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Report of the North Sea Saithe Management Strategy Evaluation

By José De Oliveira, Jonathan Gillson, Chris Darby

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North Sea Saithe Management Strategy Evaluation

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Summary

A Management Strategy Evaluation (MSE) analysis was conducted for North Sea saithe (subarea IV, Division IIIa and subarea VI) in response to a joint EU–Norway request to ICES for an assessment on options to revise the long-term management plan for saithe in the North Sea. Population trajectories for North Sea saithe were explored under five alternative management scenarios in conjunction with the potential for optimistic (high recruitment and growth) and pessimistic (low recruitment and growth) biological production. B-Adapt was used for the operating model, and XSA was used as the basis for the management model corresponding with the methodology used in the 2012 ICES WGNSSK working group report. Future population trajectories for North Sea saithe depend on the management options adopted as well as the level of incoming recruitment and growth. Results for 2020 indicate that although the current management plan yields a favourable trade-off between the risk of spawning stock biomass remaining above B_{lim} and median catch under an optimistic biological production scenario, this trade-off deteriorates under a pessimistic biological production scenario. When just considering the probability of spawning stock biomass remaining above B_{lim}, the management options that use alternative TAC stability mechanisms achieve similar values to the current plan under an optimistic biological production scenario, but also perform slightly more favourably under a pessimistic biological production scenario.

Introduction

A Management Strategy Evaluation (MSE) analysis was conducted for North Sea saithe (subarea IV, Division IIIa and subarea VI) in response to a joint EU–Norway request to ICES for an assessment on options to revise the long-term management plan for saithe in the North Sea (see Appendix 1; the current long-term management plan is described in Appendix 2).

A difference in the recruitment and growth dynamics (level and variability) of North Sea saithe prior to and subsequent to 1988 was estimated by the ICES North Sea Working Group (WGNSSK ICES, 2012). Recruitment and stock weight decreased by a factor of about 1.5 and 1.25, respectively, after 1988. Consequently, the future productivity of the stock in terms of recruitment and growth are uncertain, and this was captured in the analysis by considering two biological production scenarios, one optimistic based on the entire period of recruitment and growth estimates, and the other pessimistic based on recruitment and growth estimates from 1988 onwards.

Fishing mortality for North Sea saithe (F = 0.28) is currently close to F_{msy} (0.3), and spawning stock biomass (SSB) in 2012 (217 000 tonnes) is marginally above $MSYB_{trigger}$ (= B_{pa} = 200 000 tonnes).

Methods

Modelling approach

The Operating model was conditioned on the data currently used in the assessment for North Sea saithe (ICES, 2012; Appendix 3). For computational reasons, it was decided to use B-Adapt (with no bias estimation) for the operating model – there is a built-in bootstrapping facility within B-Adapt software, which can be used to characterise historic uncertainty in the assessment based on observation error, but not within XSA. Figure 3.1 presents a comparison of spawning stock biomass, recruitment and fishing mortality estimates obtained from the B-Adapt operating model and the XSA assessment model used in the most recent ICES WGNSSK working group report (ICES, 2012).

Output from the B-Adapt and XSA models were historically similar but SSB trends diverged in the most recent years; recruitment and average fishing mortality were consistent. The difference was found to be a result of differing assumptions within the models in determining F at the oldest true age (age 9), which was also used for the plus group F (age 10+) in both models. The ICES WG XSA formulation applies light shrinkage, resulting in higher weighting of the cpue data along each cohort within the estimation of F at the oldest age. The survey cpue at the oldest ages is noisy with high coefficients of variation (CV), resulting in a highly variable oldest age, and consequently the plus group fishing mortality. In contrast, B-Adapt assumes F at age 9 to be the average of F at ages 6–8, and is therefore heavily constrained (equivalent to strong shrinkage). F at age 9 is more consistent with that of the younger ages; this is illustrated in Figure 3.2, which compares fishing mortality estimates for ages 6–9 over the period 1997 to 2011: the XSA-estimated F at age 9 evolves independently of the other ages with substantial noise. The populations at age 9, and especially the plus group, dominated the dynamics of SSB in recent years, and this resulted in the differences between the recent estimates in the time-series generated by XSA and B-Adapt.

Whether F at the oldest true age really does fluctuate as much relative to the preceding ages, as indicated by XSA, is open to question, and this and the consequences for the estimated SSB dynamics when a substantial part of the population is at the oldest ages, is something that a future benchmark may want to investigate in detail. The decision was made to continue with operating models conditioned on B-Adapt fits to the original data. A comparison of the XSA and B-Adapt model fits to data are shown in Appendix 4.

Figure 3.3 presents the assessment summary obtained from the B-Adapt operating model. The assessment summary from the B-Adapt operating model revealed a reduction in spawning stock biomass, fishing mortality, recruitment and yield since 1985.

Figure 3.4 presents stock–recruitment pairs for entire time-series from 1967 to 2011. The last five years (2007 to 2011) have been characterised by below average recruitment and spawning stock biomass.

Management model

XSA was used as the basis for the management model, corresponding with the methodology used in the ICES WGNSSK working group (ICES, 2012). The management model was used to replicate the annual working group assessment and short-term forecast, and application of the harvest control rule (HCR) together with the TAC stability mechanism (currently ±15% TAC constraint, applied when SSB>B_{lim}). When the short-term forecast was performed, the same assumption as the ICES WGNSSK working group regarding the intermediate year catch (constrained to the actual TAC previously set for that year) is made (ICES, 2012).

Operating model (OM)

The OM, reflecting different assumptions about population dynamics and fishery characteristics, considers the existence of optimistic and pessimistic biological production (high or low recruitment and growth, respectively) for North Sea saithe.

Recruitment (SR) scenarios

Two alternative recruitment scenarios were explored (Figure 3.5):

1) Optimistic recruitment: A stock–recruitment relationship was fitted to the entire time-series of stock and recruitment estimates obtained from the original fit (not the bootstrap estimates) of the B-Adapt operating model for the period 1967 to 2011.

2) Pessimistic recruitment: A stock–recruitment relationship was fitted to a relatively short time-series of stock and recruitment estimates obtained from the original fit (as above) of the B-Adapt operating model for the period 1988 to 2011.

[Note that because of the version of software used for the MSE, based on the same code used for evaluation of cod stocks in 2008/9, a hockey-stick model was not functional within the MSE code, although it could provide a fit to the data. As a pragmatic solution, the "fits" mentioned in SR scenarios 1 and 2 above were achieved by fitting a hockey–stick model, as indicated, but then fitting a Beverton–Holt model to the estimated hockey–stick model in order to achieve a constrained Beverton–Holt formulation that was as close to the hockey–stick as possible. This method was used because fitting a Beverton–Holt model directly to the original stock–recruit pairs led to very high steepness values with little information close to the origin to characterise the steepness.].

In order to check whether recruitment simulated on the basis of Figure 3.5 would be consistent with what has been seen historically, qq plots have been constructed for the two recruitment scenarios by taking log recruitment residuals from the fit in Figure 3.5, normalising these by the standard deviation about the fit for each scenario (CV=0.52 for scenario 1 and 0.44 for scenario 2), and comparing the resultant values to what could be expected from a N(0;1) distribution. The resultant qq plots are shown in Figure 3.6 for each recruitment scenario, and indicate that a lognormal assumption about the curves in Figure 3.5 with the associated CVs are a reasonable assumption for generating future recruitment levels for each scenario.

Growth scenarios

Two alternative growth scenarios were considered (Figure 3.7):

1) Optimistic growth: Re-sampling, with replacement, year vectors of weights at age from the entire time-series of stock weight estimates from 1967 to 2011.

2) Pessimistic growth: Re-sampling, with replacement, year vectors of weights at age from a relatively short time-series of stock weight estimates from 1988 to 2011.

Re-sampling in this manner preserved any within-year correlations of weights at age present (but not within-cohort correlations), in order to reflect variable growth in future.

Biological production scenarios

Both the optimistic recruitment and growth scenarios were considered in unison to provide an optimistic biological production scenario (Opt; high recruitment and growth). An identical approach was undertaken for the pessimistic recruitment and growth scenarios to formulate a pessimistic biological production scenario (Pess; low recruitment and growth). An illustration of the types of trajectories to be expected when applying an F = 0.3 is given in Figure 3.8. [Note that Figure 3.8 does not include a management model and applies F = 0.3 directly to the operating model.]

Discarding scenarios

Discarding of North Sea saithe is considered to be low, with no quantitative information on discard rates available in the ICES assessment (ICES, 2012). Consequently, no projections of discarding are presented for this stock.

Observation error model (OEM)

The OEM captures the way in which observation error is included when sampling from the operating model for data to be supplied to the management model. Observation error has only been included in indices of abundance (assumed to derive from a single survey, with a CV of 0.3). Catch-at-age, and catch and stock mean weights at age (along with maturity and natural mortality) in the management model were assumed to be the same as the operating model (apart from the short-term forecasts, which assumed 3-year averages for mean catch and stock weights at age, maturity and natural mortality – note, the latter two are in any case constant).

Management scenarios

Five alternative management scenarios were explored in conjunction with the potential for optimistic and pessimistic biological production:

1) Applying the current management plan (a HCR with a TAC stability mechanism) unchanged

2) Applying the HCR with no TAC stability mechanism under optimistic and pessimistic biological production

3) Applying the HCR with the following stability mechanisms when the SSB is above B_{lim}:

a) Setting a TAC in the TAC year based on the average of the projected TACs at target F over three years starting with the TAC year under optimistic and pessimistic biological production

b) Setting the TAC to be the average of the current TAC and the TAC that would result from the application of the HCR for the TAC year under optimistic and pessimistic biological production

c) Applying a TAC constraint of ±15%, but where the resulting fishing mortality is not allowed to deviate by more than 15%, 20% or 25% from the target F under optimistic and pessimistic biological production

4) Applying the HCR with the above mentioned stability mechanisms, but applying them only when the stock is above B_{pa} under optimistic and pessimistic biological production

5) Allowing an inter-annual quota flexibility of ±10% under optimistic and pessimistic biological production

[Note that management scenario 5 above was not investigated in this report.]

In order to carry out investigations into TAC stability mechanisms 1–4 above, certain clarifications were sought for how to interpret some of the text, and these were as follows:

- Under management scenarios 3 and 4 above, it is not immediately clear which SSB is referred to, and there are several candidates, ranging from SSB at the start of the final year of data to SSB at the end of the TAC year. An email exchange with Norwegian scientists (ICES records) led to the decision to use the SSB at the end of the final year of data (i.e. at the beginning of the intermediate year).
- Under management scenarios 3 and 4 above, it was not immediately clear which "target F" was being referred to. Communication with scientists undertaking the concurrent North Sea herring MSE analysis revealed their interpretation as being the F from application of the HCR (the sliding rule), and in the spirit of following a consistent approach, the same is done here.
- Under management scenarios 3 and 4 above, no TAC stability mechanism is applied at or below B_{lim} and B_{pa} respectively.

Output

Tables 1, 2 and 3 present the results of this Management Strategy Evaluation analysis for 2015, 2020 and the average over the period 2020-2029, respectively. The number of iterations carried out was 250. Each row corresponds to a combination of OM and TAC options, with columns 5–9 referring to stock status as follows (at the start of 2015 or 2020, or average over 2020-2029):

- p(>B_{lim}), p(>B_{pa}): probability that SSB is above precautionary reference points
- median(SSB): median spawning stock biomass, in thousands of tonnes
- median(C): median catch, in thousands of tonnes
- median(FC): median fishing mortality (ages 3–6)

Associated figures can be found in Appendix 5.

Discussion

Future population trajectories for North Sea saithe depend on the management options adopted as well as the level of incoming recruitment and growth, as illustrated by the spawning stock biomass and catch outcomes for the twelve alternative management scenarios (Tables 1–4, Figures in Appendix 5). Results for 2020 and the average over 2020-2029 indicate that although the current management plan yields a favourable trade-off between the risk of remaining above B_{lim} "p(>B_{lim})" and median Catch "median(C)" under an optimistic biological production scenario, this trade-off deteriorates somewhat under a pessimistic biological production scenario. When just considering "p(>B_{lim})", there are management options that use alternative TAC stability mechanisms that achieve similar values as the current plan under an optimistic biological production scenario, but that perform slightly more favourably under a pessimistic biological production scenario, although, given the number of iterations carried out, this difference may not be significant.

References

ICES, 2012. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27 April – 3 May 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/ACOM: 11, 61pp.

Acknowledgements

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Table 1. Results in 2015 from the Management Strategy Evaluation (MSE) assuming the HCR in the EU–Norway long-term plan is implemented as stipulated in the plan. The highlighted lines correspond to the way the assessment is conducted. OM – Operating Model; TACopt – TAC option; C – Catch; FC – fishing mortality (ages 3–6). Please see further details in the methods section above.

	OM	TACopt	p(>B_{lim})	p(>B_{pa})	median(SSB)	median(C)	median(FC)
Current Plan	**Opt**	**1**	**1.00**	**0.97**	**378**	**128**	**0.21**
No TAC cnstr	Opt	2	1.00	0.95	350	145	0.29
>Blim: av 3-yr proj TAC	Opt	3	1.00	0.95	349	144	0.28
>Blim: av intyr and HCR	Opt	4	1.00	0.96	376	137	0.25
>Blim: 15% tgt F	Opt	5	1.00	0.96	366	143	0.27
>Blim: 20% tgt F	Opt	6	1.00	0.96	372	139	0.26
>Blim: 25% tgt F	Opt	7	1.00	0.97	377	134	0.25
>Bpa: av 3-yr proj TAC	Opt	8	1.00	0.95	352	144	0.28
>Bpa: av intyr and HCR	Opt	9	1.00	0.96	376	137	0.25
>Bpa: 15% tgt F	Opt	10	1.00	0.96	366	143	0.27
>Bpa: 20% tgt F	Opt	11	1.00	0.96	372	139	0.26
>Bpa: 25% tgt F	Opt	12	1.00	0.97	377	135	0.25
Current Plan	**Pess**	**1**	**0.99**	**0.74**	**259**	**114**	**0.30**
No TAC cnstr	Pess	2	0.98	0.66	237	117	0.35
>Blim: av 3-yr proj TAC	Pess	3	0.99	0.64	232	118	0.35
>Blim: av intyr and HCR	Pess	4	1.00	0.74	252	117	0.32
>Blim: 15% tgt F	Pess	5	0.99	0.71	248	118	0.33
>Blim: 20% tgt F	Pess	6	0.99	0.72	252	118	0.33
>Blim: 25% tgt F	Pess	7	0.99	0.74	254	117	0.32
>Bpa: av 3-yr proj TAC	Pess	8	0.99	0.66	237	118	0.34
>Bpa: av intyr and HCR	Pess	9	1.00	0.76	255	117	0.32
>Bpa: 15% tgt F	Pess	10	0.99	0.71	248	118	0.34
>Bpa: 20% tgt F	Pess	11	0.99	0.72	253	118	0.33
>Bpa: 25% tgt F	Pess	12	0.99	0.74	255	117	0.32

Weights in 000's tonnes

Table 2. Results in 2020 from the Management Strategy Evaluation (MSE) assuming the HCR in the EU–Norway long-term plan is implemented as stipulated in the plan. The highlighted lines correspond to the way the assessment is conducted. OM – Operating Model; TACopt – TAC option; C – Catch; FC – fishing mortality (ages 3–6). Please see further details in the methods section above.

	OM	TACopt	p(>B_{lim})	p(>B_{pa})	median(SSB)	median(C)	median(FC)
Current Plan	**Opt**	**1**	**0.99**	**0.95**	**476**	**185**	**0.26**
No TAC cnstr	Opt	2	0.97	0.87	352	158	0.30
>Blim: av 3-yr proj TAC	Opt	3	0.98	0.89	375	158	0.28
>Blim: av intyr and HCR	Opt	4	0.95	0.88	391	177	0.32
>Blim: 15% tgt F	Opt	5	0.96	0.88	381	166	0.30
>Blim: 20% tgt F	Opt	6	0.96	0.88	386	170	0.31
>Blim: 25% tgt F	Opt	7	0.96	0.90	401	176	0.30
>Bpa: av 3-yr proj TAC	Opt	8	0.98	0.89	375	160	0.28
>Bpa: av intyr and HCR	Opt	9	0.96	0.88	389	177	0.31
>Bpa: 15% tgt F	Opt	10	0.96	0.88	379	166	0.31
>Bpa: 20% tgt F	Opt	11	0.96	0.88	384	169	0.30
>Bpa: 25% tgt F	Opt	12	0.96	0.90	399	176	0.30
Current Plan	**Pess**	**1**	**0.91**	**0.63**	**243**	**111**	**0.33**
No TAC cnstr	Pess	2	0.94	0.60	230	106	0.31
>Blim: av 3-yr proj TAC	Pess	3	0.90	0.58	221	106	0.32
>Blim: av intyr and HCR	Pess	4	0.88	0.58	229	112	0.33
>Blim: 15% tgt F	Pess	5	0.91	0.59	226	109	0.31
>Blim: 20% tgt F	Pess	6	0.90	0.60	229	110	0.32
>Blim: 25% tgt F	Pess	7	0.90	0.62	231	111	0.32
>Bpa: av 3-yr proj TAC	Pess	8	0.93	0.63	233	107	0.31
>Bpa: av intyr and HCR	Pess	9	0.90	0.61	234	113	0.32
>Bpa: 15% tgt F	Pess	10	0.92	0.59	228	109	0.31
>Bpa: 20% tgt F	Pess	11	0.90	0.60	231	110	0.31
>Bpa: 25% tgt F	Pess	12	0.90	0.62	234	112	0.31

Weights in 000's tonnes

Table 3. Results (average from 2020 to 2029) from the Management Strategy Evaluation (MSE) assuming the HCR in the EU–Norway long-term plan is implemented as stipulated in the plan. The highlighted lines correspond to the way the assessment is conducted. OM – Operating Model; TACopt – TAC option; C – Catch; FC – fishing mortality (ages 3–6). Please see further details in the methods section above.

	OM	TACopt	p(>B_{lim})	p(>B_{pa})	median(SSB)	median(C)	median(FC)
Current Plan	**Opt**	**1**	**0.95**	**0.86**	**435**	**178**	**0.29**
No TAC cnstr	Opt	2	0.97	0.87	371	158	0.29
>Blim: av 3-yr proj TAC	Opt	3	0.98	0.90	404	160	0.28
>Blim: av intyr and HCR	Opt	4	0.93	0.83	370	165	0.30
>Blim: 15% tgt F	Opt	5	0.96	0.87	381	161	0.29
>Blim: 20% tgt F	Opt	6	0.96	0.87	385	163	0.29
>Blim: 25% tgt F	Opt	7	0.96	0.87	391	165	0.29
>Bpa: av 3-yr proj TAC	Opt	8	0.98	0.91	411	162	0.27
>Bpa: av intyr and HCR	Opt	9	0.94	0.84	375	166	0.29
>Bpa: 15% tgt F	Opt	10	0.96	0.87	380	162	0.29
>Bpa: 20% tgt F	Opt	11	0.96	0.87	385	162	0.29
>Bpa: 25% tgt F	Opt	12	0.96	0.87	391	164	0.28
Current Plan	**Pess**	**1**	**0.92**	**0.70**	**267**	**107**	**0.27**
No TAC cnstr	Pess	2	0.95	0.69	250	112	0.30
>Blim: av 3-yr proj TAC	Pess	3	0.95	0.66	241	110	0.30
>Blim: av intyr and HCR	Pess	4	0.91	0.67	249	111	0.29
>Blim: 15% tgt F	Pess	5	0.94	0.70	255	112	0.29
>Blim: 20% tgt F	Pess	6	0.94	0.70	256	112	0.29
>Blim: 25% tgt F	Pess	7	0.94	0.71	260	112	0.28
>Bpa: av 3-yr proj TAC	Pess	8	0.96	0.72	259	113	0.29
>Bpa: av intyr and HCR	Pess	9	0.93	0.69	256	114	0.29
>Bpa: 15% tgt F	Pess	10	0.94	0.70	255	112	0.29
>Bpa: 20% tgt F	Pess	11	0.94	0.70	256	112	0.29
>Bpa: 25% tgt F	Pess	12	0.94	0.71	259	113	0.29

Weights in 000's tonnes

Table 4. Results for Interannual Catch Variability (ICV) from the Management Strategy Evaluation (MSE) assuming the HCR in the EU–Norway long-term plan is implemented as stipulated in the plan. The highlighted lines correspond to the way the assessment is conducted. ICV is calculated as the absolute value of {1 – Catch(year y+1)/Catch(year y)}, averaged over either y=2013 to 2020 "ICV (2013-20)" or y=2020 to 2029 "ICV (2020-29)". The values shown in the table are medians (over the number of iterations) of these averages. Please see further details in the methods section above.

	OM	TACopt	ICV (2013-20)	ICV (2020-29)
Current Plan	**Opt**	**1**	0.12	0.13
No TAC cnstr	Opt	2	0.22	0.25
>Blim: av 3-yr proj TAC	Opt	3	0.17	0.19
>Blim: av intyr and HCR	Opt	4	0.12	0.13
>Blim: 15% tgt F	Opt	5	0.16	0.18
>Blim: 20% tgt F	Opt	6	0.15	0.17
>Blim: 25% tgt F	Opt	7	0.14	0.16
>Bpa: av 3-yr proj TAC	Opt	8	0.18	0.19
>Bpa: av intyr and HCR	Opt	9	0.13	0.15
>Bpa: 15% tgt F	Opt	10	0.16	0.19
>Bpa: 20% tgt F	Opt	11	0.15	0.18
>Bpa: 25% tgt F	Opt	12	0.15	0.17
Current Plan	**Pess**	**1**	0.12	0.13
No TAC cnstr	Pess	2	0.25	0.27
>Blim: av 3-yr proj TAC	Pess	3	0.18	0.21
>Blim: av intyr and HCR	Pess	4	0.12	0.15
>Blim: 15% tgt F	Pess	5	0.16	0.20
>Blim: 20% tgt F	Pess	6	0.15	0.19
>Blim: 25% tgt F	Pess	7	0.14	0.18
>Bpa: av 3-yr proj TAC	Pess	8	0.21	0.22
>Bpa: av intyr and HCR	Pess	9	0.14	0.20
>Bpa: 15% tgt F	Pess	10	0.18	0.22
>Bpa: 20% tgt F	Pess	11	0.17	0.20
>Bpa: 25% tgt F	Pess	12	0.16	0.21

Appendix 1: North Sea saithe management strategy evaluation request

Joint EU-Norway request to ICES on Options to Revise the Long-Term Management Plan for Saithe in the North Sea

In accordance with point 5.3.3 of the Agreed record of Fisheries Consultations between Norway and the European Union for 2012, signed on 2 December 2011, it was agreed to convene a seminar on long term management plans. The objective of this seminar was to establish the basis for further developing long-term management plans for joint stocks.

Based on the most recent assessment of the stock of saithe in ICES Subarea IV, Division IIIa and Subarea VI, ICES is requested to conduct an evaluation, by 1 October 2012, of the current harvest control rule with the following variations:

1) Applying the current management plan unchanged.

2) Applying the harvest control rule with no TAC stability mechanism.

3) Applying the HCR with the following stability mechanisms when the SSB is above B_{lim}:

   a) Setting a TAC in the TAC year based on the average of the projected TACs at target F over three years starting with the TAC year.

   b) Setting the TAC to be the average of the current TAC and the TAC that would result from the application of the HCR for the TAC year.

   c) Applying a TAC constraint of +/- 15%, but where the resulting fishing mortality is not allowed to deviate by more than 15%, 20% or 25% from the target F

4) Applying the HCR with the above mentioned stability mechanisms, but applying them only when the stock is above B_{pa}.

5) Allowing an inter-annual quota flexibility of +/- 10%

ICES is invited to suggest alternative values for the constraints and ranges where appropriate.

Appendix 2: Current EU–Norway Management plan for North Sea saithe

In 2008 the EU and Norway renewed the existing agreement on "a long-term plan for the saithe stock in the Skagerrak, the North Sea and west of Scotland, which is consistent with a precautionary approach and designed to provide for sustainable fisheries and high yields. The plan shall consist of the following elements.

1) Every effort shall be made to maintain a minimum level of Spawning Stock Biomass (SSB) greater than 106,000 tonnes (B_{lim}).

2) Where the SSB is estimated to be above 200,000 tonnes the Parties agreed to restrict their fishing on the basis of a TAC consistent with a fishing mortality rate of no more than 0.30 for appropriate age groups.

3) Where the SSB is estimated to be below 200,000 tonnes but above 106,000 tonnes, the TAC shall not exceed a level which, on the basis of a scientific evaluation by ICES, will result in a fishing mortality rate equal to 0.30-0.20*(200,000-SSB)/94,000.

4) Where the SSB is estimated by the ICES to be below the minimum level of SSB of 106,000 tonnes the TAC shall be set at a level corresponding to a fishing mortality rate of no more than 0.1.

5) Where the rules in paragraphs 2 and 3 would lead to a TAC which deviates by more than 15% from the TAC of the preceding year the Parties shall fix a TAC that is no more than 15% greater or 15% less than the TAC of the preceding year.

6) Notwithstanding paragraph 5 the Parties may where considered appropriate reduce the TAC by more than 15% compared to the TAC of the preceding year.

7) A review of this arrangement shall take place no later than 31 December 2012.

8) This arrangement enters into force on 1 January 2009."

Appendix 3: Conditioning

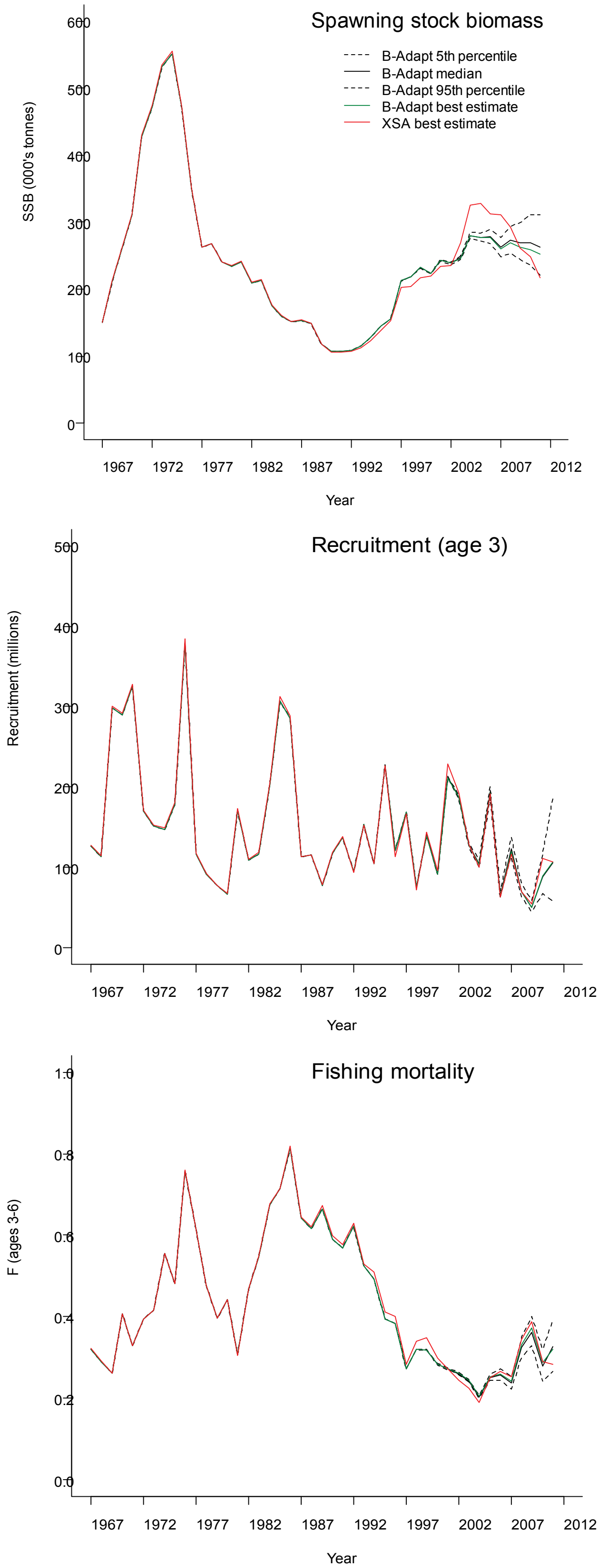


Figure 3.1. A comparison of spawning stock biomass, recruitment and fishing mortality estimates from the B-Adapt operating model and the XSA assessment model.

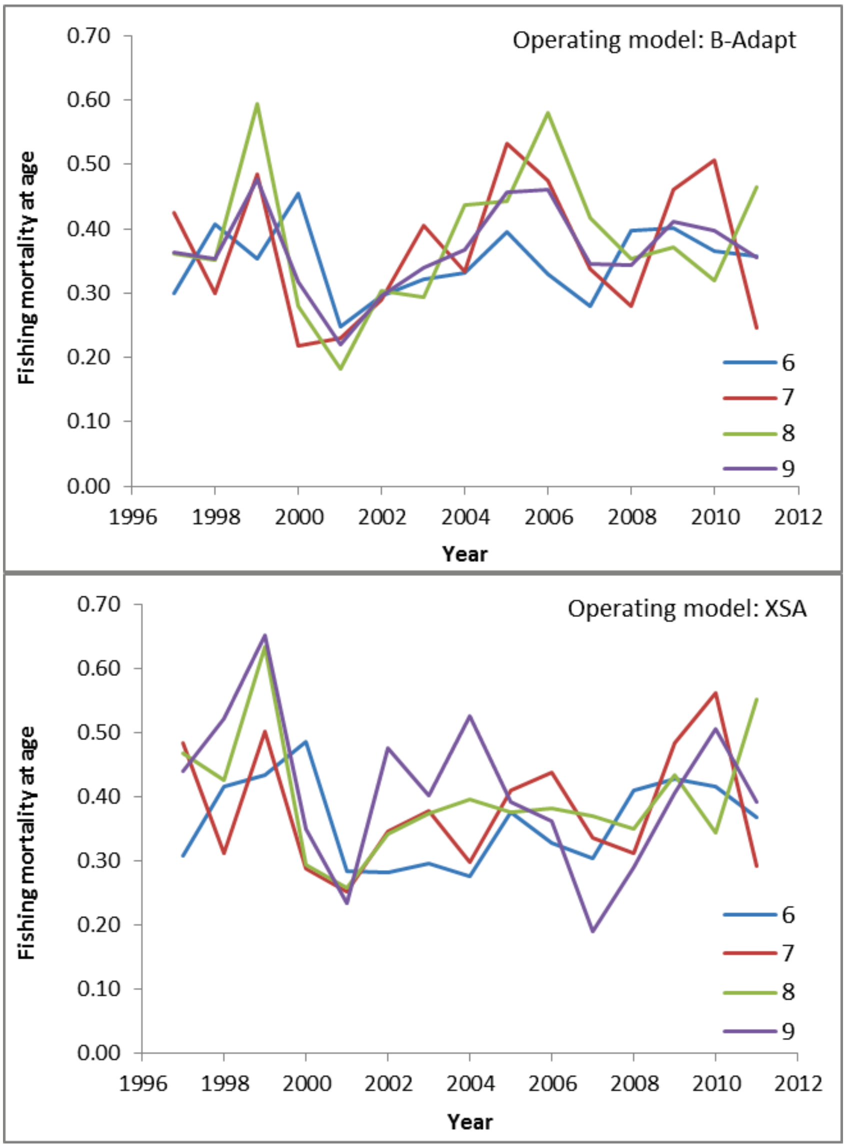


Figure 3.2. A comparison of fishing mortality for ages 6–9 over the period 1997 to 2011 for B-Adapt (top) which assumes F at age 9 is the average of ages 6–8 and XSA (bottom) operating models in which F at age 9 is estimated independently of the other ages.

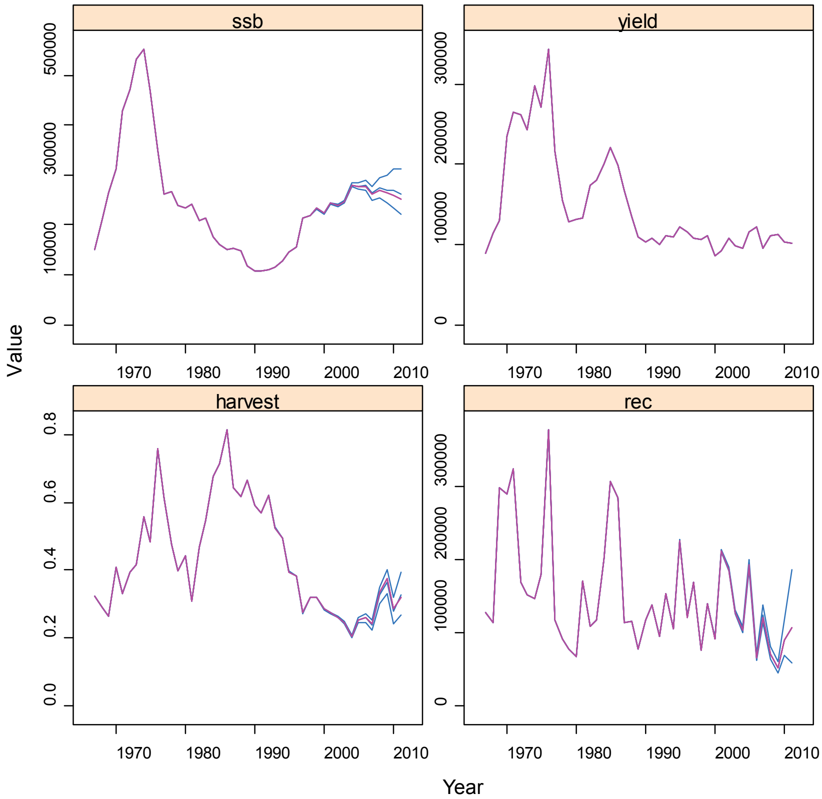


Figure 3.3. Assessment summary generated from the B-Adapt operating model. The red line indicates the best model fit, while the blue line indicates the bootstrap median together with the 5th and 95th percentiles.

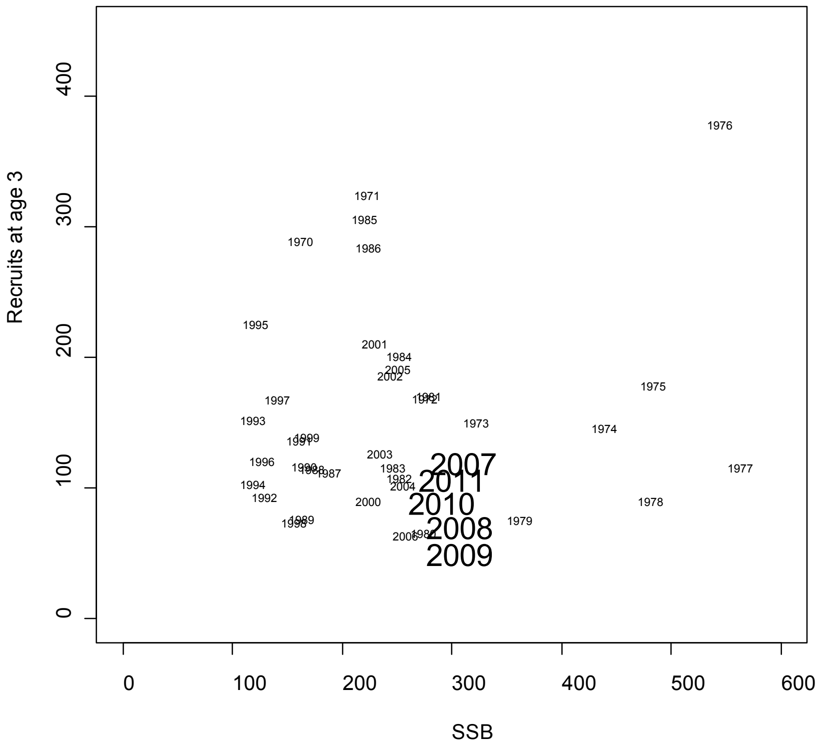


Figure 3.4. Stock–recruitment pairs for the entire time-series from 1967 to 2011. Note that the most recent five years have been highlighted in a larger font size.

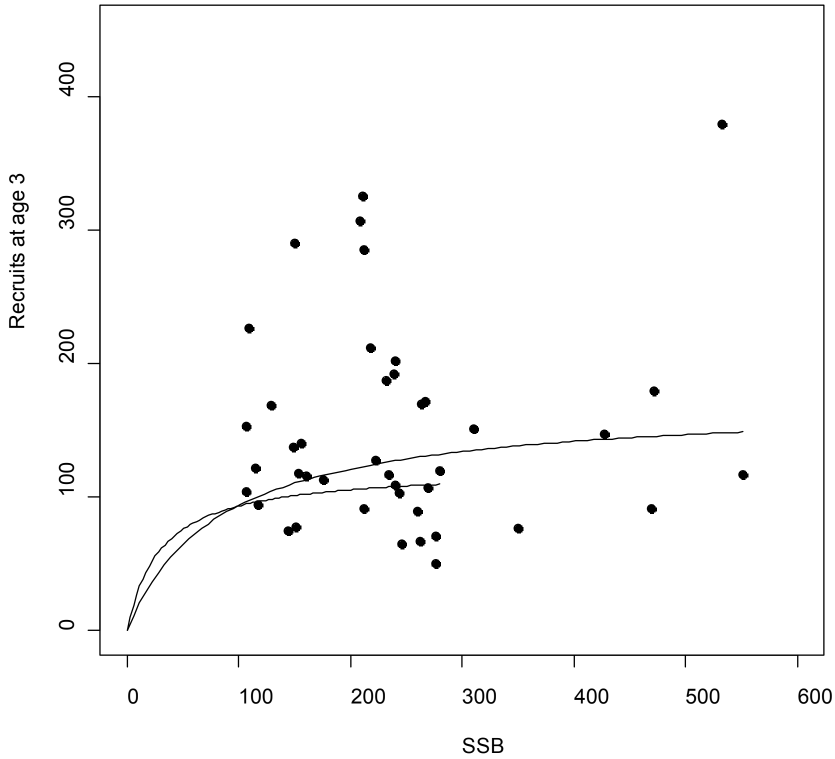


Figure 3.5. Stock–recruitment estimates for North Sea saithe. Note that the long and short lines indicate the optimistic (1967–2011) and pessimistic (1988–2011) recruitment scenarios, respectively.

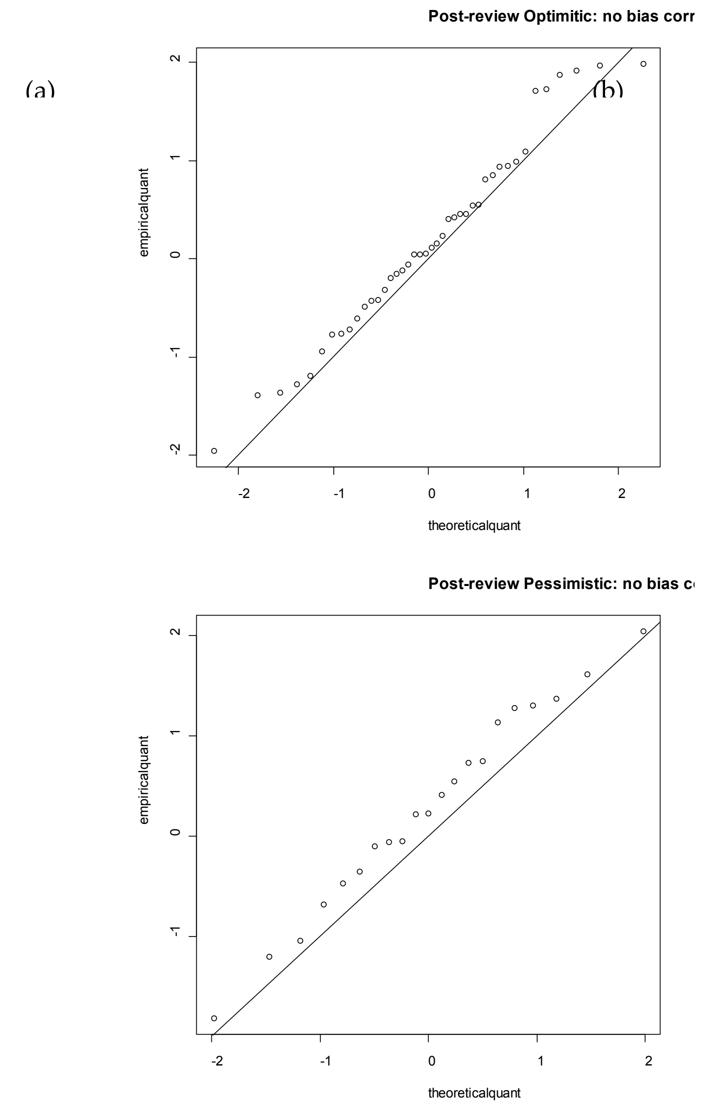


Figure 3.6. Standardised log recruitment residual qq plots (to check consistency with Normal (0; 1) distribution), based on the fits shown in Figure 3.5., for the optimistic (a) and pessimistic (b) biological production scenarios.

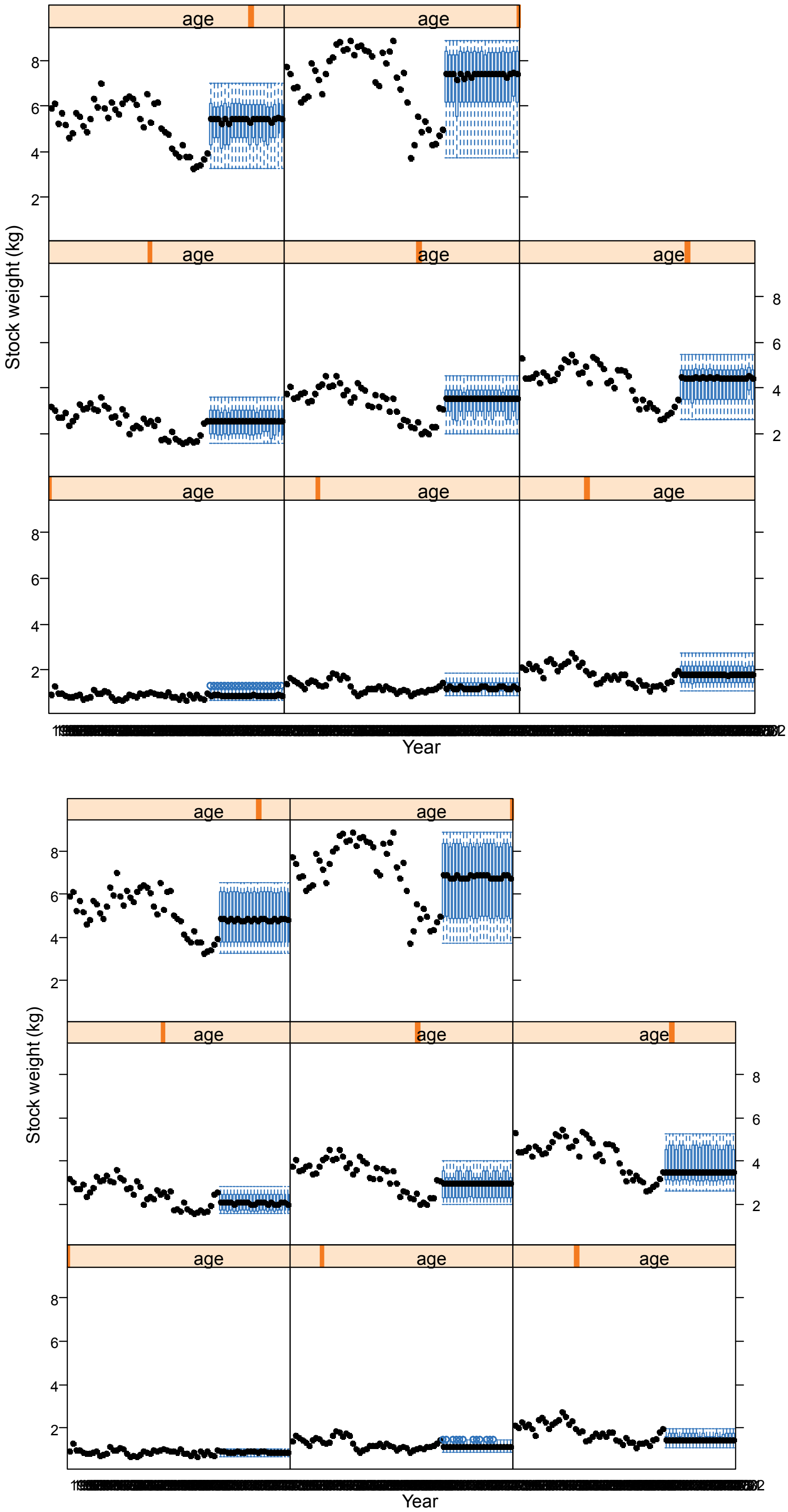


Figure 3.7. Historic and projected weight at age for North Sea saithe from 1967 to 2032. The default box and whisker plots from R present inter-quartile ranges (minimum, 25% quartile; median, 75% quartile and maximum ranges) for future projected weight at age. Note that the first set of plots illustrates the optimistic growth scenario and the second the pessimistic growth scenario.

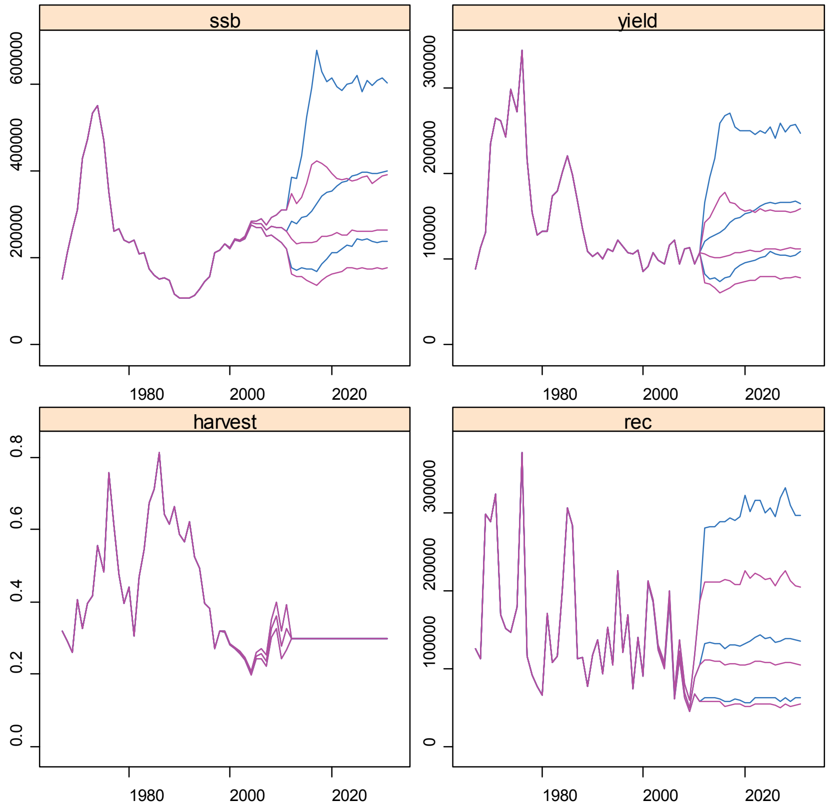
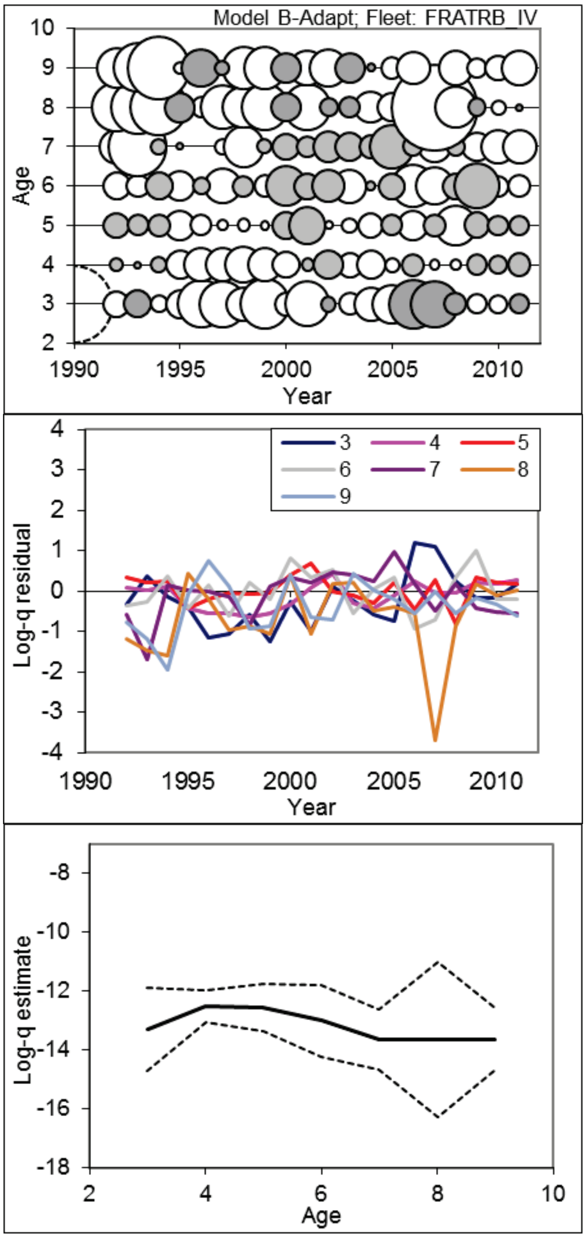


Figure 3.8. North Sea saithe historic and projected spawning stock biomass, yield, fishing mortality and recruitment for the optimistic (blue) and pessimistic (red) biological production scenarios. Projections from 2012 onwards illustrate the median value (middle line) together with the 5th (lower line) and 95th (upper line) percentiles.

Appendix 4: Comparisons B-Adapt vs. XSA fit



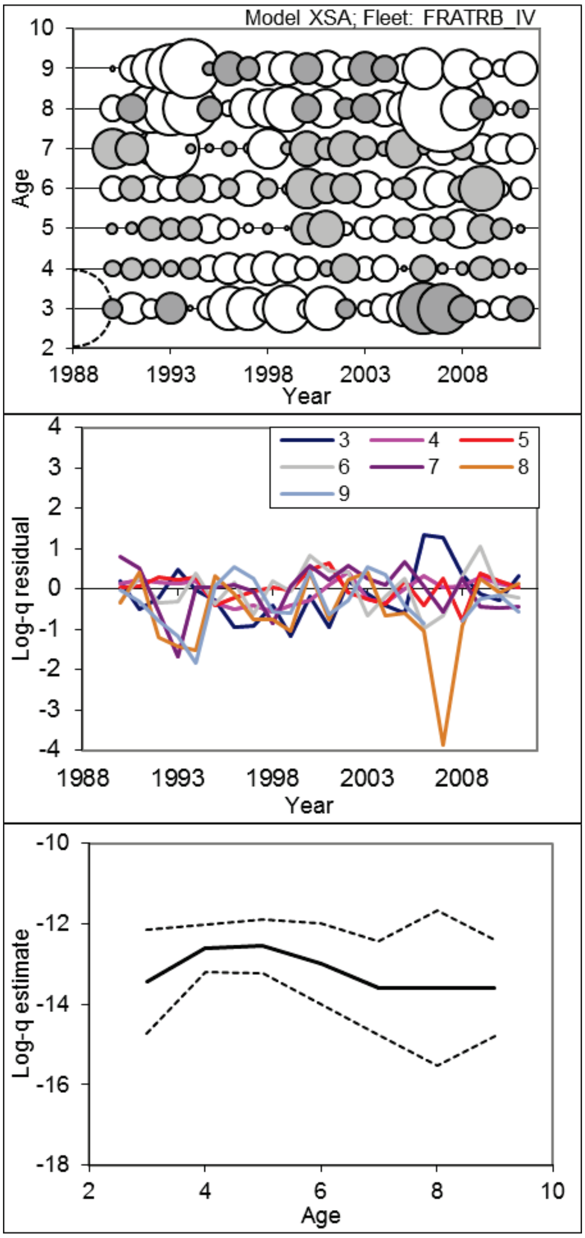
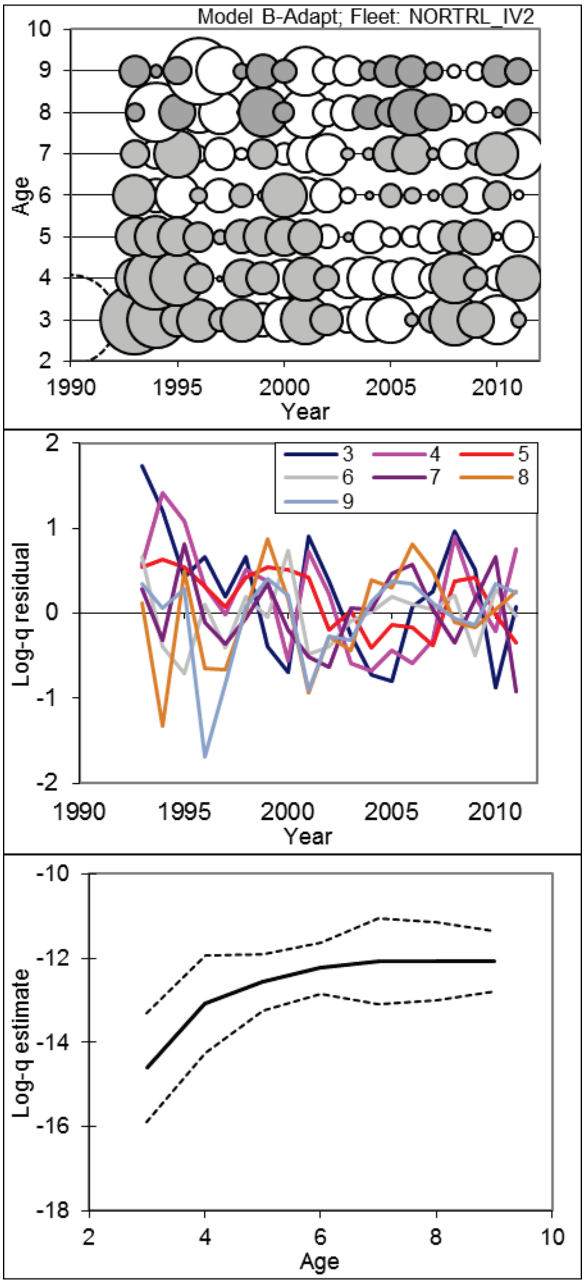


Figure 4.1. Log catchability residuals and estimates for the FRATRB_IV fleet generated from B-Adapt (top) and XSA (bottom) operating models.


Model B-Adapt; Fleet: NORTRL_IV2
Age
Year
Log-q residual
3
4
5
6
7
8
9
Year
Log-q estimate
Age

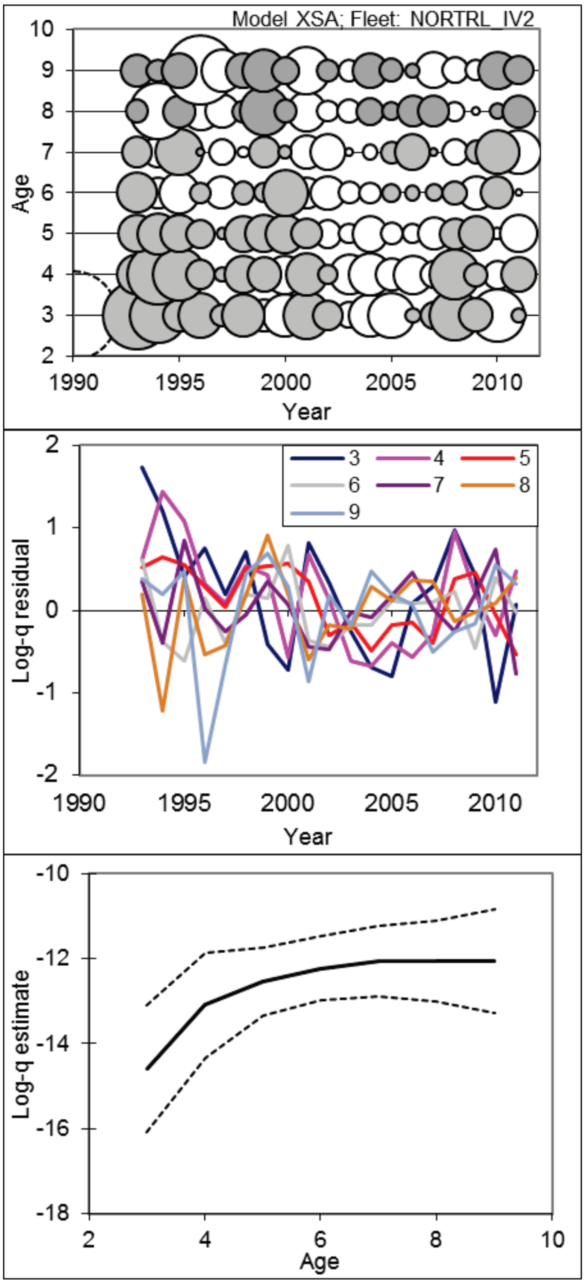
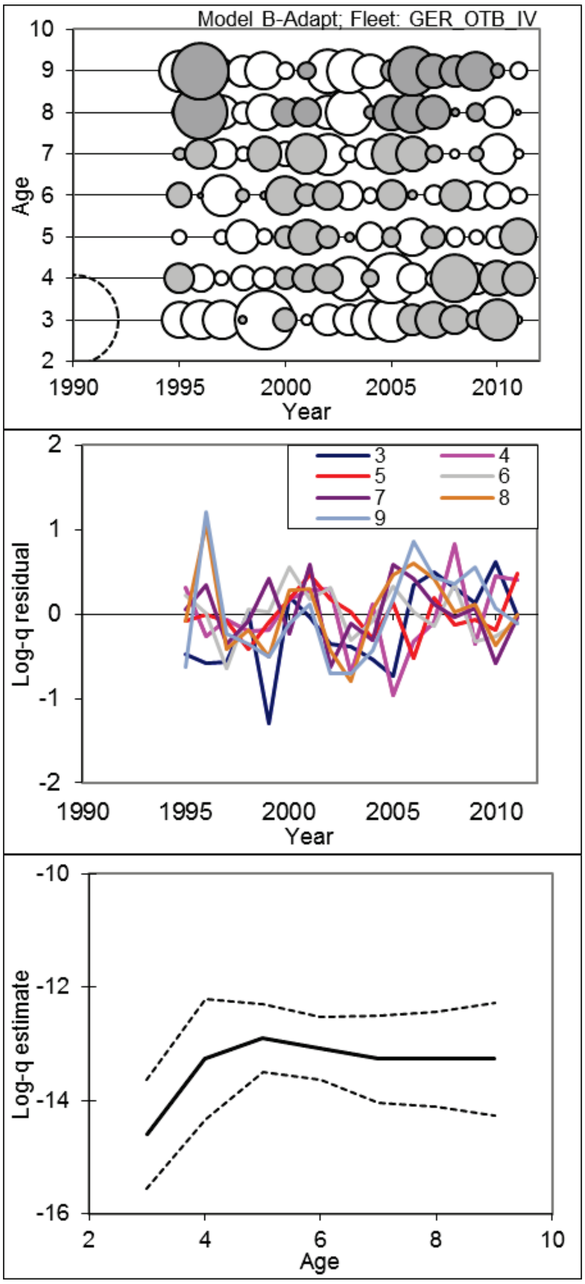


Figure 4.2. Log catchability residuals and estimates for the NORTRL_IV2 fleet generated from B-Adapt (top) and XSA (bottom) operating models.


Model B-Adapt; Fleet: GER_OTB_IV
Age
Year
Log-q residual
3
4
5
6
7
8
9
Year
Log-q estimate
Age

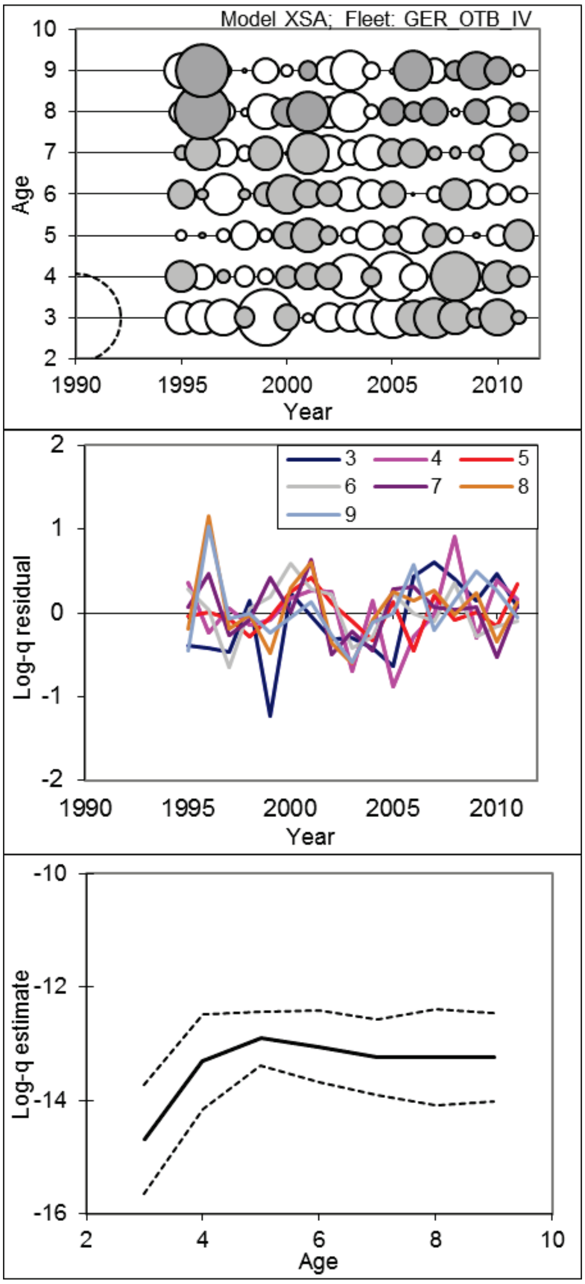
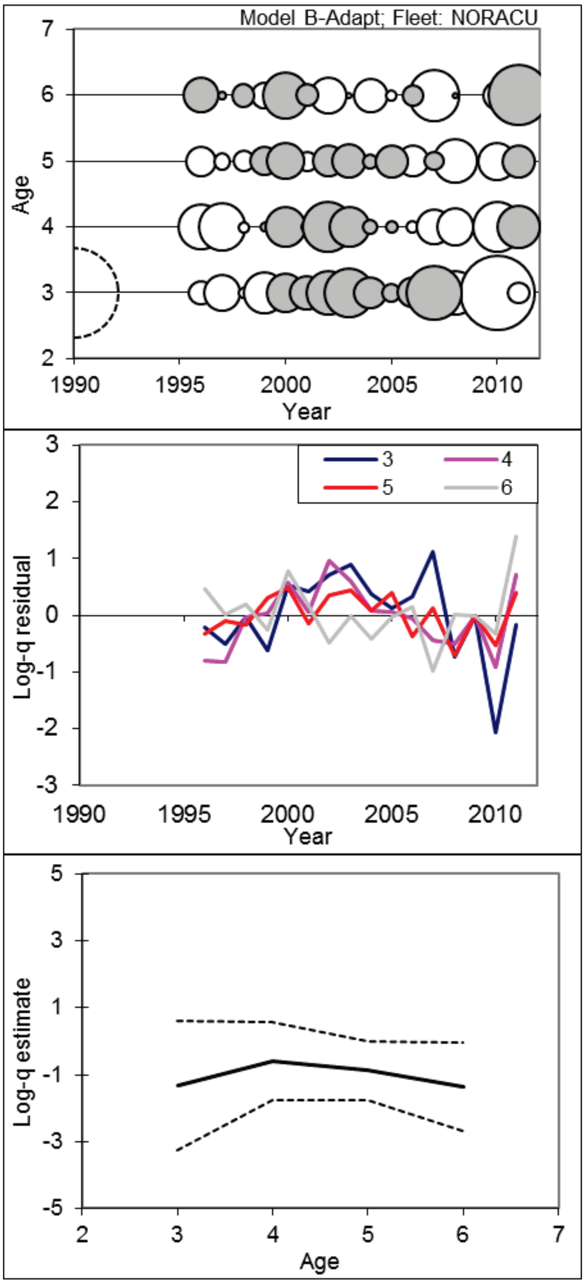


Figure 4.3. Log catchability residuals and estimates for the GER_OTB_IV fleet generated from B-Adapt (top) and XSA (bottom) operating models.


Model B-Adapt; Fleet: NORACU
Age
Year
Log-q residual
Year
3
4
5
6
Log-q estimate
Age

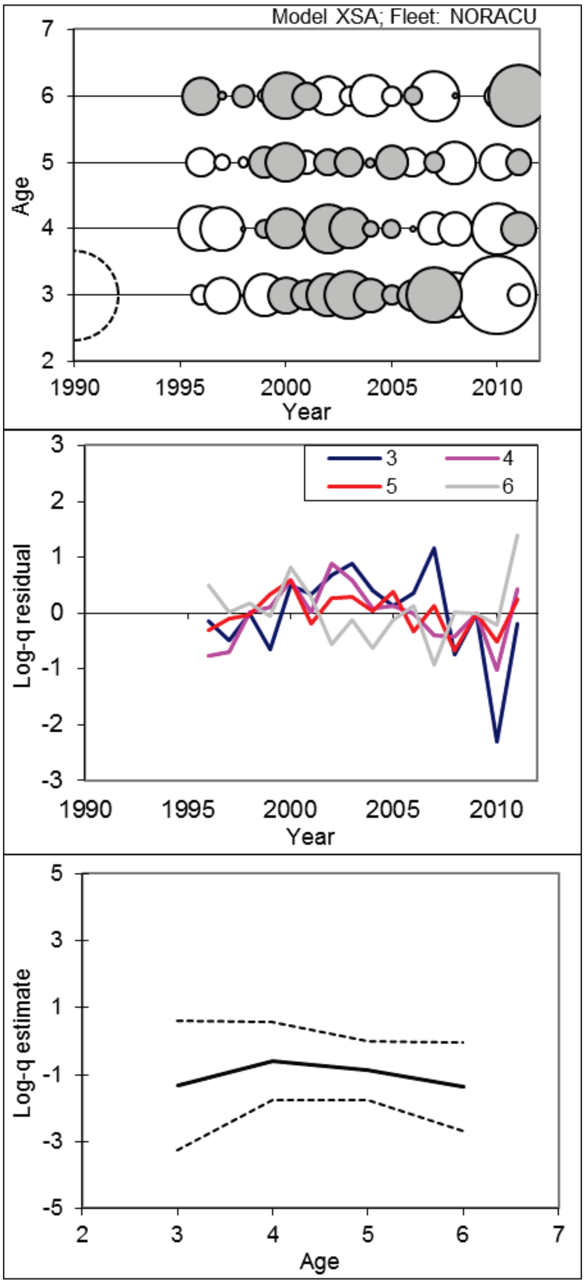
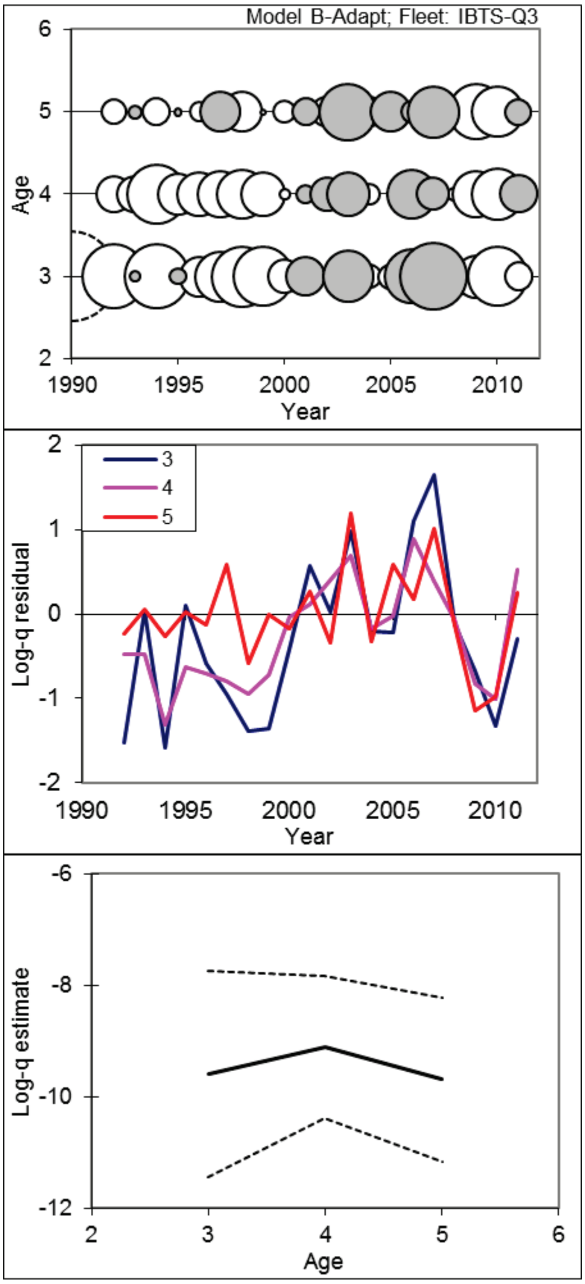


Figure 4.4. Log catchability residuals and estimates for the NORACU fleet generated from B-Adapt (top) and XSA (bottom) operating models.


Model B-Adapt; Fleet: IBTS-Q3
Age
Year
Log-q residual
Year
Log-q estimate
Age

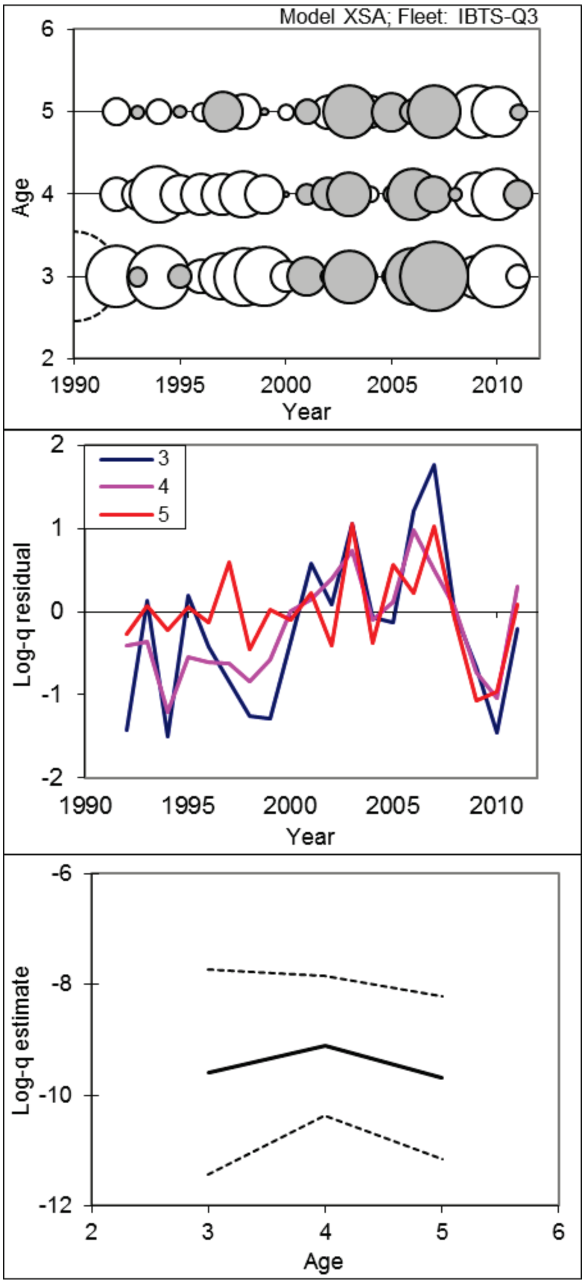
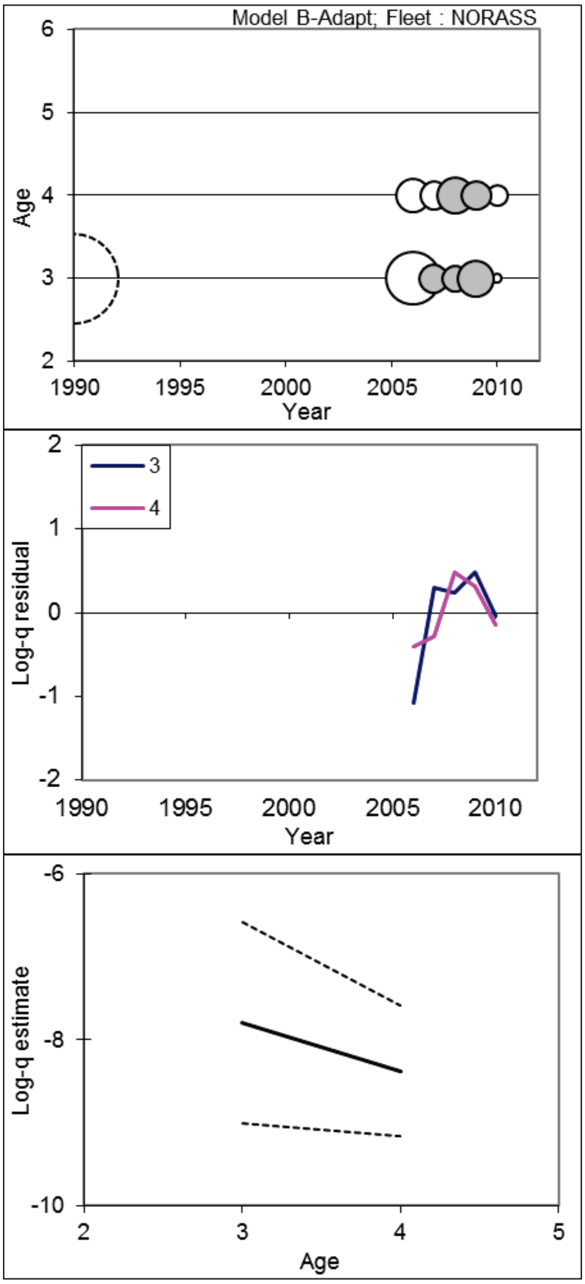


Figure 4.5. Log catchability residuals and estimates for the IBTS_Q3 fleet generated from B-Adapt (top) and XSA (bottom) operating models.



Model B-Adapt; Fleet : NORASS
Age
Year
Log-q residual
3
4
Log-q estimate
Age

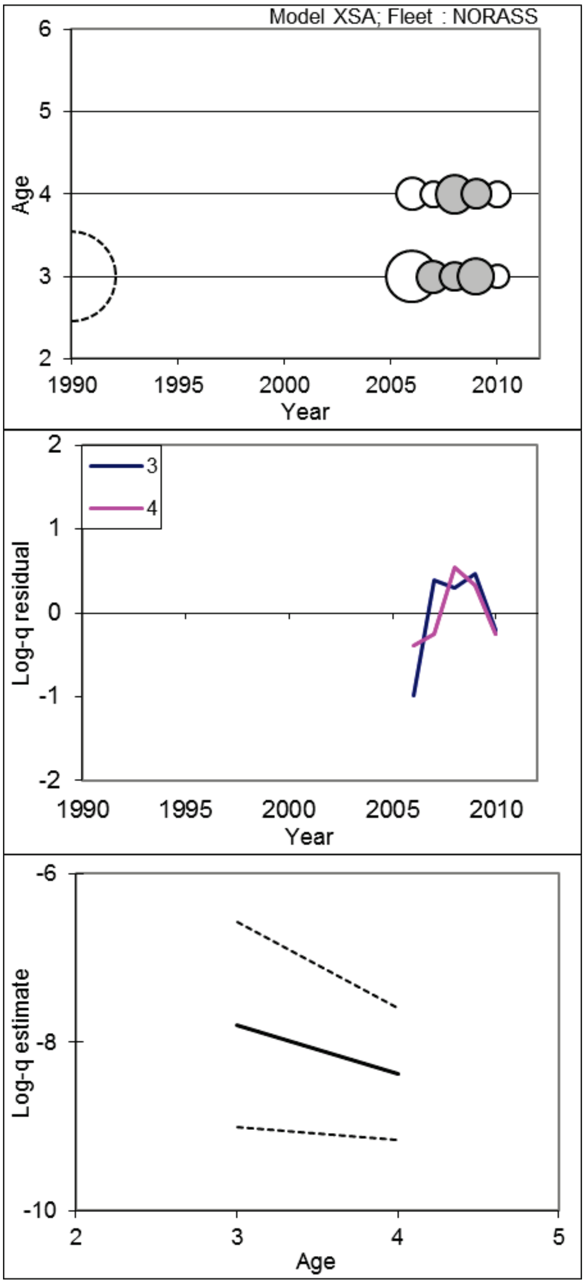
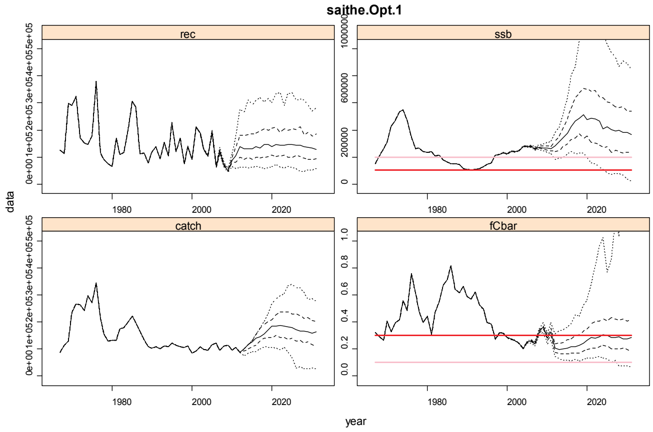


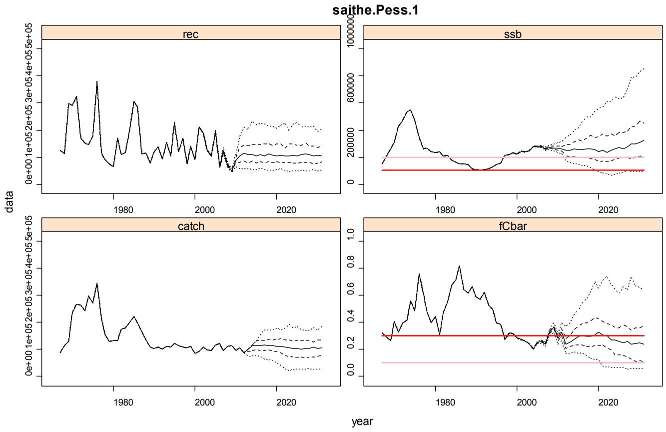
Figure 4.6. Log catchability residuals and estimates for the NORASS fleet generated from B-Adapt (top) and XSA (bottom) operating models.

Appendix 5: TAC stability options

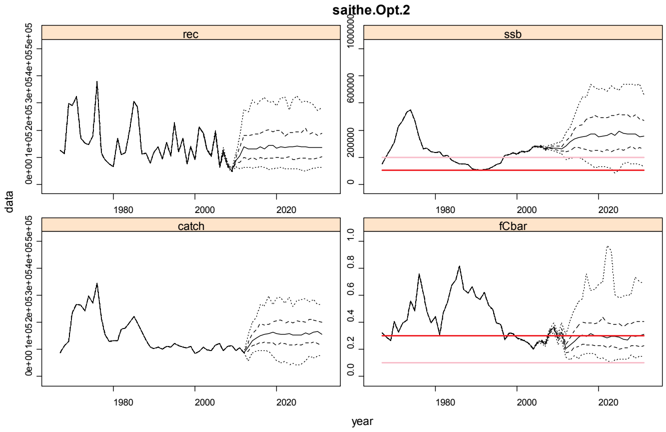
saithe.Opt.1



saithe.Pess.1



saithe.Opt.2



saithe.Pess.2

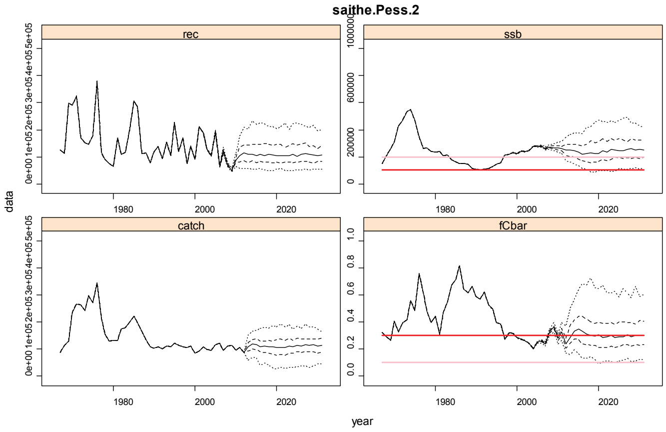
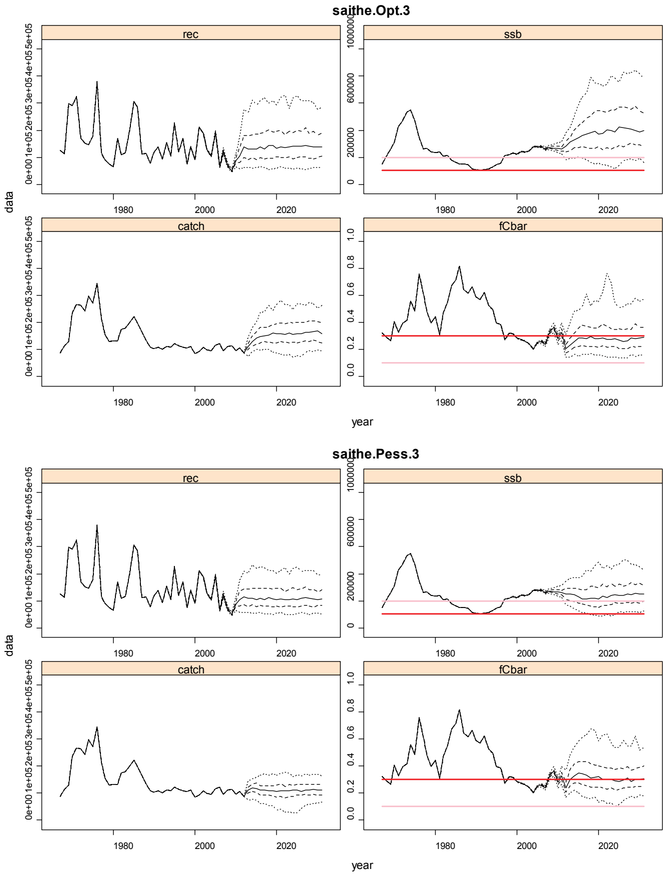


Figure 5.1. Historic and projected recruitment, SSB, catch and fCbar (Fbar 3–6 for the catch) for applying the current management plan unchanged (Opt.1 and Pess.1) as well as for applying the HCR with no TAC stability mechanism (Opt.2 and Pess.2) under optimistic (left) and pessimistic (right) biological production scenarios. Projections from 2012 onwards illustrate the 5th and 95th percentiles (lower and upper dotted lines, respectively), the 50th percentile (solid line) as well as the 25th and 75th percentiles (lower and upper dashed lines, respectively). Note that the reference lines indicate B_{pa} (pink) and B_{lim} (red) for SSB as well as the upper and lower F targets in the sliding rule of the current Management Plan (F = 0.3 in red; F = 0.1 in pink).



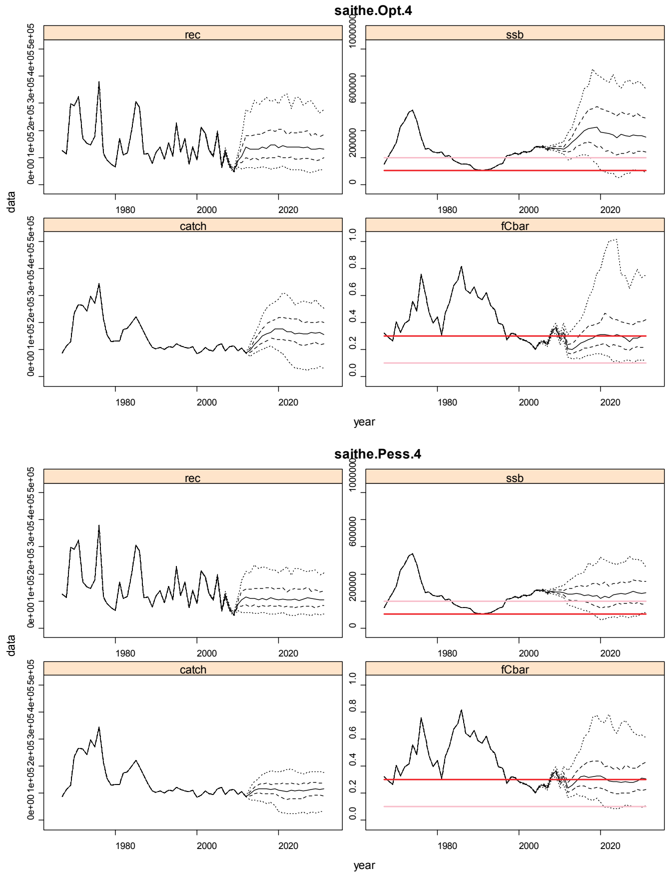
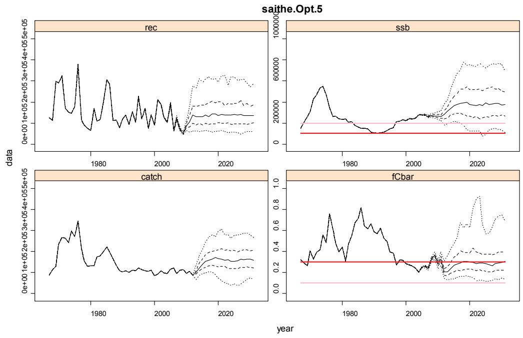
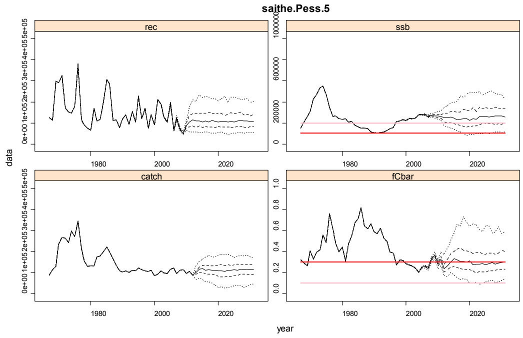
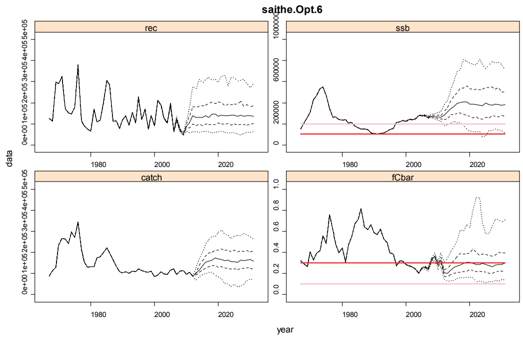
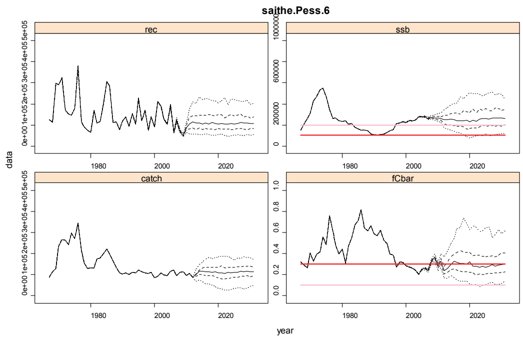


Figure 5.2. Historic and projected recruitment, SSB, catch and fCbar for setting a TAC in the TAC year based on the average of the projected TACs at target F over three years starting with the TAC year when SSB is above B_{lim} (Opt.3 and Pess.3) as well as for setting the TAC to the average of the current TAC and the TAC that would result from the application of the HCR for the TAC year when SSB is above B_{lim} (Opt.4 and Pess.4) under optimistic (left) and pessimistic (right) biological production scenarios. See Figure 5.1. for further details.


saithe.Opt.5
rec
ssb
catch
fCbar
data
year
1980
2000
2020


saithe.Pess.5
rec
ssb
catch
fCbar
data
year
1980
2000
2020


saithe.Opt.6
rec
ssb
catch
fCbar
data
year
1980
2000
2020


saithe.Pess.6
rec
ssb
catch
fCbar
data
year
1980
2000
2020

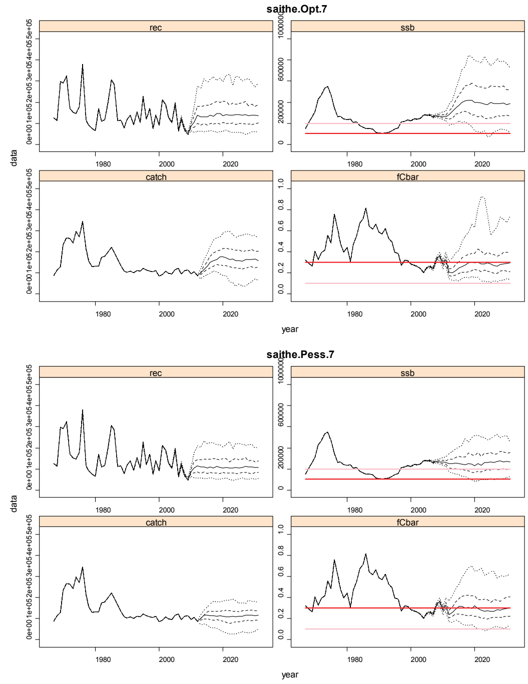
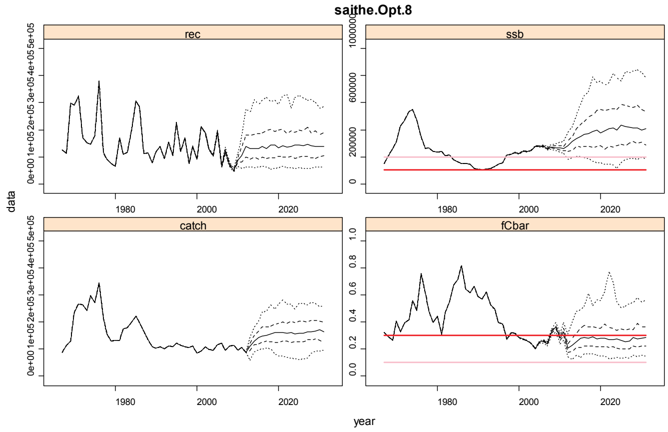
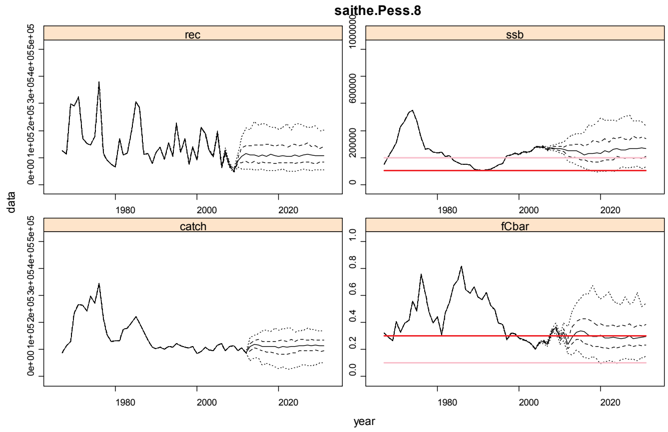


Figure 5.3. Historic and projected recruitment, SSB, catch and fCbar for applying a TAC constraint of ±15% but where the resulting fishing mortality is not allowed to deviate by more than 15% (Opt.5 and Pess.5), 20% (Opt.6 and Pess.6) or 25% (Opt.7 and Pess.7) from the target F when SSB is above B_{lim} under optimistic (left) and pessimistic (right) biological production scenarios. See figure 5.1. for further details.


saithe.Opt.8
rec
ssb
catch
fCbar
data
year


saithe.Pess.8
rec
ssb
catch
fCbar
data
year

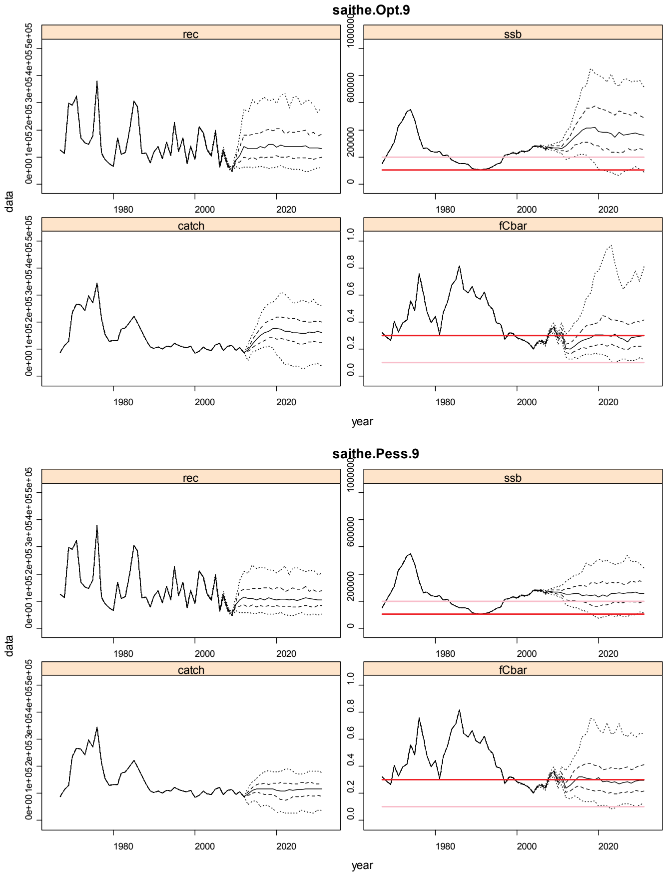
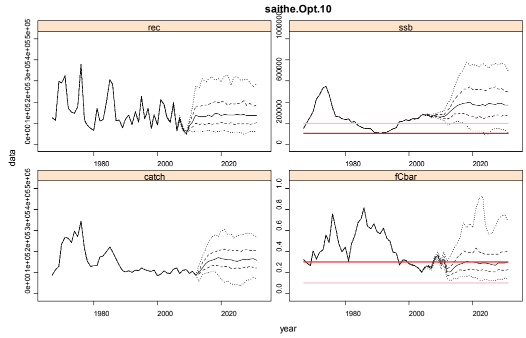


Figure 5.4. Historic and projected recruitment, SSB, catch and fCbar for setting a TAC in the TAC year based on the average of the projected TACs at target F over three years starting with the TAC year when the stock is above B_{pa} (Opt.8 and Pess.8) as well as for setting the TAC to the average of the current TAC and the TAC that would result from the application of the HCR for the TAC year when the stock is above B_{pa} (Opt.9 and Pess.9) under optimistic (left) and pessimistic (right) biological production scenarios. See Figure 5.1. for further details.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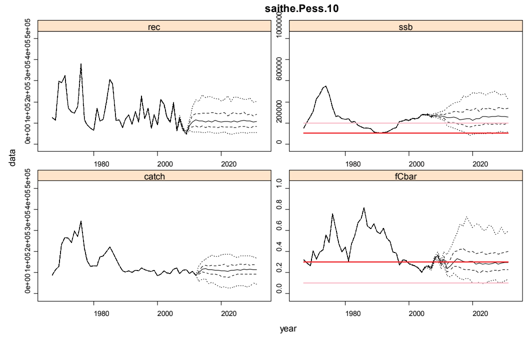
rec
ssb
catch
fCbar
data
year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catch
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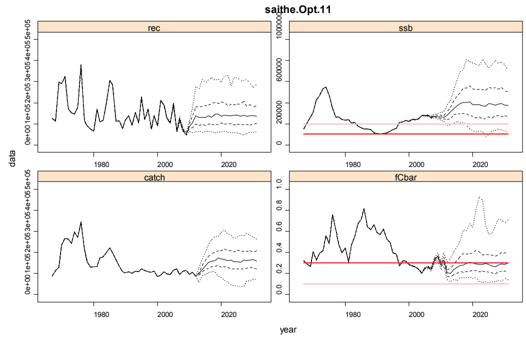
year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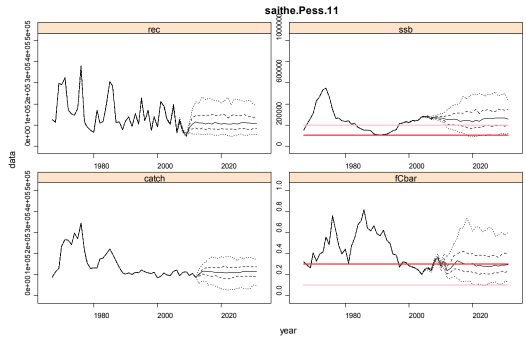
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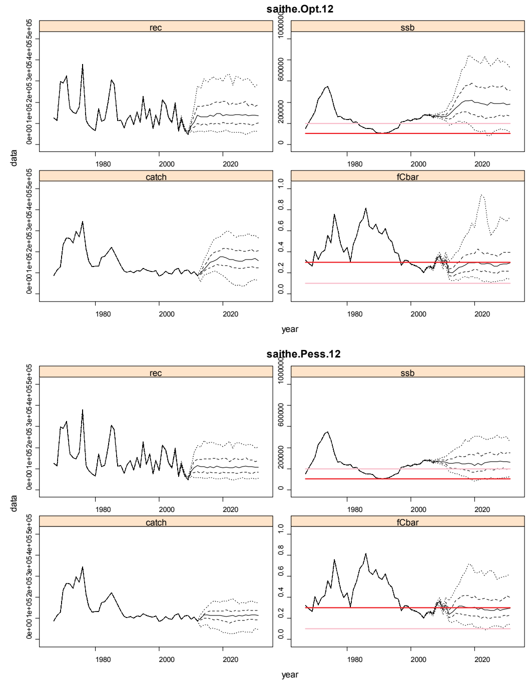

Figure 5.5. Historic and projected recruitment, SSB, catch and fCbar for applying a TAC constraint of ±15% but where the resulting fishing mortality is not allowed to deviate by more than 15% (Opt.10 and Pess.10), 20% (Opt.11 and Pess.11) or 25% (Opt.12 and Pess.12) from the target F when the stock is above B_{pa} under optimistic (left) and pessimistic (right) biological production scenarios. See Figure 5.1. for further details.