A Further Updated Analysis of the Implications of Different Choices for the Frequency of Updates to OFLs and ABCs for the CSNA

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Background

Punt (2019a) outlines a simulation framework to compare alternative frequencies to update overfishing limits (OFL) and acceptable biological catches (ABC), alternative buffers between OFL and ABC, and alternative thresholds when changing the nominal values for OFL and ABC given changes in monitoring data. The framework (Figure 1) was applied to compare several sets of alternative choices for the parameters that determine how the flowchart of Figure 1 is implemented given scenarios regarding the stock-recruitment relationship, and the precision of monitoring for the Central Subpopulation of Northern Anchovy (CSNA). Key concepts of the modelling structure on which the analyses of this document are based are:

- The operating model (see Appendix A for the equations on which this model is based) for the projections allows for regime-shift-like dynamics in the stock-recruitment relationship, uncertainty in recruitment about the stock-recruitment as well as in the parameters of the stock-recruitment relationship, uncertainty in the estimates of abundance from the survey used as the basis for setting OFLs and ABCs, and improvement over time in the estimates of E_{MSY} when stock assessments are assumed to be conducted.
- Control parameters used to determine ABCs and OFLs include:
  - Y, the frequency of assessment in years;
  - Z, the frequency of OFL updates in years;
  - X, the frequency of ABC updates in years;
  - Q, the ABC buffer (i.e. the ABC equals Q * OFL);
  - x_1, the threshold for changing OFL due to changes in the long-term biomass estimate; and
  - x_2, the threshold for reducing ABC due to changes in the short-term biomass estimate.
- The evaluation of the relative performance of a set of choices for the control parameters is based on an MSE-like process (closed loop simulation).

An October 3-4, 2019 meeting (PFMC, 2019) reviewed the framework and concluded that it is appropriate as the basis for management of the CSNA, but that the values for the parameters of Fig. 1 must be specified. PFMC (2019) noted that the analyses comparing alternative parameters were illustrative but not sufficient. PFMC (2019) identified additional analyses that should be provided to the November Council meeting to allow the Council advisory bodies to provide advice on the values for the parameters. The set of factors to consider in the additional simulations and levels for those factors are listed in Table 1. PFMC (2019) also recommended that analyses to inform the choice of the parameters of Figure 1 include two new performance statistics (a measure of the probability of overfishing and a measure of how low the population biomass may drop to). The aim of the runs is to enable the Council's advisory bodies to more deeply consider the trade-offs associated with the choices (PFMC, 2019).

The specifications in Table 1 lead to 51,840 model runs. The results are not all combinations of all levels in Table 1. For example, the constraint Y $\geq$ Z $\geq$ X was imposed and the (5,3) combination of long-term and short-term biomass definition was not run given the similarity of the values. The analyses are based on one of the operating models in Punt (2019a), the base-case operating model with the Beverton-Holt stock-recruitment relationship, but the results in Punt (2019a) indicate that even the quantitative results of the projections are robust to the choice of stock-recruitment relationship. This base-case operating model includes a 60-year regime period with an amplitude of 0.8. The values for the performance metrics for all the scenarios regarding parameters are listed in the file RunSummary.xls, which is available on the Council's ftp site: ftp://ftp.pcouncil.org/pub/CPS/CPSMtgOct2019/ (which also contains electronic versions of the documents presented to the meeting at which the framework was reviewed). It is not possible to compare every possible combination of factors. This document reports on some ways to summarize the results, and provides an initial interpretation of the results.

Methods

Punt (2019a) considered five performance statistics and PFMC (2019) added an additional two performance statistics. To keep the volume of results somewhat limited, this document only considers five performance statistics:

- the probability that the spawning stock biomass is smaller than 0.5 B_{MSY};
- the probability that the ABC is larger than the product of the true E_{MSY} (one value for each draw from the posterior) and the true 1+ biomass;
- the probability of the 1+ biomass dropping below a reference level, computed as the lower 5$^{\text{th}}$ percentile of 1+ biomass in an unfished situation;
- the probability that the ABC is smaller than 25,000mt; and
- the probability that the ABC is smaller than 10,000mt.

The two performance statistics not reported here (but included in the file RunSummary.xls) are the probability that the spawning stock biomass is smaller than B_{MSY} (which is highly correlated with the probability that the spawning stock biomass is smaller than 0.5 B_{MSY}) and the probability that the ABC is smaller than 5,000mt (which is highly correlated with the probabilities that the ABC is smaller than 25,000mt and 10,000mt).

The results have been divided into six "sets' based on the value of Y (the frequency at which benchmark assessments of the CSNA are conducted; values 4, 8 and 16 years) and MAXCAT (none or 25,000t). MAXCAT is a proxy in the model that caps catch levels to the maximum perceived capacity or need by the industry. PFMC (2019) notes that inclusion of MAXCAT in the modelling is not meant as a proposal for a new management policy for this stock. Rather, the concept of MAXCAT is as a proxy to limit catch in the model to help evaluate what happens to the modelled biomass when fisheries cannot take the full ABC given occasional very large ABCs and the capacity and needs of the fishery. The results for Y=8 and the two levels of MAXCAT are provided here. This is because there is almost no difference in results among the three choices for Y (see Figure 2 for a comparison of differences in the values of the performance statistics for the three choices for Y). Figure 2 also shows the impact of MAXCAT, which is to lead to more optimistic results for all five performance statistics (i.e., lower probability of overfishing, a spawning stock biomass less than 0.5B_{MSY}, and a lower probability of an ABC of 25,000t or less).

Results

Figures 3 and 4 (no MAXCAT and MAXCAT=25,000t respectively) show the results for Y=8 when all the results for a specific level of a factor and a given value for Q (row) are combined and summarized using a box plot. The red and blue lines on Figures 3 and 4 are for a reference set of parameters (Y=8, Z=4, X=2, x_1=0.1, x_2=0.2, long-term term biomass based on 10 years and short-term biomass based on 3 years) with Q differing between the red and blue lines. The value of Q corresponding to the red line varies by row in the figure, while the blue line always corresponds to Q = 0.5. The results in panels a, b and c respectively show how the performance statistics change as a function of Z and X (a), the definitions of long- and short-term biomass (b), and x_1 and x_2 (c).

The values for the performance statistics are better (lower) for more frequent changes in OFL and ABC (Figures 3a, 4a), particularly for the risk-related performance statistics (i.e. 811 [Y=8; Z=1;X=1], 841 [Y=8; Z=4;X=1, this naming convention remains throughout], and 881 achieve lower values for the performance statistics compared to 842, 882 and 884), with the effect increasing with Q (marginal difference in results for Q=0.05; quite marked for Q=0.95).

The values for the performance statistics are lowest when short-term biomass is defined by the most recent estimate but performance is better when the long-term biomass is based on at least 5 rather than 1 years (e.g. 5-1, 10-1 and 60-1 outperform 1-1 in Figures 3b and 4b). The results are not sensitive to the values for x_1 and x_2 (Figures 3c, 4c).

The results for MAXCAT=25,000t are qualitatively the same as those for no MAXCAT but, as expected from Figure 2, the values for the performance statistics are generally more optimistic.

Figures 5 and 6 (no MAXCAT and MAXCAT=25,000t respectively) show results for Y=8, x_1=0.1, and x_2=0.2 as the value for Q is changed (lines with different colours) and given values for the definitions of long-term and short-term biomass (rows). A series of dots is provided for context. The dots correspond to results for the ten values for Q when Y=8, Z=4, X=2, x_1=0.1, x_2=0.2, long-term term biomass based on 10 years and short-term biomass based on 3 years.

The colours of the lines in Figure 5 and 6 relate to Q as follows (0.05 & 0.15: red, 0.25 & 0.35 blue; 0.45 & 0.55 green; 0.65 & 0.75 black; 0.85 and 0.96 magenta). As expected, higher values for Q lead to higher probabilities of the stock being below 0.5 B_{MSY}, higher probabilities of ABC larger than OFL, and higher probabilities of 1+ biomass being below the lower 5th percentile of 1+ biomass in an unfished state. In contrast, higher values for Q generally lead to lower probabilities of ABC values less than 25,000t and 10,000t. The relationship between Q and P(ABC < 25,000t) and P(ABC < 10,000t) is not linear, with the intermediate values for Q leading to the lowest values for these performance statistics (Punt, 2019a, Fig. 5). The lowest values of Q (red lines) perform quite poorly for ABC values and the highest values of Q (magenta lines) perform quite poorly for risk.

Figures 7 and 8 (no MAXCAT and MAXCAT=25,000t respectively) show results for Y=8, long- and short-term biomass defined as 5 and 2 years as the value for Q is changed (lines with different colours) and given values for the definitions of x_1 and x_2 (rows). A series of dots is provided for context. The dots correspond to results for the ten values for Q when Y-8, Z=4, X=2, x_1=0.1, x_2=0.2, long-term term biomass based on 10 years and short-term biomass based on 3 years.

Additional discussion and caveats

The results in this document should be interpreted in a relative sense rather than treating the values for the performance statistics as absolute estimates. The sensitivity of the results to MAXCAT highlights that the ability to achieve management goals depends on how ACLs and HGs are set as well as how often OFLs and ABCs are re-evaluated. As noted by PFMC (2019a), the analyses are based on values for biological parameters that are quite dated and a new benchmark assessment could change the quantitative (though likely not the qualitative) results. In addition, as noted by PFMC (2019a), the conservation-related statistics reported in this document likely overestimate risk because they assume 100% attainment of the ABC.

The analyses of this document are based on the five performance statistics selected by PFMC (2019a). These statistics relate to the probability of overfishing, the spawning biomass being lower than 0.5 B_{MSY} and the probability of the ABC being less than thresholds. However, there are no performance statistics that capture short-term fluctuations in ABC (the OFL and ABC will naturally fluctuate with regime-like changes in biomass). Inter-annual variation in catch is often a statistic considered when making decisions on parameters such as those of Figure 1.

Acknowledgment

Will Satterthwaite (SWFSC), Greg Krutzikowsky (ODFW), and Owen Hamel (NWFSC) are thanked for comments on the draft of this document.

References

Anon. 2016. Review and Re-evaluation of Minimum Stock Size Thresholds for Finfish in the Coastal Pelagic Species Fishery Management Plan for the U.S. West Coast. Agenda Item E.1.a. September 2016 Council meeting. 33pp.

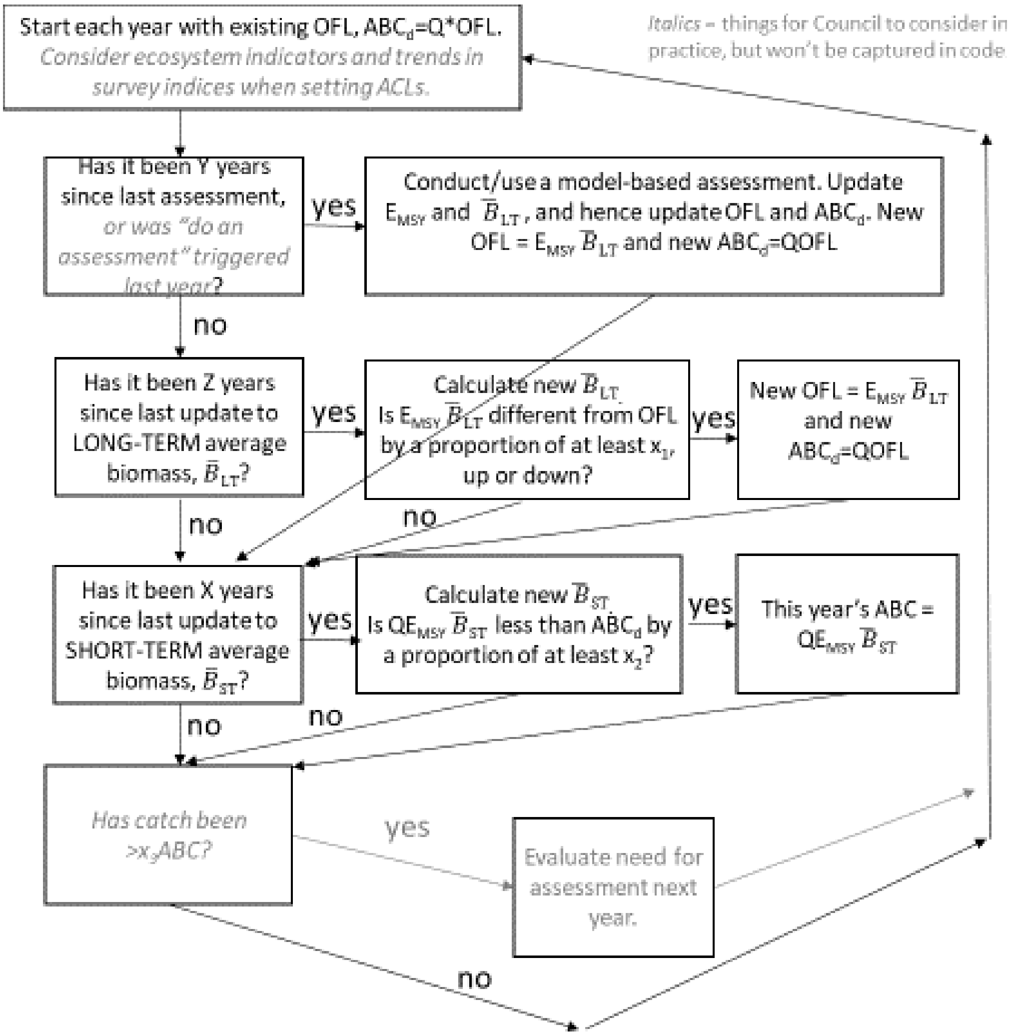
PFMC. 2019. Report of the joint meeting of representatives of the CPS Management Team, CPS Advisory Subpanel, and SSC CPS subcommittee on issues related to the management of the central subpopulation of northern anchovy. November 2019 Agenda Item D.4, Attachment 1. Punt, A.E. 2019a. An updated analysis of the implications of different choices for the frequency of updates to OFLs and ABCs for the CSNA. Document presented to the 3-4 October 2019 PFMC meeting on the CSNA (6pp).

Punt, AE. 2019a. An updated analysis of the implications of different choices for the frequency of updates to OFLs and ABCs for the CSNA. Document presented to the 3-4 October 2019 PFMC meeting on the CSNA (6pp).

Punt, A.E. 2019b. An approach for computing F_{MSY}, B_{MSY} and MSY for the CNSA. Agenda Item E4, Attachment 1. April 2019 Council meeting. (18pp).

Table 1. The parameters and the levels to be considered in this document.

Parameter	Values to consider
Frequency of assessment (Y)	4, 8, 16
Frequency of OFL update (Z)	1, 4, 8
Frequency of ABC update (X)	1, 2, 4
Q (ABC buffer)	0.05 to 0.95 in steps of 0.1
x_1 (OFL update threshold)	0, 0.1, 0.2, 0.3
x_2 (ABC update threshold)	0, 0.1, 0.2, 0.3
Definition of long-term biomass	1, 5, 10, 60
Definition of short-term biomas2	1, 2, 3
MAXCAT	None, 25,000t



Y = interval for full assessments regardless of trigger (could be infinity)
Z = interval for updating long-tem biomass (from survey)
X = interval for updating short-tem biomass (from survey), X≤Z≤Y.
Q = ABC buffer. Now 0.25, might be larger with more frequent updates.
X_1 is the threshold for changes in OFL due to changes in B_{LT}
X_2 is the threshold for reducing ABC in response to low B_{ST}
X_3 is a threshold for attainment

Figure 1. The framework considered in this document. Note that the boxes in light font are not evaluated in the simulation modelling.

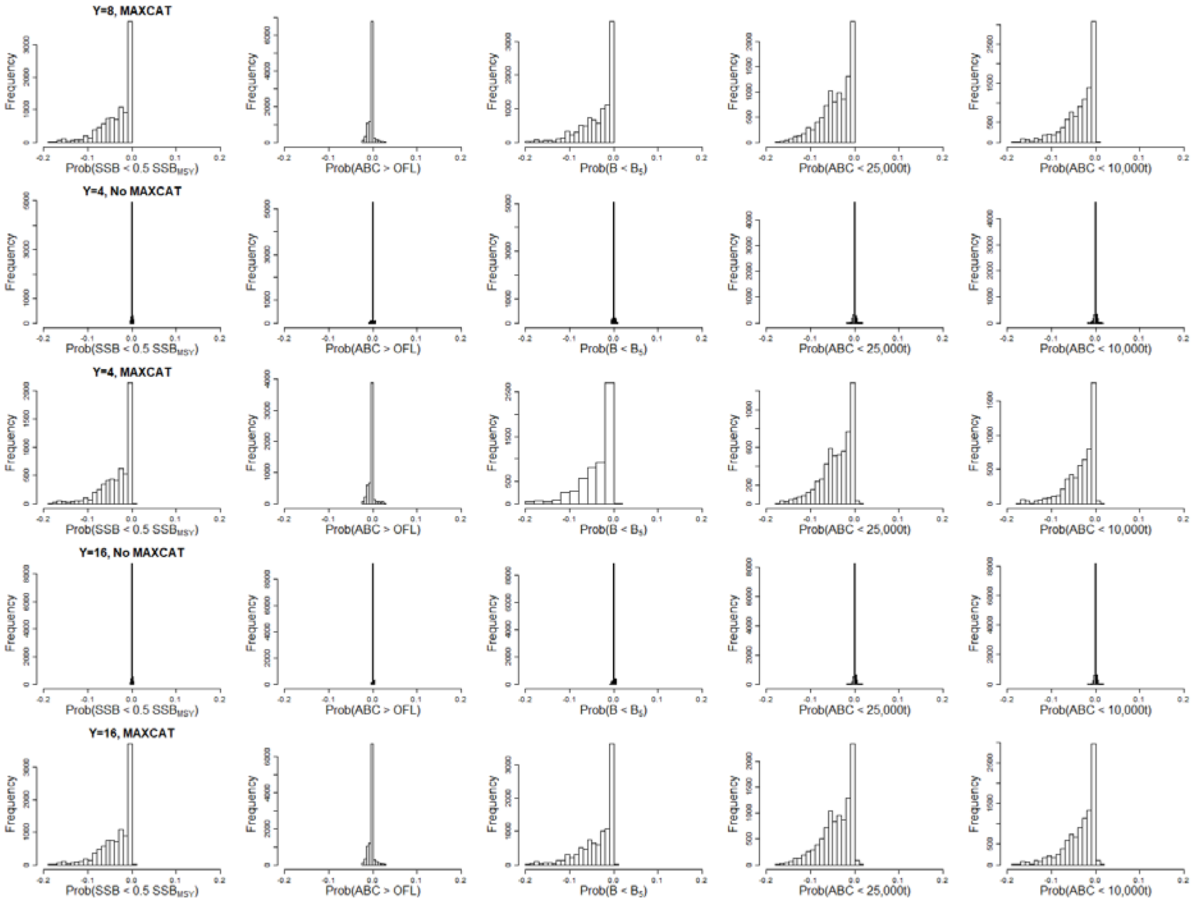


Figure 2. Histogram of differences between the scenarios (combinations of values for parameters) for various values for Y (frequency with which benchmark stock assessments are conducted) and MAXCAT (none or MAXCAT=25,000t) and the scenarios for Y=8 and no MAXCAT.

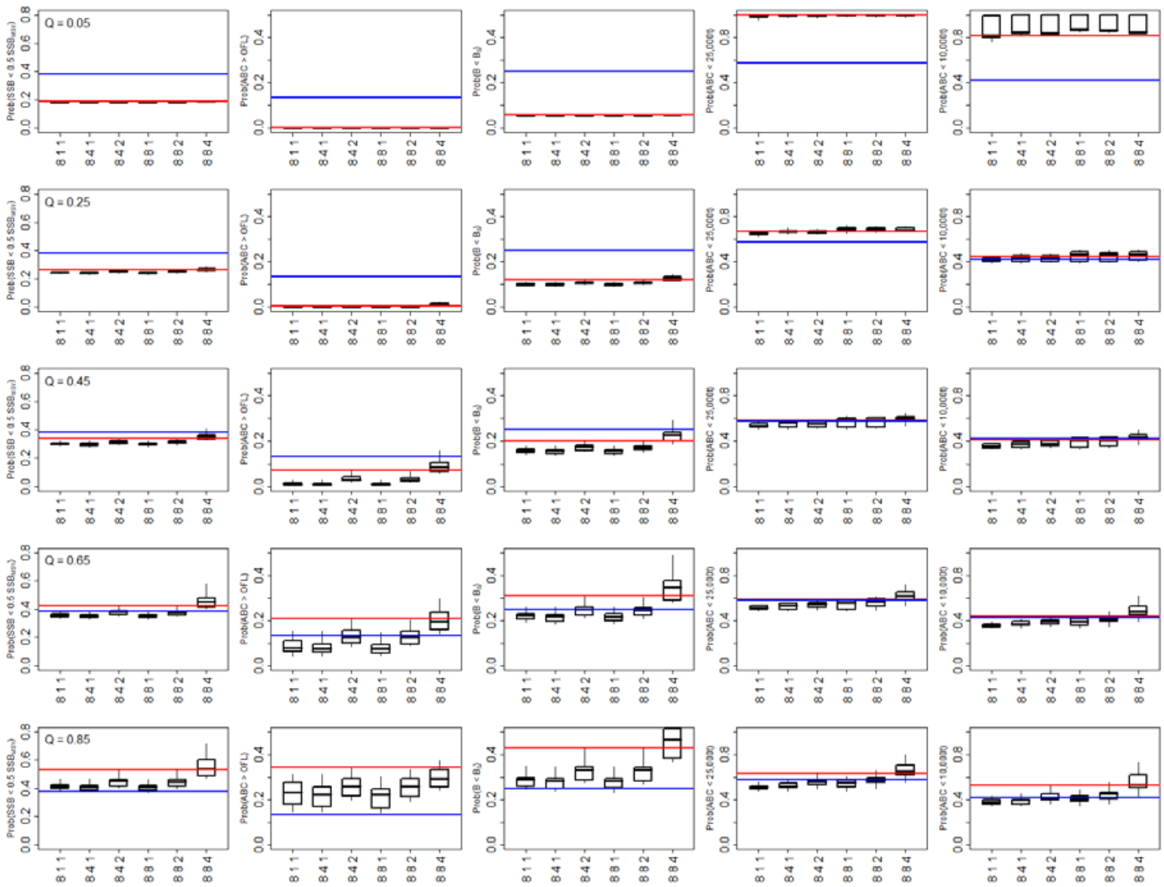


Figure 3(a). Box plots comparing outcomes corresponding to different values for the parameters Z and X. Each box plot represents the results for all of the model runs with the specified combination of Z and X (integrated over x_1 and x_2, and the definitions of long- and short-term biomass). The results in this figure pertain to Y=8 and there is no MAXCAT. Each row is for a different choice for Q, and the red and blue lines are results for a reference set of parameters (the red lines are for the value of Q for the row concerned, and the blue line is the version of the reference set of parameters with Q=0.5). X-axis labels reflect values for Y, Z, and X respectively (i.e. 811 denotes Y=8, Z=1, and X=1).

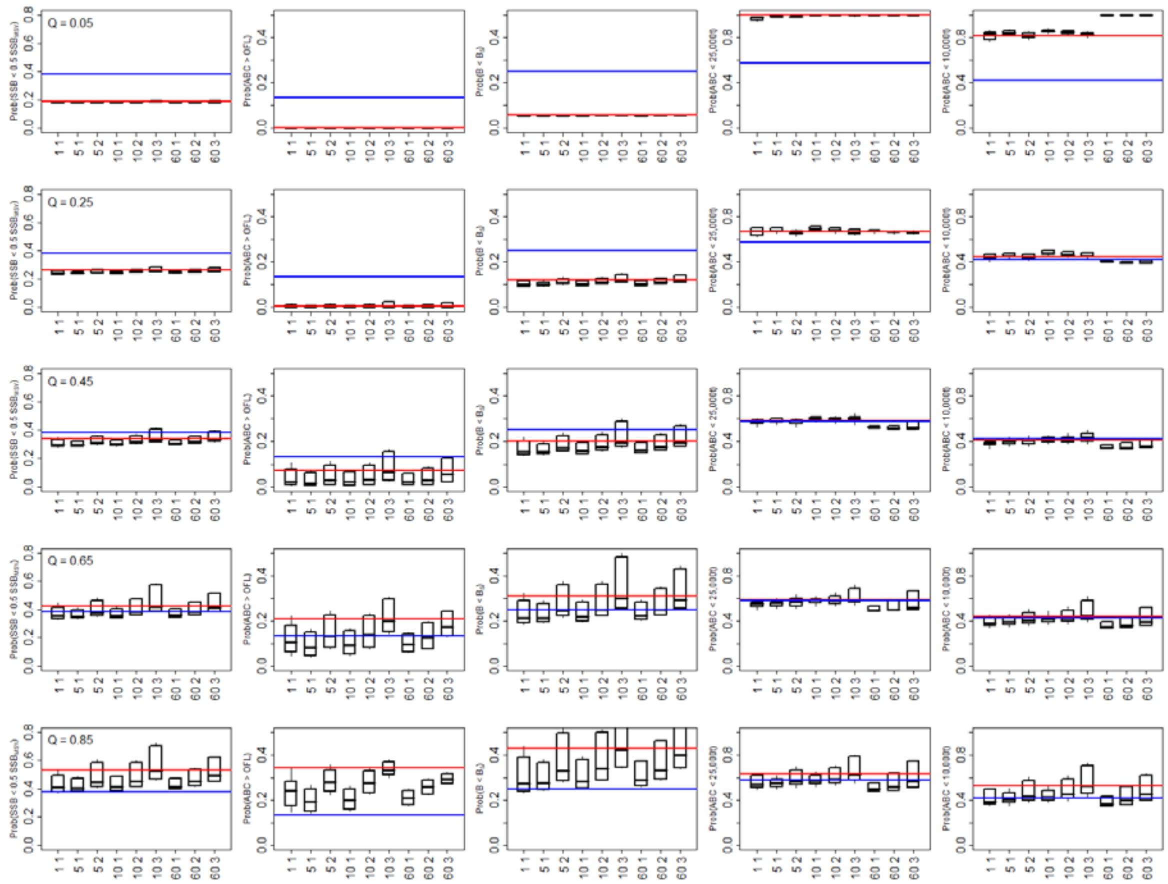


Figure 3(b). Box plots comparing outcomes corresponding to different values for the definitions of long- and short-term biomass. Each box plot represents the results for all of the model runs with the specified combination for the definitions of long- and short-term biomass (integrated over X, Z, x_1 and x_2). The results in the figure pertain to Y=8 and there is no MAXCAT. Each row is for a different choice for Q, and the red and blue lines are results for a reference set of parameters (the red lines are for the value of Q for the row concerned, and the blue line is the version of the reference set of parameters with Q=0.5). X axis labels represent the number of years included in the long- and short-term biomass calculations.

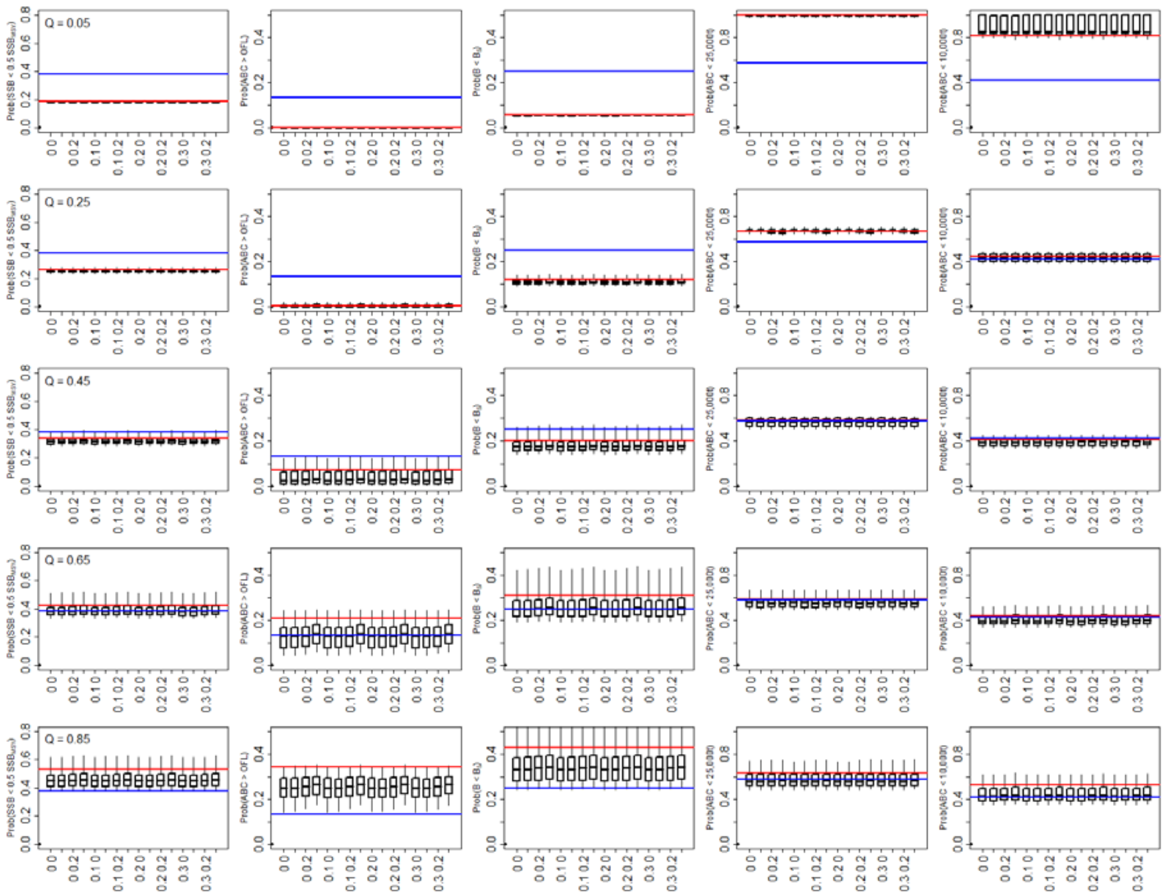


Figure 3(c). Box plots comparing outcomes corresponding to different values for parameters x_1 and x_2. Each box plot represents the results for all of the model runs with the specified combination of x_1 and x_2 (integrated over X, Z, and the definitions of long- and short-term biomass). The results in the figure pertain to Y=8 and there is no MAXCAT. Each row is for a different choice for Q, and the red and blue lines are results for a reference set of parameters (the red lines are for the value of Q for the row concerned, and the blue line is the version of the reference set of parameters with Q=0.5). X-axis labels represent the thresholds for updating the OFL (x_1) and ABC (x_2).

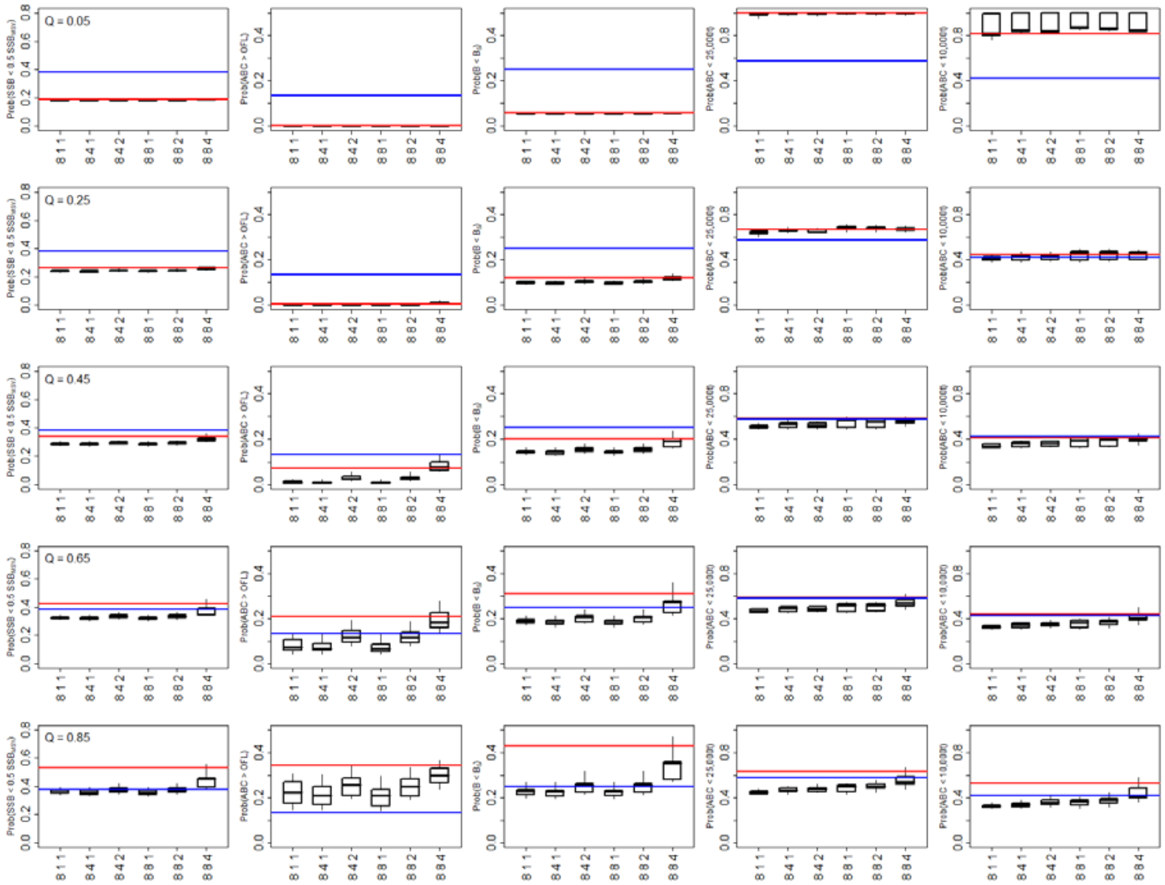


Figure 4(a). As for Figure 3(a), except the results pertain to MAXCAT=25,000t.

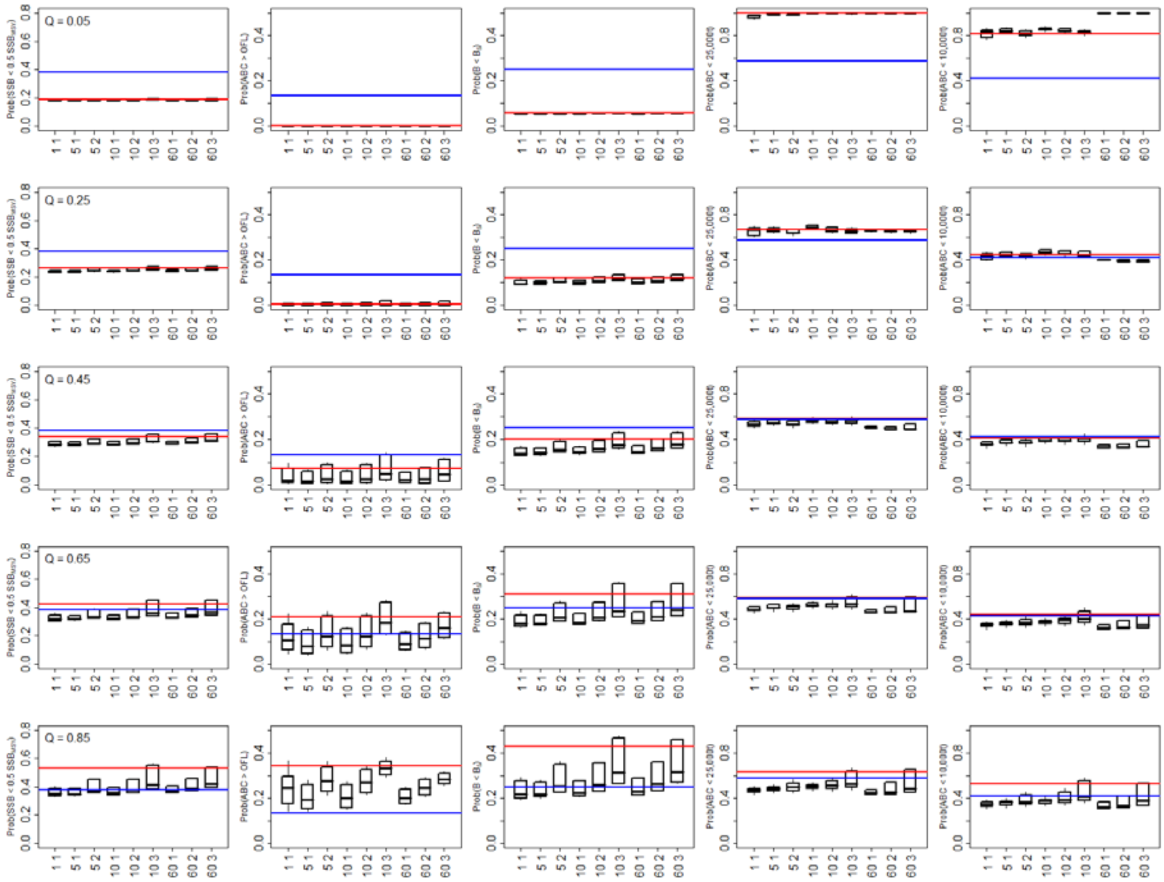


Figure 4(b). As for Figure 3(b), except the results pertain to MAXCAT=25,000t.

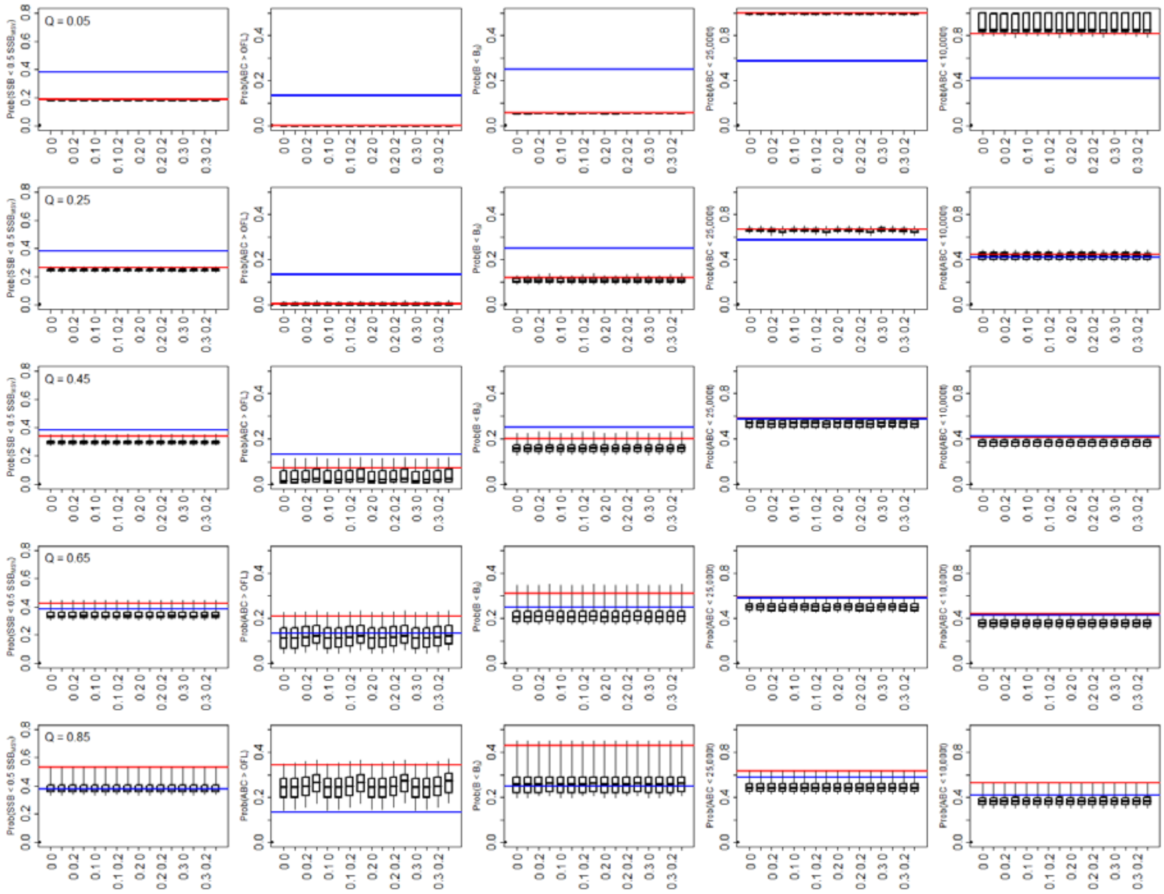


Figure 4(c). As for Figure 3(c), except the results pertain to MAXCAT=25,000t.

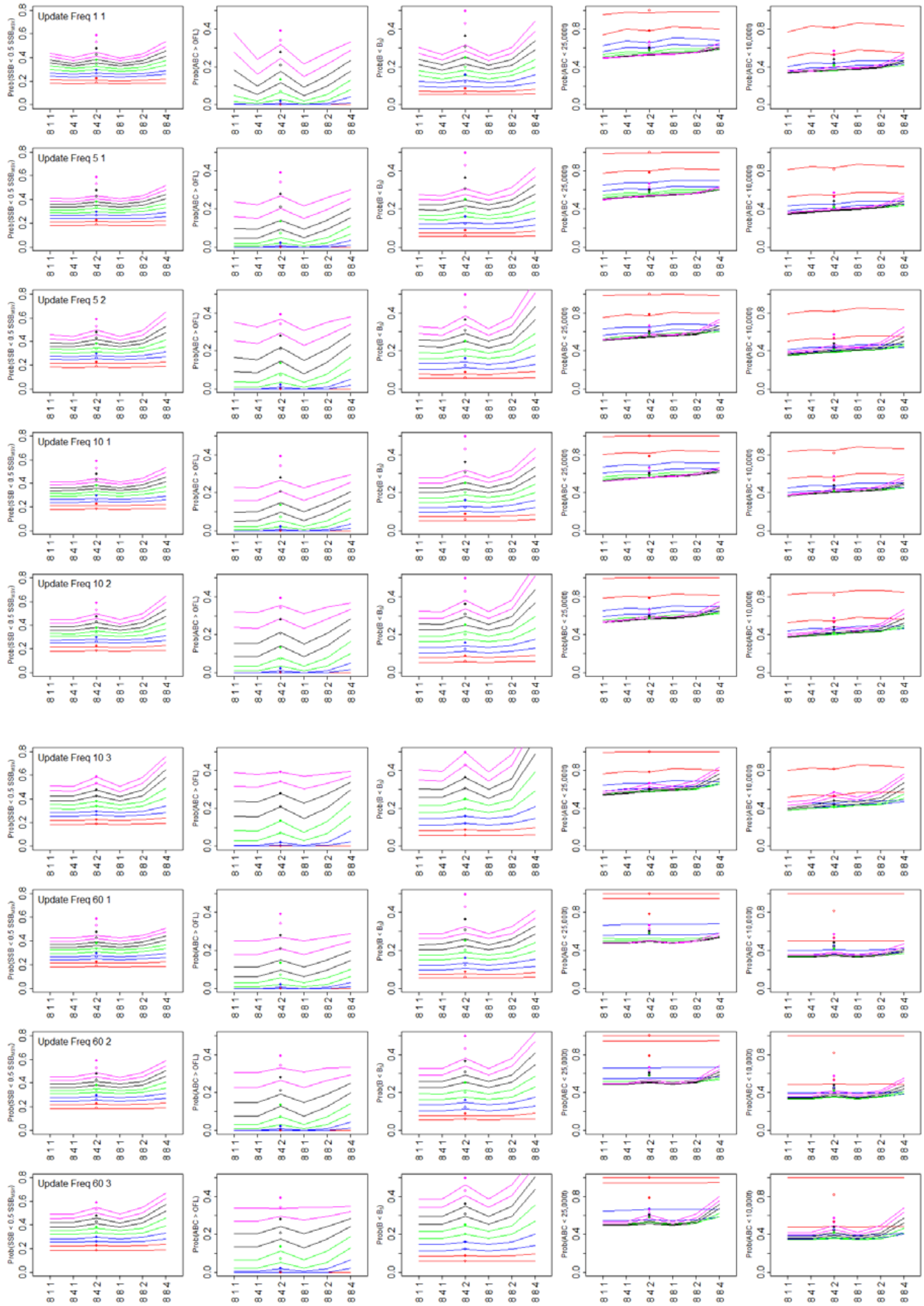


Figure 5. Results comparing outcomes for different values of Z, X, and for the definitions of long- and short-term biomass when Y=8, x_1=0.1, x_2=0.2, and there is no MAXCAT. The lines in each panel are results for values for Q (lines with different colours, red represents the smallest Q and magenta the largest). Rows correspond to differing frequencies of OFL and

ABC updates. The dots show results for the ten values for Q when Y=8, Z=4, X=2, x_1=0.1, x_2=0.2, long-term term biomass is based on 10 years and short-term biomass is based on 3 years. X-axis labels reflect values for Y, Z, and X respectively (i.e. 811 denotes Y=8, Z=1, and X=1).

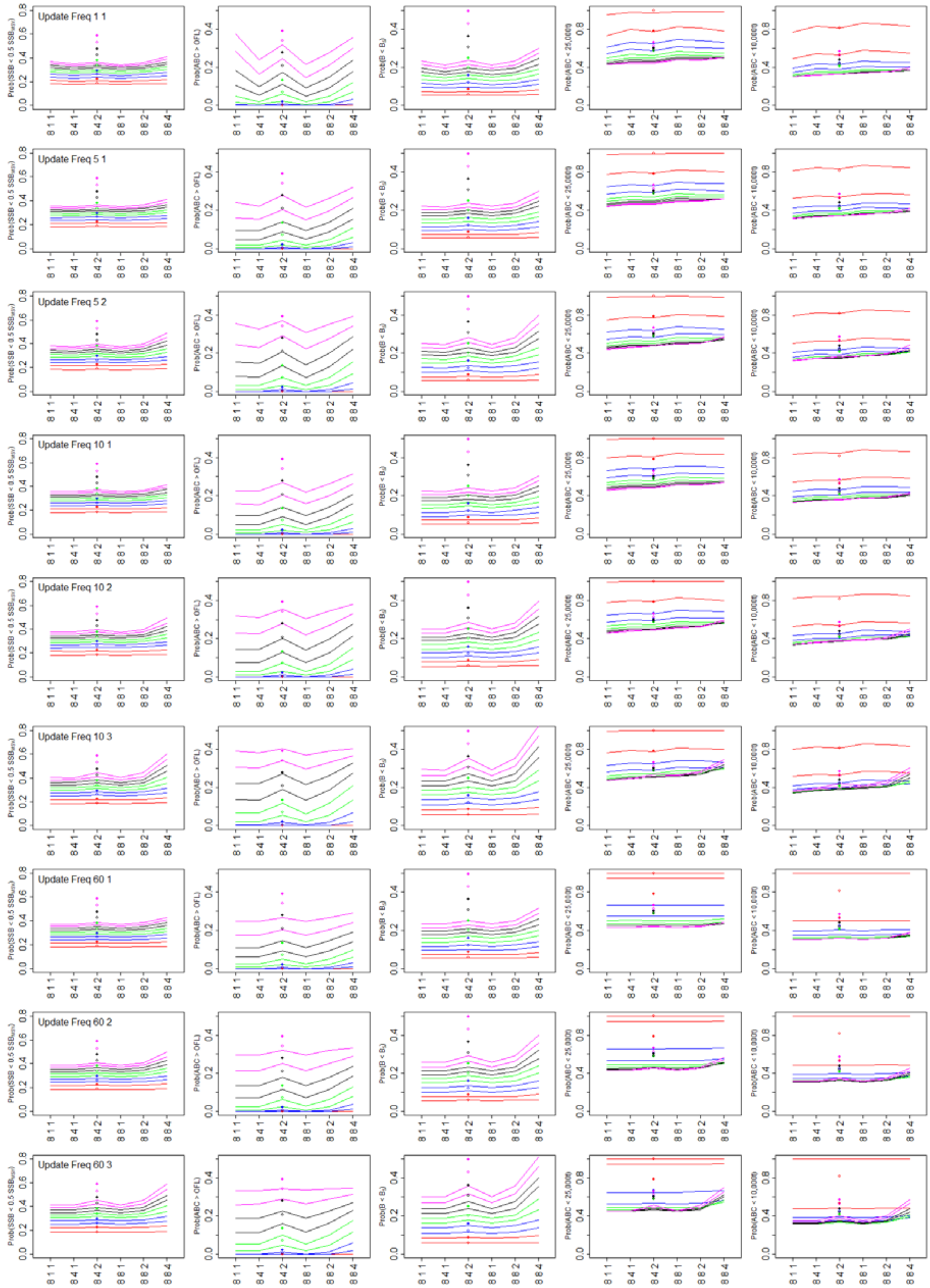
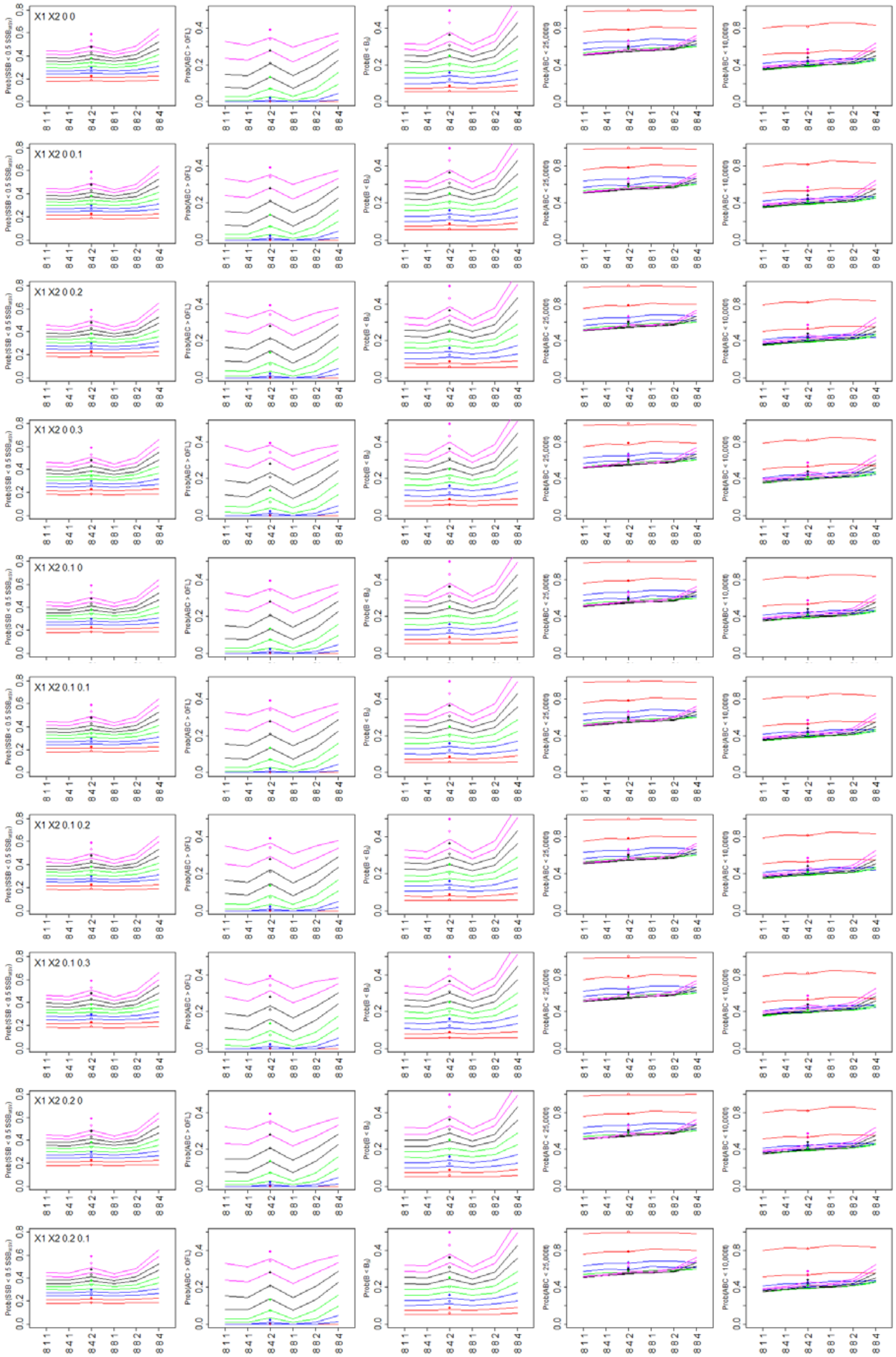


Figure 6. As for Figure 5, except that MAXCAT is 25,000t.


X1 X2 0 0
X1 X2 0 0.1
X1 X2 0 0.2
X1 X2 0 0.3
X1 X2 0.1 0
X1 X2 0.1 0.1
X1 X2 0.1 0.2
X1 X2 0.1 0.3
X1 X2 0.2 0
X1 X2 0.2 0.1
Prob(ABC > OFL)
Prob(ABC < 25,000)
Prob(ABC < 10,000)

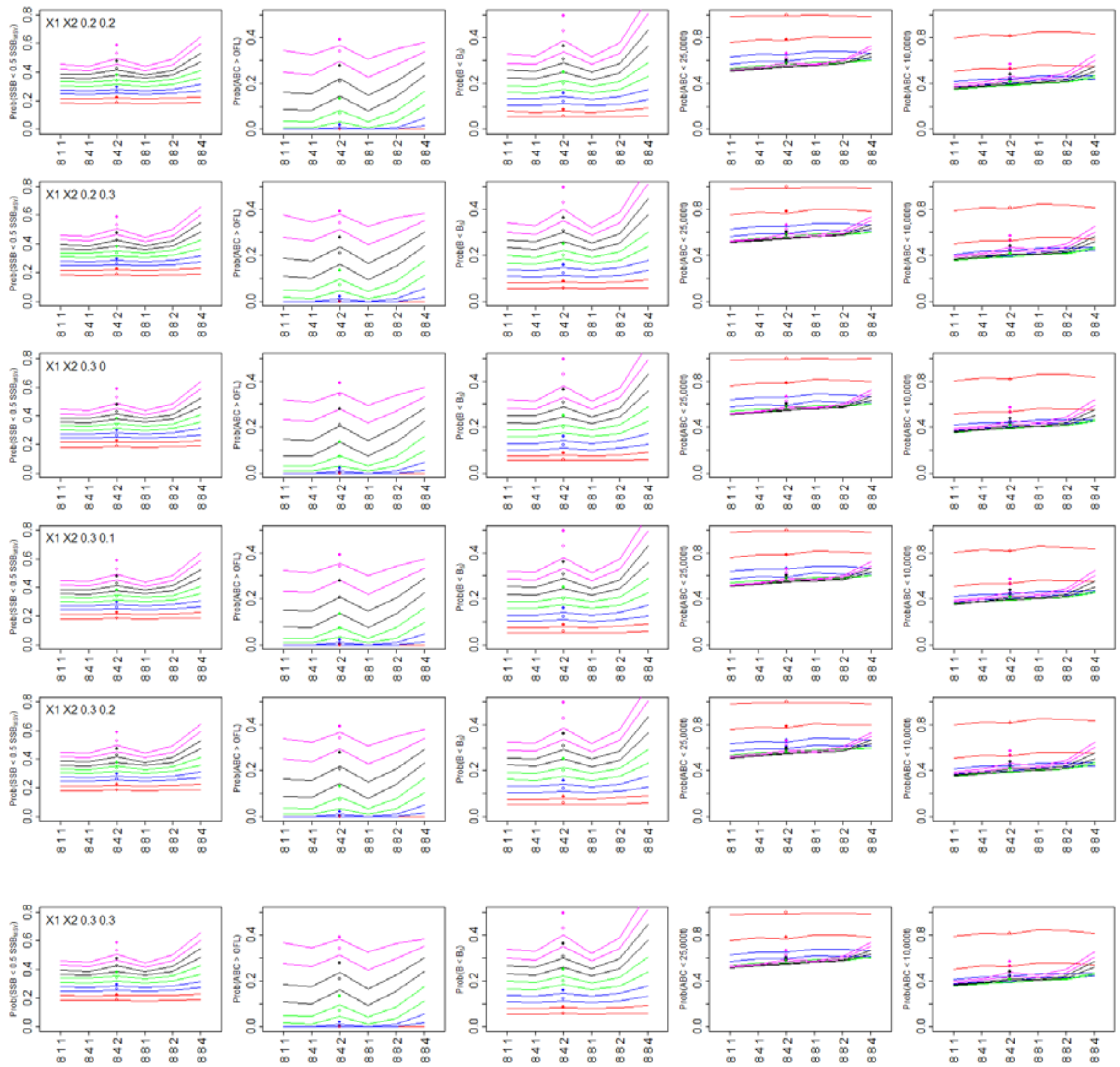
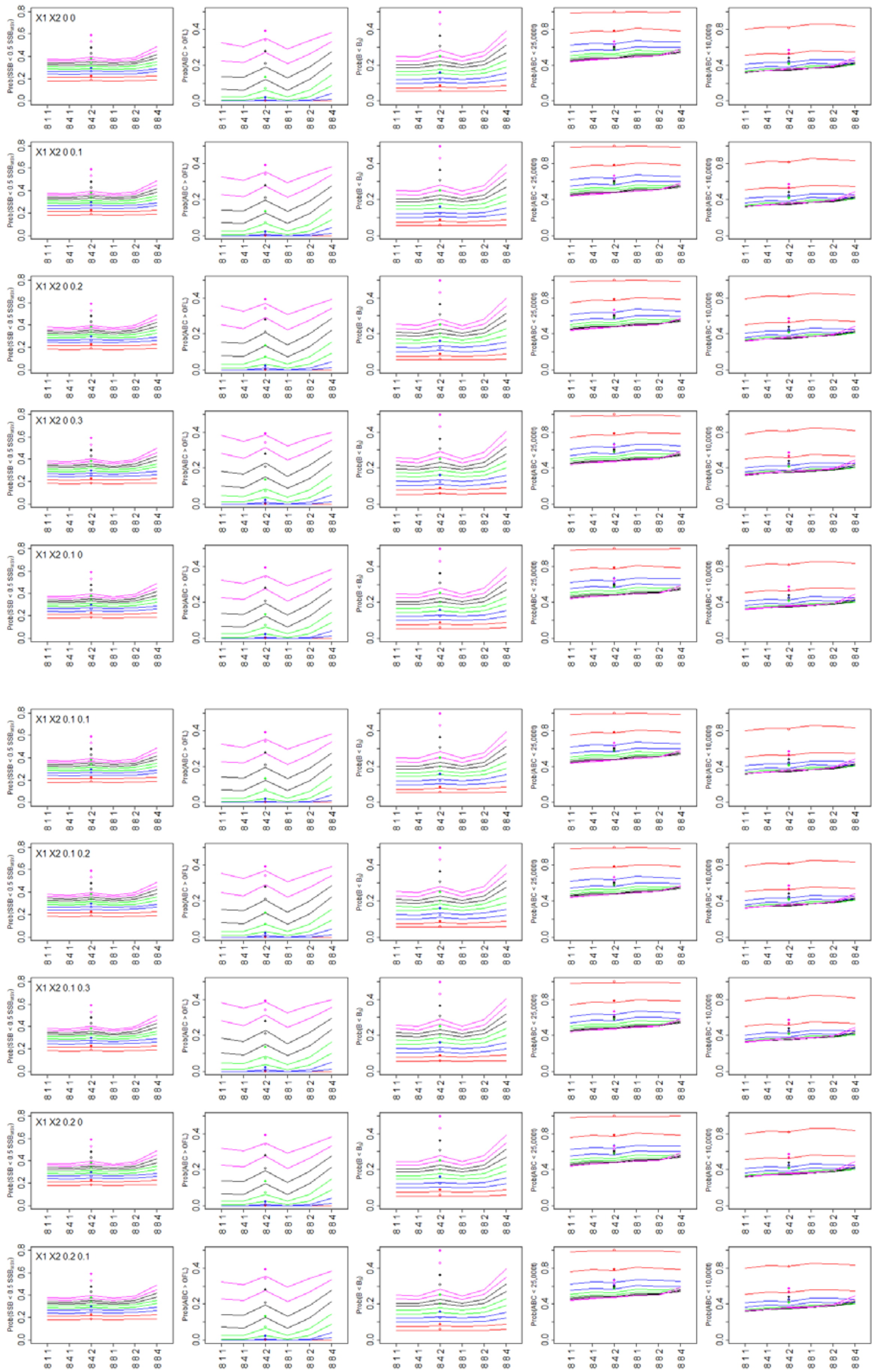


Figure 7. As for Figure 5, but the results compare different values for Z, X, x_1, and x_2 when the definitions of long-term and short-term biomass are 5 and 2 years.


X1 X2 0 0
X1 X2 0 0.1
X1 X2 0 0.2
X1 X2 0 0.3
X1 X2 0.1 0
X1 X2 0.1 0.1
X1 X2 0.1 0.2
X1 X2 0.1 0.3
X1 X2 0.2 0
X1 X2 0.2 0.1
Prob(SSB < 0.5 SSB$_{MSY}$)
Prob(ABC > OFL)
Prob(B < B$_0$)
Prob(ABC < 25,000t)
Prob(ABC < 10,000t)
8 1 1
8 4 1
8 4 2
8 8 1
8 8 2
8 8 4

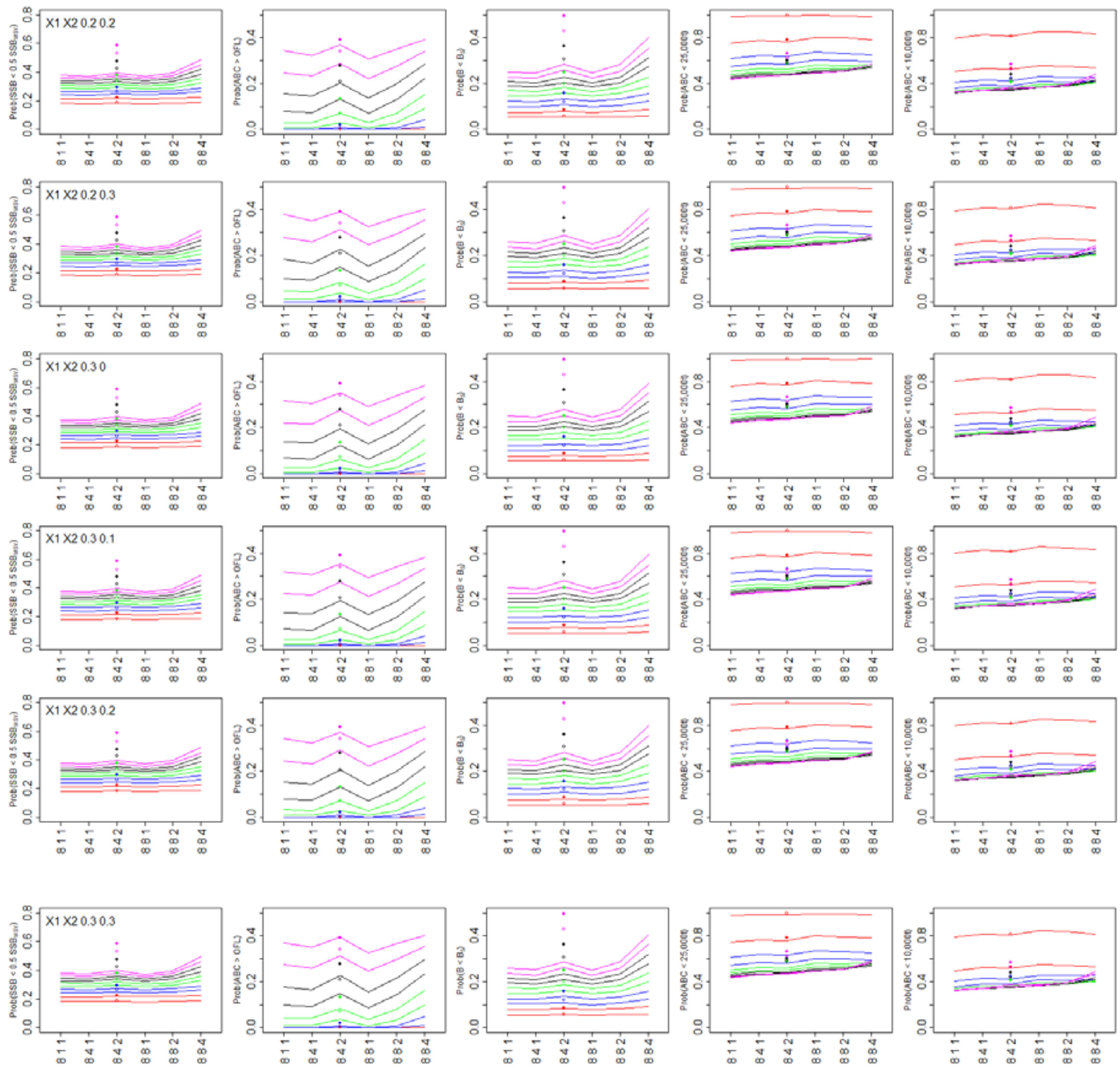


Figure 8. As for Figure 7, except that MAXCAT is 25,000t.

Appendix A: Technical details of the operating model

The operating model is the age-structured model developed to estimate F_{MSY} and B_{MSY} for the CNSA (Punt, 2019b), i.e.:

$$N_{y+1,a}=\begin{cases} R_{y+1} & \text{if } a=0 \\ N_{y,a-1}e^{-(M+S_{a-1}F_y)} & \text{if } 1\le a<x \\ N_{y,x-1}e^{-(M+S_{x-1}F_y)}+N_{y,x}e^{-(M+S_xF_y)} & \text{if } a=x \end{cases} \quad \text{(App.1)}$$

where $N_{y,a}$ is the number of animals of age a at the start of year y, F_y is the fully-selected fishing mortality during year y, S_a is fishery selectivity for an animal of age a, M is the rate of natural mortality, and R_y is the generated age-0 abundance for year y (accounting for the log-normal bias-correction factor), i.e.:

$$\hat{R}_y=\frac{4hR_0\,(SSB_y/SSB_0)}{(1-h)+(5h-1)SSB_y/SSB_0}e^{\varepsilon_y-d_y-\sigma_R^2/2} \quad \text{(App.2)}$$

where R_0 is the expected unfished recruitment, SSB_y is the spawning biomass in year y, SSB_0 is the unfished spawning biomass (= R_0 $SSBR_0$), $SSBR_0$ is the spawning biomass-per-recruit in the absence of fishing, h is the steepness of the stock-recruitment relationship, ε_y is the recruitment residual for year y, σ_R is the extent of variation in recruitment due to white noise, and d_y is a sine-curve with a period of 60 years and an amplitude of 0.8. The recruitment residuals are modelled as:

$$\varepsilon_y=\rho\varepsilon_{y-1}+\sqrt{1-\rho^2}\eta_y \qquad \eta_y\sim N(0;\sigma_R^2) \quad \text{(App.3)}$$

The value of $SSBR_0$ is computed as:

$$SSBR_0=\sum_a \tilde{N}_a\,P_a\;w_a^p \quad \text{(App.4)}$$

where $\tilde{N}_a$ is the numbers-per-recruit:

$$\tilde{N}_a=\begin{cases} 1 & \text{if } a=0 \\ \tilde{N}_{a-1}\,e^{-M} & \text{if } 1\le a<x \\ \tilde{N}_{x-1}\,e^{-M}\,/\,(1-e^{-M}) & \text{if } a=x \end{cases} \quad \text{(App.5)}$$

P_a is the proportion mature at age, w_a^p is the population weight-at-age, and x is the plus-group age (age 6).

The catch during year y is computed using the equation:

$$C_y=\sum_a w_a^c\,\frac{S_aF_y}{M+S_aF_y}N_{y,a}(1-e^{-(M+S_aF_y)}) \quad \text{(App.6)}$$

where w_a^c is the population weight-at-age.

The value of F_y is computed by solving Equation App.6 where the catch is given by the ABC from an alternative (see below). For the operating model variants with a MAXCAT, the catch is minimum of the ABC and MAXCAT.

Parameterization of the operating model

The values for the biological parameters are listed in Table App.1. Each of the 1,000 simulations involve values for the parameters of the stock-recruitment relationship (R_0, h, ρ, and σ_R) drawn from the posteriors developed by Punt (2019b) [100 sets of parameters, each replicated 10 times]. Thus, E_{MSY} (and B_{MSY}) differ among simulations. The R_0 estimated by Punt (2019b) is assumed to relate to the average component of the cycle (although the qualitative results and relative rankings in performance across alternatives should be independent of the assumed scale of the population).

Future data

The future data are generated from a pseudo unbiased acoustic trawl survey (with 10 past estimates):

$$\hat{B}_y = B_y\, e^{\phi_y - \sigma_I^2/2} \qquad \phi_y \sim N(0;\sigma_I^2) \qquad \text{(App.7)}$$

where $\hat{B}_y$ is the estimate of 1+ abundance, B_y is the true (operating model) 1+ biomass, and σ_I is the standard error (in log-space) of the observation error associated with the estimates of 1+ biomass. Future surveys are assumed to be conducted annually.

Table App.1. Biological parameters for the CSNA (source: Anon, 2016)

Age	**M (yr^{-1})**	S_a	P_a	W_a^c **(kg)**	W_a^p **(kg)**
0	0.8	0.161	0	0.0130	0.0000
1	0.8	0.666	0.55	0.0165	0.0096
2	0.8	0.993	1	0.0196	0.0150
3	0.8	1.000	1	0.0221	0.0190
4	0.8	0.668	1	0.0253	0.0217
5	0.8	0.300	1	0.0284	0.0243
6	0.8	0.000	1	0.0311	0.0311