Assessment update for Alaska sablefish

by
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Executive summary

The purpose of this document is to present some preliminary responses to the 2016 Center for Independent Experts review of the sablefish assessment. Additionally, some potential assessment models for the November Plan Team are presented that address some of the key CIE recommendations. The main potential changes for 2017 include propgating additional uncertainty and addressing whale depredation.

CIE Summary

Overall

The 2016 Center for Independent Experts (CIE) review of Alaska sablefish took place during May 10 – 12 in Juneau, AK. The panel was positive about the overall assessment and the quality of the data, but as expected had many helpful suggestions for improvements. We provide responses to most of the short-term recommendations and some of the long-term recommendations in the attached Appendix which contains the review panel's consensus recommendations. The following three themes received the most attention in the review reports.

Model precision

The panel was concerned that the assessment was overly precise (i.e., the estimated confidence bounds were too narrow to depict the true uncertainty). There was considerable discussion on ways to allow for more uncertainty into the assessment results, but most were centered around the very precise abundance index (the AFSC longline survey), estimating natural mortality as a free or constrained parameter, and showing more of the structural uncertainty based on assumptions in the model. We show some ways to address these points in some preliminary work below.

Whale depredation

The panel was unanimously in favor of including whale depredation adjustments for the survey index and fishery catch in the assessment and for calculation of ABCs. Two studies (one for the survey and one for the fishery) that provide estimates and methods to do these adjustments are in journal review at this time. The panel reviewed these papers and provided helpful feedback. They agreed with our proposed approach of increasing the survey CPUE at stations where whales depredated, and including fishery depredation as additional catch in the fixed gear fishery.We briefly describe the methods of these studies and show preliminary applications of results from these depredation models in the stock assessment below, recognizing that these results are subject to change based on journal review outcomes.

Apportionment and spatial modeling

The review panel was presented information about tagging data, movement rates, and a spatial assessment model that estimated stock size using movement rates derived from the tagging data. They concluded that the mixing rate was very high and that an apportionment of catch that was not severely spatially concentrated was not a biological issue. They recommended that the spatial modeling be continued both to inform management strategy evaluations (MSEs) and to identify gaps in our knowledge of sablefish life history. They strongly recommended that clear objectives on what an apportionment strategy should accomplish be identified before in-depth MSE work proceeds. Based on the CIE's recommendations, we will suggest in November that the apportionment continues to remain fixed,while the objectives of the apportionment are futher clarified by stakeholders and management.

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Whale depredation estimation

Sperm whales on the longline survey

For the AFSC longline survey, killer whale affected sets have always been removed from the calculations because of their obvious impact on catch rates, while sperm whale depredation is more difficult to detect and has not previously been considered when calcuting survey catch rates. Presence and evidence of depredation by sperm whales on the AFSC longline survey have increased significantly over time (Figure 1). In the past, we have presented a number of different methods to estimate the sperm whale effect on the longline survey. We have submitted a more complete examination of different modeling techniques for journal review. This study 1) evaluates fixed and mixed-effects generalized linear models to estimate the sperm whale effect on the sablefish survey abundance index within and across Gulf of Alaska management areas, and 2) evaluates the impact of accounting for whale depredation in the sablefish stock assessment. Model evaluation and simulations showed that mixed-effect models were superior to fixed-effect models in terms of precision and confidence interval coverage of the true value (Figure 2). Sablefish catch rate reductions ranged from 12%-18% for area-specific and across-area models. Correcting for sperm whale depredation in the assessment resulted in a 3% increase in estimated female spawning biomass in the terminal year and a 6% higher quota recommendation. We recommended applying this correction in the assessment when estimates of additional sablefish mortality due to whale depredation on the commercial fishery become available. Table 1 shows the effect sizes estimated for evidence of sperm whale depredation on the survey at a station for the recommended mixed-effects model, including an area-wide effect and area-specific effects. For the assessment applications described below we use the result of Model 1 which inflates catches at survey stations with depredation evidence by a factor of 1.14 (i.e., 1/0.88).

Killer and sperm whales in the fishery

Killer whales have a long history of depredating the fishery and survey, while sperm whales have become a problem more recently. In the study described in the section above, we have estimated the sperm whale effect and recommended using it to correct survey estimates. Accounting for sablefish mortality due to whale depredation on the survey in the sablefish assessment would need to be done in tandem with correcting for depredation in the commercial fishery. We have submitted a manuscript for journal review that advances our understanding of the impact of whale depredation on the commercial sablefish fishery in Alaska and evaluates the impact depredation in the fishery may have on the sablefish assessment. We used data from the observer program, comparing “good performance” sets with those with “considerable whale depredation.” A generalized additive mixed modeling approach was used to estimate the whale effect on commercial sablefish fishery catch rates; killer whale depredation was more severe (catch rates declined by 45%-70%) than sperm whale depredation (24%-29%). A statistical approach was also used to evaluate fishery characteristics associated with depredation; significant covariates included higher sablefish catches, location, set length, and average vessel lengths. Total estimated sablefish catch removals during 1995-2014 ranged widely from 1251 t – 2407 t by killer whales in western Alaska management areas and 482 t – 1040 t by sperm whales in the Gulf of Alaska from 2001-2014. Including annual sablefish mortality (Figure 3) due to whale depredation on the commercial fishery in the 2015 sablefish stock assessment model (independent of correcting for whale depredation on the survey) resulted in a 1% reduction in the recommended ABC (Figure 4). We use these estimates of additional catch due to depredation in our assessment model applications described below.

Model applications

Maintenance upgrades

Variance estimation

Several model improvements have been available but not incorporated. The CIE recommended that these be applied. The first is that we have had analytically calculated variances for the longline survey relative population numbers (RPNs) available for several years, but in recent assessments we assumed a fixed 5% CV for all years, which was based on a bootstrap analysis. These new analytical variances were derived during the process of estimating the effect of sperm whales on the survey. The equations for estimating the variance of the Relative Population Numbers are shown in Table 2. They follow standard stratified estimation but also include the covariance between station estimates in each depth strata. The full variance equations that include the variance of the effect of whale depredation will be presented in a later document. While they are not a large departure from the previously assumed 5% CV for the domestic longline survey (Figure 5), they account for annual variance and make tuning the input variance of the index more meaningful.

GIS-based area sizes

The CPUE values for the RPN index are scaled up to area sizes that were originally determined with charts and a plenometer. These area-sizes have been recalculated using modern GIS techniques (Echave et al. 2013). Most of the subareas are not vastly different (Figure 6), with the exception of Spencer Gully and Bering 3 slope. Overall, more area was added in the 200-300 meter depth zone (Figure 7). Going forward, we recommend adopting these new area sizes for calculation of the longline survey abundance index, and eventually for simulations on apportionment.

Gaining imprecision

The CIE suggested three major axes of exploration to address the “overly-precise” estimates of spawning biomass that result from the stock assessment model: 1) estimate more parameters (particurly natural mortality), 2) use the same method used to reweight the compositional data to reweight the longline survey index, and 3) show managers more of the structural uncertainty of assumptions through sensitivity runs and figures. The following describes some preliminary models that address these recommendations.

Downweighting the longline survey

We tuned the standardized deviation of the normalized residuals (SDNR) for the domestic longline survey to be one while maintaining the SDNR of near 1 for the compositional data for sources where we had ages, and sources where we only had lengths (e.g., the trawl fishery). We weighted the rest of the abundance indices the same relative to the domestic longline survey which resulted in SDNRs close to one for the cooperative survey and the GOA trawl survey, but lower than one for the fishery CPUE indices (Table 3).

In model B2 we used the variances shown in Figure 5, which slightly increased the uncertainty around results. Significantly reducing the overall input variance on the abundance indices had minor impacts on model results, but did slightly increase uncertainty around SSB and ABC.

Natural mortality

Natural mortality (M) is one of the most difficult paramters to estimate in stock assessments so it is commonly fixed to avoid confounding with other parameters such as catchability (i.e., it is often difficult to estimate both of these at the same time). The sablefish model estimates many catchability parameters and historically, also estimated natural mortality, but with a tight prior to constrain it near 0.10. Because the prior essentially constrained *M* to 0.10, a fixed value of 0.10 was adopted in recent assessments. For this example, we show the effect of estimating *M* and all the catchabilities simultaneously on the uncertainty of terminal year spawning (model B3 – B5 in Table 3) and ABC. In terms of model fits, the estimation of *M* resulted in a negligible improvement in the fit to the data in terms of the negative log likelihood.

Estimating natural mortality does not change the point estimate of *M* or model results substantially, but does have a significant impact on precision. For example, the CV of 2016 female spawning biomass more than doubles when *M* is estimated with no constraint (model B4).

Estimating maturity in the model

We used the pooled visual scan maturity data from the domestic longline survey form 1990-2015 and estimated the maturity ogive within the model (B5). We have reservations about the use of these data because they are collected during the summer and maturity stages can be mistinterpreted. Further research to validate these visual maturity scans is underway. However, the CIE suggested it be attempted within the model to see if it propogated additional uncertainty. We used the same methods that Hulson et al. (2015) applied to the Gulf of Alaska Pacific ocean perch assessment, by conducting logistic regression within the model to estimate proportions mature at age. The 50% maturity was estimated to be slightly higher than currently used in the model (6.9 vs. 6.5), but it had a negligible effect on uncertainty in estimates of SSB.

Structural uncertainty/sensitivities

Another way to convey additional uncertainty is through an annual sensitivity run that shows the sensitivity of important results to key assumptions in the model. We will include in future assessments a selection of model runs that deviate from the reference model (Table 4). These runs show the effects of the assumed variance of data components, the shape of selectivity curves, the assumed value of *M*, the assumed priors, and the effect of removing individual abundance indices. The largest structural uncertainties in the model results come from changes in the value of *M*, using dome-shaped fishery selectivity, and the precision assumed for the domestic longline survey abundance index (Figure 8). The CIE panel had many concerns about the fishery CPUE index, but as can be seen in this sensitivity run its not a primary axis of uncertainty.

Whale depredation incorporation

We incorporated the results of the two previously described studies into the stock assessment model in three steps. These models start from model B1 in the previous sensitivity model runs described above. First, we use the corrected domestic longline survey index (Figure 9, Depredation) for whale depredation in model W1. The second model is only including additional fixed gear fishery catch from killer and sperm whales (Figure 3) into the model (W2). Third, we include both of these new adjustments in the model (W3).

Incorporating the depredation survey correction (W1) shows about a 7% increase in ABC and a 4% increase in the estimate of 2016 spawning biomass (Figure 10). There is little effect on the fit to the data, but the fit is slightly worse. Incorporating the additional catch from depredation in the fishery (W2), results in a very small increase in ABC and spawning biomass for 2016. When both are included the overall ABC is about 8% larger (Figure 11).

If we were to adopt something similar to W3 that results in a higher ABC, it would be appropriate to recommend an adjusted ABC that accounts for expected depredation in that year. We show an example of this in Table 5. In this example, we use the recommended model apportioned ABC for 2016 from the 2015 assessment without correcting for depredation and the same model corrected for whale depredation. We then take the three year average whale depredation in each area and increase it or decrease it by the amount the ABC would increase or decrease for 2016 under the uncorrected model. In this case, the 3 year-average depredation is multiplied by 0.86 because the ABC was declining from 2015 to 2016. We then subtract off the adjusted three year average depredation for each area from the corrected model to come up with a new recommended 2016 ABC.

The total change in recommended adjusted ABC is a 2% increase. Overall, the corrections would result in small increases to the ABC in each area with the exception of the Western GOA which would see a small decrease. This is because the killer whale depredation relative to total catch is highest there. The three-year average depredation is arbitrary, but some number of years smoothing would be recommended as the estimates can be variable. We recommend a method like this that takes whale depredation into account at the stock assessment level rather than creating additional regulations or burden on in-season management.

Table 1. Estimates of sperm whale depredation for across-area models. SE = standard error of the estimate. Estimates of proportional change are given by exp(Estimate) with approximate 95% confidence intervals shown (LCI, UCI).

						Proportional change			Delta
Model	Flag	Area	Estimate (λ)	SE	P value	e^{λ}	LCI	UCI	AIC
1	Evidence	All	-0.133	0.03	<0.001	0.88	0.82	0.94	0
2	Evidence	CGOA	-0.117	0.06	0.07	0.89	0.78	1.01	3.9
		WY	-0.13	0.06	<0.001	0.88	0.78	0.99	
		EY/SE	-0.148	0.05	<0.001	0.86	0.77	0.96	

Table 2. Equations for estimating the variance for the Relative Population Numbers (RPN) sablefish index.

Equation	Description
$\hat{V}[\hat{\psi}_i] = \sum_j w_j^2 \hat{V}[\bar{\theta}_j] + 2\sum_j \sum_{m \neq j} w_j w_m \operatorname{cov}[\bar{\theta}_j, \bar{\theta}_m],$	Area variance estimate
$\hat{V}[\bar{\theta}_j] = \dfrac{s^2\{\hat{\theta}_k\}}{n_k}$	Sample variance for stratum/depth CPUE estimates
$\operatorname{cov}[\bar{\theta}_j, \bar{\theta}_m] = \dfrac{n_{k \cap z} \operatorname{cov}[\{\hat{\theta}_k\}, \{\hat{\theta}_z\}]}{n_k n_z}$	Covariance between station estimates by depth stratum
$\hat{V}[\hat{\psi}_{Total}] = \sum_i \hat{V}[\hat{\psi}_i]$	Total variance for total RPN

Table 3. Model runs that aim to address overly-precise estimation of results from the stock assessment. B0 is the base model, B1 is the model that includes the "maintenance upgrades", and B2 – 5 build on the previous model. SDNR = Standard deviation of the normalized residuals

Description	B0 2015 model	B1 Variance estimates, new area sizes	B2 Tune LL survey to SDNR = 1	B3 Estimate M with 20% CV prior	B4 Estimate M with 500% CV prior	B5 Estimate maturity inside model
SDNR						
Domestic LL survey	1.92	1.83	1.00	1.00	1.00	1.00
Cooperative LL survey	1.50	1.51	0.83	0.83	0.83	0.83
Domestic Fishery CPUE	0.87	0.84	0.45	0.45	0.45	0.45
Japanese Fishery CPUE	1.29	1.42	0.87	0.75	0.75	0.75
GOA Trawl survey	1.82	1.81	0.95	0.95	0.95	0.95
Fishery ages	1.14	1.14	1.01	1.01	1.01	1.01
Fixed fishery lengths	0.89	0.89	0.37	0.37	0.37	0.37
Trawl fishery lengths	0.84	0.81	0.99	0.99	0.99	0.99
Survey ages	1.02	1.01	1.01	1.01	1.01	1.01
Domestic LL survey lengths	0.30	0.29	0.30	0.30	0.30	0.30
Coop. LL survey lengths	0.32	0.32	0.33	0.33	0.33	0.33
GOA trawl survey lengths	0.97	0.97	0.98	0.98	0.98	0.98
Precision/parameters						
2015 SSB	86.6	83.3	85.5	88.6	88.6	83.9
2015 SSB CV	4%	5%	6%	12%	13%	13%
ABC CV	7%	10%	12%	25%	27%	27%
M	0.1	0.1	0.1	0.102	0.103	0.103
Domestic q	7.63	7.56	7.39	7.17	7.12	7.12
-lnL	1558.7	1532.3	**1363.9**	**1361.1**	**1361.1**	**1361.1**

Table 4. Sensitivity run that tests effects of key structural uncertainties on key model results.

Model Name	**Description**
BASE	2015 Model
NOQPR	No priors on catchability
DOME	Dome shaped for recent fixed gear fishery (gamma)
M=0.08	Lower fixed natural mortality
M=0.12	Higher fixed natural mortality
SigR=1.6	Higher sigma-R
SigR=0.8	Lower sigma-R
NLLS1	Do not fit the domestic longline survey abundance
NLLS2	Do not fit the cooperative longline survey abundance
NFCPUE	Do not fit the fishery CPUE index
NTS	Do not fit the GOA trawl survey
FAGEL	Reduce weight on fishery ages by 50%
FAGEH	Increase weight on fishery ages by 50%
SAGEL	Reduce weight on LL survey ages by 50%
SAGEH	Increase weight on LL survey ages by 50%
FLEN1L	Decrease weight on fixed gear lengths by 50%
F1LENH	Increase weight on fixed gear lengths by 50%
S1LENL	Decrease weight on domestic LL survey lengths by 50%
S1LENH	Increase weight on domestic LL survey lengths by 50%
S2LENL	Decrease weight on cooperative LL survey lengths by 50%
S2LENH	Increase weight on cooperative LL survey lengths by 50%
F3LENL	Decrease weight on trawl fishery lengths by 50%
F3LENH	Increase weight on trawl fishery lengths by 50%
S7LENL	Decrease weight on GOA trawl survey lengths by 50%
S7LENH	Increase weight on GOA trawl survey lengths by 50%

Table 5. An example of how the recommended ABC would have changed if the whale depredation estimates were applied in the 2015 stock assessment.

Area	EY	WY	CG	WG	AI	BS	Total
2015 ABC	2,823	1,567	4,658	1,473	1,802	1,333	13,657
Apportionment	21%	11%	34%	11%	13%	10%	100%
2016 ABC	2,438	1,353	4,023	1,272	1,556	1,151	11,795
Whale corrected 2016 ABC	2,585	1,435	4,265	1,349	1,650	1,220	12,503
3-year average depredation (t)	77	48	104	112	91	63	495
Multiply by ratio of 2016/2015 ABC before whale corrections	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Deduct adjusted 3-year average whale depredation (t)	66	41	90	97	79	55	428
2016 ABC*	**2,518**	**1,393**	**4,175**	**1,252**	**1,571**	**1,166**	**12,075**
% Change from base model	3.3%	2.9%	3.8%	-1.6%	1.0%	1.3%	2.4%

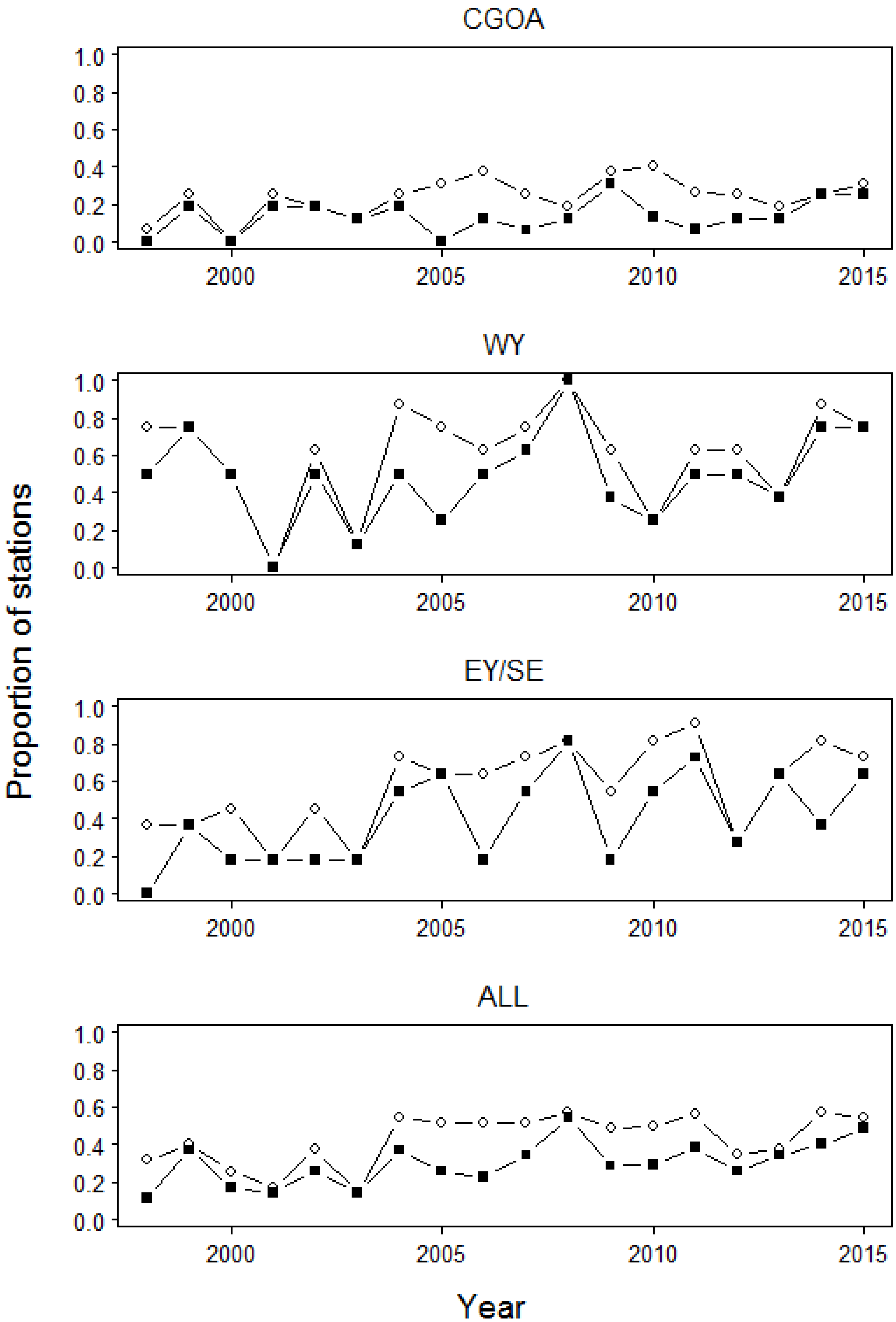

Figure 1. Proportion of stations with sperm whale presence (open circles) and evidence of depredation (solid squares) by management area and pooled, 1998-2015.

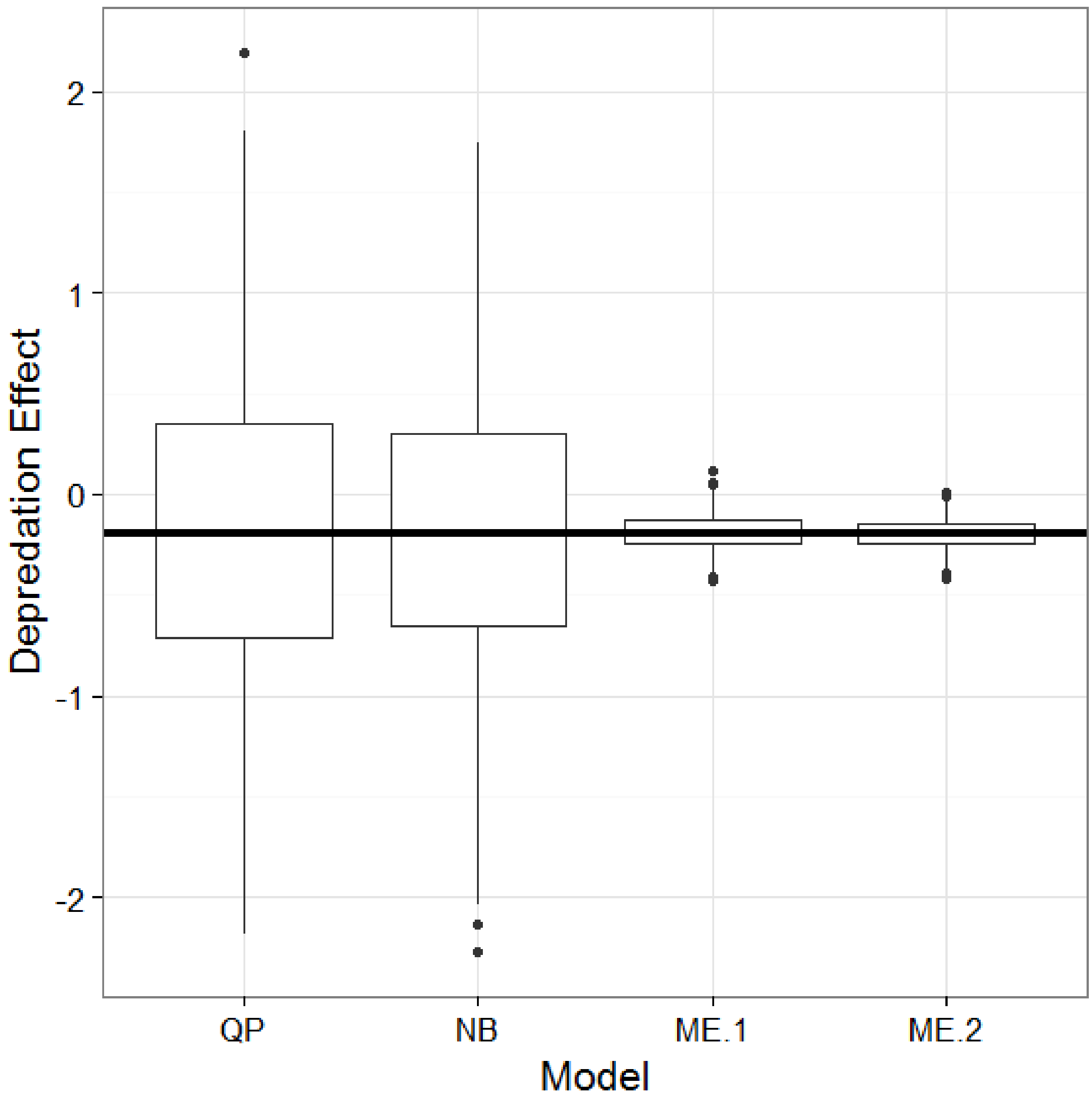

Figure 2. Boxplots of simulation estimates (1000 trials) of sperm whale depredation by model for simulation 1 (true simulated value of the depredation effect = -0.2). QP = Quasipoisson GLM, NB = negative bionmail GLM, ME.1 = Mixed effects Poisson without interactions, ME.2 = saturated mixed effects Poisson.

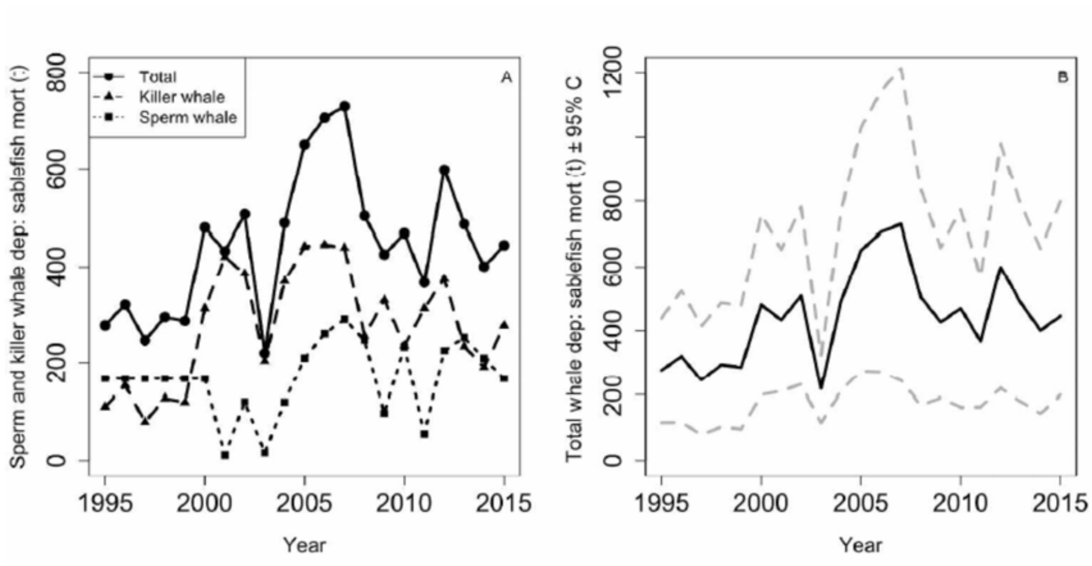

Figure 3. Estimated sablefish catch removals (t) due to sperm whale and killer whale depredation 1995-2015.Additional estimated sablefish mortality by whale species (A), and total whale mortality by year with 95% asymptotic normal confidence intervals (B).

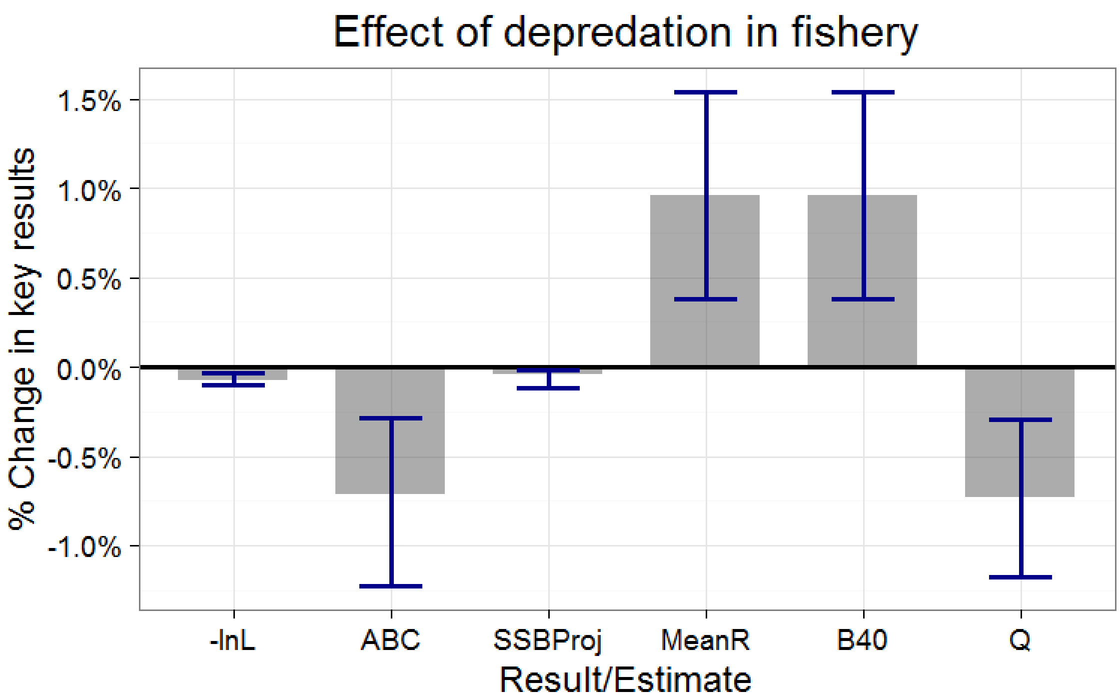

Figure 4. Effect of including whale depredation mortality in the fishery in the stock assessment model on key results with 95% confidence intervals based on model runs using the confidence intervals on depredation estimates in Figure 3.

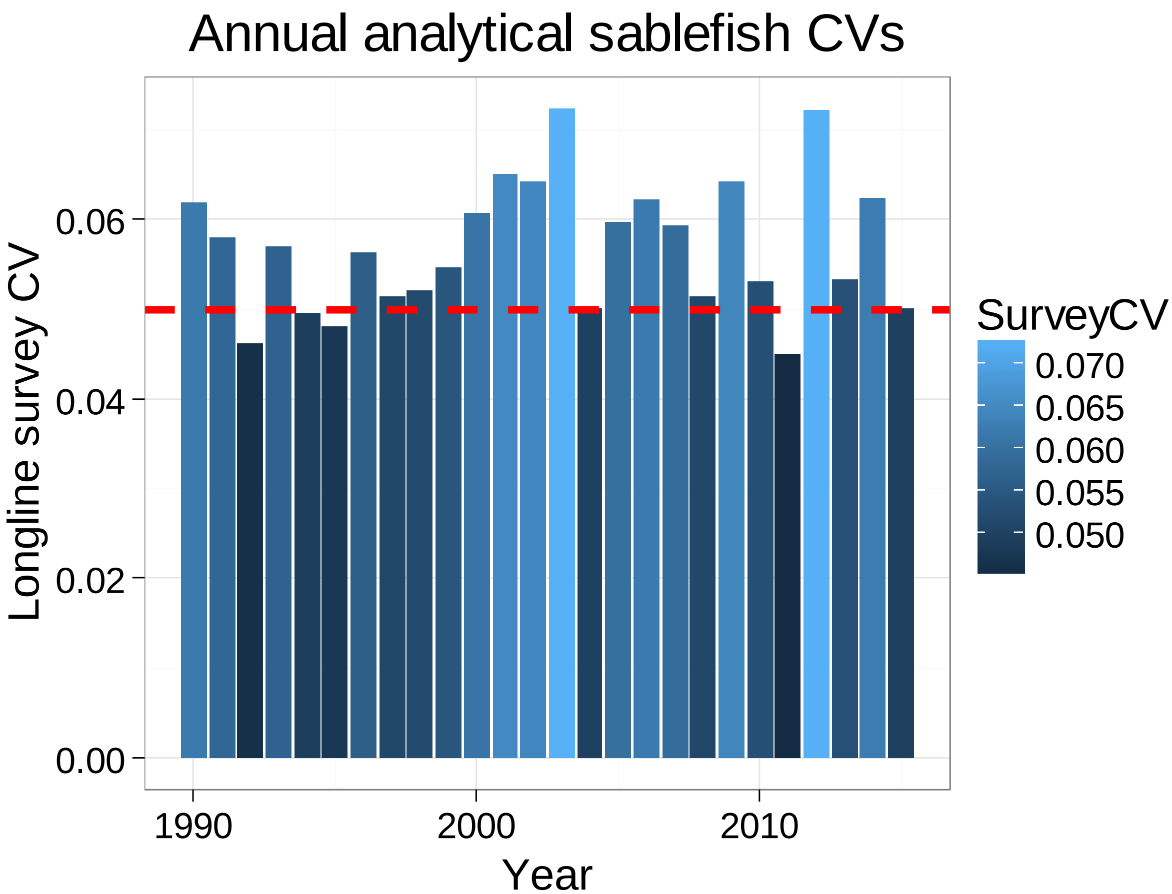

Figure 5. Annual analytical CVs for the longline survey relative population number (RPN) index for sablefish. Red dashed line is the currently assumed value of 5%.

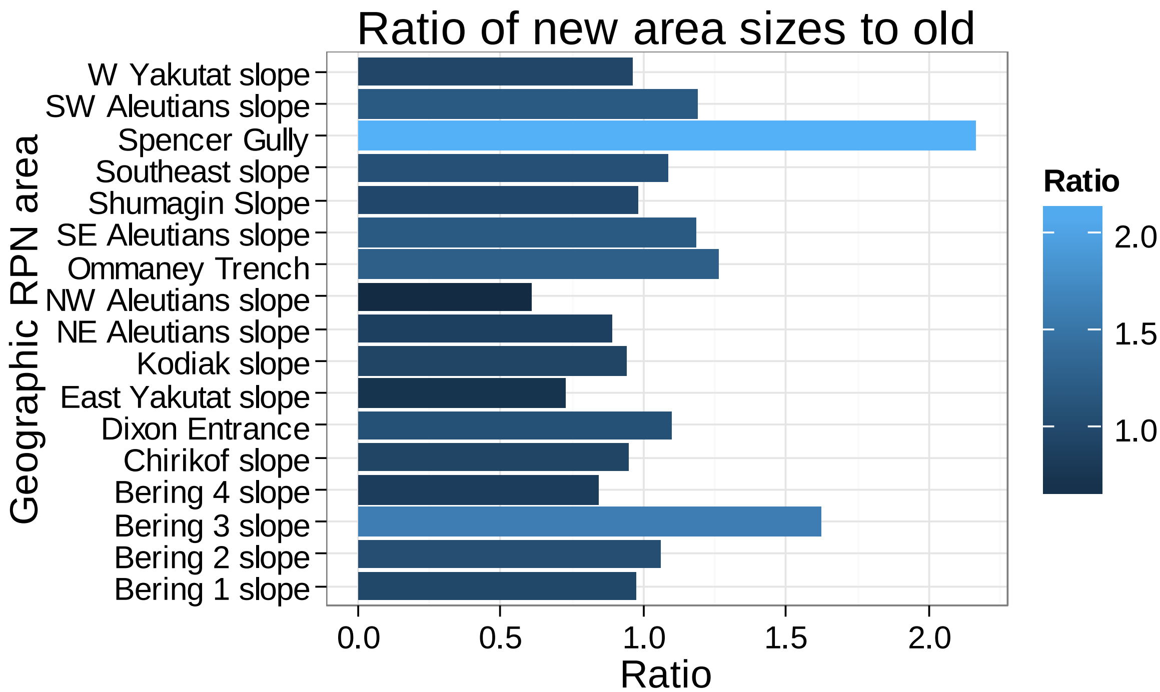

Figure 6. Comparison of old and new area sizes by sub-area used in calculating the AFSC longline survey relative population numbers index.

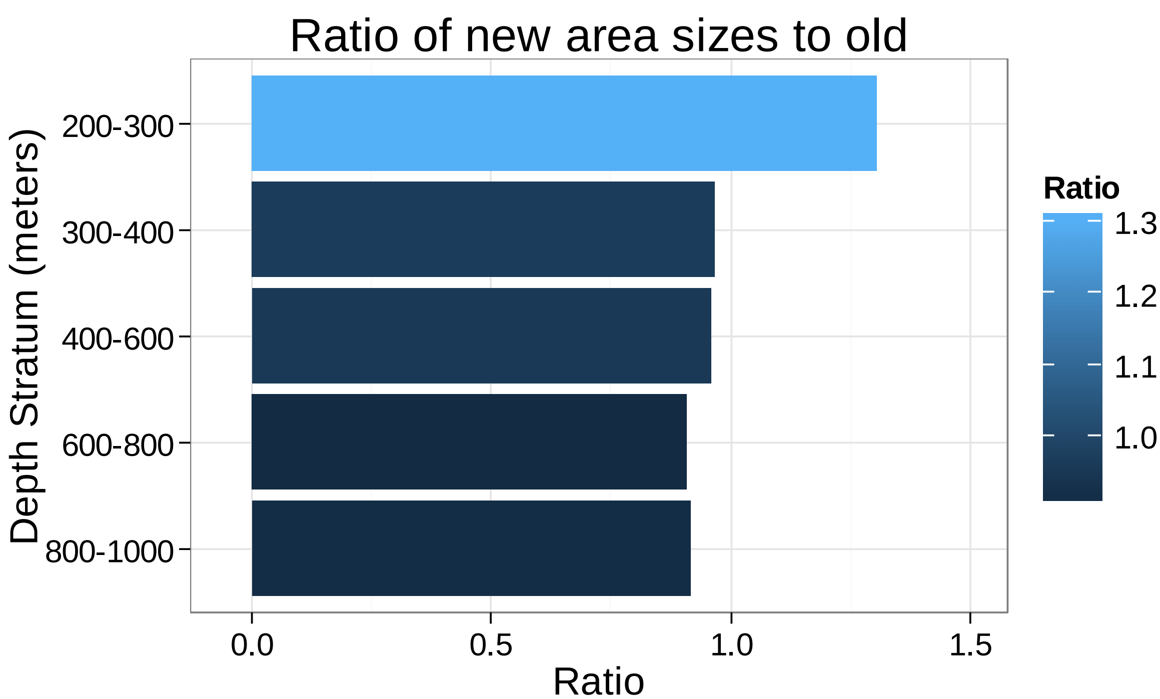

Figure 7. Comparison of old and new area sizes by depth-stratum used in calculating the AFSC longline survey relative population numbers index.

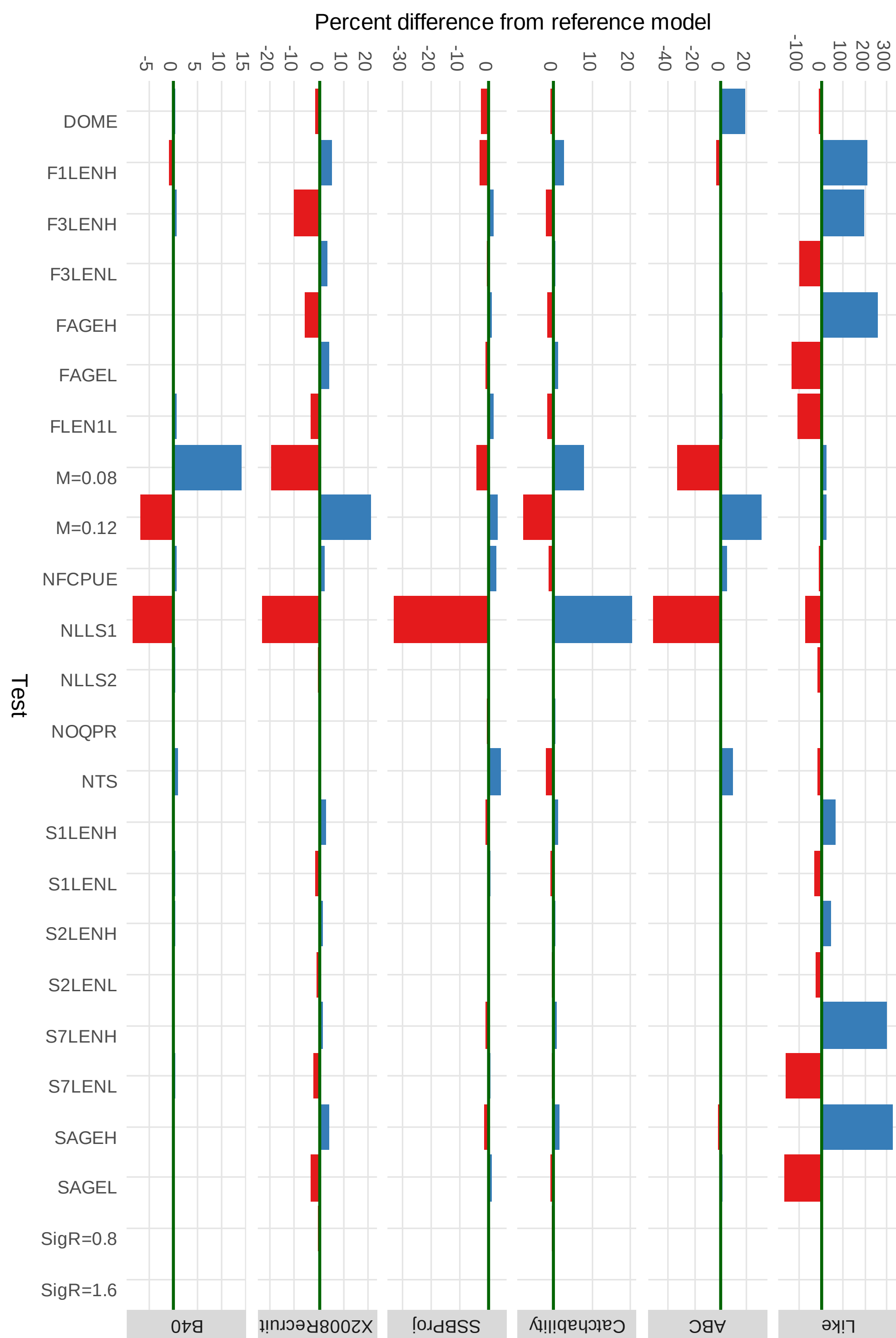

Figure 8. Effects of structural uncertainties in Table X on key model parameters and results. Like = Total data likelihood, ABC = Acceptable Biological Catch, Catchability = the catchability estimate of the domestic longline survey, SSB proj = 2016 estimate of spawning stock biomass, 2008 Recruit = the point estimate of the 2008 year class, B40 = the $B_{40\%}$ reference point.

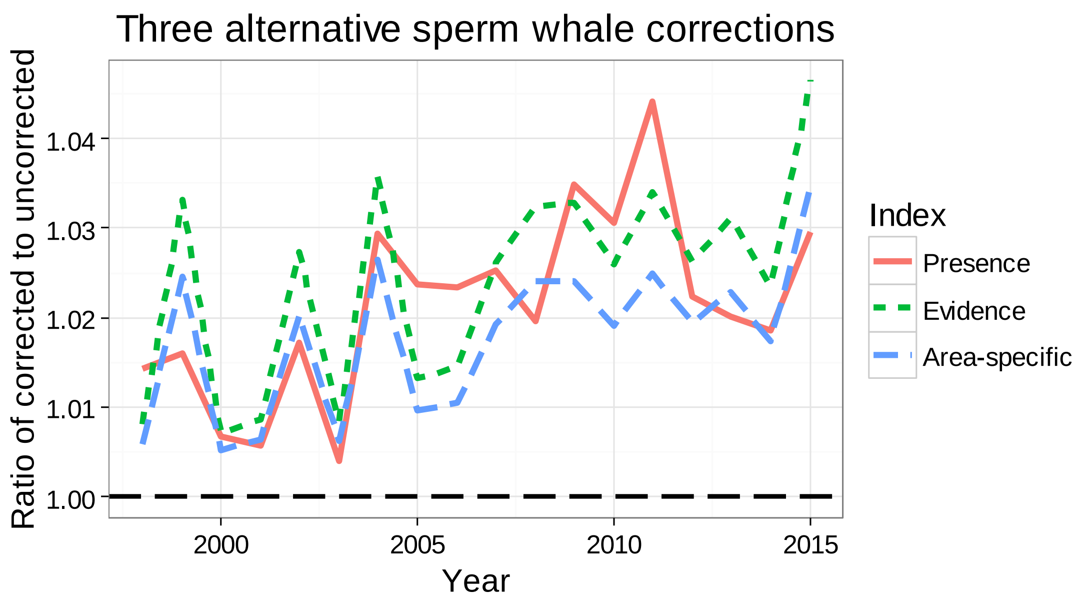

Figure 9. The proportional size of the longline survey index compared to the base model after correcting for sperm whale depredation. Black dashed line at unity corresponds to the uncorrected survey estimates, red line is expansion from across-area Model 4 (presence); green/short-dash line is Model 1 from the across area Model 1; and the blue/long-dash line is expansion from model ME.2 of the area-specific models.

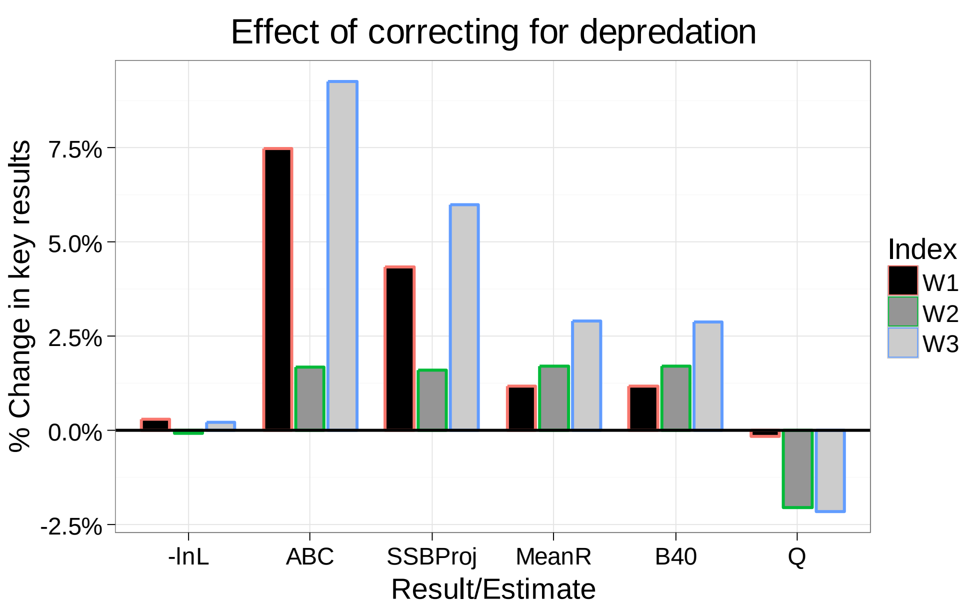

Figure 10. Change in key results in Alaska sablefish assessment when whale depredation is accounted for in the longline survey and the fishery; "-lnL" is the negative log likelihood, "ABC" is the Acceptable Biological Catch recommendation, "SSBProj" is the female spawning biomass projected for the following year, "MeanR" is the average recruitment, B40 is the estimated $B_{40\%}$ target reference point, and "Q" is the catchability or proportionality constant for the longline survey abundance index. Red border/black bar (W1) is accounting for the survey depredation; green border/dark gray (W2) is accounting for fishery depredation; and the light gray/blue border bar (W3) is accounting for both.

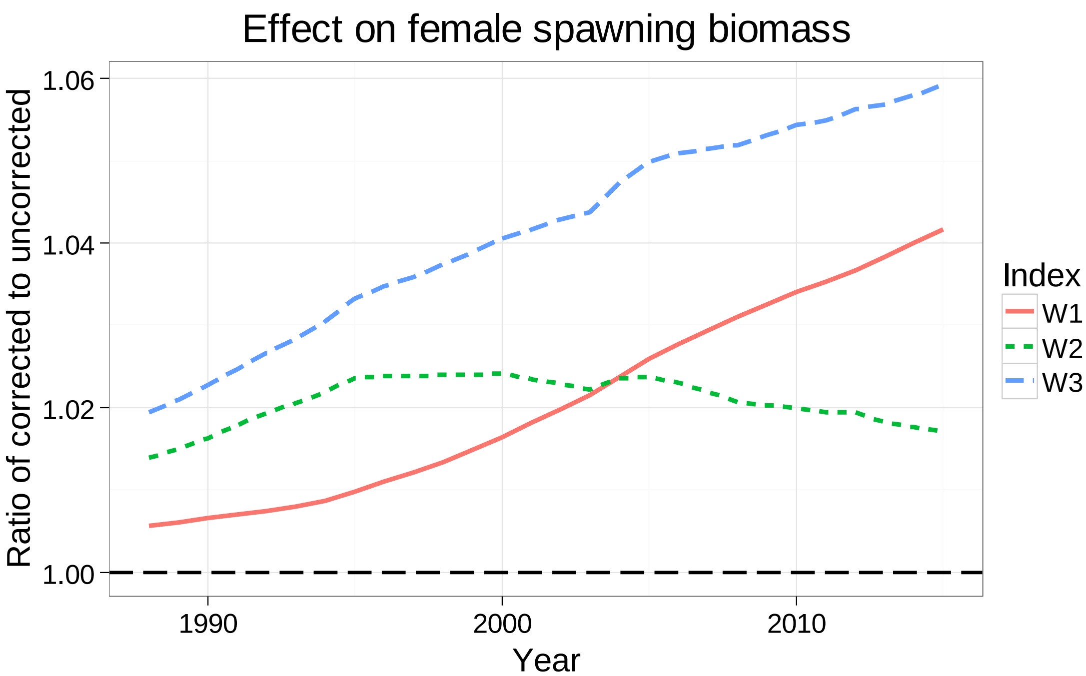

Figure 10. Change in female spawning biomass from 1988 – 2015 for models accounting for whale depredation. Red solid line (W1) is accounting for the survey depredation; green dotted line (W2) is accounting for fishery depredation; and the blue dashed line (W3) is accounting for both.

Appendix

Review Panel Summary Recommendations for the 2015 assessment of Alaskan sablefish (*Anoplopoma fimbria*)

Mike Sigler, National Marine Fisheries Service, Alaska Fisheries Science Center (Chair)

Noel Cadigan, Center for Independent Experts

Neil Klaer, Center for Independent Experts

Tom Carruthers, Center for Independent Experts

INCLUDING:
AUTHOR RESPONSES TO SELECTED RECOMMENDATIONS IN BLUE

Review meeting
Ted Stevens Marine Research Institute
17109 Pt. Lena Loop Rd
Juneau, Alaska

May 10th – 12th, 2016

Terms of reference a. Evaluation, findings, and recommendations on quality of input data and methods used to process them for inclusion in the assessment.

Short-term (next 2 years)

i) Develop alternative catch scenarios to provide bounds on uncertainty of historical catches for assessment model sensitivity testing.

This will be presented in the November 2016 assessment.

ii) Use GIS-derived area by depth and region for calculations of stock indices, depredation and apportionment.

A model alternative will include the GIS-derived area estimates from Echave et al. (2013) in November 2016.

iii) Investigate if improved indices of juvenile fish abundance can be created from available survey data by selecting only stations <200m. Selectivity for such data may also be more clearly dome-shaped.

This sensitivity was investigated briefly during the CIE review; the change from stations <500 m to stations <200 m has a negligible impact, but may be worth further exploration for 2017.

Longer term

i) Available IPHC and gully station indices should be considered for inclusion in the assessment.

Given that the IPHC data are closely correlated with the GOA trawl survey data, we expect that their inclusion will have a minimal impact on model results, but may provide further power to estimate other parameters more precisely. The gully stations may assist in providing information on recruitment. We will continue to track these additional indices in the assessment, and work toward evaluating their utility for inclusion in the model.

ii) In the context of a single area model, consider Kriging or a spatio-temporal survey model (e.g. year + space + year*space) as an additional alternative for filling missing years of sampling in the domestic longline survey.

We have explored several alternatives to fill in data in areas in years they are not sampled (i.e., the Bering Sea in even years and the Aleutian Islands in odd years), but have not come up with a preferred alternative. Exploring spatial models to do so is a top research priority.

iii) Continuing the recent work to include killer and sperm depredation presence and evidence in the fishery logbooks is encouraged.

Starting in 2017, data on whale presence and depredation will be collected in logbooks.

iv) Fishery CPUE standardization should be pursued further:

a. Model based approach, standardizing for relevant factors affecting catch rates (season, location, etc).
b. Consider a stratified CPUE index if year*area interactions are important.
c. Consider categorical rather than continuous variables for some factors (e.g. area-habitat definitions rather than continuous variables for longitude and latitude).
d. Consider some factors as random-effects rather than fixed-effects.
e. Consider a CPUE index workshop to evaluate and gain acceptance of proposed methods
f. If continuing with the non-modelling framework:
    - Alternative methods for assignment of target species for multispecies fisheries are available e.g. based on species composition by trip or catch value among vessels fishing common areas/times. Maximum weight/numbers in the catch may not be the best available procedure. Consider possible bias in mis-specification of target species, and whether this procedure is useful or not in a detailed model context.

- Data filtering may introduce bias and this should be considered in more detail. Factors used to filter could be accounted for in a standardization of model factors.

Improving the fishery CPUE index is an area of active research for us. Mateo and Hanselman (2014) presented some alternative GAM and Boosted Regression Tree standardization approaches, but did not take it far enough to consider whales and apportionment. We appreciate and recognize some of the CIE suggestions and will be attempting to further refine the fishery CPUE index for use in our production model in the coming years.

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v) Measurement error in age should be accounted for in growth model analyses and construction of age-length keys. Further consideration of the distribution of measurement errors (i.e. Geometric) will be useful.

vi) The current assessment is based on two time periods for growth (based on two temporally distinct sampling methods). Consider other growth models with time-varying parameters to assess if growth rates have changed over time.

We are currently initating new research extending the growth analysis of Echave et al. (2012) which informs the growth patterns currently being used in the assessment.

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vii) Continue work on skip-spawning and determine whether adjustment to the maturity ogive is required.

A second winter survey was conducted in December 2015 to gather more data on this interesting phenomenom. These histological data are currently being analyzed.

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viii) Consider models of maturation data including time varying parameters.

The overall mean maturity ogive from the domestic longline survey is negligibly different from the current ogive used in the assessment. The apparent time-variation may be more of an artefact of annual differences in the initiation of maturation. However, we may attempt a model that fits these data internally to contribute to the propagation of uncertainty in the model.

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ix) Use essential fish habitat (EFH) derived area, by depth and region, for calculation of relative abundance indices, depredation and apportionment (subject to validation of EFH).

These habitat suitability models are a work in progress and are currently only available for the Gulf of Alaska. We will monitor the progress of this project and its applicability for computing relative abundance.

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x) Create a data document that summarises available data series and the methods used to create them. This would be valuable for review and as an archive (this would be useful, for example for comparing indices of abundance and their modelling assumptions).

Documentation exists for all the series in the assessment, but are not aggregated into one document. We will synthesize existing materials into a standalone data document.

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xi) The survey takes 80 days on average. Consider methods to address uncertainty due to fish movement within the time-frame of the survey, esp. in space-aggregated model.

xii) Account for AK sport fishery catches (these are increasing).

Sport fishery catches are reported in the SAFE chapter, but remain an insignificant amount of the total catch (<<1%).

Terms of reference b. Evaluation, findings, and recommendations of the analytical approach used to assess stock condition and stock status.

Short term

i) Model biomass estimates appear very precise due to the fixed M value, high precision on catch and reasonably consistent trends in available abundance indices. An important additional source of uncertainty may be the form of the stock-recruitment relationship.

The current estimation of recruitment has a very low penalty on recruitment deviations (i.e., the model freely fits the compositional data to inform recruitment); imposing a stock recruitment relationship would likely increase the precision of model results as it is imposing a link between stock size and recruitment.

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a) These could form the basis for major axes of uncertainty for sensitivity analyse that may be communicated to management.
b) Consider placing a prior on M.

We will introduce a model in 2016 that estimates *M* with a prior. We are generally skeptical of the utility of fitting a stock-recruitment relationship in the model considering the low contrast in spawning biomass estimates and the existence of large recruitments during periods of low spawning biomass.

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ii) Application of the calculated SNDR weighting to adjust the CV of the domestic longline survey should be considered for this assessment.

We can re-examine the weighting given to the abundance indices. This may naturally result in a decrease in the weight of compositional data if the weight on the surveys is reduced.

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iii) Consider alternative time periods for the current regime of recruitment productivity and the effect on stock status and projections (e.g. the most recent 10 years). The choice of time period could be informed by recruitment covariates.

We will consider alternative recruitment regimes for the 2017 or 2018 assessment. The ongoing GOA integrated ecosystem project may help inform what plausible recruitment regimes and covariates are.

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iv) Consider a sensitivity analysis with respect to Canadian landings in northern B.C. that assigns these to the most appropriate selectivity (e.g. longline).

We will include this sensitivity as part of a broader sensitivity analysis of major uncertainties to be included as standard in future assessments as described in response to item 2 (vi) below.

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v) Consider initializing the model from fishing rates estimated in the early time period of the model rather than an arbitrary rate.

The model is robust to this value as shown during the CIE review. The value was adjusted from 10% to 200% average fishing mortality with little effect on model results. However, we can set this value to the average of the first few years of the model to be less arbitrary.

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vi) Additional model diagnostics should include tables (but possibly plots) of likelihood components for all sensitivities. Unweighted (via lambda) values subtracted from the base model are most useful.

A section and a figure will be added to the SAFE that describes the major axes of uncertainty and sensitivity to parameter assumptions. Sensitivities will include but not be limited to: natural mortality, data weighting, catch accuracy, and whale depredation.

Longer term

The CIE reviewers have provided a number of potential model improvements that we will examine over the next few years. Among them, the development of a tag-integrated model is a high priority.

i) Explore replacement of sex-specific age-based selectivities with length-based selectivity to simplify the model.

ii) Develop an integrated spatial assessment model, including tagging data. In the interim, develop a prior for natural mortality rate (for example based on tagging data).

iii) Include a Canadian component. All available evidence (tagging, comparison of abundance index trends) suggests that the Northern BC area also forms part of the assessed stock and efforts should be made to at least include appropriate BC catches in the assessment. Canada would then become an additional apportionment area for TAC calculations.

iv) External estimation of growth is subject to bias due to selectivity effects and is potentially best estimated in the model – particularly enabled by using available length at age data as a model input.

v) Use predictors of recruitment to define current regime (relevant historical recruitment period) for making projections. (see 2.1 iii)

vi) Investigate time-series models of recruitment to potentially improve short-term forecasting.

vii) Include a density-dependent stock-recruitment relationship in the assessment at least as a sensitivity scenario, and seriously consider the implications for current stock status and projections and bounds of certainty in the base assessment results.

Spatial model

i) It is important to define MSE performance measures that better indicate sociological and economic performance of the fishery including regional CPUE, catch/area of habitat, TAC variability, TAC underages, dollar yield etc.

ii) Consider a spatially implicit model (ie areas as fleets). Since the stock is so well mixed it may be simpler to model a single mixed population (no explicit spatial structure) and estimate area-specific selectivity and catchability by fleet (or potentially link these parameters by hyperpriors).

This may be a useful compromise between fully modeling the spatial dynamics explicitly and the current assumption being made of a fully mixed stock. We will look into this as an intermediate comparison.

iii) Spatial modelling at the scale of the management areas (not just 3 coarse areas) could provide advice at a resolution appropriate to management.

For the estimation model using sablefish data, we found that three areas was the limit of how much the data could be parsed without sample sizes becoming too small. In a 6 area model, there are missing data and areas that have very few ages. Simulations using a 6 area operating model will help test sensitivities to this assumption as well as better understand the trade-offs between spatial resolution and precision.

iv) Update estimation of movement matrix using spatial model F's. Ideally this would be done in a single model formulation.

The reviewers make an excellent suggestion. The movement model is currently parameterized with fishing mortality estimates derived from simply catch divided by estimates biomass for each area. The spatial model estimates of spatial Fs could be fed back into the 3 area movement model and used instead of the Fs that are currently estimated outside of the model. At the very least, this would be a useful sensitivity test.

Terms of reference c. Evaluation, findings, recommendations on estimation and strategies for accounting for whale depredation

Are the data and methods used in estimating depredation effects sufficient?

i) Available adjustments for killer and sperm whale depredation should be applied to both indices and catches.

We will include estimates of whale depredation on the survey and the fishery in the 2016 assessment and at least one model will include corrections for depredation.

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ii) Develop alternative plausible depredation scenarios for model sensitivity testing (e.g. different plausible values for the depredation effect).

We will include this sensitivity as part of a broader sensitivity analysis of major uncertainties to be included as standard in future assessments as described in response to item 2 (vi) above.

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iii) Explore the relationship between the magnitude of survey cpue and depredation by killer whales regarding the efficacy of deleting depredated sets. If killer whales target high cpue stations then simply deleting depredated sets may not adequately adjust for this effect.

We have explored this to some extent, and this does not appear to be a concern. Correcting for killer whale depredation in a modeling framework is challenging because the effect of killer whale depredation has high variability. One set may lose 95% of the catch while another set appears almost unaffected. The mean effect is quite high, however, and expanding catches by it could result in merely adding much more variability to the index.

Should depredation estimates be used in the assessment model, and if so, how?

i) Depredation should be included in the assessment.

We will include estimates of whale depredation on the survey and the fishery in the 2016 assessment and at least one model will include corrections for depredation.

ii) ABC recommendations should account for depredation.

Including an adjustment for whale depredation will likely result in increases to the overall ABC. Rather than impose an additional burden on catch accounting and in-season management conducted by the Regional Office we would likely recommended an ABC reduction based on our fishery whale depredation estimates. For example, we will likely recommend that the overall maximum ABC produced by the model (that accounts for whale depredation) be decremented by an average amount (e.g. 3 year average) of whale depredation in the fishery adjusted by the increase or decrease in ABC recommended for the following year. This would be done at the stock assessment level. We will present some alternative scenarios in 2016.

Terms of reference d. Evaluation, findings, recommendations of areal harvest apportionment strategy as related to movement and optimizing spawning stock biomass

Are there biological reasons to adjust apportionment by area?

The default biological objective of apportionment should be to achieve equal exploitation rate across the stock to maintain regional spawning biomass. In a highly mixed stock, apportionment may not have strong biological implications relative to the socio-economic implications. Therefore, apportionment strategies that emphasize stability are likely to be well suited to highly mixed stocks.

We have maintained that the apportionment strategy has relatively minor implications for the stock when exploitation rates are relatively low (e.g., <15%) in each area. The CIE strongly agreed that in a stock as well mixed as sablefish appear, other factors, such as stability in the fishery quotas, may be more important. The dominant concerns are likely to be more socioeconomic than biological. In light of the lack of concern by the CIE about the effect of the current static apportionment on the quality and robustness of the assessment results, we will continue to develop an MSE, and refine the objectives of what a good apportionment strategy should accomplish. Meanwhile, we do not have good support for any interim changes in the apportionment, and we will recommend keeping apportionment static for another year while other objectives are investigated.

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i) If spatial models are used for apportionment, alternative scenarios for movement should be considered (sensitivity analysis).

The current developments of the spatial model include extensive testing of alternative movement patterns. These sensitivities will be extended to apportionment calculations during our planned MSE work.

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ii) Use MSE analyses to evaluate the performance of various apportionment strategies (e.g. regional economic performance).

iii) If apportionment is to be 'optimized' or evaluated in an MSE, explicit management objectives need to be provided.

We request additional guidance from stakeholders, Plan Teams, SSC and the Council regarding objectives for the apportionment strategy. The CIE reviewers indicated little concern about any apportionment strategy that did not severely spatially concentrate the catch, given the high mixing rate of sablefish.

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iv) Investigate the implication of localized depletions for apportionment strategies.

v) Investigate whether certain areas disproportionately contribute to recruitment (e.g. higher recruits per spawner).

The recently developed spatial model, further research into the tagging data, and individual based models developed during the GOA Integrated Ecosystem Research Plan will likely provide better insights on the spatial distribution of recruits. Recent satellite tagging of large female sablefish should also help elucidate the location where spawning occurs and inform how apportionment could affect spawners and recruits alike.

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vi) Might consider apportionment by vulnerable biomass

Previously we have suggested that apportioning by a minimum length (related to maturity or value of different fish sizes) would be an easily implementable strategy. Apportioning by fishery selectivity or spatial reference points would also help achieve this goal.

Is stability more important than close alignment to annual areal abundance changes?

In a highly mixed stock like sablefish close alignment to areal abundance may be less important for biological productivity and economic considerations may take precedence.

Other issues

i) Industry priorities for apportionment include minimisation of volatility, stakeholder buy-in, and the effects of changes by area (e.g. in size comps). Need answers in the short-term, not necessarily by MSE.

Terms of reference e. Recommendations for further improvements

General recommendations

See longer-term recommendations

Recommendations relating to recruitment and projections

Currently the assessment is used to project abundance subject to highly uncertain recruitment. Additionally, sablefish recruitment has been relatively low over the most recent 15 years. There is the potential to improve the precision of short-term recruitment forecasts based on covariate data.

i) Continue to research predictors of recruitment including oceanographic conditions and early life survival such as lipid density and isotope analysis.

We are working closely with some of the investigators for the GOA Project, who are currently developing ecosystem metrics and sablefish agent-based models that should help us further define the conditions under which sablefish exhibit low and high survival. This yearm YOY, 1 year-old, and 2-year old sablefish were collected for energetics analysis to try to understand why the 2014 year class may be particularly large.

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ii) Include model structural uncertainty in management recommendations (e.g. high/low recruitment, high/low natural mortality rate scenarios)

We will include this sensitivity as part of a broader sensitivity analysis of major uncertainties to be included as standard in future assessments as described in response to item 2 (vi) below.

iii) Continue to conduct ecosystem research that may be used to provide improved tactical fisheries management advice (e.g. definition of regimes, improved precision of short term recruitment forecasts, incorporation of environmental variables in long term recruitment forecasts, essential fish habitat).

iv) Continue research to improve understanding of spawning dynamics of sablefish (e.g. timing, location, its relationship with spatial distribution of recruitment).

This comment is responded to in section 4.1.v.