	1.4	0.6	0.2	0.1	0.1
1984	100.2	43.2	41.9	26	13.3	8.6	7.6	9.1	4.3	1.1	0.8	0.4	0.1	0.1
1985	136	82	35.4	33.9	19.9	9.4	5.6	4.6	5.3	2.6	0.7	0.5	0.2	0.1
1986	75.5	111.3	67.2	28.6	25.8	14.1	6.1	3.4	2.6	3.1	1.5	0.4	0.3	0.1
1987	47.9	61.8	91.2	54.1	21.5	17.8	8.7	3.5	1.8	1.5	1.7	0.9	0.2	0.2
1988	31.1	39.2	50.6	73.2	40	14.3	10.3	4.6	1.7	0.9	0.7	0.9	0.5	0.1
1989	44	25.5	32.1	40.7	54.6	27	8.5	5.6	2.3	0.9	0.5	0.4	0.5	0.3
1990	22.2	36	20.8	25.8	30.5	37.1	16.2	4.7	2.9	1.3	0.5	0.3	0.2	0.3
1991	29.7	18.2	29.5	16.7	19.1	20.2	31.4	8.6	2.3	1.5	0.6	0.3	0.1	0.1
1992	26.6	24.3	14.9	23.6	12.3	12.5	11.4	16.2	4.1	1.1	0.7	0.3	0.1	0.1
1993	44.9	21.7	19.9	11.9	17.4	8.1	7.1	5.9	7.7	2	0.5	0.4	0.2	0.1
1994	38.7	36.7	17.8	16	8.7	11.2	4.4	3.6	2.7	3.7	0.9	0.3	0.2	0.1
1995	25.5	31.7	30.1	14.2	11.5	5.4	5.9	2.1	1.5	1.2	1.5	0.4	0.1	0.1
1996	13.2	20.9	25.9	24	10.2	7.1	2.8	2.7	0.9	0.7	0.5	0.7	0.2	0.1
1997	46.3	10.8	17.1	20.8	17.5	6.6	3.9	1.4	1.2	0.4	0.3	0.3	0.4	0.1
1998	47.7	37.9	8.9	13.5	14.7	11.4	3.9	2.1	0.7	0.6	0.2	0.1	0.1	0.2
1999	82.1	39	31	7	9.9	10	7.3	2.3	1.2	0.4	0.3	0.1	0.1	0.1
2000	96.2	67.2	31.9	24.7	5.1	6.7	6.3	4.2	1.2	0.6	0.2	0.2	0.1	0
2001	108.4	78.7	55	25.4	17.8	3.4	4.2	3.6	2.2	0.6	0.3	0.1	0.1	0
2002	38.5	88.7	64.5	43.9	18.7	12.3	2.2	2.5	2	1.2	0.4	0.2	0.1	0.1
2003	108.3	31.5	72.6	51.3	32	12.7	7.9	1.3	1.4	1.1	0.7	0.2	0.1	0

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2004	62.5	88.7	25.8	57.8	37.5	21.9	8.2	4.7	0.7	0.7	0.6	0.4	0.1	0.1
2005	27.8	51.2	72.6	20.3	39.4	23.5	13.5	5.2	3	0.5	0.5	0.4	0.2	0.1
2006	39.1	22.7	41.9	57	13.6	24.1	14.2	8.3	3.3	1.8	0.3	0.3	0.2	0.1
2007	57.3	32	18.6	32.7	37.5	8.1	14.1	8.5	5.1	1.9	1.1	0.2	0.2	0.1
2008	54.8	46.9	26.2	14.6	21.9	22.9	4.9	8.7	5.4	3.2	1.2	0.6	0.1	0.1
2009	65.7	44.9	38.4	20.4	9.5	12.8	13.1	2.9	5.3	3.1	1.8	0.7	0.4	0.1
2010	61	53.8	36.8	30	13.4	5.6	7.4	7.8	1.8	3.1	1.9	1	0.4	0.2
2011	63	49.9	44	28.8	20	8.1	3.4	4.6	4.9	1.1	1.9	1.1	0.6	0.2
2012	45.3	51.6	40.9	34.6	19.5	12.4	5	2.1	2.9	3.1	0.7	1.1	0.6	0.4
2013	139.1	37.1	42.2	32.2	23.5	12.2	7.6	3.1	1.3	1.8	1.9	0.4	0.7	0.4
2014	64.1	113.8	30.3	33.1	21.3	14.1	7.2	4.6	1.9	0.8	1.1	1.1	0.2	0.4
2015	86.6	52.5	93.2	24	23	13.8	9	4.7	3.1	1.3	0.5	0.7	0.7	0.1
2016	24.9	70.9	42.9	73.8	16.8	15	8.9	5.9	3.1	2	0.8	0.3	0.4	0.4
2017	57.1	20.4	58	34.1	52.3	11.1	9.9	5.9	4	2.1	1.3	0.5	0.2	0.3
2018	71.1	46.7	16.7	46.3	24.9	36.1	7.6	6.8	4.2	2.8	1.4	0.9	0.4	0.1
2019	64.1	58.3	38.2	13.2	32.9	16.5	23.8	5.1	4.6	2.8	1.9	0.9	0.6	0.2
2020	53	52.4	47.7	30.4	9.4	21.9	10.9	15.9	3.5	3.1	1.9	1.2	0.6	0.4
2021	52.4	43.4	42.9	38.1	22.2	6.5	15	7.6	11.2	2.4	2.2	1.3	0.8	0.4
2022	52.4	43.4	42.9	38.1	22.2	6.5	15	7.6	11.2	2.4	2.2	1.3	0.8	0.4
2023	53.2	43.6	35.7	28.3	35.8	6.8	14.2	8.3	11.5	2.4	2.2	1.2	0.8	0.4

Table 8.10. Saithe in Division 5.a. Fishing mortality rate. Shaded areas show predictions i.e. where catches are unknown.

Year	3	4	5	6	7	8	9	10	11	12	13	14
1980	0.016	0.085	0.177	0.294	0.362	0.434	0.403	0.434	0.337	0.356	0.356	0.356
1981	0.015	0.076	0.158	0.263	0.323	0.388	0.36	0.388	0.301	0.318	0.318	0.318
1982	0.017	0.088	0.183	0.303	0.373	0.448	0.415	0.448	0.347	0.367	0.367	0.367
1983	0.014	0.07	0.146	0.243	0.299	0.359	0.333	0.359	0.278	0.294	0.294	0.294
1984	0.013	0.067	0.14	0.231	0.285	0.342	0.317	0.342	0.265	0.28	0.28	0.28
1985	0.014	0.071	0.148	0.245	0.302	0.363	0.337	0.363	0.282	0.297	0.297	0.297
1986	0.016	0.082	0.171	0.283	0.348	0.418	0.388	0.418	0.324	0.342	0.342	0.342
1987	0.02	0.102	0.212	0.352	0.434	0.521	0.483	0.521	0.404	0.426	0.426	0.426
1988	0.018	0.094	0.195	0.323	0.398	0.478	0.443	0.478	0.371	0.391	0.391	0.391
1989	0.017	0.089	0.185	0.307	0.378	0.454	0.421	0.454	0.352	0.372	0.372	0.372
1990	0.019	0.101	0.211	0.35	0.432	0.518	0.481	0.518	0.402	0.424	0.424	0.424
1991	0.021	0.108	0.226	0.374	0.461	0.554	0.514	0.554	0.43	0.454	0.454	0.454
1992	0.02	0.106	0.221	0.366	0.452	0.542	0.503	0.542	0.42	0.444	0.444	0.444
1993	0.022	0.115	0.239	0.397	0.489	0.587	0.544	0.587	0.455	0.481	0.481	0.481
1994	0.025	0.13	0.271	0.45	0.554	0.665	0.617	0.665	0.516	0.545	0.545	0.545
1995	0.025	0.133	0.276	0.458	0.564	0.678	0.628	0.678	0.525	0.555	0.555	0.555
1996	0.022	0.116	0.241	0.399	0.492	0.591	0.548	0.591	0.458	0.483	0.483	0.483
1997	0.035	0.144	0.229	0.309	0.41	0.511	0.545	0.515	0.519	0.471	0.471	0.471
1998	0.028	0.116	0.185	0.249	0.331	0.413	0.44	0.416	0.42	0.381	0.381	0.381
1999	0.03	0.121	0.192	0.259	0.344	0.429	0.457	0.433	0.436	0.396	0.396	0.396
2000	0.031	0.127	0.202	0.272	0.361	0.451	0.481	0.455	0.458	0.416	0.416	0.416
2001	0.026	0.106	0.169	0.228	0.302	0.377	0.402	0.38	0.383	0.348	0.348	0.348
2002	0.028	0.115	0.184	0.248	0.329	0.41	0.437	0.414	0.417	0.378	0.378	0.378
2003	0.028	0.113	0.18	0.242	0.321	0.401	0.428	0.405	0.408	0.37	0.37	0.37
2004	0.039	0.184	0.268	0.28	0.261	0.238	0.264	0.267	0.301	0.317	0.317	0.317

Year	3	4	5	6	7	8	9	10	11	12	13	14
2005	0.042	0.201	0.292	0.306	0.286	0.26	0.289	0.291	0.329	0.346	0.346	0.346
2006	0.046	0.218	0.318	0.333	0.311	0.283	0.314	0.317	0.358	0.376	0.376	0.376
2007	0.043	0.202	0.294	0.307	0.287	0.261	0.29	0.292	0.33	0.347	0.347	0.347
2008	0.05	0.234	0.341	0.357	0.333	0.303	0.337	0.34	0.384	0.403	0.403	0.403
2009	0.047	0.223	0.324	0.34	0.317	0.288	0.32	0.323	0.365	0.383	0.383	0.383
2010	0.043	0.203	0.296	0.31	0.289	0.263	0.292	0.295	0.333	0.35	0.35	0.35
2011	0.04	0.19	0.276	0.289	0.27	0.246	0.273	0.275	0.311	0.327	0.327	0.327
2012	0.04	0.188	0.274	0.287	0.268	0.244	0.271	0.273	0.308	0.324	0.324	0.324
2013	0.045	0.211	0.308	0.322	0.301	0.273	0.304	0.306	0.346	0.364	0.364	0.364
2014	0.034	0.162	0.235	0.247	0.23	0.209	0.232	0.234	0.265	0.278	0.278	0.278
2015	0.033	0.157	0.228	0.239	0.223	0.203	0.225	0.227	0.257	0.27	0.27	0.27
2016	0.031	0.145	0.211	0.221	0.206	0.187	0.208	0.21	0.237	0.249	0.249	0.249
2017	0.025	0.116	0.17	0.178	0.166	0.151	0.168	0.169	0.191	0.201	0.201	0.201
2018	0.03	0.144	0.21	0.22	0.205	0.186	0.207	0.209	0.236	0.248	0.248	0.248
2019	0.03	0.14	0.204	0.213	0.199	0.181	0.201	0.203	0.229	0.241	0.241	0.241
2020	0.025	0.117	0.17	0.178	0.166	0.151	0.168	0.169	0.191	0.201	0.201	0.201
2021	0.034	0.159	0.231	0.242	0.226	0.205	0.228	0.23	0.26	0.274	0.274	0.274
2022	0.038	0.181	0.263	0.275	0.257	0.234	0.26	0.262	0.296	0.311	0.311	0.311

Table 8.11. Mohns rho for the 5 models compared as candidate assessment model. The value is based on assessment years 2017–2021. Oldsetting is the adopted model today.

model	B4+	ssb	N3	hr	f4-9
Oldsettings	0.043	0.101	-0.074	-0.054	-0.084
Sameepsreweight	0	0.079	-0.086	-0.031	-0.064
eps01reweight	0.056	0.146	-0.085	-0.073	-0.106
surveyCV	0	0.068	-0.122	-0.029	-0.059
SurAge314eps01	0.02	0.076	-0.135	-0.039	-0.067

Table 8.12. Bias, CV and Mohns rho for the 5 models compared as candidate assessment model based on "converged assessment" i.e. results from assessment years 2000–2017 compared to results for same years from the 2021 assessment.

Parameter	Model	Bias	CV	Mohns rho
B4+	Oldsettings	-0.071	0.2	-0.051
B4+	Sameepsreweight	-0.113	0.22	-0.087
B4+	eps01reweight	-0.053	0.253	-0.022
B4+	surveyCV	0.028	0.222	0.053
B4+	SurAge314eps01	-0.17	0.232	-0.136
F4-9	Oldsettings	0.042	0.224	0.068
F4-9	Sameepsreweight	0.069	0.248	0.104
F4-9	eps01reweight	0.013	0.283	0.053
F4-9	surveyCV	-0.034	0.219	-0.01
F4-9	SurAge314eps01	0.136	0.265	0.185
hr	Oldsettings	0.035	0.187	0.053
hr	Sameepsreweight	0.057	0.199	0.079
hr	eps01reweight	0.009	0.232	0.035
hr	surveyCV	-0.036	0.195	-0.018
hr	SurAge314eps01	0.108	0.213	0.139
N3	Oldsettings	-0.302	0.383	-0.211
N3	Sameepsreweight	-0.352	0.323	-0.261
N3	eps01reweight	-0.328	0.333	-0.242
N3	surveyCV	-0.217	0.353	-0.147
N3	SurAge314eps01	-0.398	0.332	-0.293
ssb	Oldsettings	-0.087	0.25	-0.057
ssb	Sameepsreweight	-0.112	0.286	-0.072
ssb	eps01reweight	-0.054	0.326	-0.005
ssb	surveyCV	0.016	0.267	0.05
ssb	SurAge314eps01	-0.198	0.306	-0.145

Table 8.13. Saithe in Division 5.a. Output from short-term projections.

2021			
B4+	SSB	Fbar	Landings
382	221	0.215	69.8

2022				2023		
B4+	SSB	F_{bar}	Landings	B4+	SSB	Rationale
374	213	0.245	77.1	343	193	20% HCR

20% HCR = average between 0.2 B4+ (current year) and last year's TAC

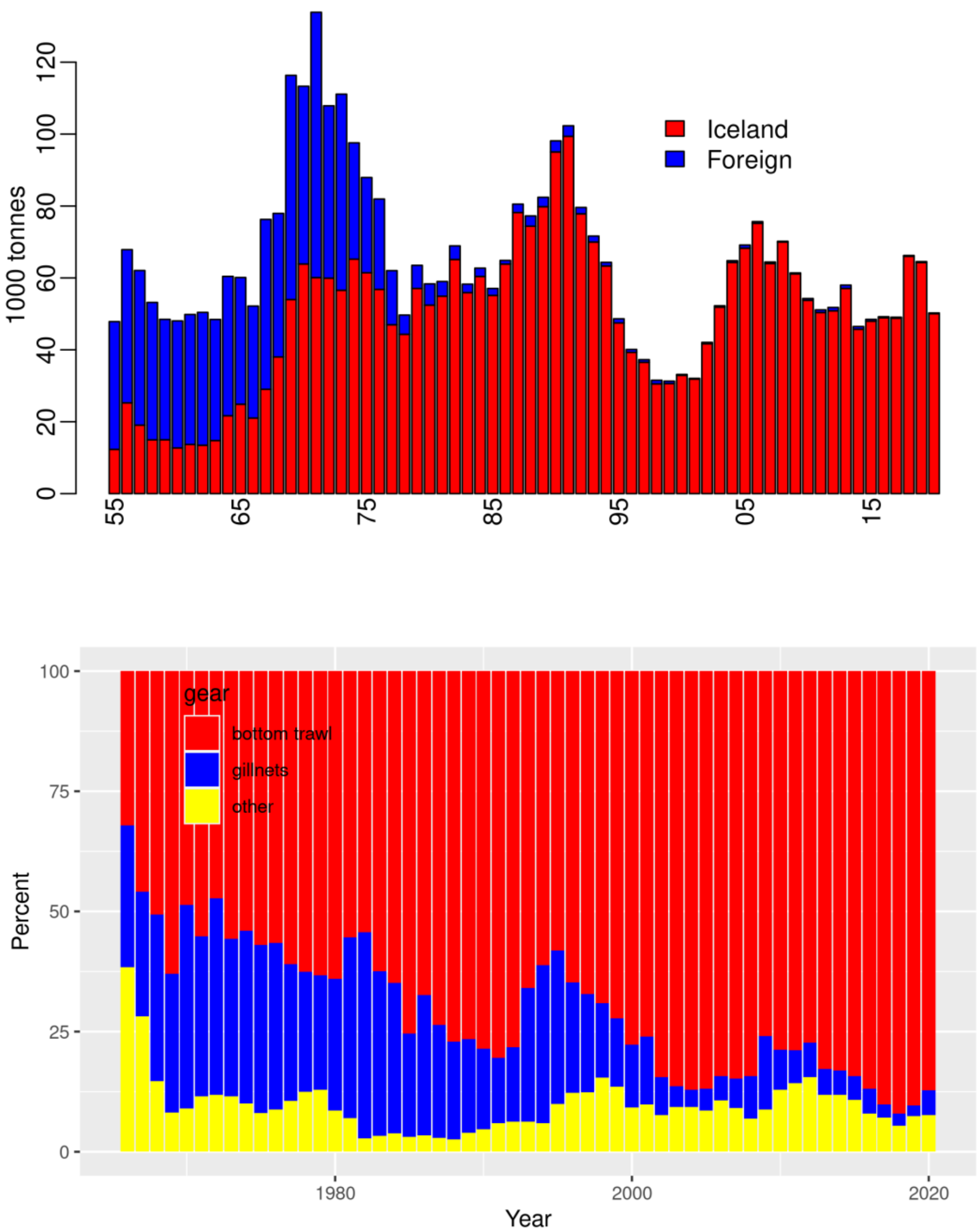

Figure 8.1 Saithe in Division 5.a. Total landings and percent by gear.

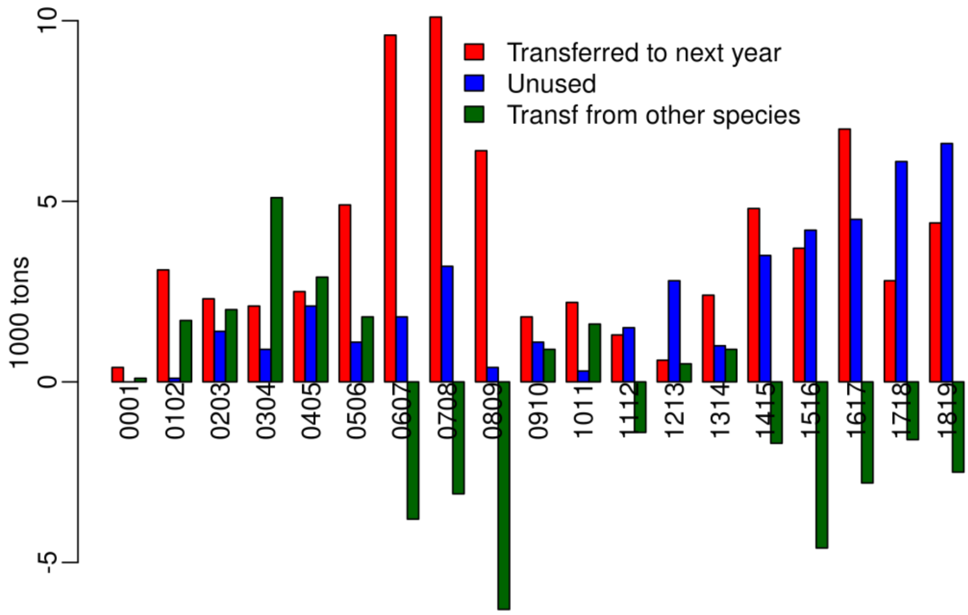

Figure 8.2 Saithe in Division 5.a. Upper figure. Cumulative landings in the current fishing year (left) and calendar year (right). The vertical (green line) in the left figure shows the quota for the current fishing year. Lower figure. Transfer of quota to next fishing year, unused quota and transfer from other species (negative transfer from other species means transfer to other species).

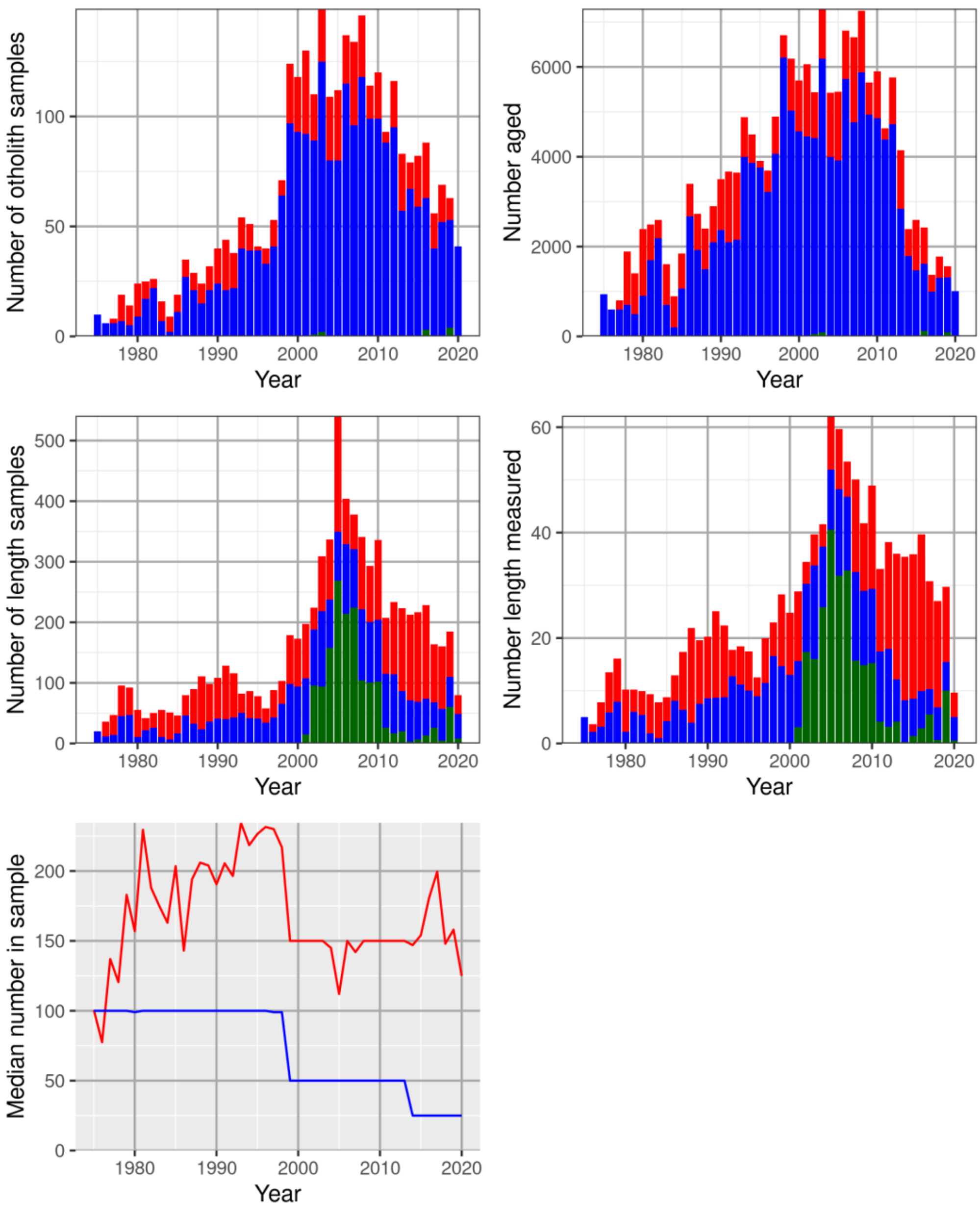

Figure 8.3 Saithe in Division 5.a. Development of sampling intensity from catches.

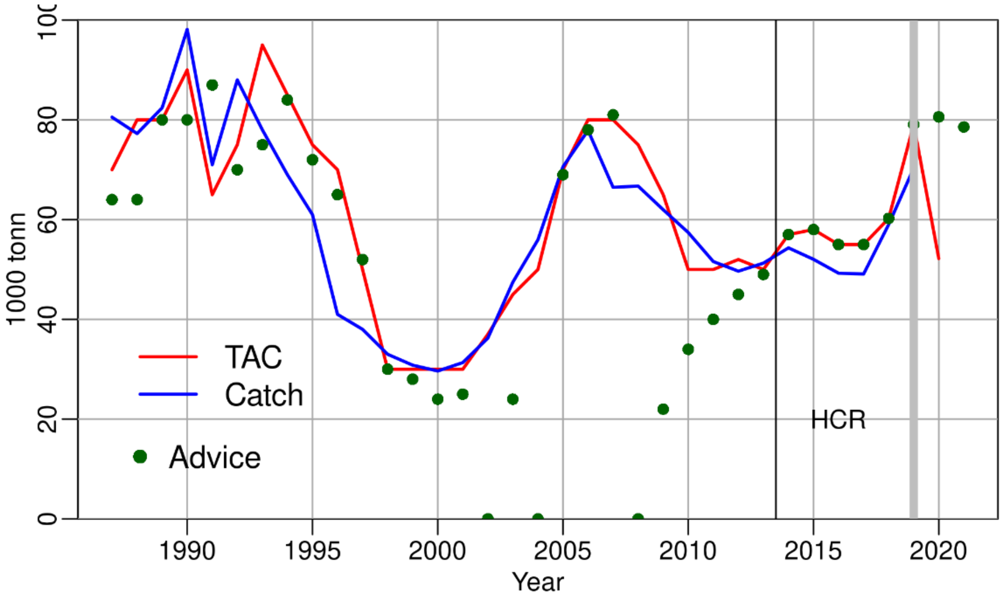

Figure 8.4. Advice, TAC and catch of saithe since 1987.

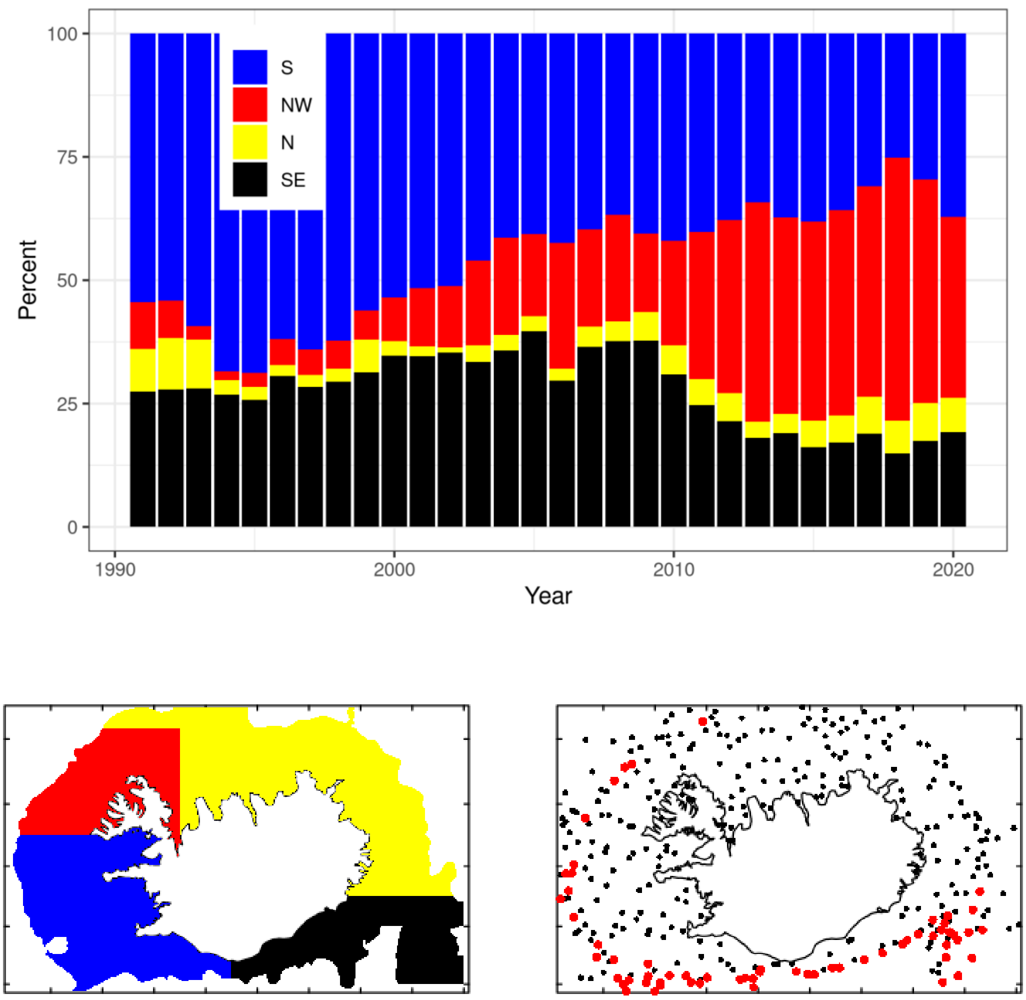

Figure 8.5. Saithe in Division 5.a. Upper figure percent of landings by regions defined in the lower figure to the left. Lower right, stations added in the autumn survey in 2000 (red dots).

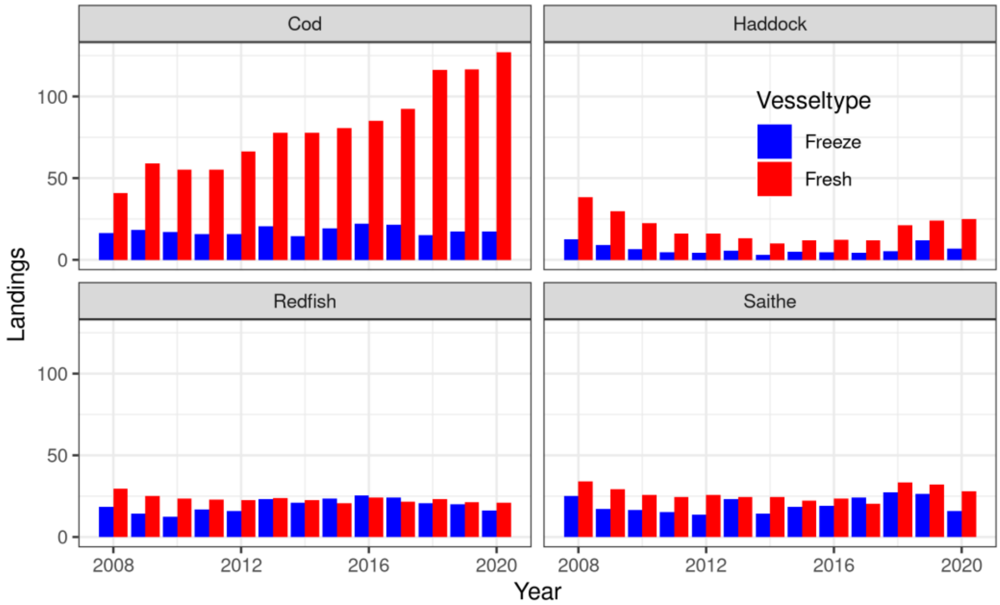

Figure 8.6 Saithe in Division 5.a. Catch by trawlers divided between those that freeze the catch and those that do not. Number of trawlers landing more than 500 tonnes has been reducing gradually from 42 in 2008 to 33 in 2020. Freezing trawlers landing > 500 tonnes were 26 in 2008 but 9 in 2020.

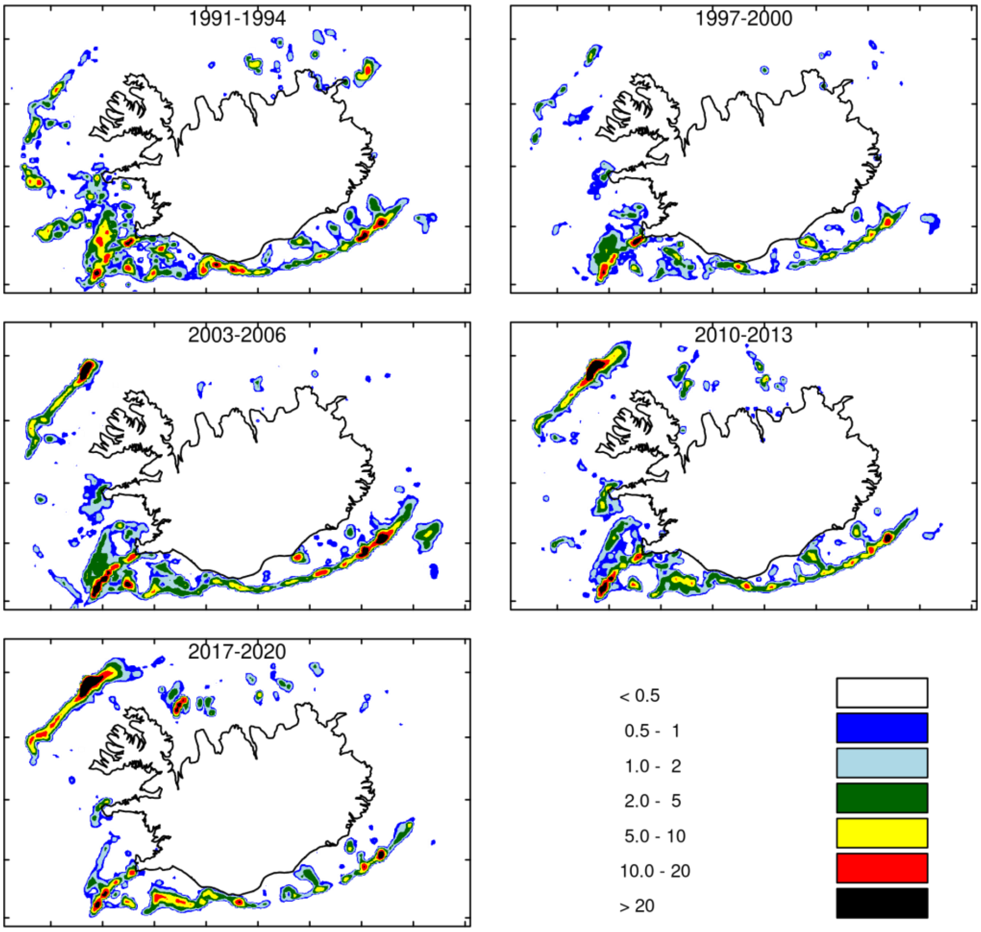

Figure 8.7. Spatial distribution of saithe catch as tonnes per square nautical mile per year.

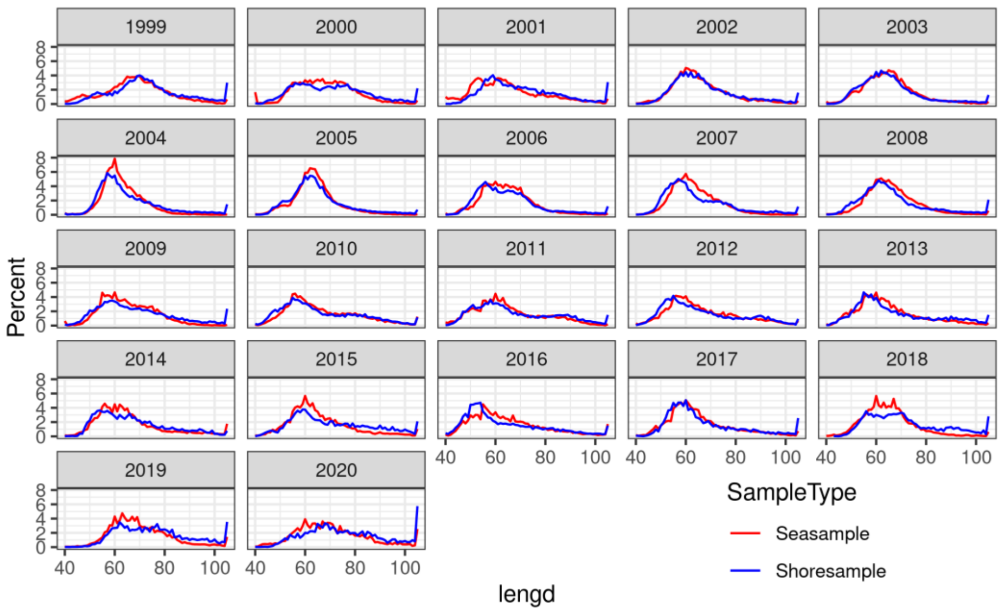

Figure 8.8. Length distributions from sea and shore samples.

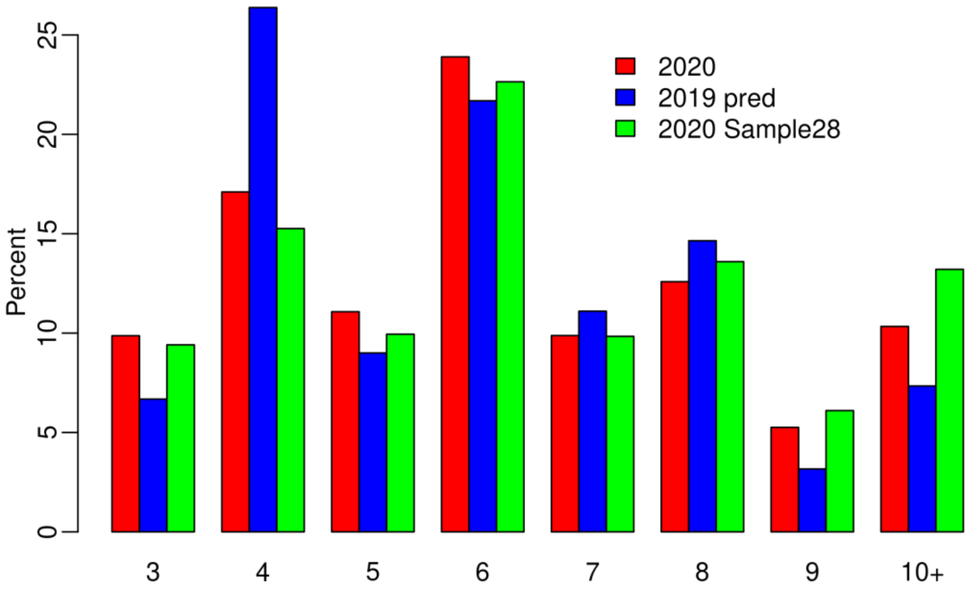

Figure 8.9. Catch in numbers 2020 compared to last year's prediction. The green bars show catch in numbers only based on shore samples.

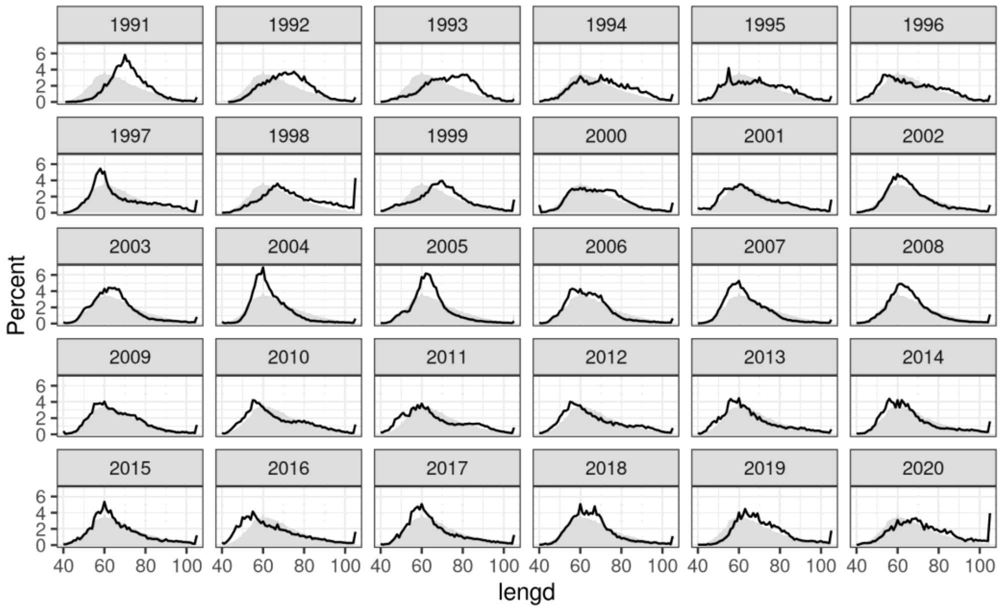

Figure 8.10. Length distributions from bottom trawl catches (lines) compared to average (grey shading).

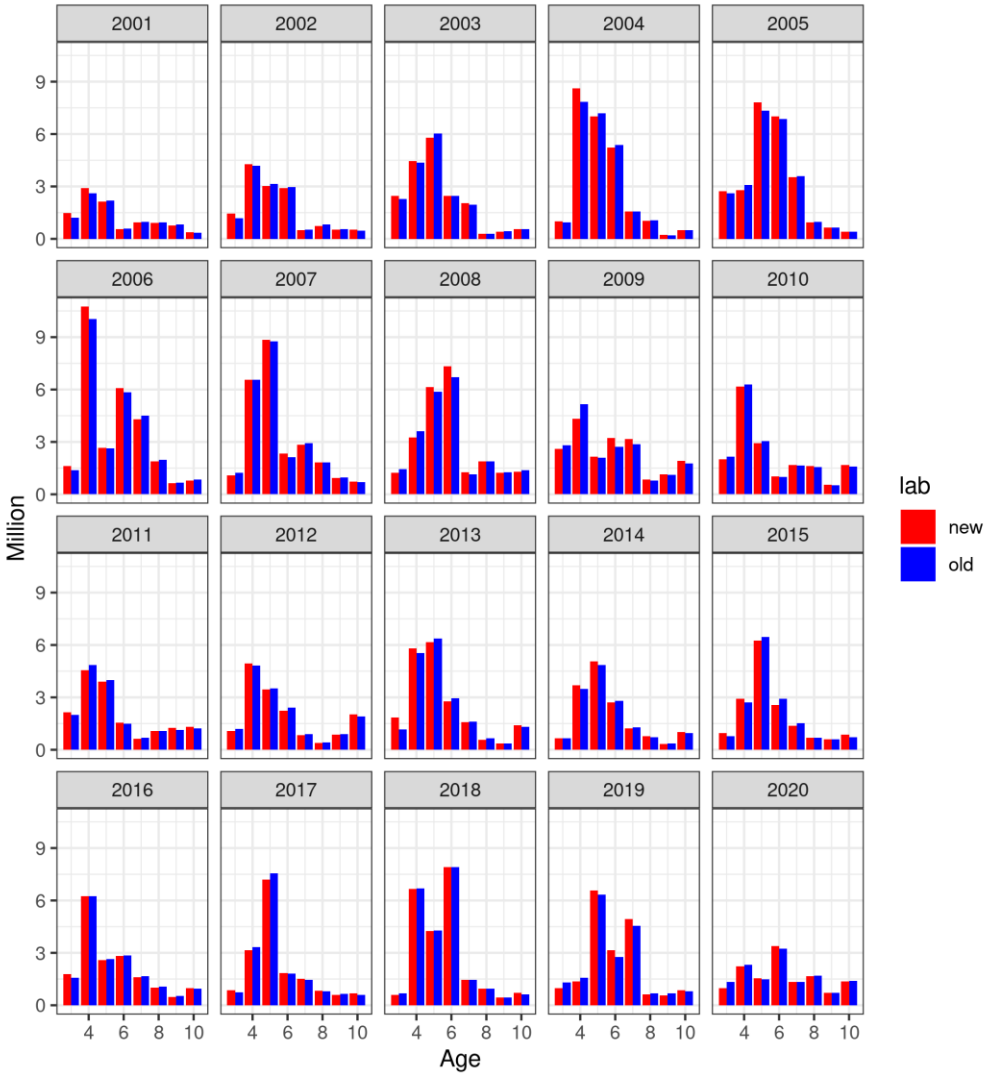

Figure 8.11. Catch in numbers 2000–2020 compiled by 1 region and 1 time interval (old) compared to catch in numbers compiled by 2 regions and 2 time interval (new). The regions are shown in Figure 8.6, north red and yellow and south blue and black.

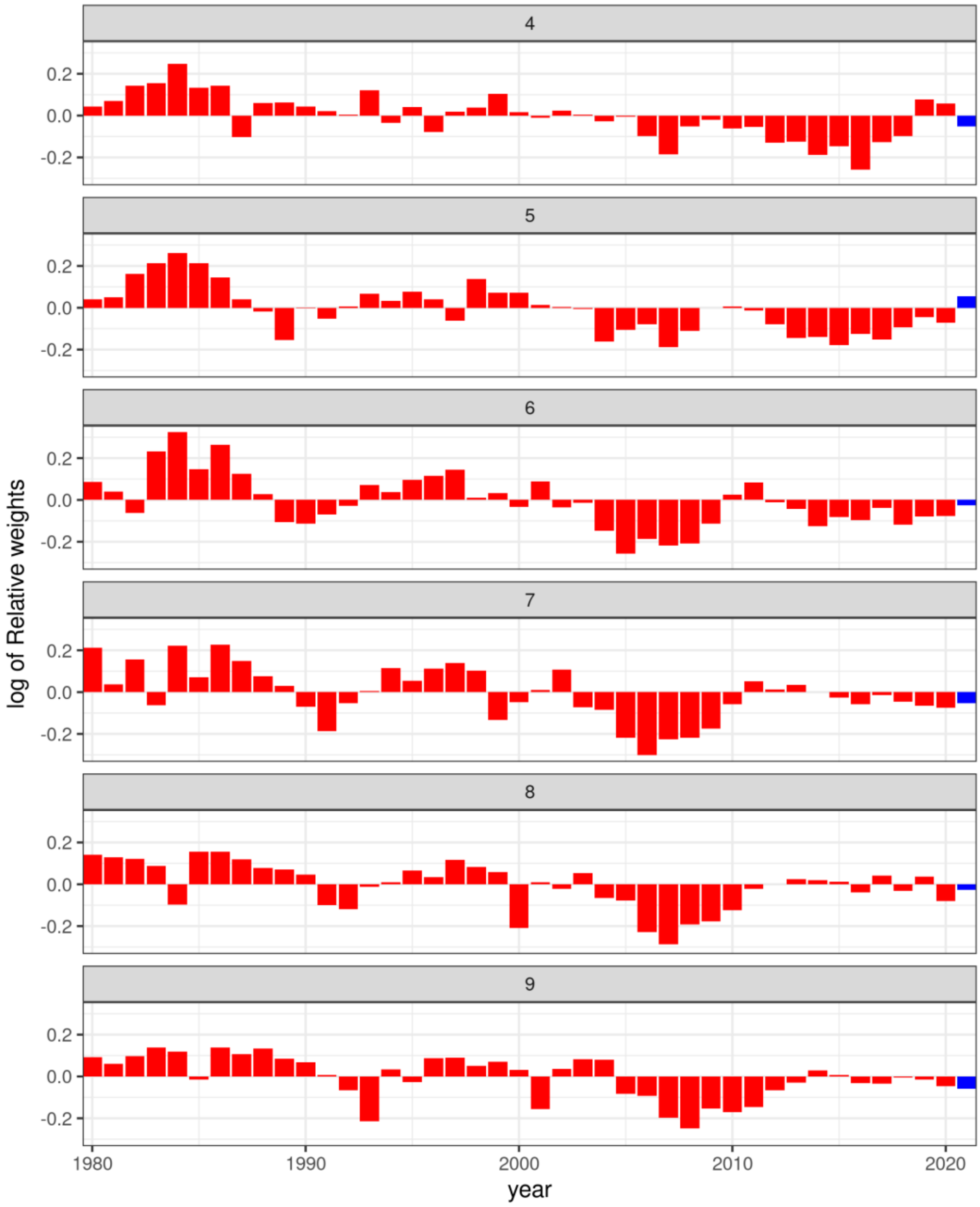

Figure 8.12. Saithe in Division 5.a. Weight at age in the catches, as relative deviations from the mean. Blue bars show prediction.

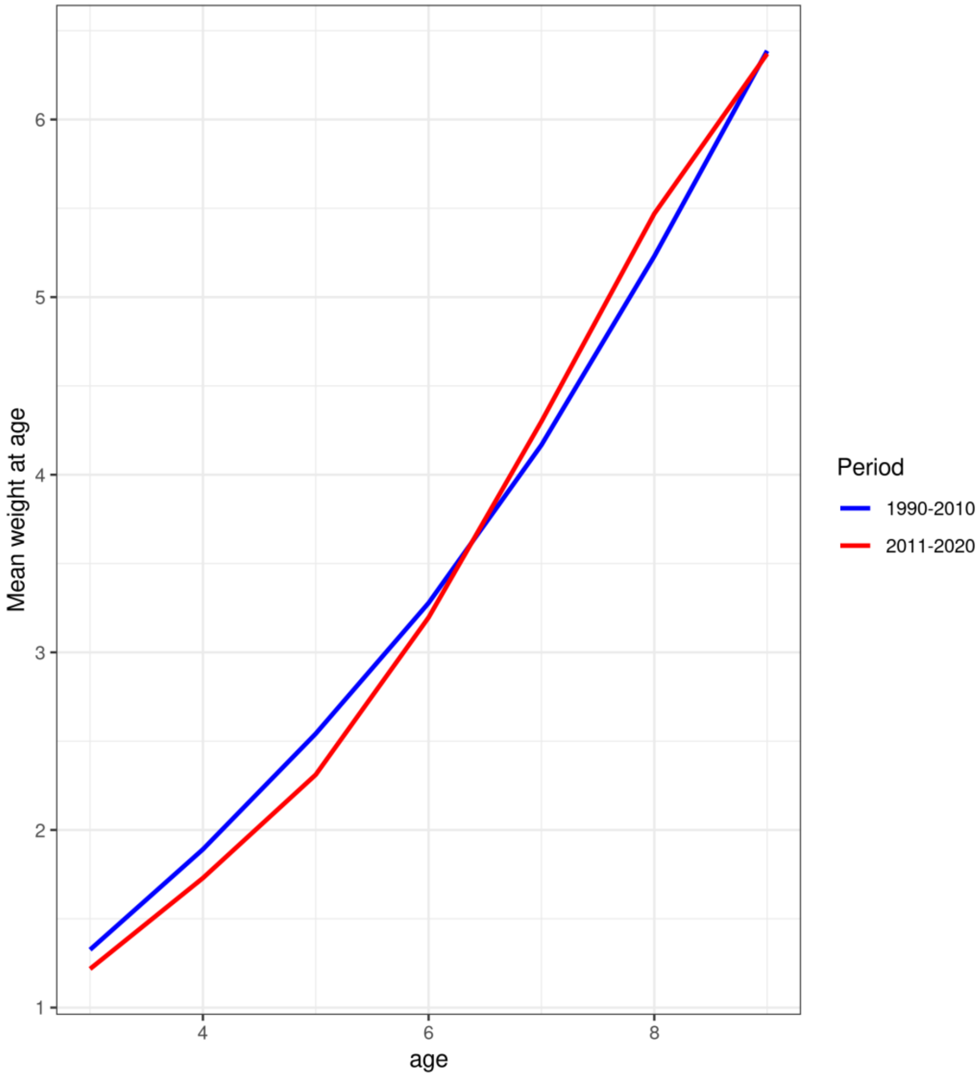

Figure 8.13. Saithe in Division 5.a. Weight at age in the catches shown as average for 2 periods.

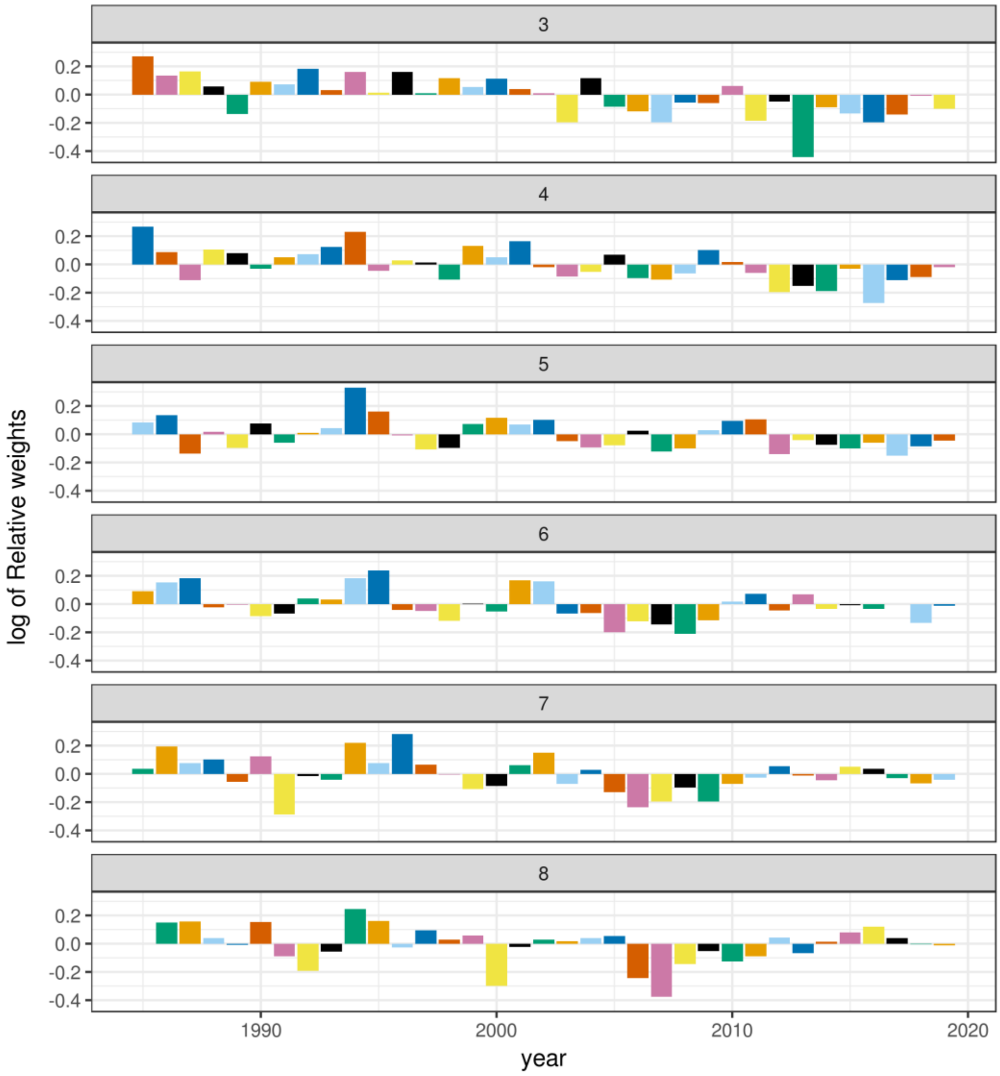

Figure 8.14 Saithe in Division 5.a. Weight at age in the survey, as relative deviations from the mean. Colours can be used to follow year classes.

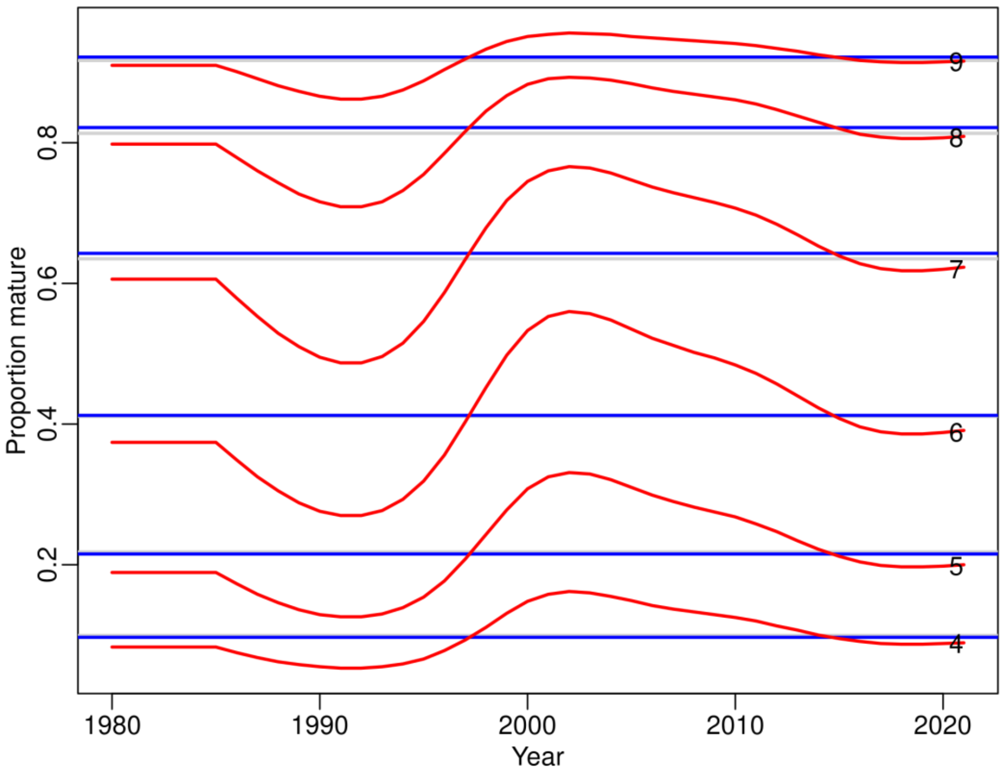

Figure 8.15. Saithe in Division 5.a. Maturity at age used for calculating the SSB. The horizonal lines show the average of last 10 years (blue one) and the average since 1985.

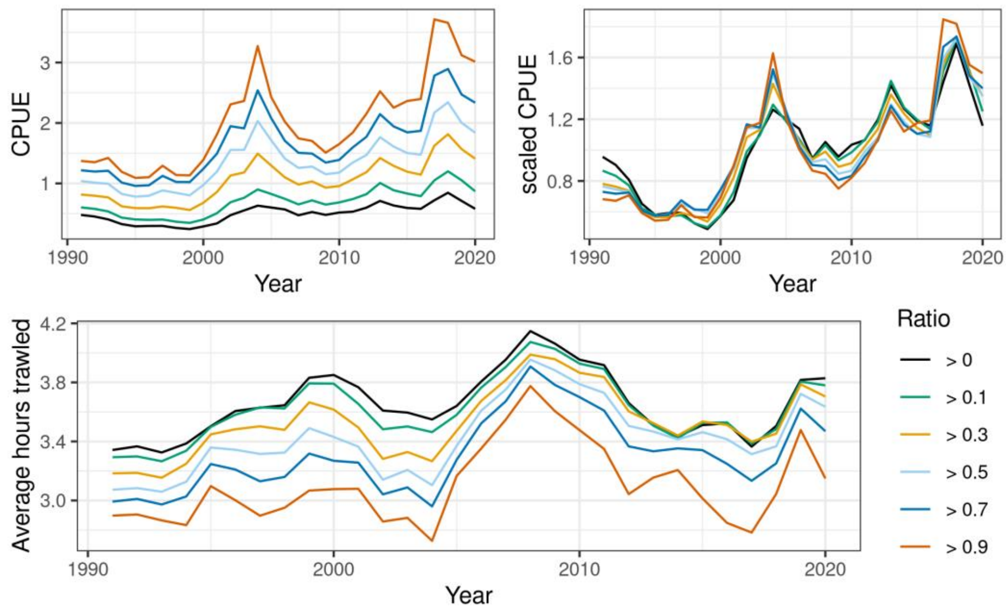

Figure 8.16. CPUE, CPUE scaled to an average of 1 and average numbers of hour trawled. Different colours indicate selection of tows where proportion of saithe of the total catch exceeds certain specified value.

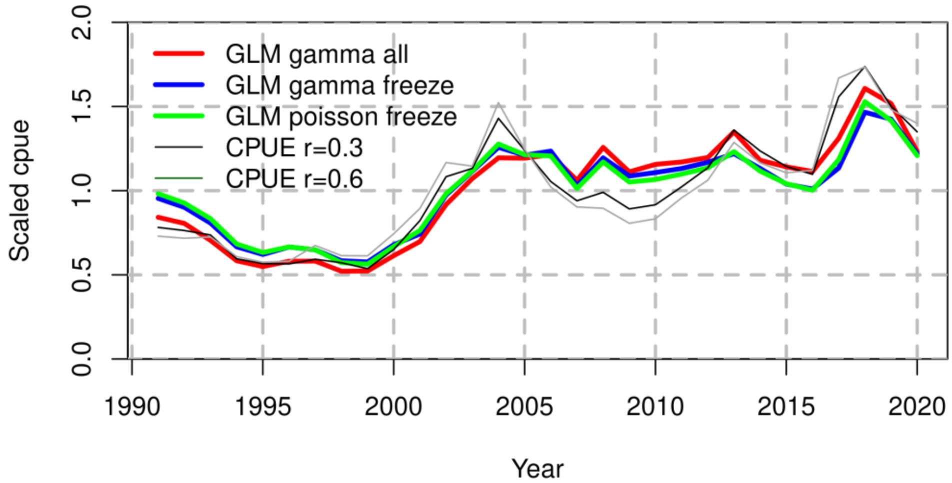

Figure 8.17. CPUE compiled from 3 different models compared to CPUE compiled in similar way as shown in figure 8.16. All curves scaled to an average of 1.

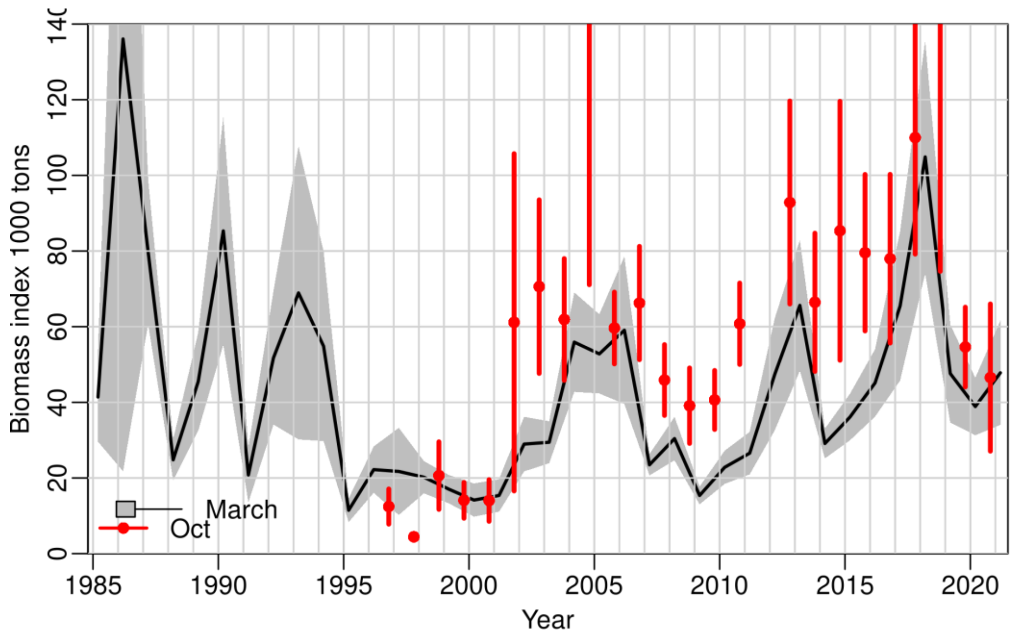

Figure 8.18. Saithe in Division 5.a. Biomass index from the groundfish surveys in March and October.

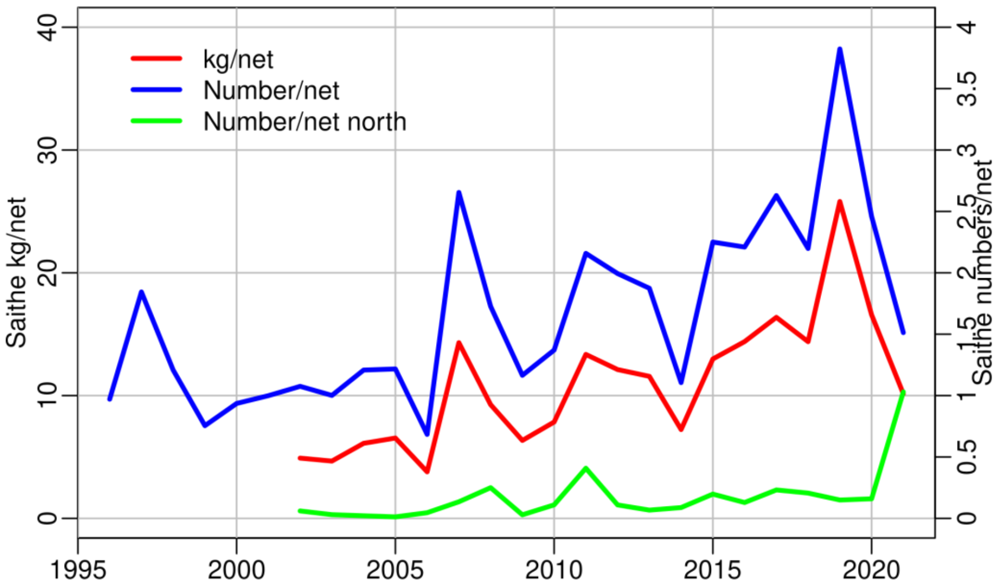

Figure 8.19. Saithe in Division 5.a. Indices from the gillnet survey in April 1996–2018. Saithe was not length measured in the survey before 2002 so catch in kg cannot be compiled. (add 2018)

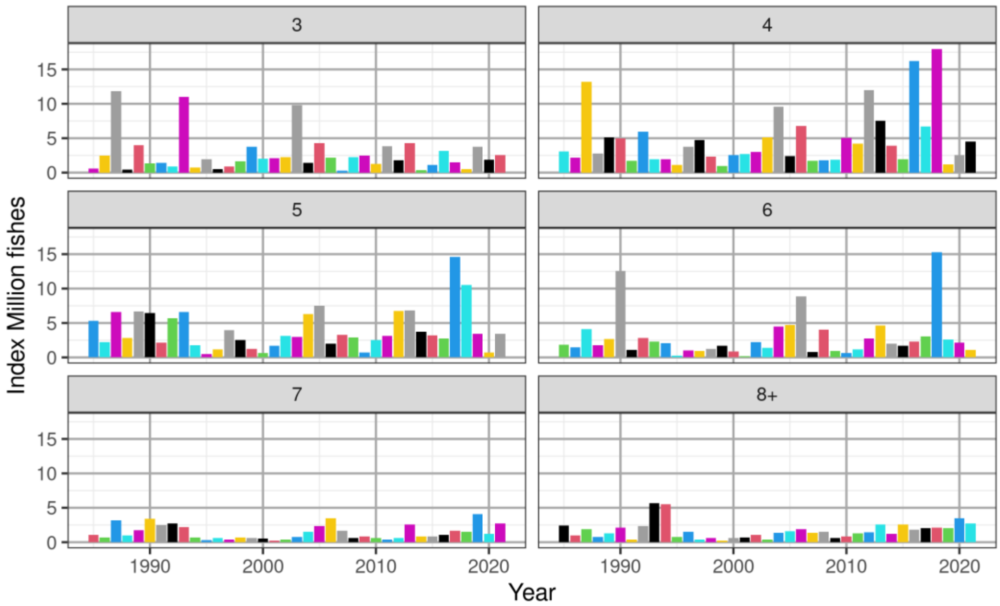

Figure 8.20. Saithe in Division 5.a. Survey indices by age from the spring survey. The colours follows year classes except of course for age 8+.

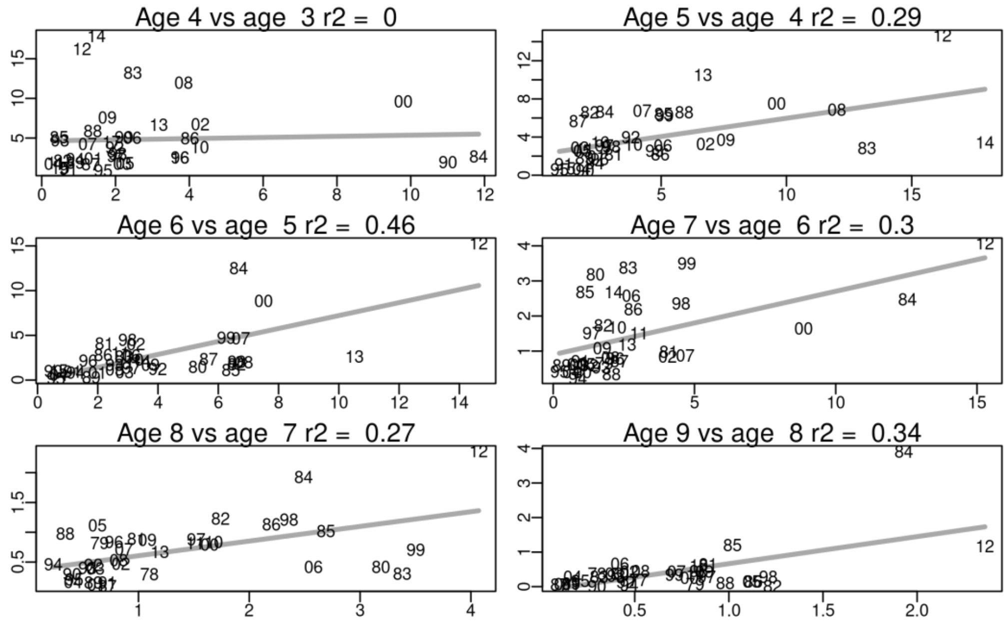

Figure 8.21. Saithe in Division 5.a. Survey indices by age from the spring survey plotted against indices of the same cohort one year earlier.

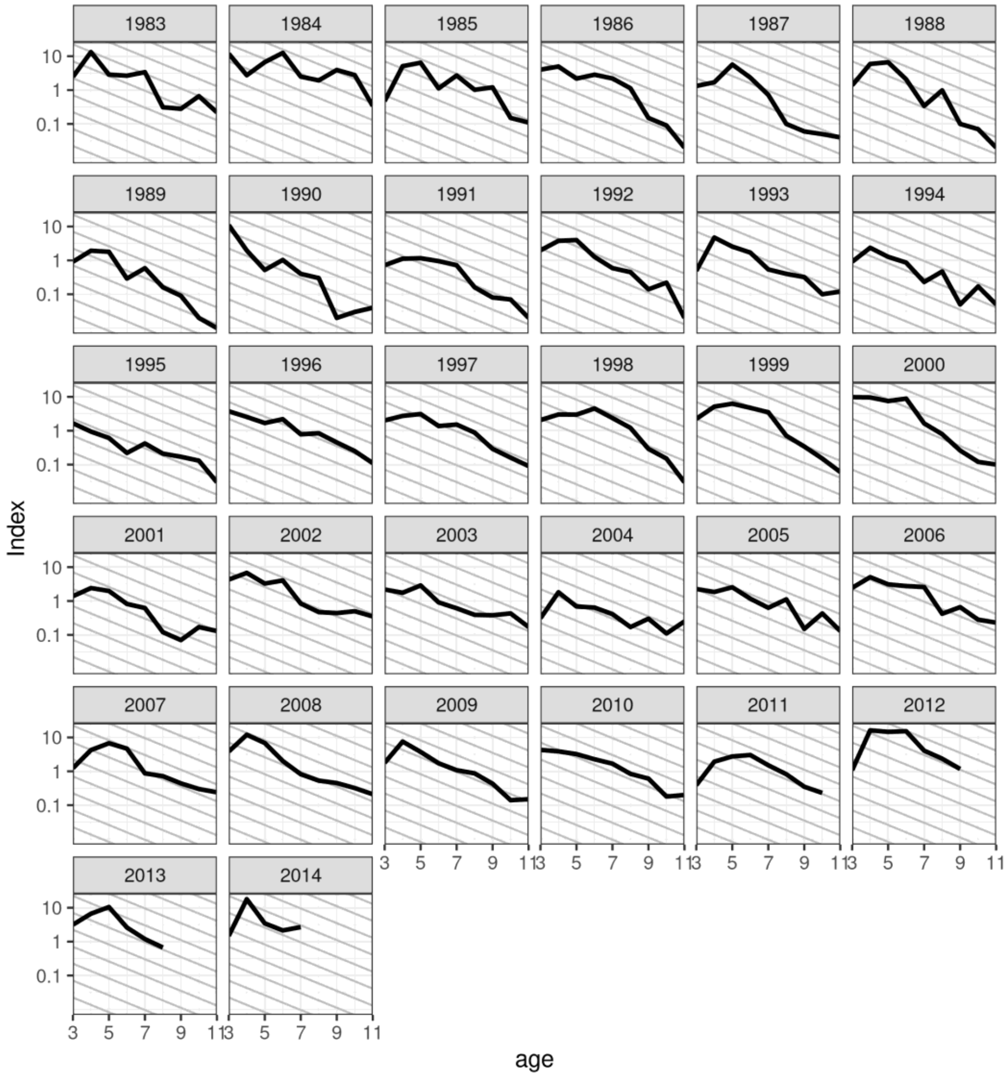

Figure 8.22. Saithe in Division 5.a. Survey indices by age from the spring survey plotted as catch curves for each yearclass. The grey lines correspond to Z=0.5.

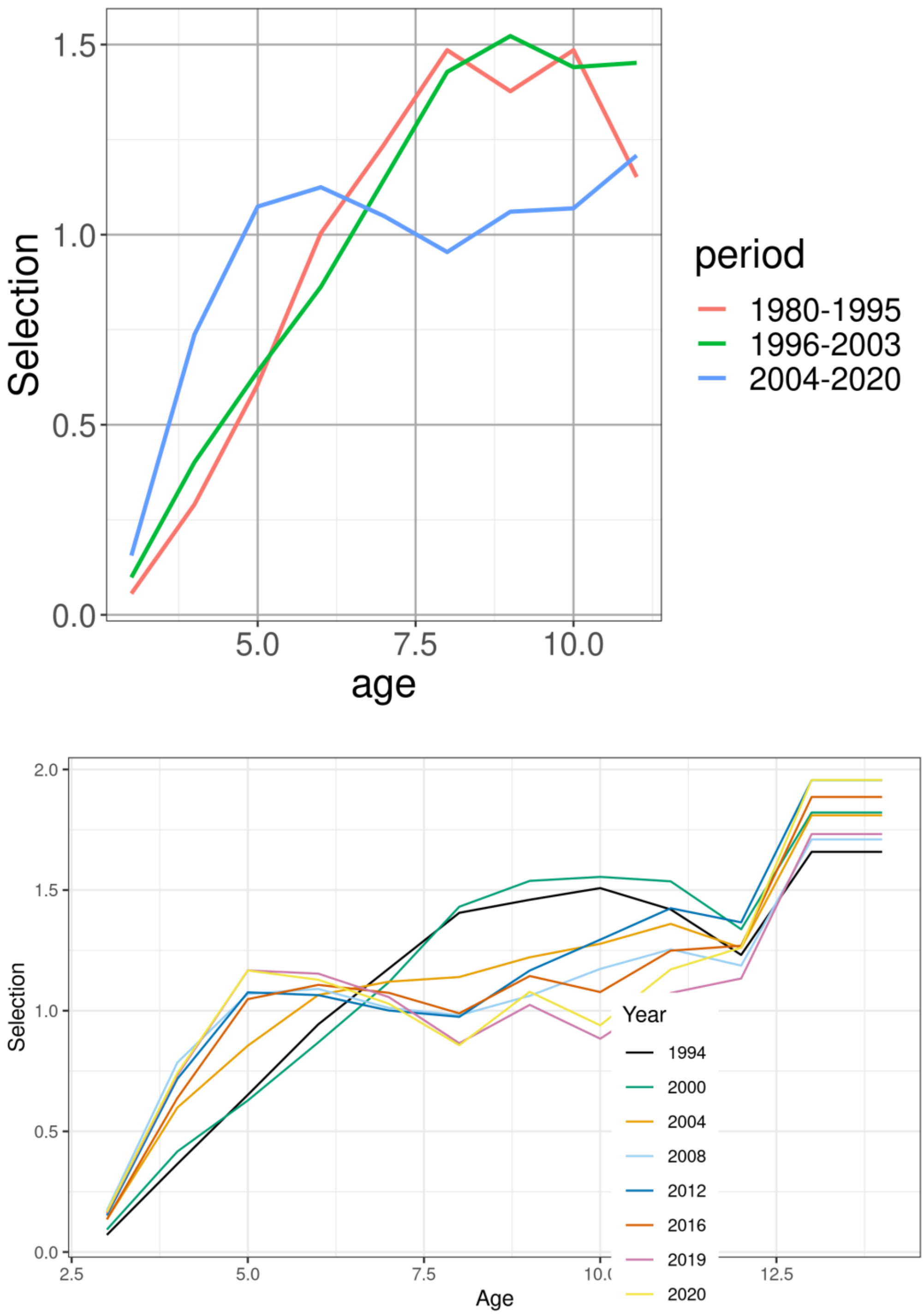

Figure 8.23. Upper figure. Estimated selectivity patterns for the 3 periods, 1980–1996, 1997–2003 and 2004–2020. Lower figure estimated selection from the SAM model. The timing of selection change around 2004 is also evident in the SAM model results.

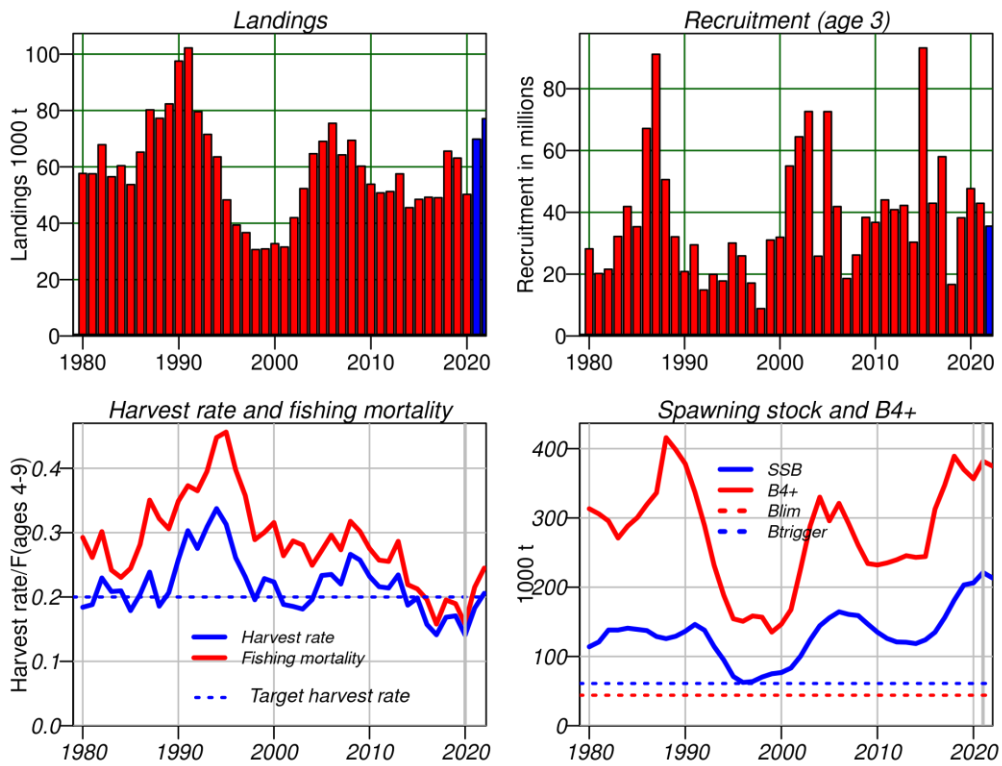

Figure 8.24. Saithe in Division 5.a. Results from the adopted benchmark (SPALY) model and short-term forecast.

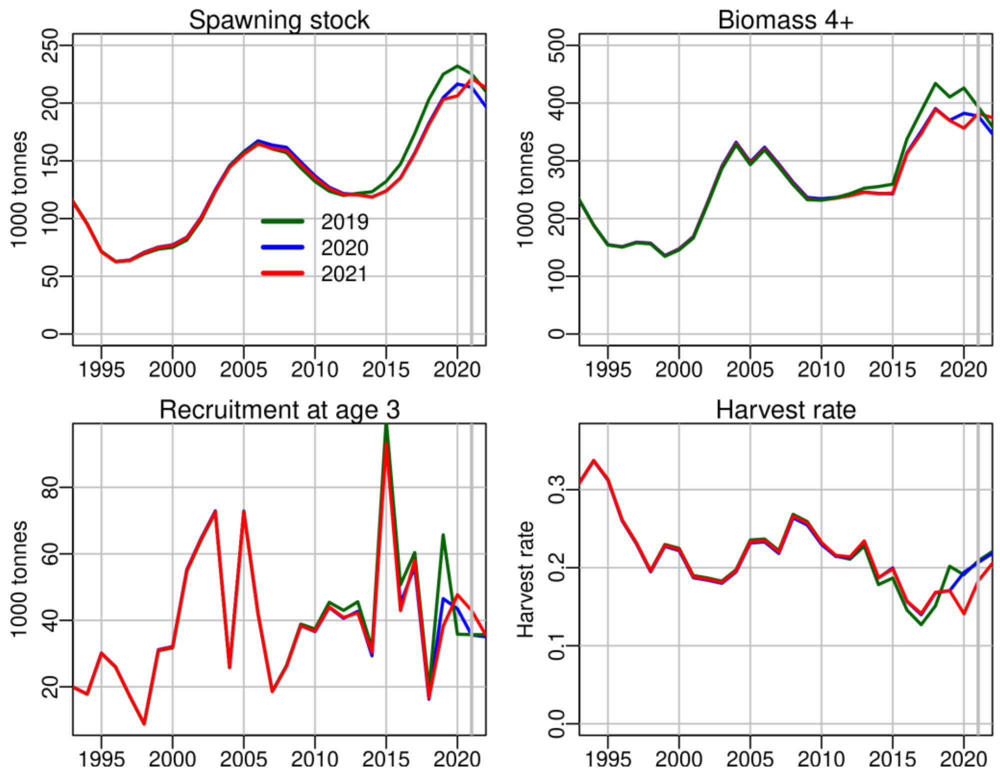

Figure 8.25. Saithe in Division 5.a. Comparison of this year's assessment and short term forecast with results from two earlier years.

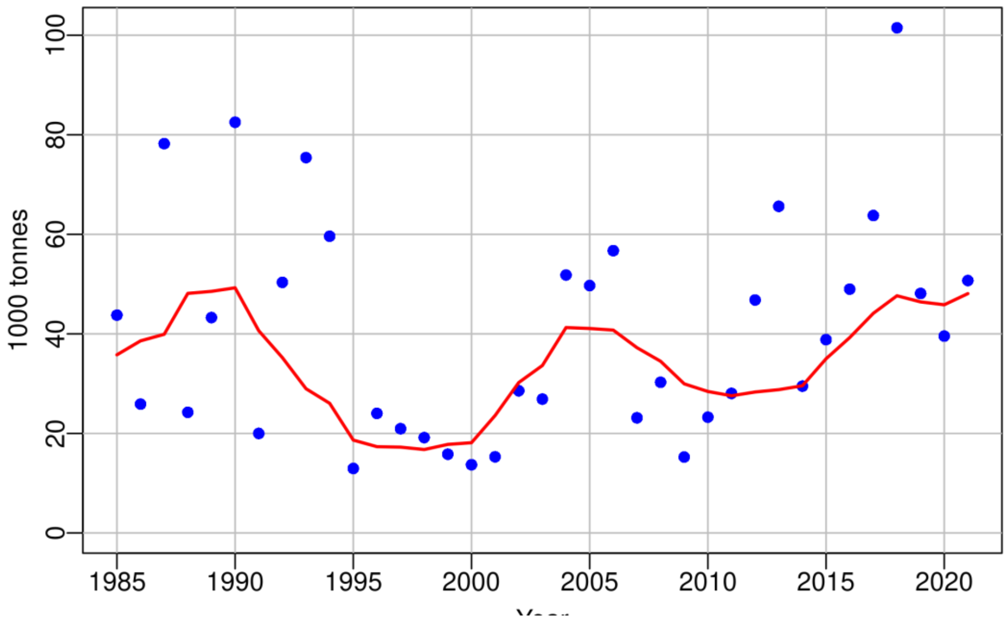

Figure 8.26. Saithe in Division 5.a. Observed and predicted survey biomass from the "SPALY model".

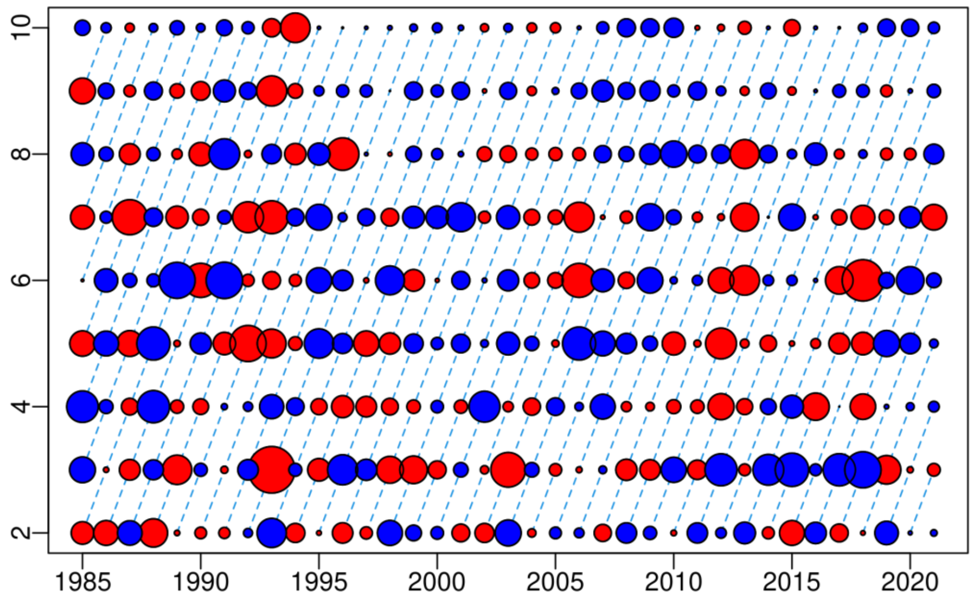

Figure 8.27. Saithe in Division 5.a. Survey residuals from the "SPALY model". The residuals are standardised.

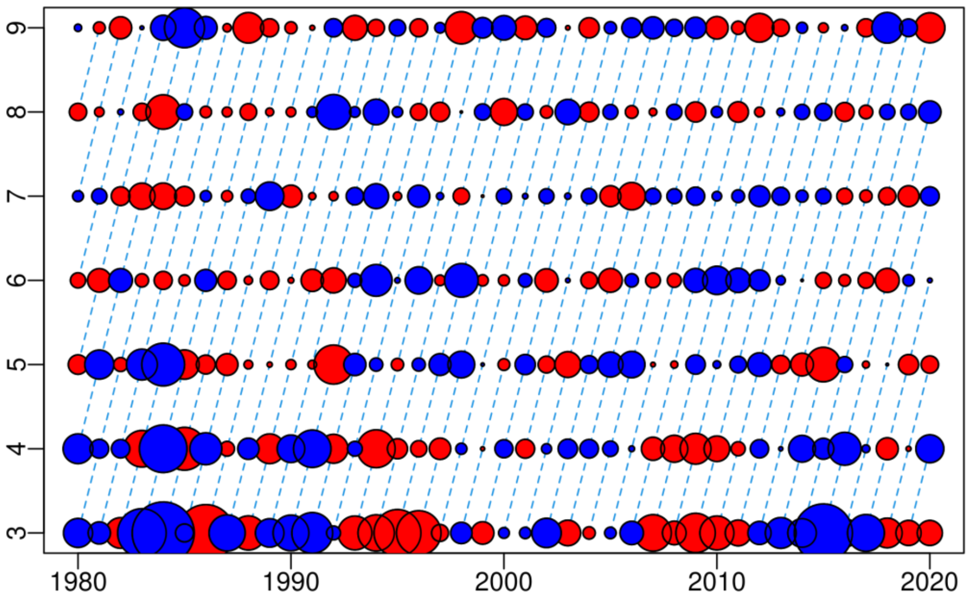

Figure 8.28. Saithe in Division 5.a. Catch residuals from the "SPALY model".

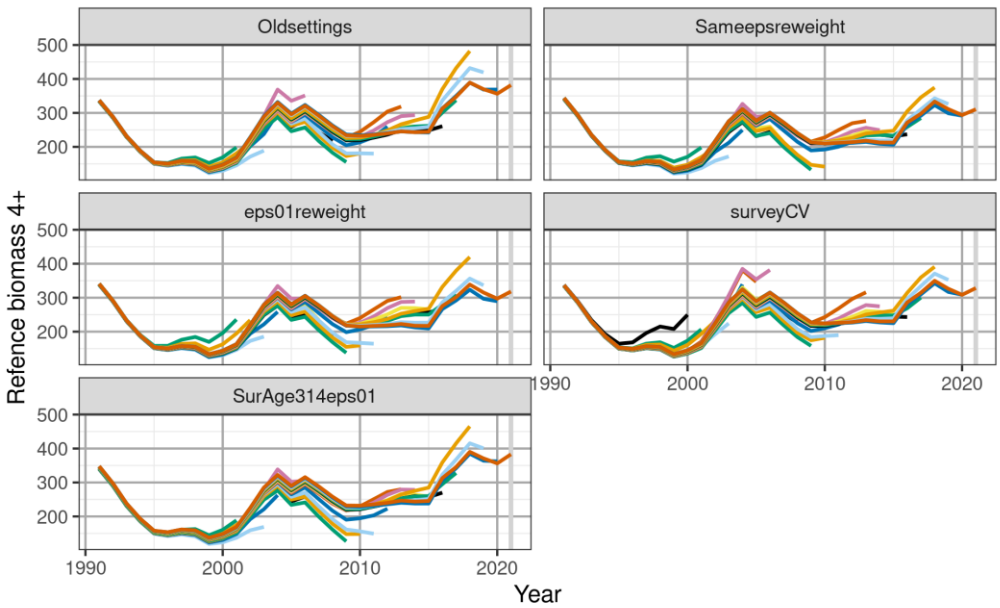

Figure 8.29. Saithe in Division 5.a. Retrospective pattern for the adopted assessment model (Oldsettings) and alternative configurations of the model. The figure shows estimate of B4+, the metric affecting advised catch. The grey vertical lines show the year 2021.

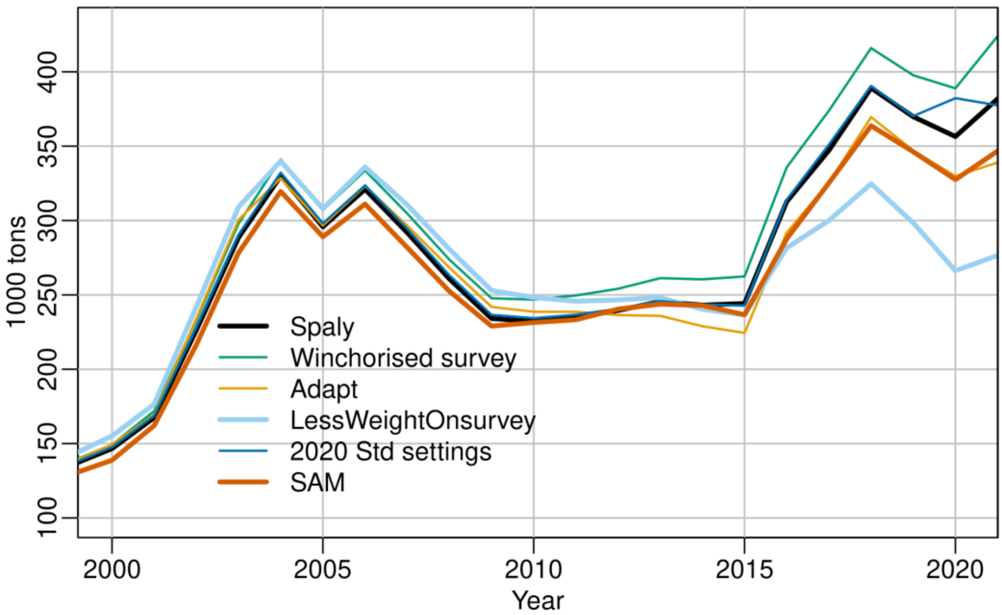

Figure 8.30. Saithe in Division 5.a. Comparison between the default separable model (Muppet) and alternative assessment model settings.

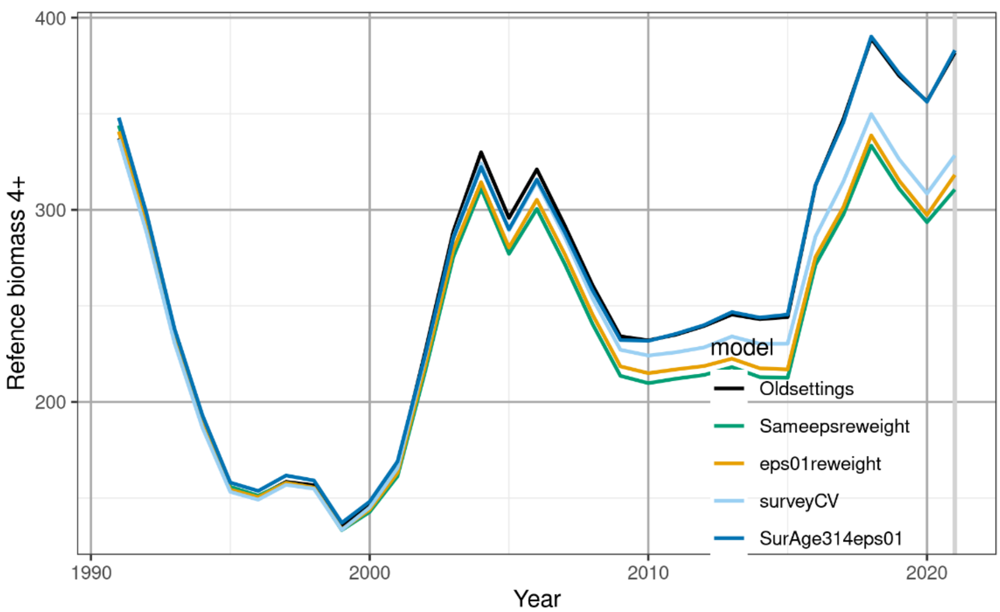

Figure 8.31. Saithe in Division 5a. Comparison between 2021 assessment results of the models shown in Figure 8.29.

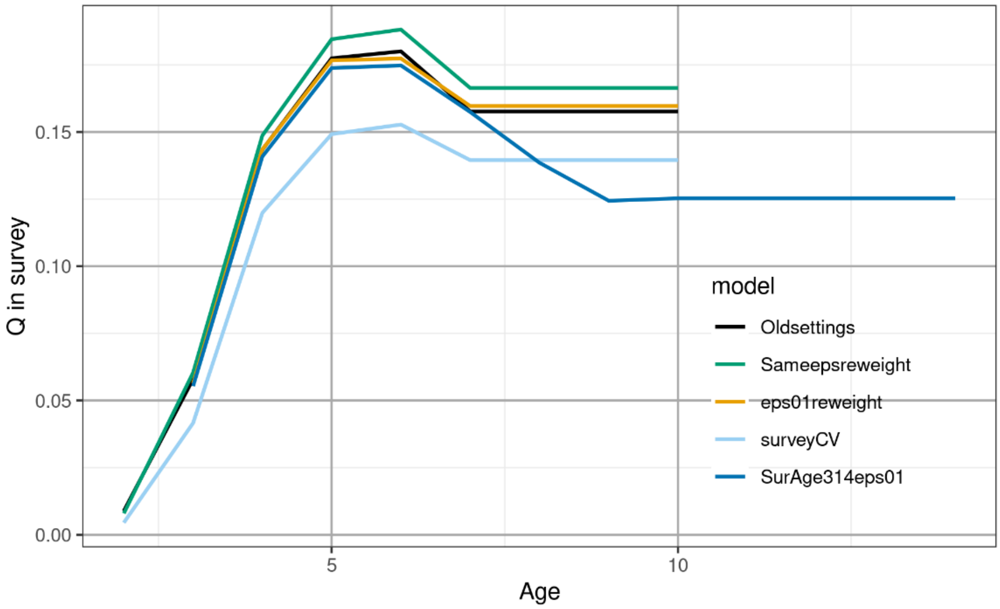

Figure 8.32. Saithe in Division 5a. Q by age in the March survey for the different models.

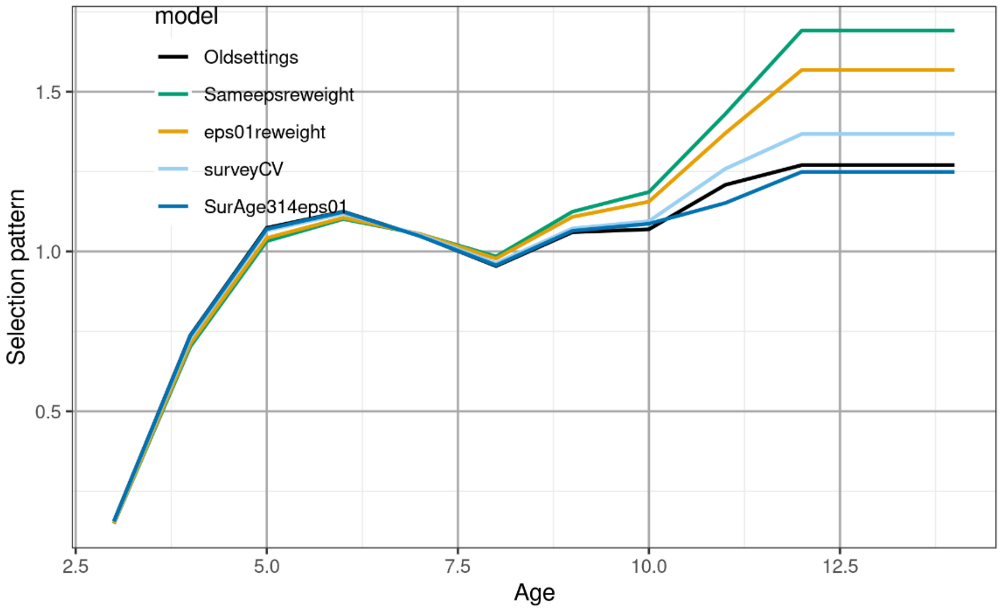

Figure 8.33. Saithe in Division 5a. Selection by age 2004–2021 for the different models.