

SAITHE

Pollachius virens

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} .

FISHERIES-DEPENDENT DATA

Landings of saithe in Icelandic waters in 2020 are estimated to have been 50 252 t (Table 1 and Figure 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 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 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 longliners 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 5 and 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 northwest 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 7) has since early in the 20th century been the most important cod fishing ground for trawlers.

LOGBOOK DATA

CPUE from the fleet show increasing trend over time (Figure 16 and 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 17 are compiled by a model of the form.

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

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

Where C is catch of saithe, T hours trawled. δ_{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).

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 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 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 overestimation 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).

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 Pálsson *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). 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 9).

Length distributions from bottom trawl show tendency to catch smaller fish from 2003–2017 but again larger fish in 2018–2020 (Figure 10). In 2020 the +110 cm group is especially abundant.

Numbers sampled in 2018–2020 is shown in Tables 2 and 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 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 4 and Figure 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 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 11) and using it in assessment leads to less than 1% difference of reference biomass.

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 5 and Figures 12–14). The large 2012 cohort 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 cohort. 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 6 and Figure 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).

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 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 7 and Figure 12). Most of the increase was caused by year class 2012 that was strong in the surveys 2015–2018 (Figure 14). The biomass index from the March survey shows lower index in 2019 than recent years (Figure 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 6) where large schools of saithe are sometimes found. Excluding these stations leads to lower but more stable index.

Catch curves from the survey indicate that $Z \sim 0.5$ assuming similar q with age (Figure 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 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 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 21).

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 23). Natural mortality is set at 0.2 for all ages. The survey residuals ($\frac{\log(I+\epsilon)}{\log(I+\epsilon)}$) 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 3, 4 and 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} .

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 re-evaluated 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} | $MSYB_{trigger}$ | $MGMTB_{trigger}$ | 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 $MSYB_{trigger}$ and HR_{pa} has changed since 2019 so those reference points were evaluated based on the same simulations as in 2019, leading to $MSYB_{trigger} = 65$ thousand tonnes and $HR_{pa} = 0.25$.

STATE OF THE STOCK

The results of the principal stock quantities (Table 8 and Figure 24) show that the reference biomass (B_{4+}) 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 $B_{4+2021} = 382$ 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 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 9 and 10.

The commercial catch-at-age residuals in 2020 (Figure 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 10), and proportion of age 9 and older in 2020 is higher than expected (Figure 9). The survey

residuals (Figure 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 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.

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 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 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 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 12 based on assessment years 2000–2017. Bias is defined as $\log\left(\frac{B_{y,y}}{B_{y,assY}}\right)$ and CV as $\sigma^{\log\left(\frac{B_{y,y}}{B_{y,assY}}\right)}$. Mohns rho is really another way to present bias. The selection of years to use is the difference between Tables 11 and 12, in 12 the results are based on the assessment years that are not used when compiling results for Table 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 30) compared to the results. The result show very low estimated biomass when the survey data are downweighed, 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 B_{4+2021} , the number that matters for the advice. The values are in thousand tonnes.

| Std settings | Winchorised survey | Adapt | Less Weight 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 B_{4+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 4). The assessment models indicate substantial reduction of fishing mortality and harvest rate in last 4 years (Figure 24), mostly because the TAC has not been fished. The selection pattern observed since 2004 (Figure 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 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 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.

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) shows 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.

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 $(\frac{\log(I+\epsilon)}{\log(I+\epsilon)})$ 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 $CV_{2,a}$ $CV_{s,y,a} = \frac{\sigma_{I_{y,a}}}{I_{y,a}} \cdot CV_{tot,y,a}$
 $= \sqrt{(CV_{s,y,a}^2 + CV_{2,a}^2)}.$

$CV_{2,a}$ 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 29 and 31 and the Tables 11 and 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.
5. Sameepsreweight. Same pattern of ϵ but CV pattern be age re estimated.
6. eps01reweight. $\epsilon = 0.1$ for all age groups. Age 2 not included.
7. surveyCV. Model uses estimated $CV_{y,a}$ in survey as described above.
8. SurAge314eps01. $\epsilon = 0.1$ 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 32). Model 5 uses all ages and q is 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 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.

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Table 1. Saithe in Division 5.a. Nominal catch (t) by countries, as officially reported to ICES.

| Year | 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 |

| Year | Belgium | Faroes | France | Germany | Iceland | Norway | UK (e/w/ni) | UK (scot) | UK | Total |
|------|---------|--------|--------|---------|---------|--------|-------------|-----------|----|--------|
| 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 |
| 2019 | | 237 | | | 64 295 | | | | | 64 532 |
| 2020 | | 194 | | | 50 058 | | | | | 50 253 |

Table 2. Saithe in Division 5.a. Sampling 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 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 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 |

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

Table 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 |

| Year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12+ |
|------|------|------|------|------|------|------|------|------|------|-------|
| 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 |
| 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 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 |

| Year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|------|---|-------|-------|-------|-------|-------|-------|----|----|----|
| 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 |
| 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 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 |

| Year | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|------|------|------|------|------|------|------|------|------|------|
| 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. 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 |

| Year | B4+ | SSB | N3 | Yield | f4–9 | HR |
|---------|-----|-----|----|-------|------|------|
| 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 |
| 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 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 |
| 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 |

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|-----|
| 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 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 |

| Year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 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 |
| 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 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 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 13. Saithe in Division 5.a. Output from short-term projections.

| 2021 | | | | | | |
|-------------|-----|------------------|----------|-------------|-----|-----------|
| B4+ | SSB | F _{bar} | 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

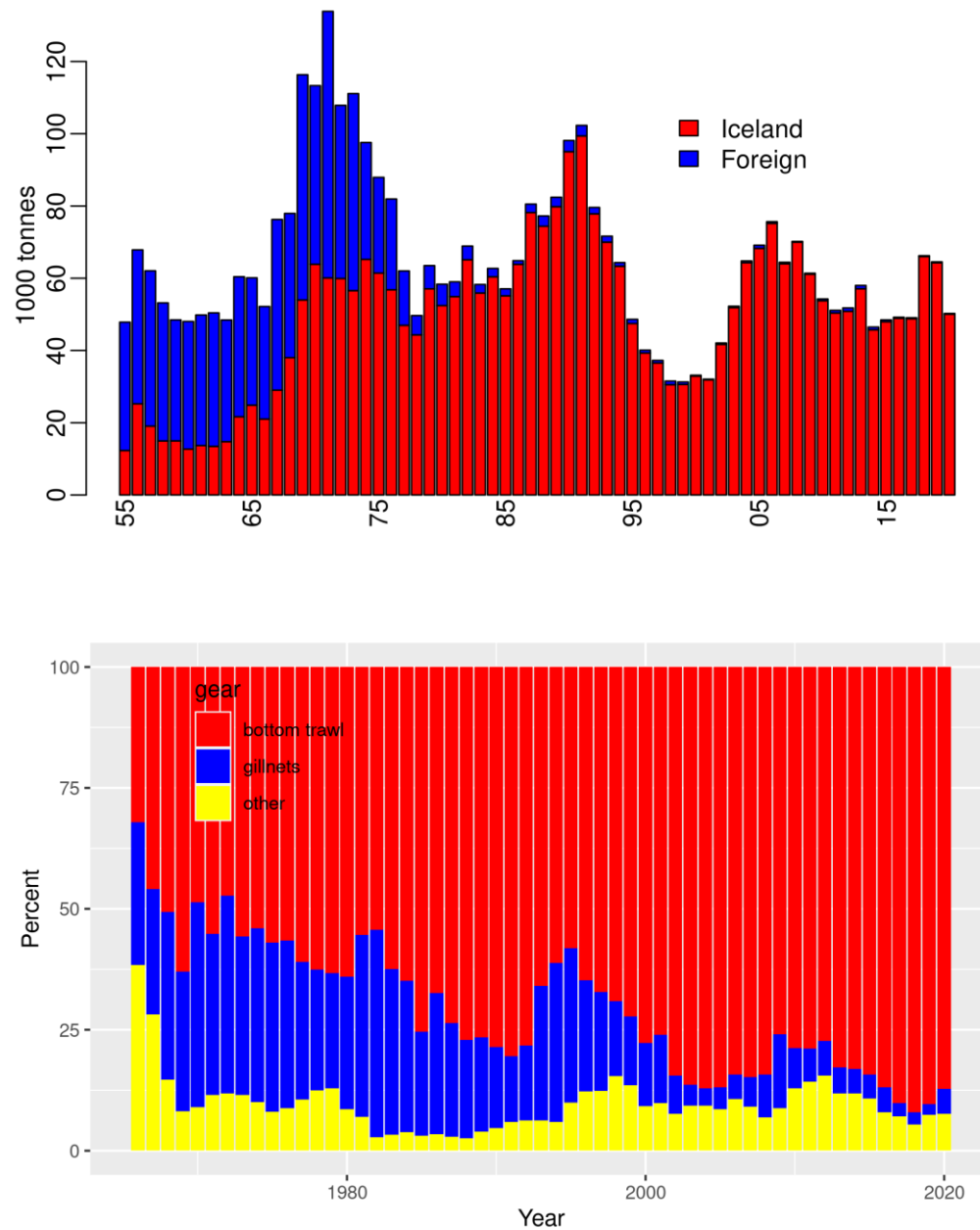


Figure 1. Saithe. Total landings and percent by gear.

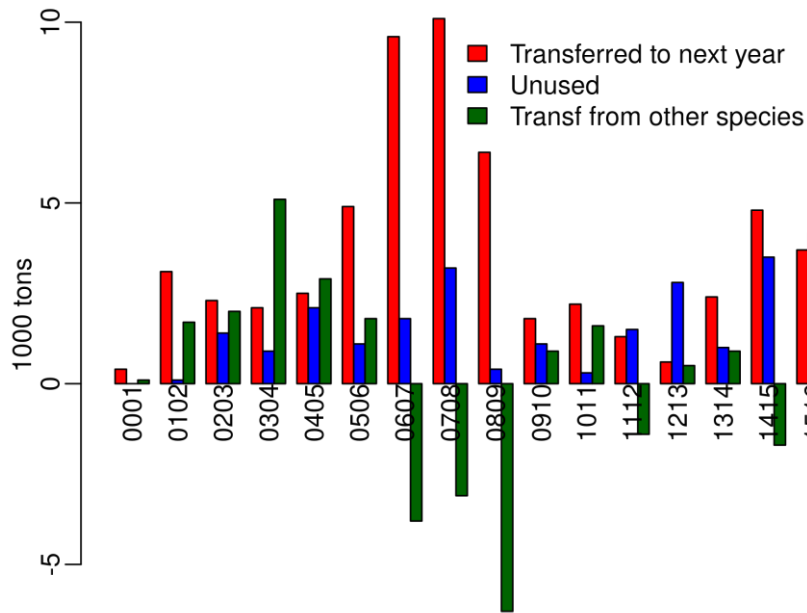


Figure 2. Saithe. Upper figure. Cumulative landings in the current fishing year (left) and calendar year (right). The vertical (green line) in the left figure shows the quota for the current fishing year. Lower figure. Transfer of quota to next fishing year, unused quota and transfer from other species (negative transfer from other species means transfer to other species).

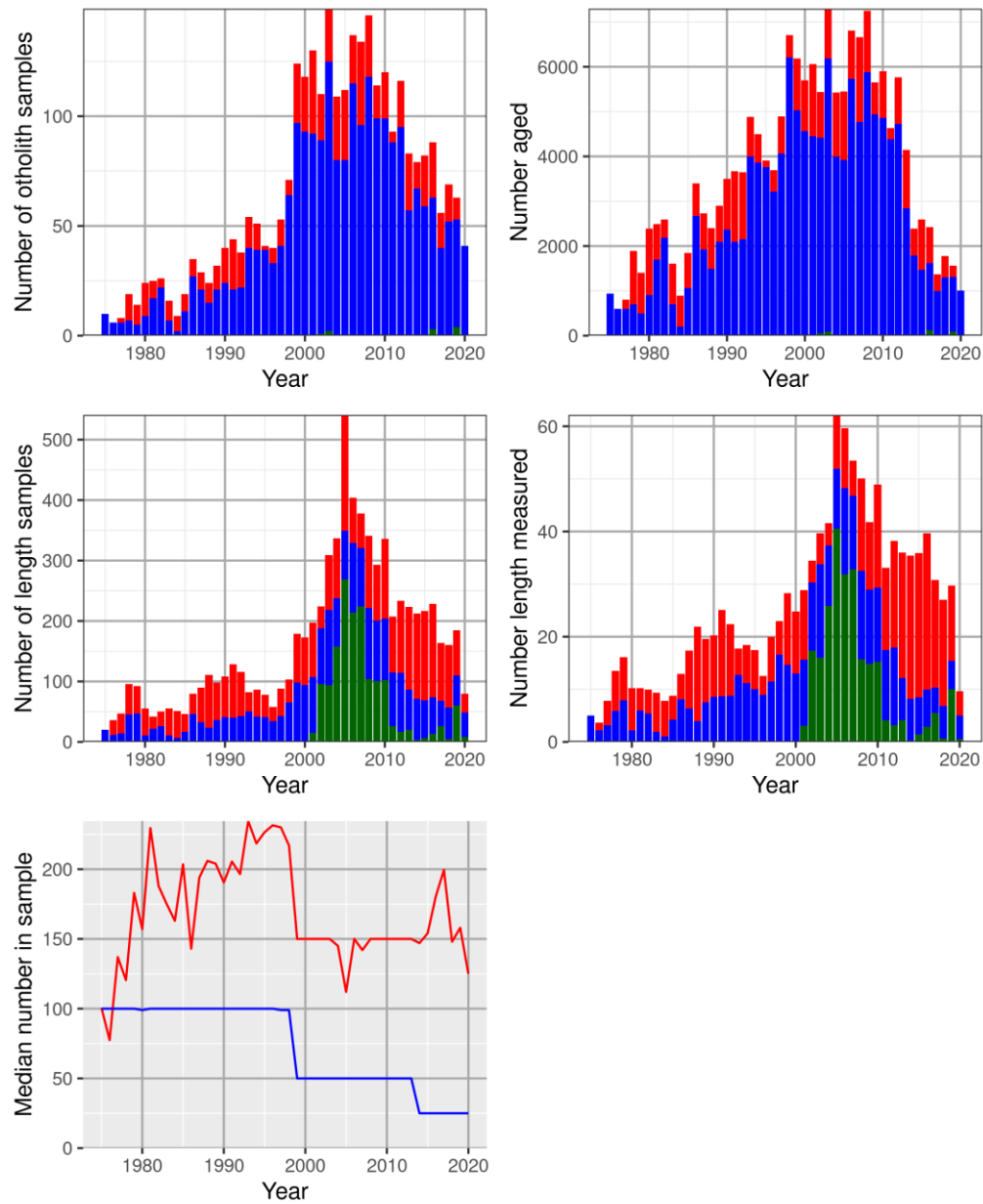


Figure 3. Saithe. Development of sampling intensity from catches.

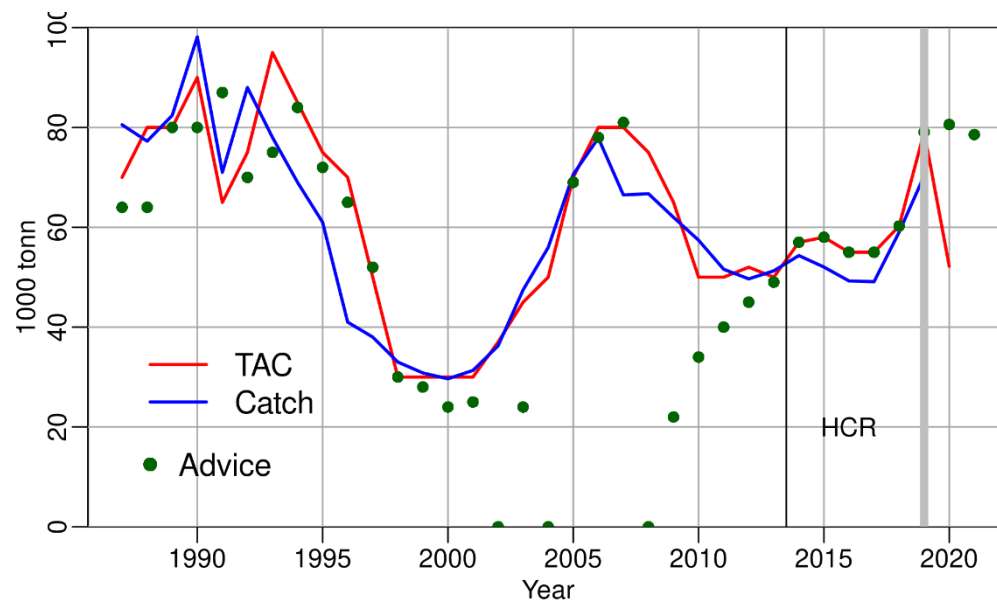


Figure 4. Saithe. Advice, TAC and catch of saithe since 1987.

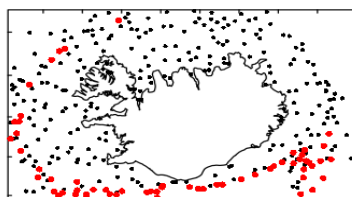
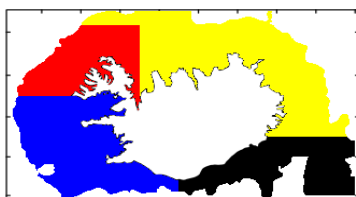
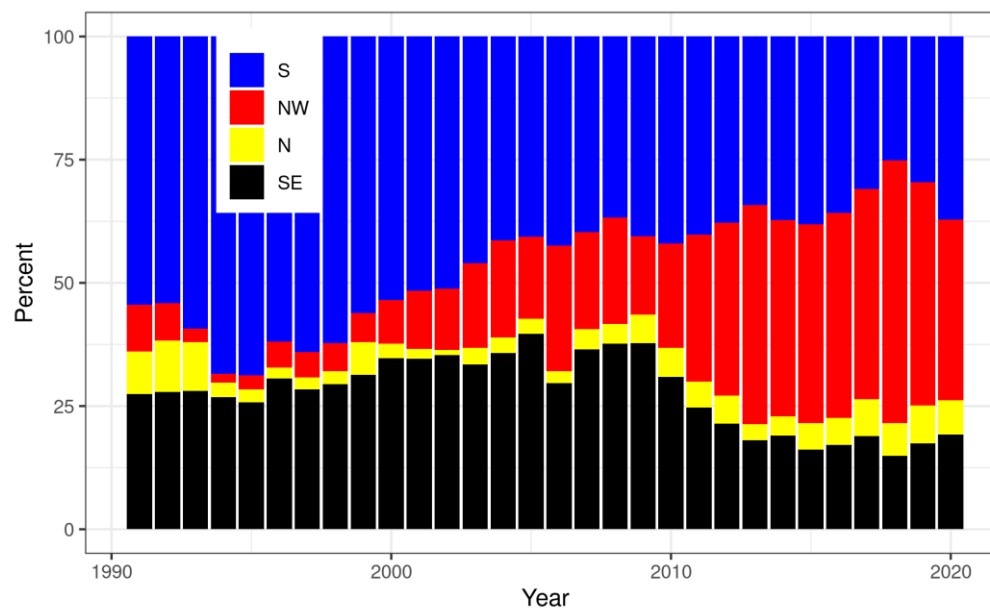


Figure 5. Saithe. Upper figure percent of landings by regions defined in the lower figure to the left. Lower right, stations added in the autumn survey in 2000 (red dots).

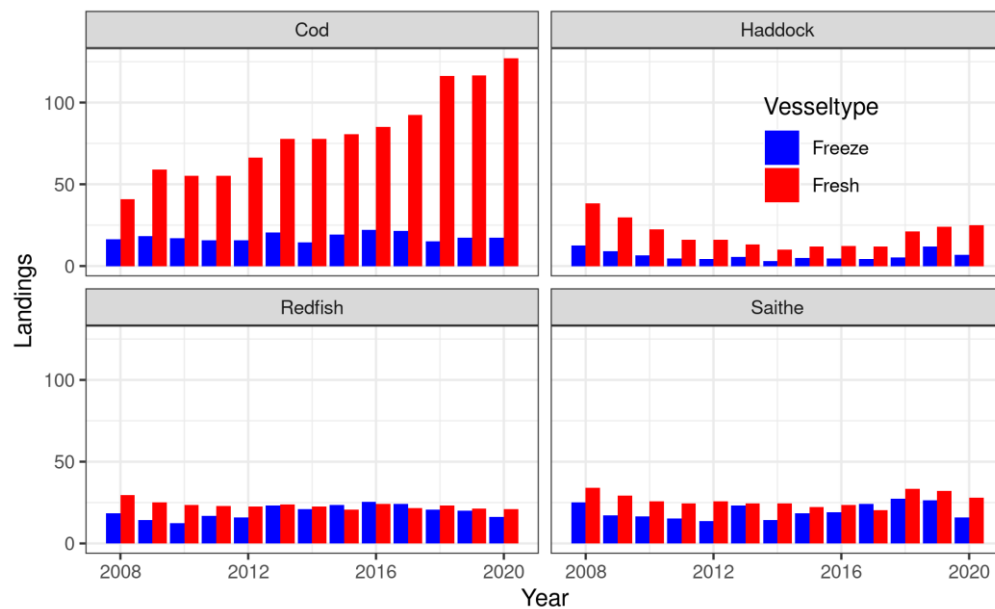


Figure 6. Saithe. Catch by trawlers divided between those that freeze the catch and those that do not. Number of trawlers landing more than 500 tonnes has been reducing gradually from 42 in 2008 to 33 in 2020. Freezing trawlers landing > 500 tonnes were 26 in 2008 but 9 in 2020.

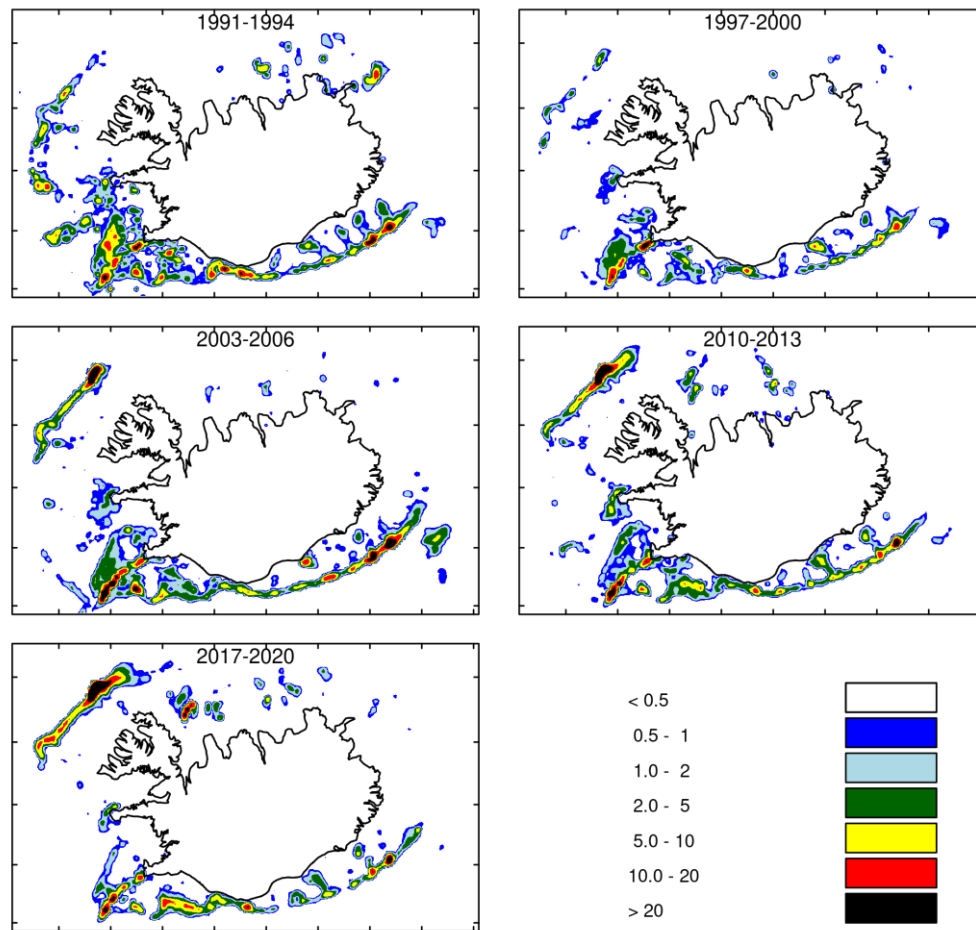


Figure 7. Saithe. Spatial distribution of saithe catch as tonnes per square nautical mile per year.

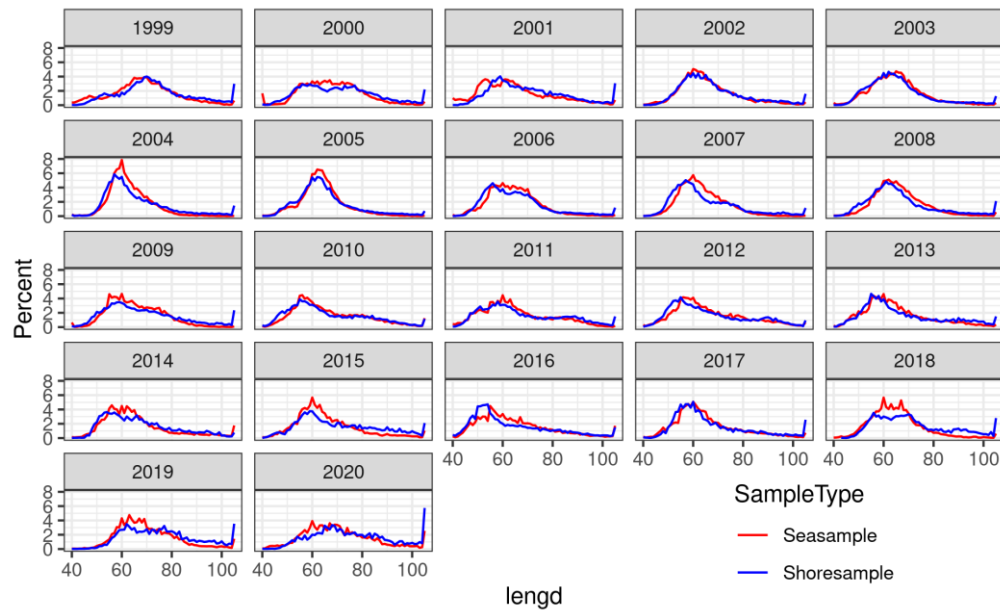


Figure 8. Saithe. Length distributions from sea and shore samples.

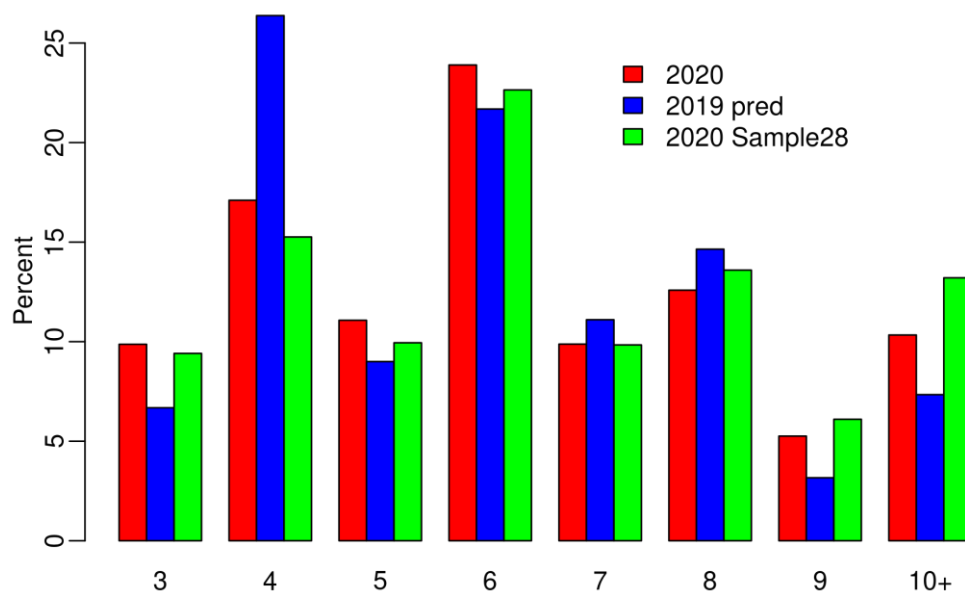


Figure 9. Saithe. Catch in numbers 2020 compared to last year's prediction. The green bars show catch in numbers only based on shore samples.

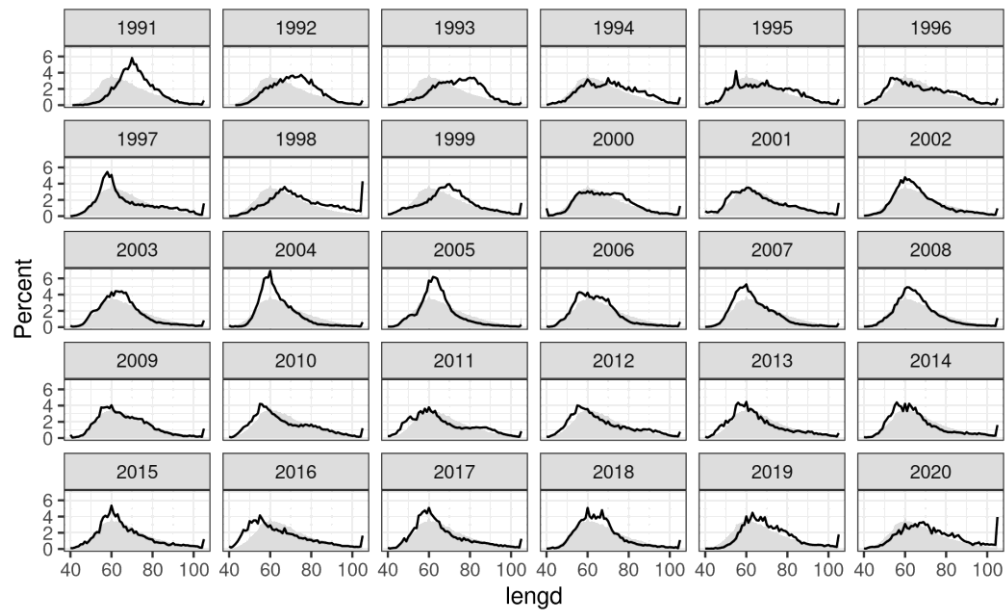


Figure 10. Saithe. Length distributions from bottom trawl catches (lines) compared to average (grey shading).

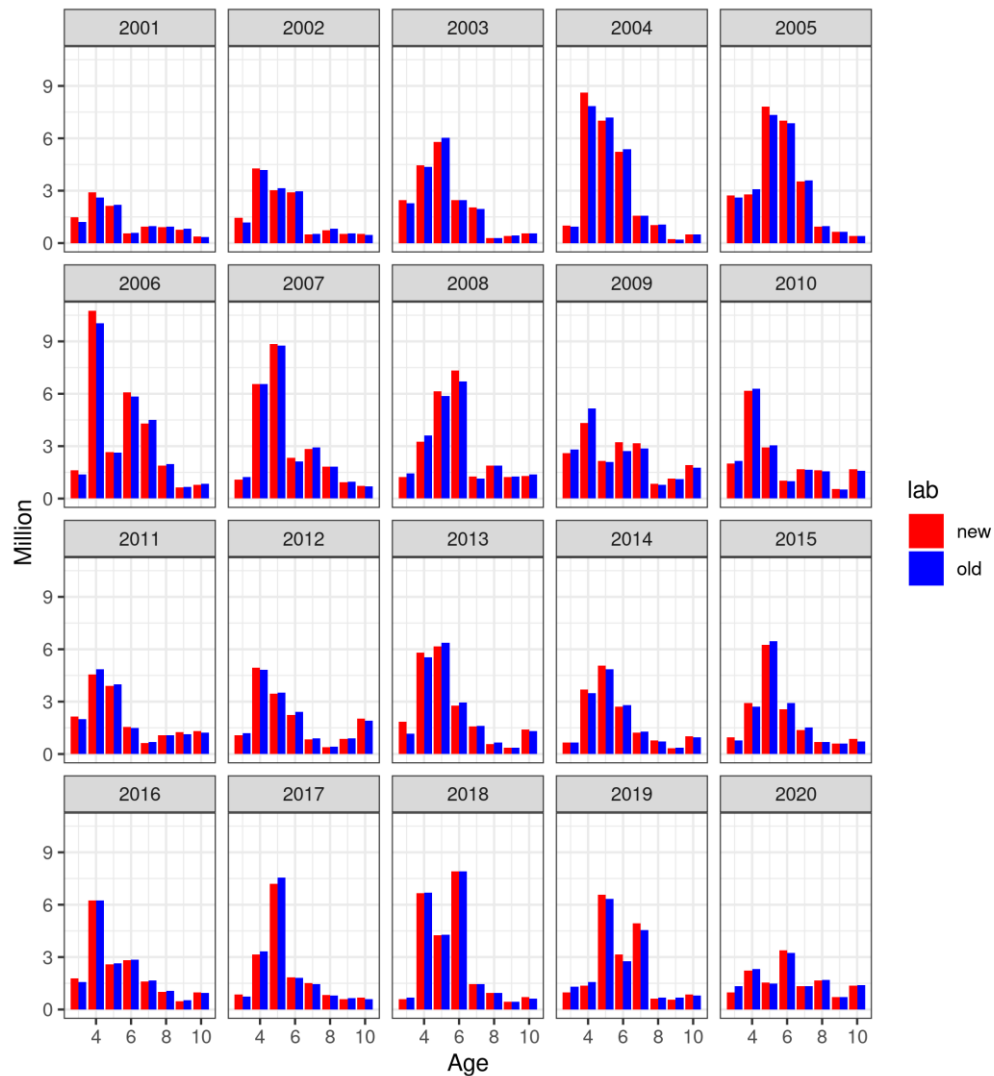


Figure 11. Saithe. Catch in numbers 2000–2020 compiled by 1 region and 1 time interval (old) compared to catch in numbers compiled by 2 regions and 2 time interval (new). The regions are shown in Figure 6, north red and yellow and south blue and black.

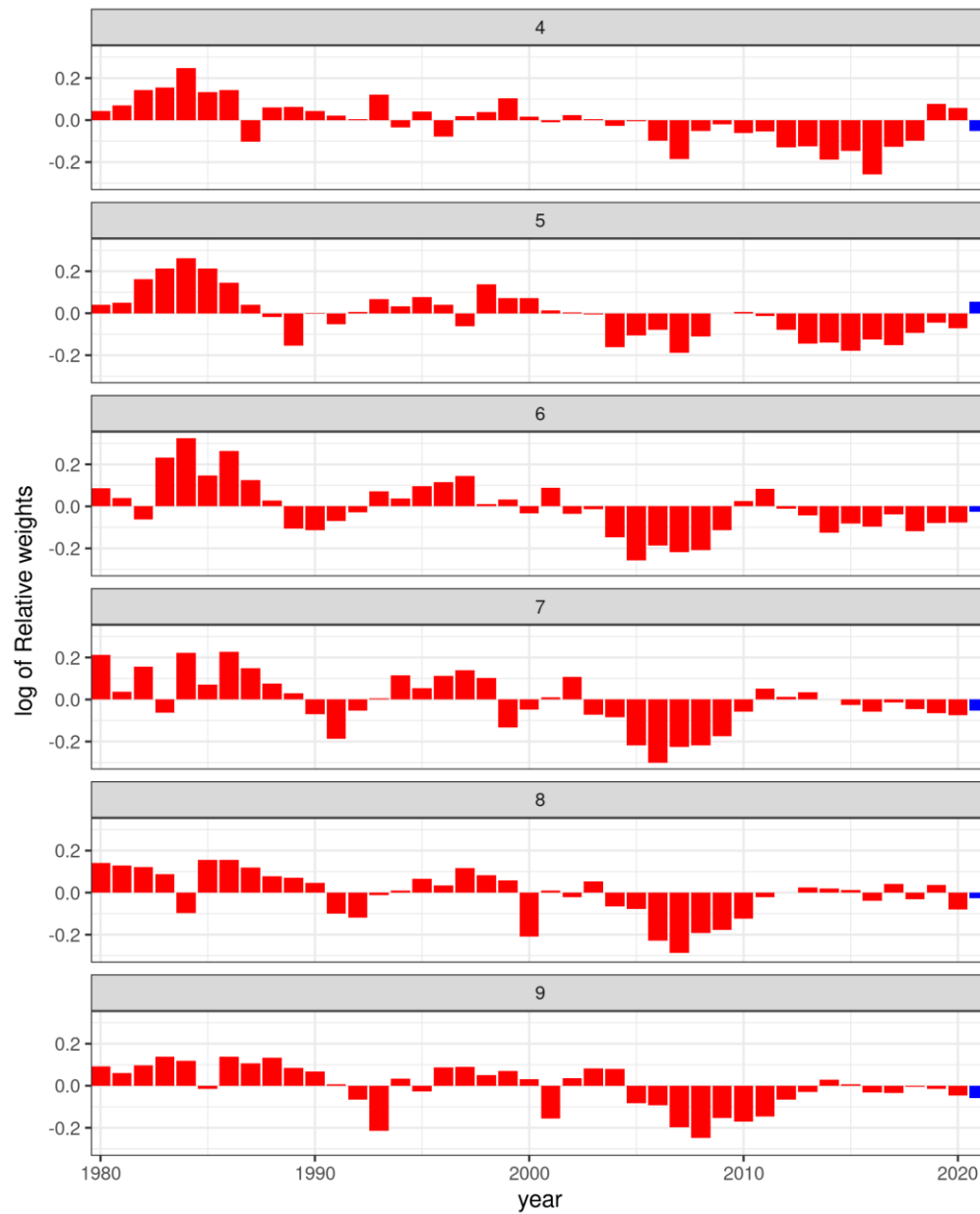


Figure 12. Saithe. Weight at age in the catches, as relative deviations from the mean. Blue bars show prediction.

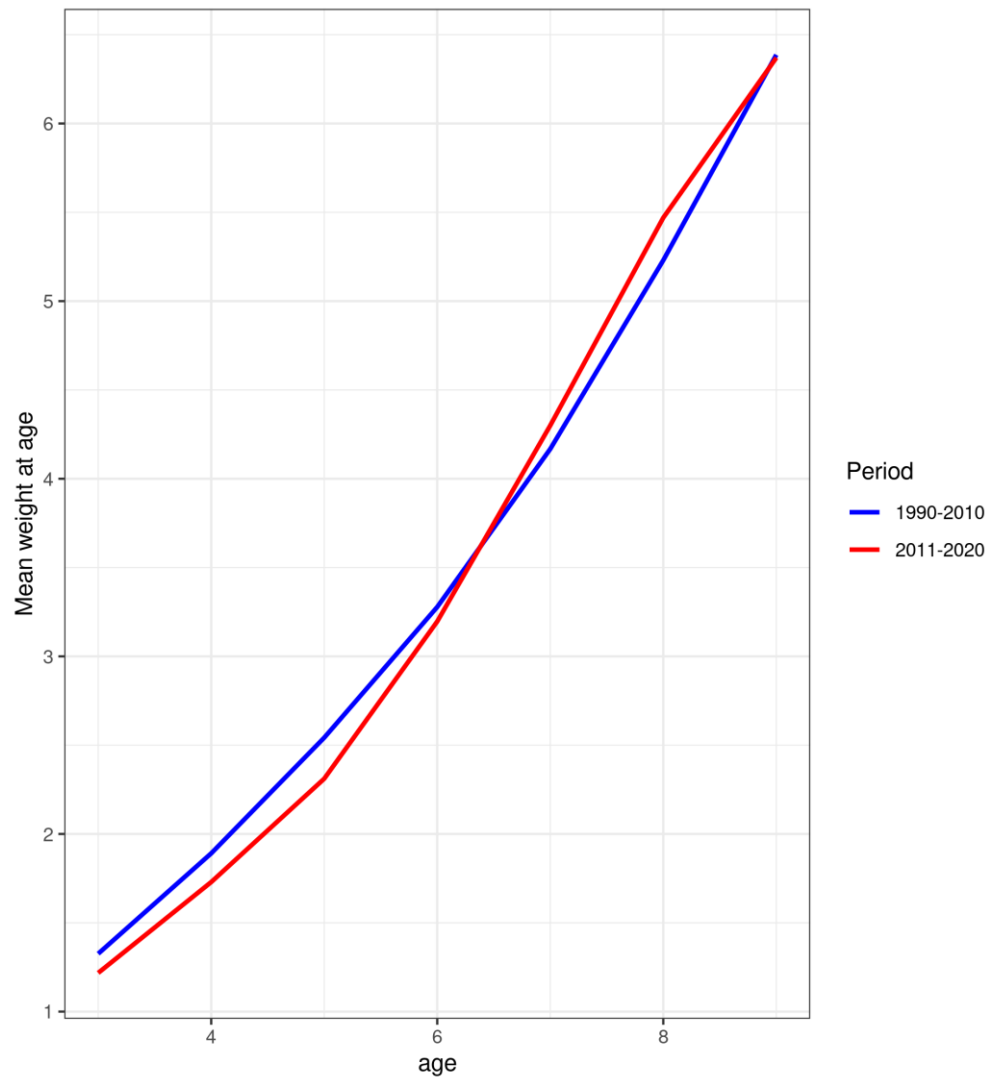


Figure 13. Saithe. Weight at age in the catches shown as average for 2 periods.

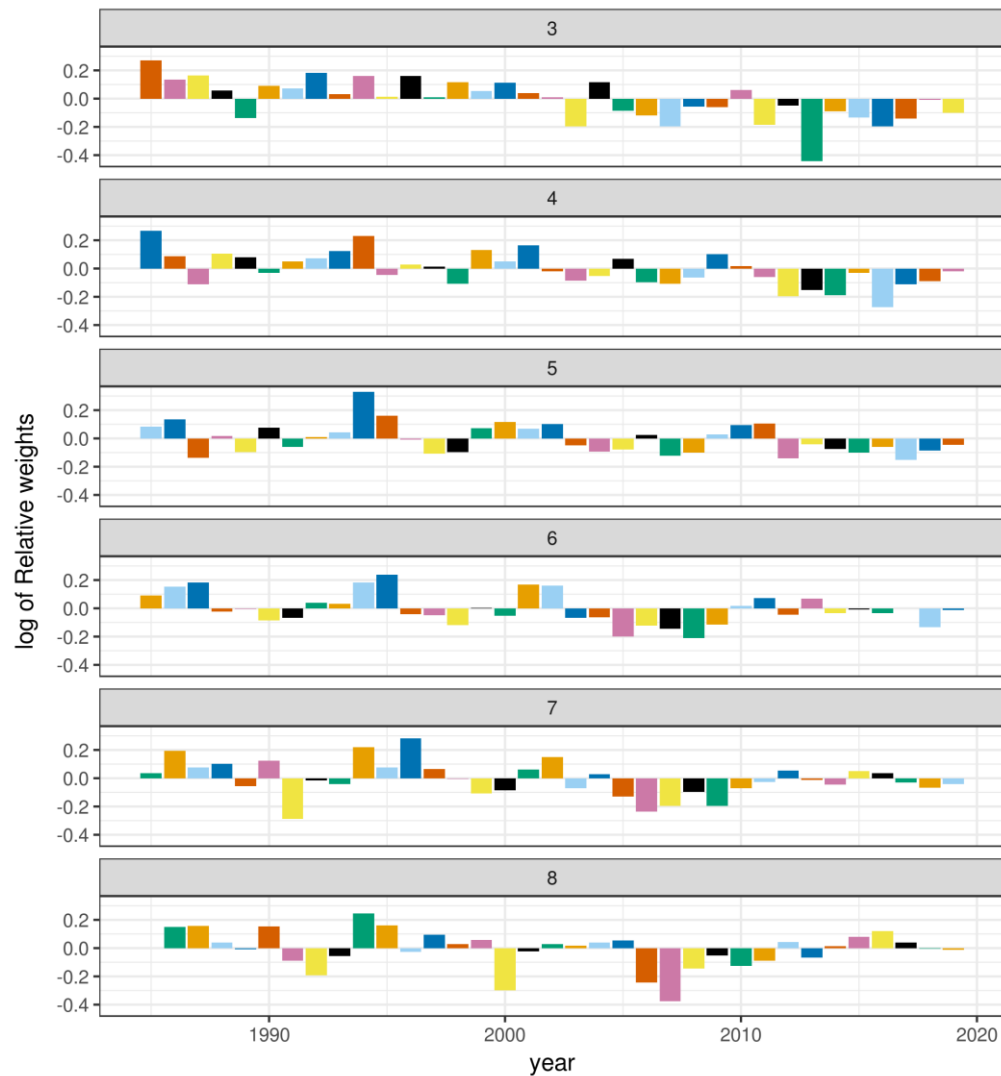


Figure 14. Saithe. Weight at age in the survey, as relative deviations from the mean. Colours can be used to follow year classes.

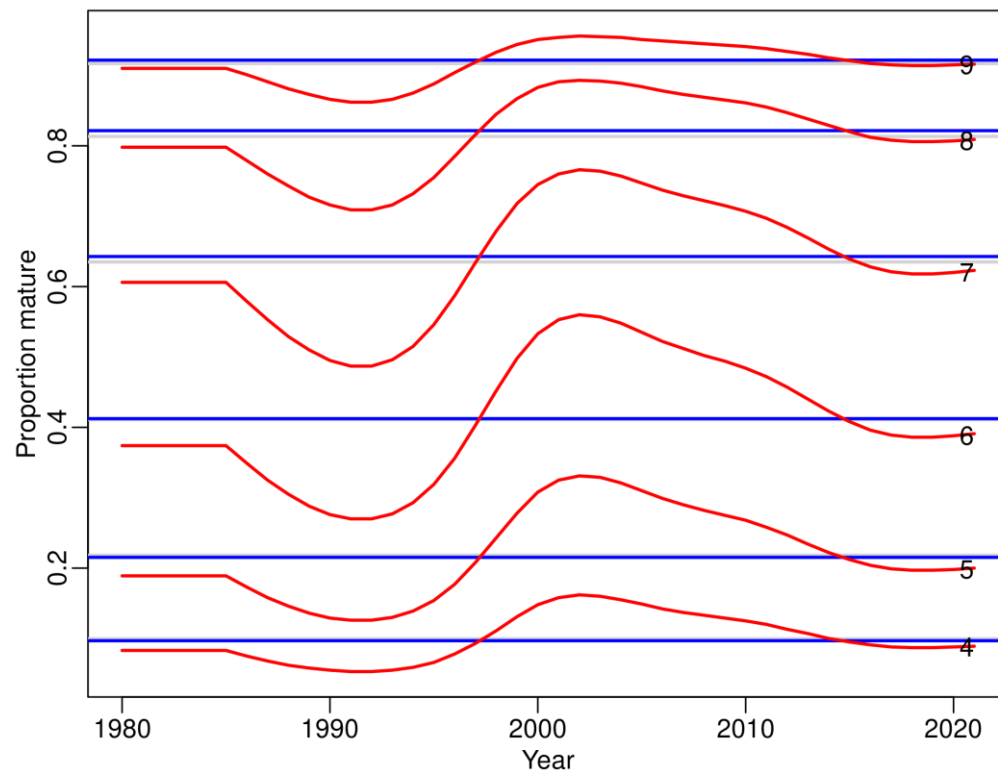


Figure 15. Saithe. Maturity at age used for calculating the SSB. The horizontal lines show the average of last 10 years (blue one) and the average since 1985.

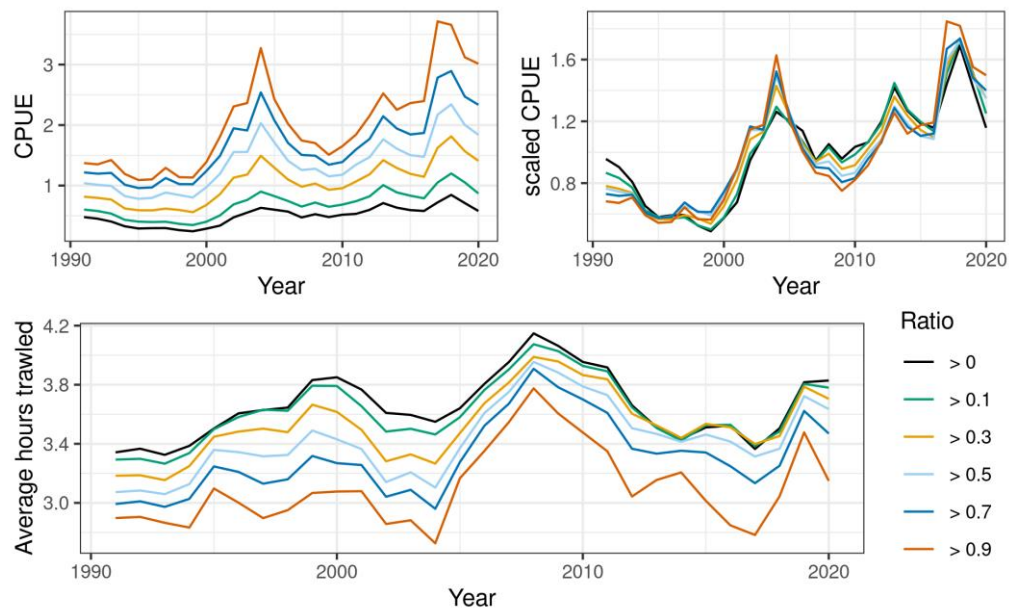


Figure 16. Saithe. CPUE, CPUE scaled to an average of 1 and average numbers of hour trawled. Different colours indicate selection of tows where proportion of saithe of the total catch exceeds certain specified value.

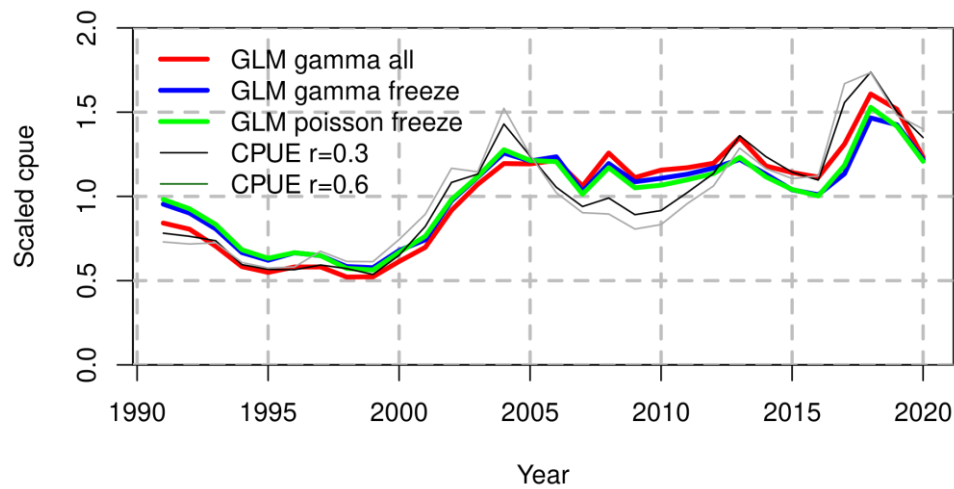


Figure 17. Saithe. CPUE compiled from 3 different models compared to CPUE compiled in similar way as shown in figure 16. All curves scaled to an average of 1.

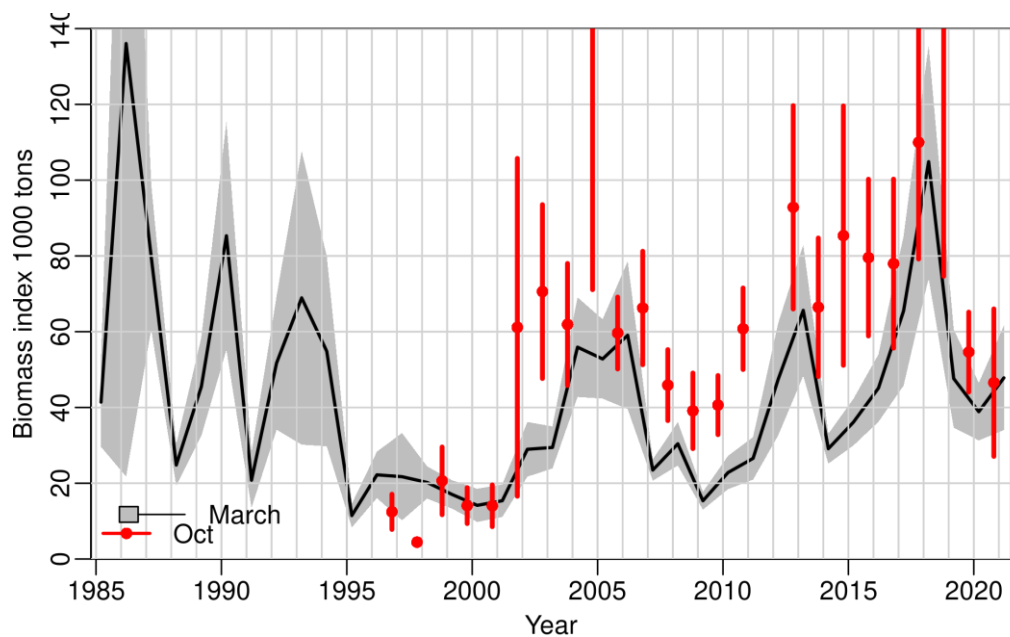


Figure 18. Saithe. Biomass index from the groundfish surveys in March and October.

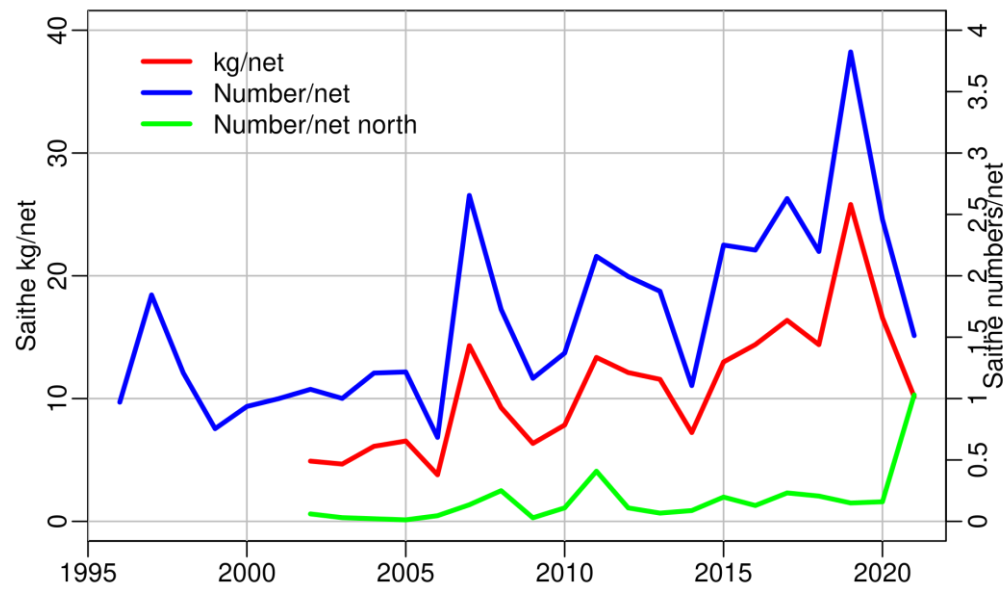


Figure 19. Saithe. Indices from the gillnet survey in April 1996–2018. Saithe was not length measured in the survey before 2002 so catch in kg cannot be compiled.

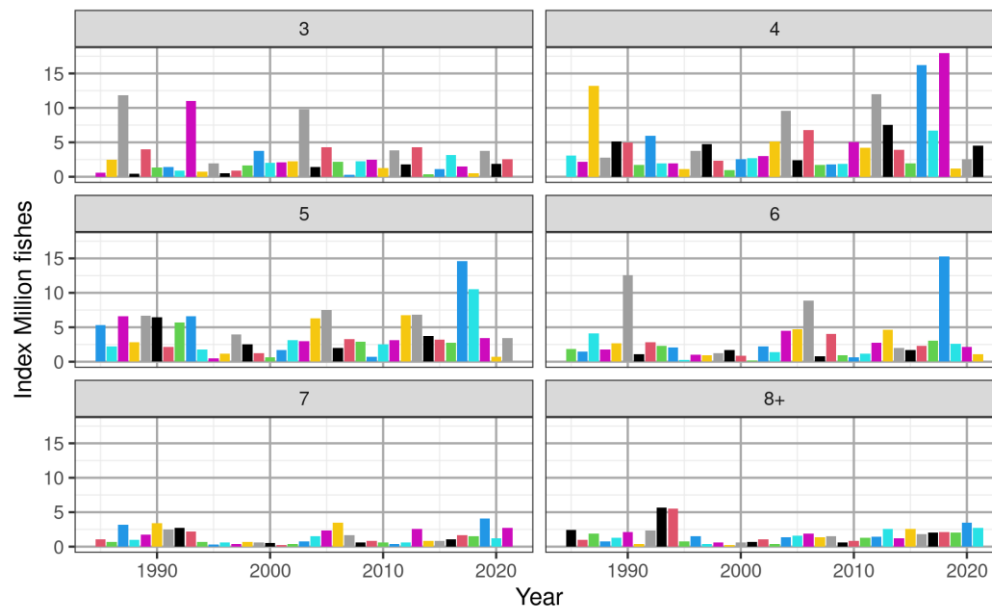


Figure 20. Saithe. Survey indices by age from the spring survey. The colours follows year classes except of course for age 8+.

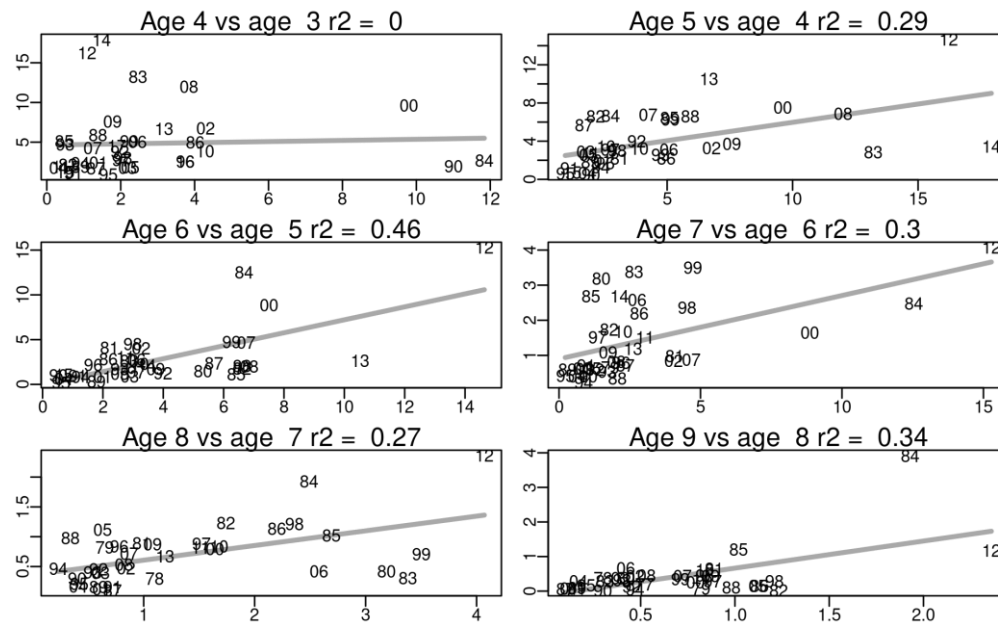


Figure 21. Saithe. Survey indices by age from the spring survey plotted against indices of the same cohort one year earlier.

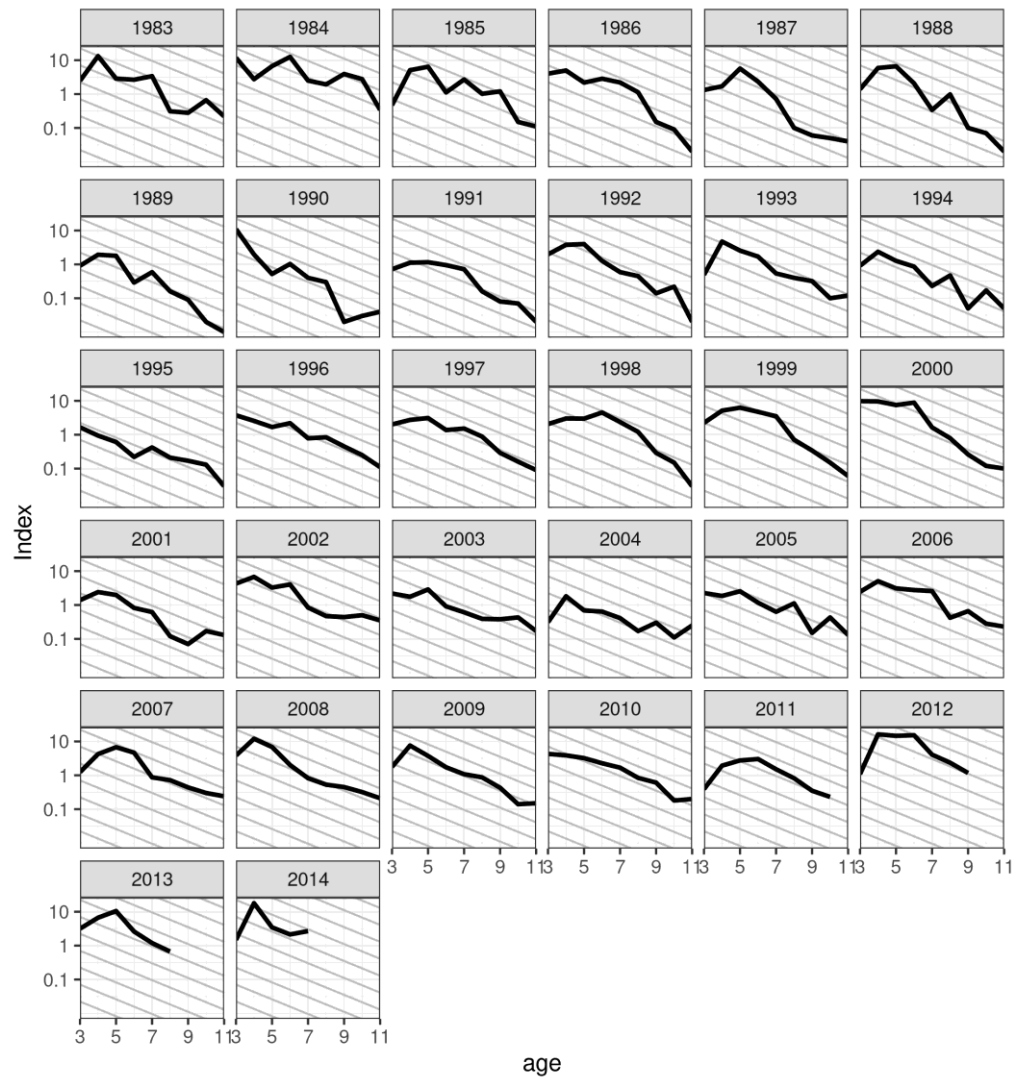


Figure 22. Saithe. Survey indices by age from the spring survey plotted as catch curves for each yearclass. The grey lines correspond to $Z=0.5$.

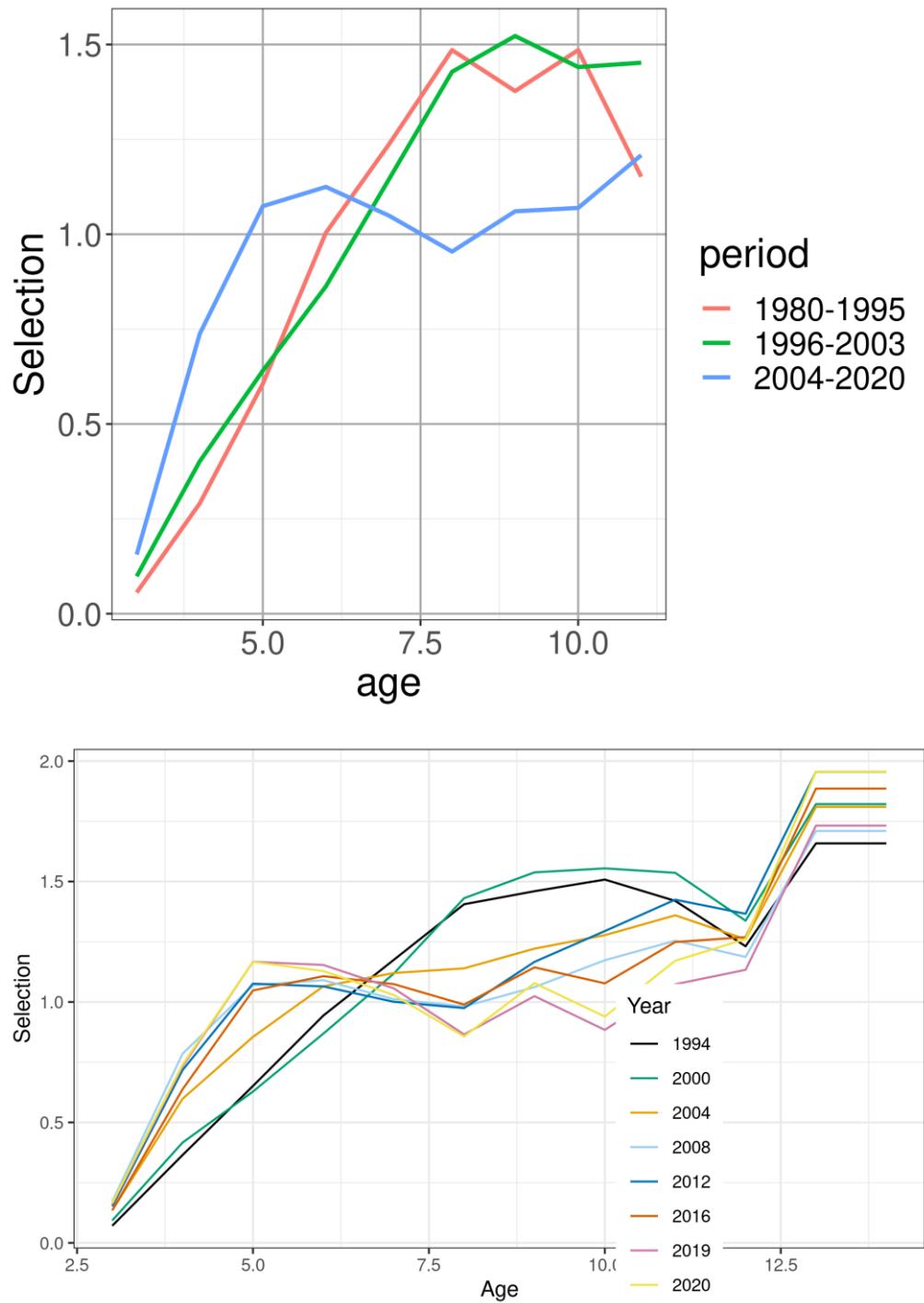


Figure 23. Saithe. Upper figure. Estimated selectivity patterns for the 3 periods, 1980–1996, 1997–2003 and 2004–2020. Lower figure estimated selection from the SAM model. The timing of selection change around 2004 is also evident in the SAM model results.

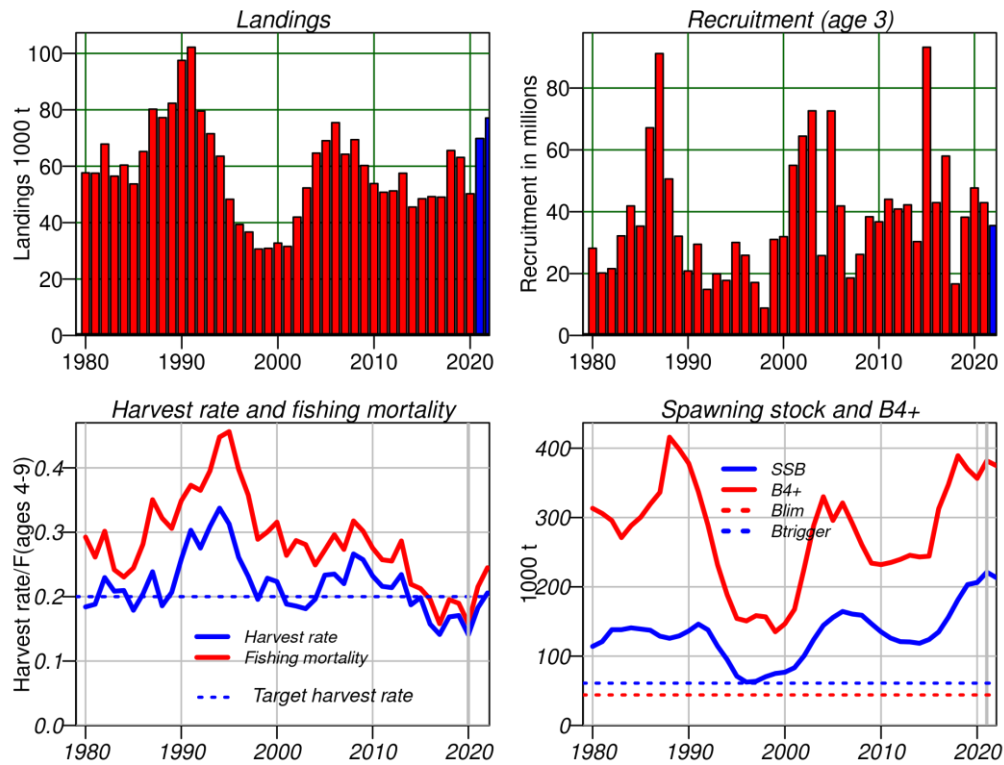


Figure 24. Saithe. Results from the adopted benchmark (SPALY) model and short-term forecast.

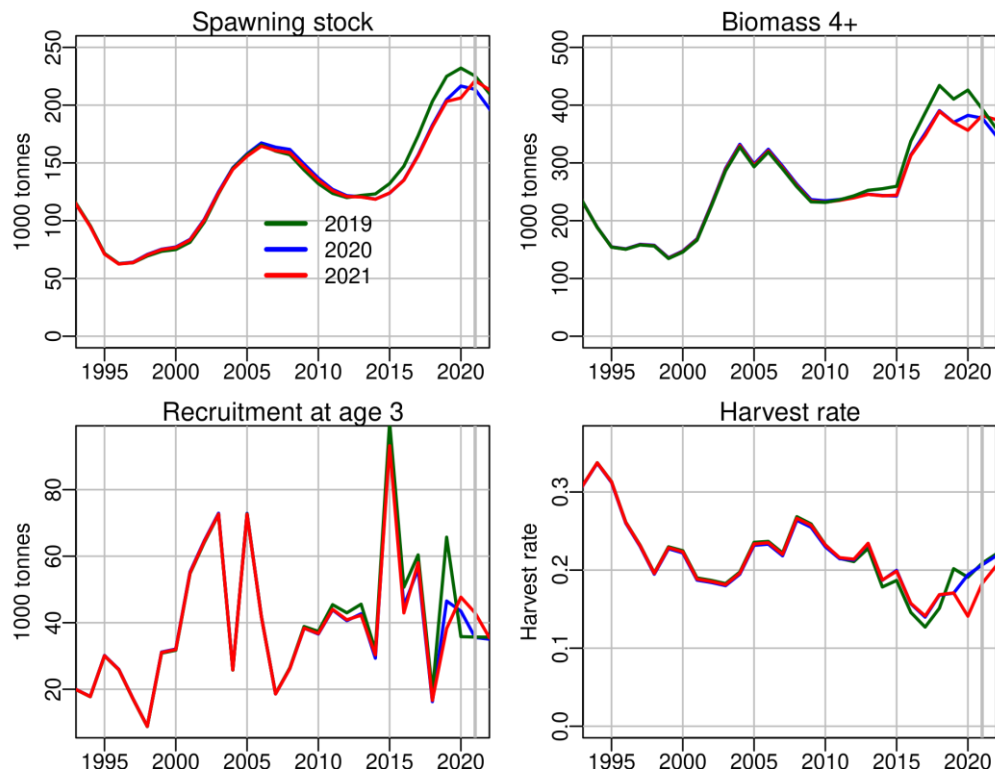


Figure 25. Saithe. Comparison of this year's assessment and short term forecast with results from two earlier years.

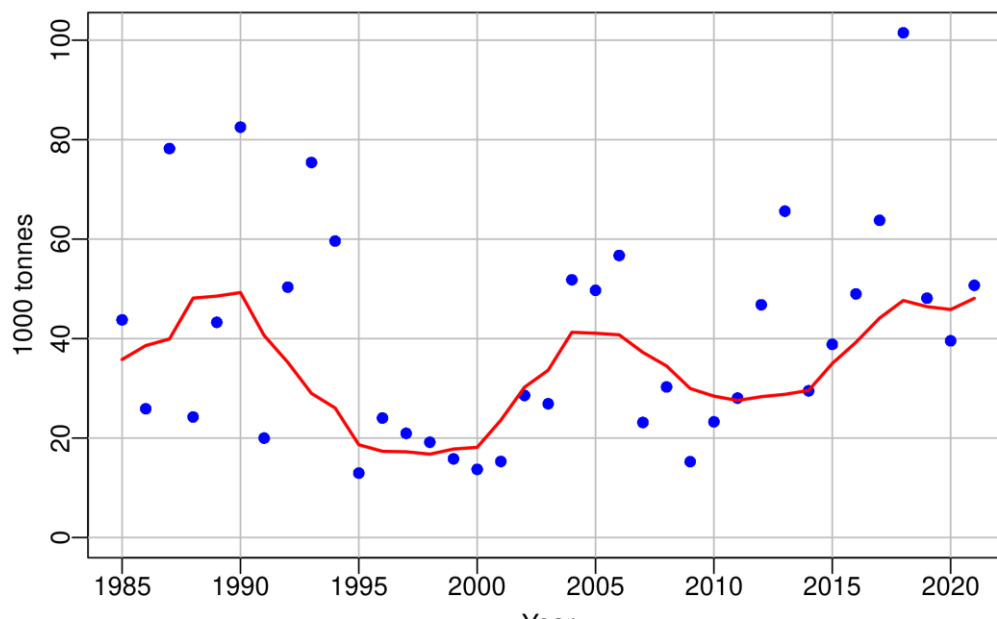


Figure 26. Saithe. Observed and predicted survey biomass from the "SPALY model".

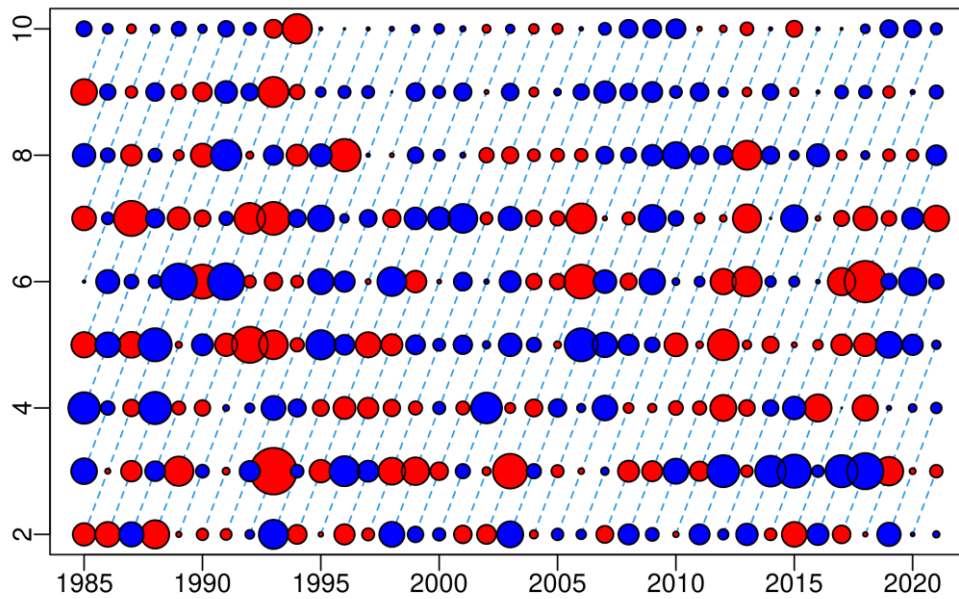


Figure 27. Saithe. Survey residuals from the "SPALY model". The residuals are standardised.

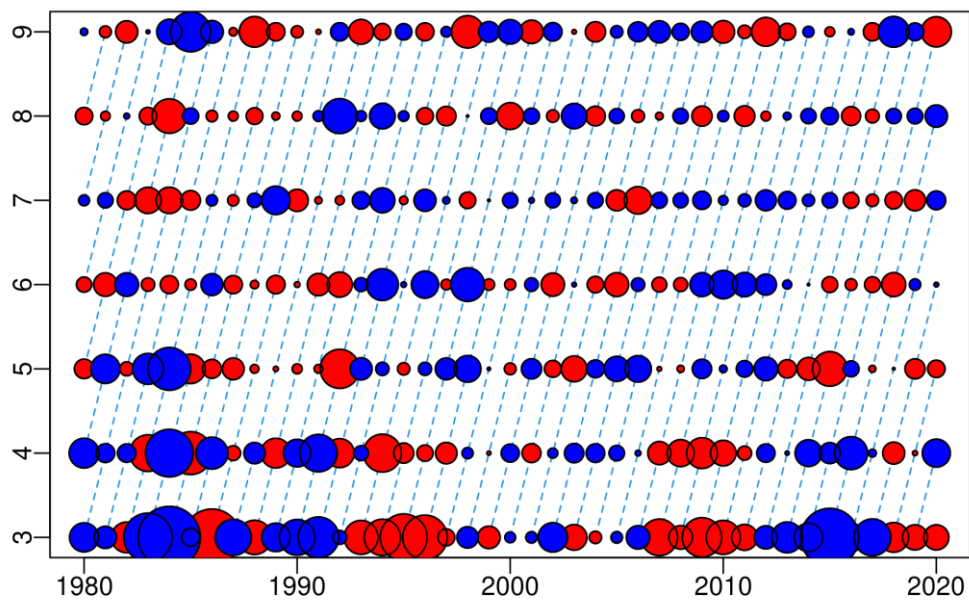


Figure 28. Saithe. Catch residuals from the "SPALY model".

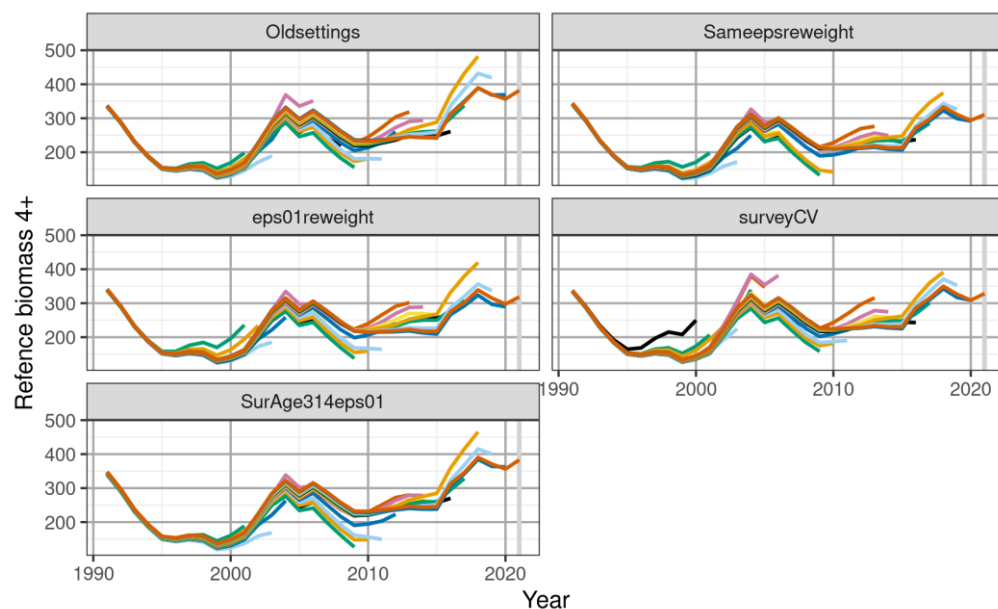


Figure 29. Saithe. Retrospective pattern for the adopted assessment model (Oldsettings) and alternative configurations of the model. The figure shows estimate of B4+, the metric affecting advised catch. The grey vertical lines show the year 2021.

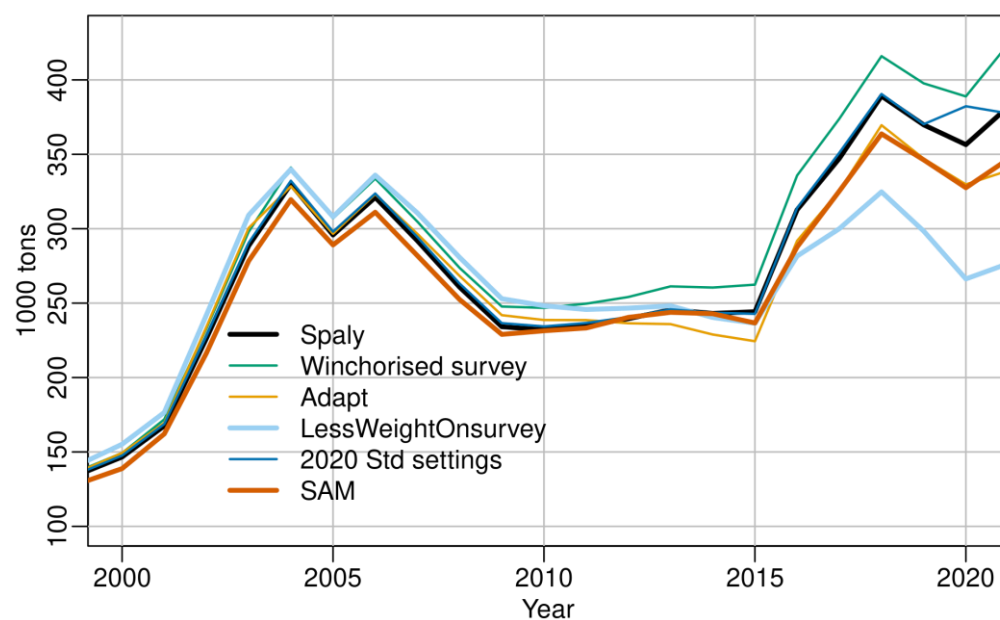


Figure 30. Saithe. Comparison between the default separable model (Muppet) and alternative assessment model settings.

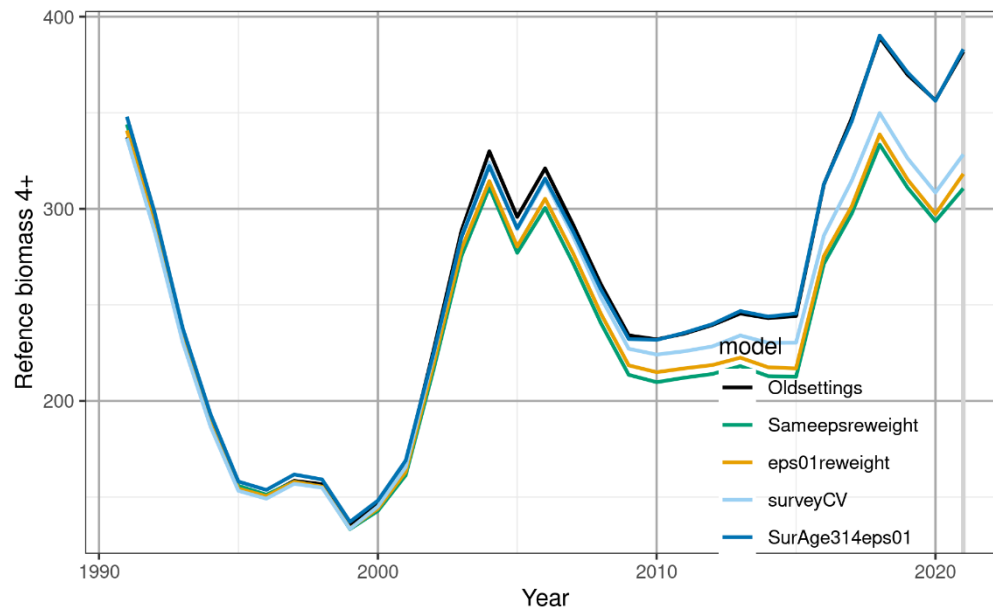


Figure 31. Saithe. Comparison between 2021 assessment results of the models shown in Figure 29.

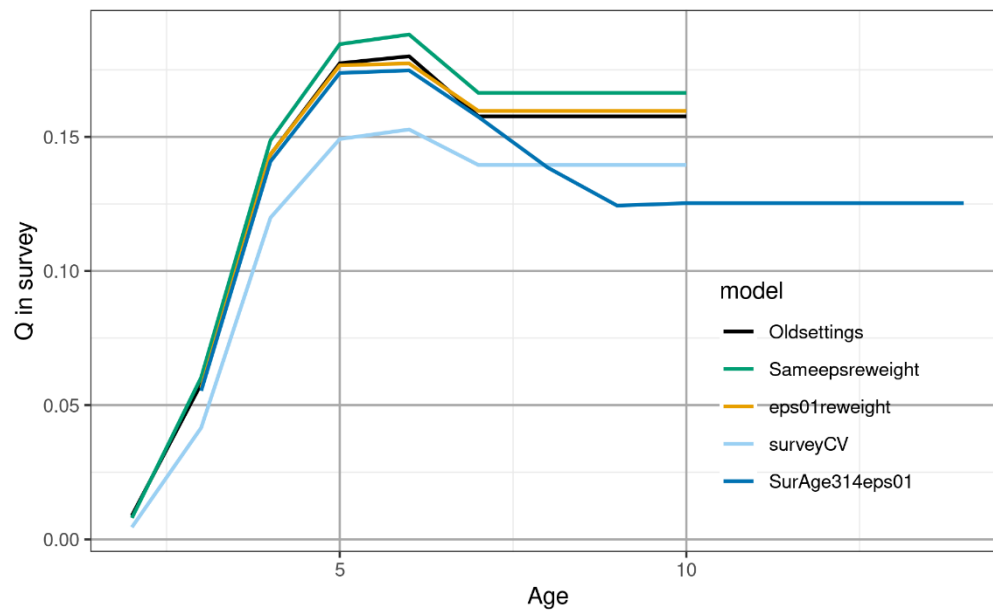


Figure 32. Saithe. Q by age in the March survey for the different models.

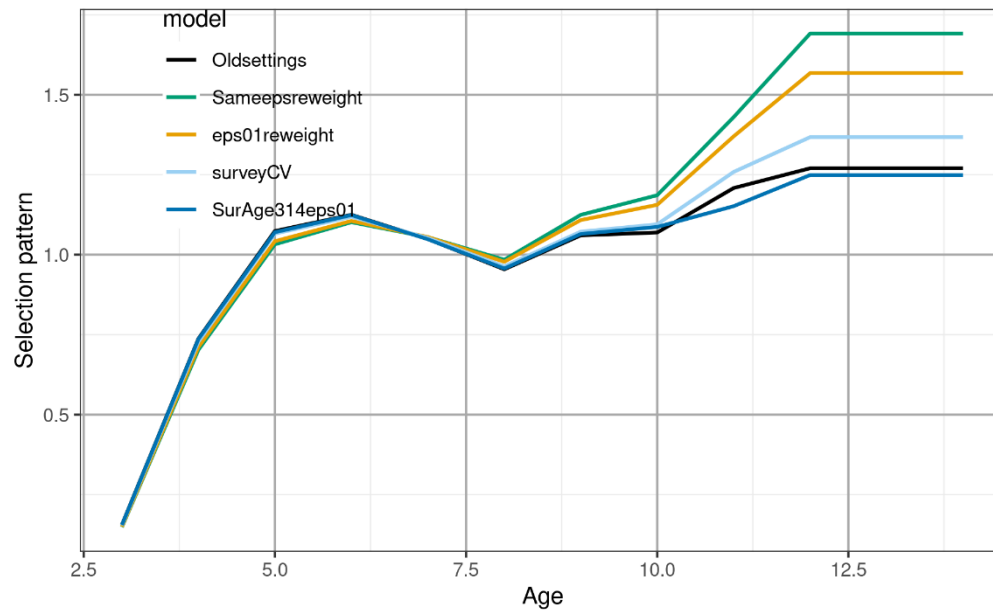


Figure 33. Saithe. Selection by age 2004–2021 for the different models.