Dover Sole
Stock Assessment Review (STAR) Panel Report

Virtual Online Meeting
May 3-7, 2021

Participants

STAR Panel Members

Tien-Shui Tsou, Washington Department of Fish and Wildlife (Chair)
Fabio Caltabellotta, Oregon State University
Matt Cieri, Center for Independent Experts
Noel Cadigan, Center for Independent Experts

Stock Assessment Team (STAT) Members

Chantel Wetzel, National Marine Fisheries Service Northwest Fisheries Science Center
Aaron Berger, National Marine Fisheries Service Northwest Fisheries Science Center

STAR Panel Advisors

Whitney Roberts, Washington Department of Fish and Wildlife, Groundfish Management Team representative
Gerry Richter, B&G Seafoods, Groundfish Advisory Subpanel representative
John DeVore, Pacific Fishery Management Council representative

Overview

A Stock Assessment Review (STAR) panel met virtually on May 3-7, 2021, through the RingCentral platform to review a draft stock assessment of the Dover Sole (*Microstomus pacificus*) prepared by Drs. Wetzel and Berger (STAT). The panel operated under the Pacific Fishery Management Council's (PFMC) Terms of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2021-2022 (PFMC, December 2020). This same panel also reviewed a draft assessment for Pacific Spiny Dogfish (*Squalus suckleyi*).

Dover Sole are distributed from Baja California to the Bering Sea and eastern Aleutian Islands, and are generally found on mud or mud-sand bottom deeper than 20 fathoms (37 m) to below 1,500 m. Dover Sole exhibit complex seasonal and ontogenetic movement, moving to deeper waters based on size but also shifting seasonally, moving from shallower feeding grounds on the continental shelf during the summer months to deeper spawning habitat on the outer continental shelf and slope in the winter. However, the specific mechanisms that drive stock structure and related variability over space and time are not well understood. These unknown mechanisms may have contributed to the model's lack of fit to some compositional data in recent decades.

This assessment was conducted with Stock Synthesis, version 3.30.16. It assumes that Dover Sole off the U.S. West Coast, bounded by the US-Canada border and US-Mexico border, comprise a single coastwide stock whose dynamics are independent of Dover Sole populations of Canada and Mexico. The assessment incorporated a wide range of data sources: landings data and discard estimates; survey indices of abundance, length- and/or age-composition data for each fishery or survey (with conditional age-at-length data used for the surveys); information on weight-at-length, maturity-at-length, and fecundity-at-length; information on natural mortality and the steepness of the Beverton-Holt stock-recruitment relationship; and estimates of ageing error. Dover Sole exhibit dimorphic growth by sex; therefore, the assessment model was structured to have two sexes. Fleet structure was changed to two fleets compared to three state-specific fleets used in 2011. The model started from an unfished equilibrium state in 1911. Recruitment was estimated in the model with steepness fixed at 0.8 and *Sigma R* at 0.35. The instantaneous rate of natural mortality for females was fixed at the median of the prior, 0.108 per year, and male natural mortality was estimated as an offset from the female value.

Results from the model indicate that the stock status was at 79% of the unfished spawning biomass level at the beginning of 2021. Fishing intensity (1 - *SPR*) over the past decade has been well below the target $SPR_{30\%}$, ranging between 0.11 and 0.2. The panel considers that the use of surveys, compositional data, and estimation of recruitment deviations makes this a Category 1 assessment. The panel recommends the Dover Sole stock assessment as the best available science and considers it a suitable basis for management decisions. The panel recommends that the next assessment be an update assessment. The panel applauds the STAT team for their well-structured presentation of the assessment and the very competent work completed before and during the STAR meeting.

Summary of Data and Assessment Models

The assessment model structure was similar to that used in 2011, but there were a few meaningful changes to the model structure.

- The double normal selectivity parameterization was used for both fishery fleets, Triennial Survey, and West Coast Groundfish Bottom Trawl Survey (WCGBTS) in the model, where the female sex-specific selectivity parameters were estimated as full offsets with a scale parameter relative to the male selectivity (offset parameters for the peak, ascending width, descending width, final selectivity, and a scale parameter).
- Selectivity functions of the Northwest Fisheries Science Center (NWFSC) and Alaska Fisheries Science Center (AFSC) Slope Surveys were modeled using a cubic spline selectivity form, which was the same as was used in the 2011 assessment.
- The fleet structure was simplified by collapsing data and catches from Oregon and Washington into a single fleet.
- Male biological parameters (natural mortality and growth) were estimated as offsets from the female parameters, which was a minor change in parameterization from the 2011 assessment.
- The base model was weighted using the "Francis method", which was based on equation TA1.8 in Francis (2011), as data weighting approaches and applications have evolved considerably since 2011 when the last assessment of Dover Sole was conducted.
- The final major changes relative to the 2011 assessment were the treatment of natural mortality rate (*M*) and the maturity-at-length. The maturity-at-length was updated based on new research conducted by Melissa Head (NOAA, NWFSC).
- The method of developing an *M* prior was changed to the current approach used for stock assessments of West Coast groundfish, which is based on Hamel (2015). Additionally, this assessment did not estimate female *M* and fixed the parameter at the median of the prior, 0.108 yr^{-1} compared to the 2011 assessment, which estimated both female and male *M* directly.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Provide historical catches by state (this can be provided after the STAR panel).

Rationale: Displaying catches by state for the record will assist in future assessments and a future flatfish catch reconstruction in WA.

STAT Response: An excel file “Dover_sole_catches_by_state.xlsx” provides the input state-specific catches used in the model. The worksheet titled “Catch by State” contains the fully processed catches incorporating all historical reconstructions, Pacific Fisheries Information Network (PacFIN) catches, and any adjustments required (e.g., fish landed in California from Oregon and Washington waters). The worksheet “CA Hist Catch to ORWA” provides the total landings identified by Don Pearson (Southwest Fisheries Science Center, SWFSC) from 1948 - 1968 that were excluded from the California catch reconstruction because the catch area was identified to be in either Oregon or Washington (provided by John Field, SWFSC). Catch history by state will be included in the revised assessment document.

Request No. 2: Investigate a time block for CA selectivity - explore 2011 (IFQ implementation) and 2003 (RCAs implementation).

Rationale: To attempt a better model fit to the CA composition data.

STAT Response: Three runs were conducted that explored additional blocks in the California fleet selectivity: 1) add a block from 2003 - 2020, 2) add a block from 2011 - 2020, and 3) add two blocks 2003 - 2010 and 2011 - 2020. The estimated selectivity curves by sex for each of these runs is shown in Figure 1 below.

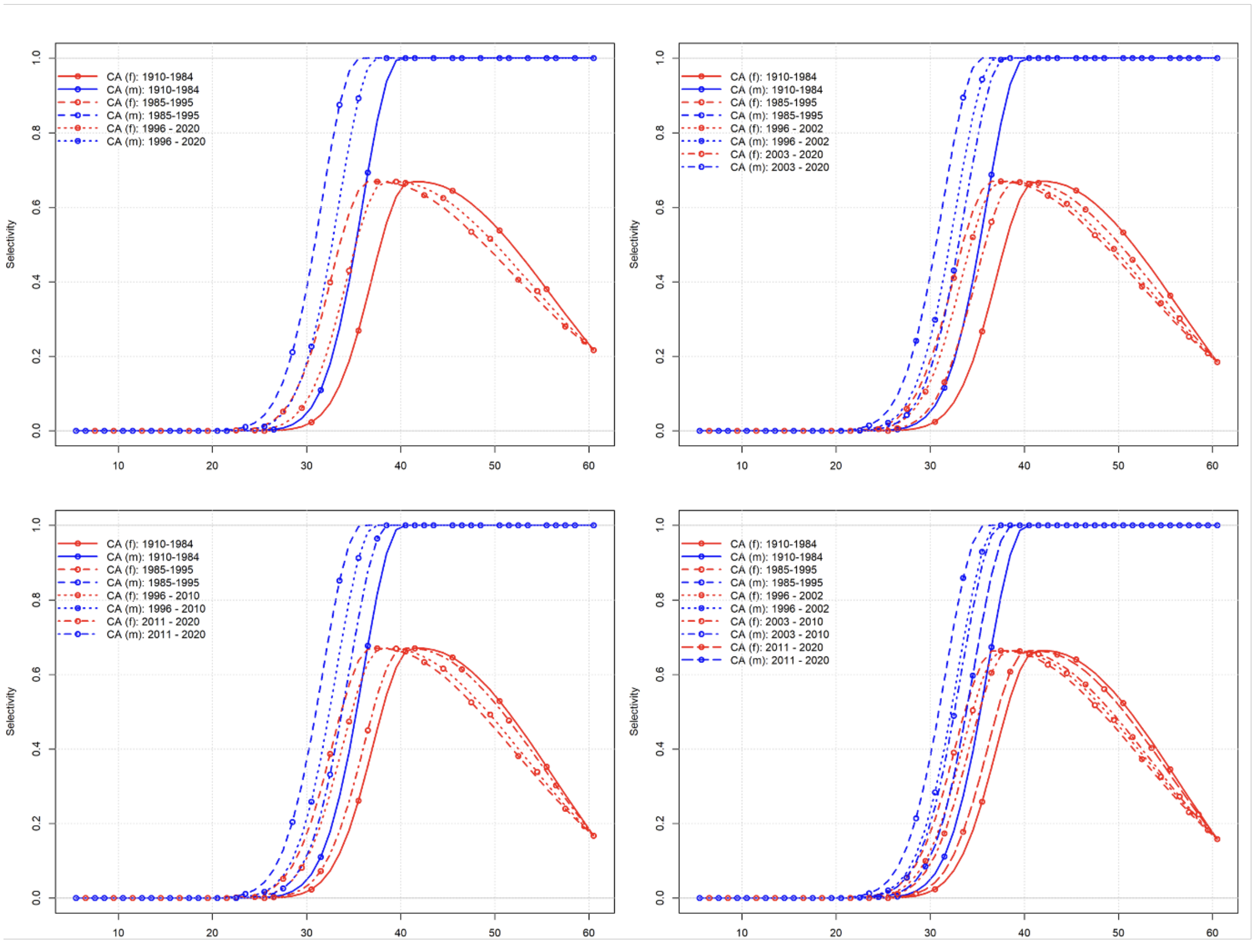

Figure 1 Estimated sex-specific selectivity curves for each of the alternative blockings for the California fleet. The top right panel is the base model, top left is the sensitivity with a block from 2003 - 2020, bottom left is the sensitivity with a block from 2011 - 2020, and the bottom right is the sensitivity with a block from 2003 - 2010 and 2011 - 2020.

Selectivity for the sensitivity runs that either applied a 2003 - 2020 block or a block from 2011 - 2020 each had an estimated right-ward shift (selecting slightly larger fish) in selectivity for both sexes relative to the selectivity estimated from 1996 - 2002 or 1996 - 2010. The estimated length at peak selectivity for each block is provided below in Table 1.

Table 1 Parameter estimates of the length at peak selectivity by sex.

	Base Model: 1996 - 2020	2003 - 2020	2011 - 2020	2003 - 2010 and 2011 - 2020
Length at peak selectivity for males (cm)	37.4	37.9	38.6	37.5 38.7
Length at peak selectivity for females (offset, cm)	0.9	1.1	1.6	0.8 1.5

The predicted fit to the mean length by year for the California fishery lengths for each sensitivity are shown in Figure 2 below. The sensitivities that applied a selectivity block from 2011 - 2020 (including the sensitivity with two blocks: 2003 - 2010 and 2011 - 2020) to the California fleet appeared to have the best visual fit to the increase in mean lengths in the final years of the model.

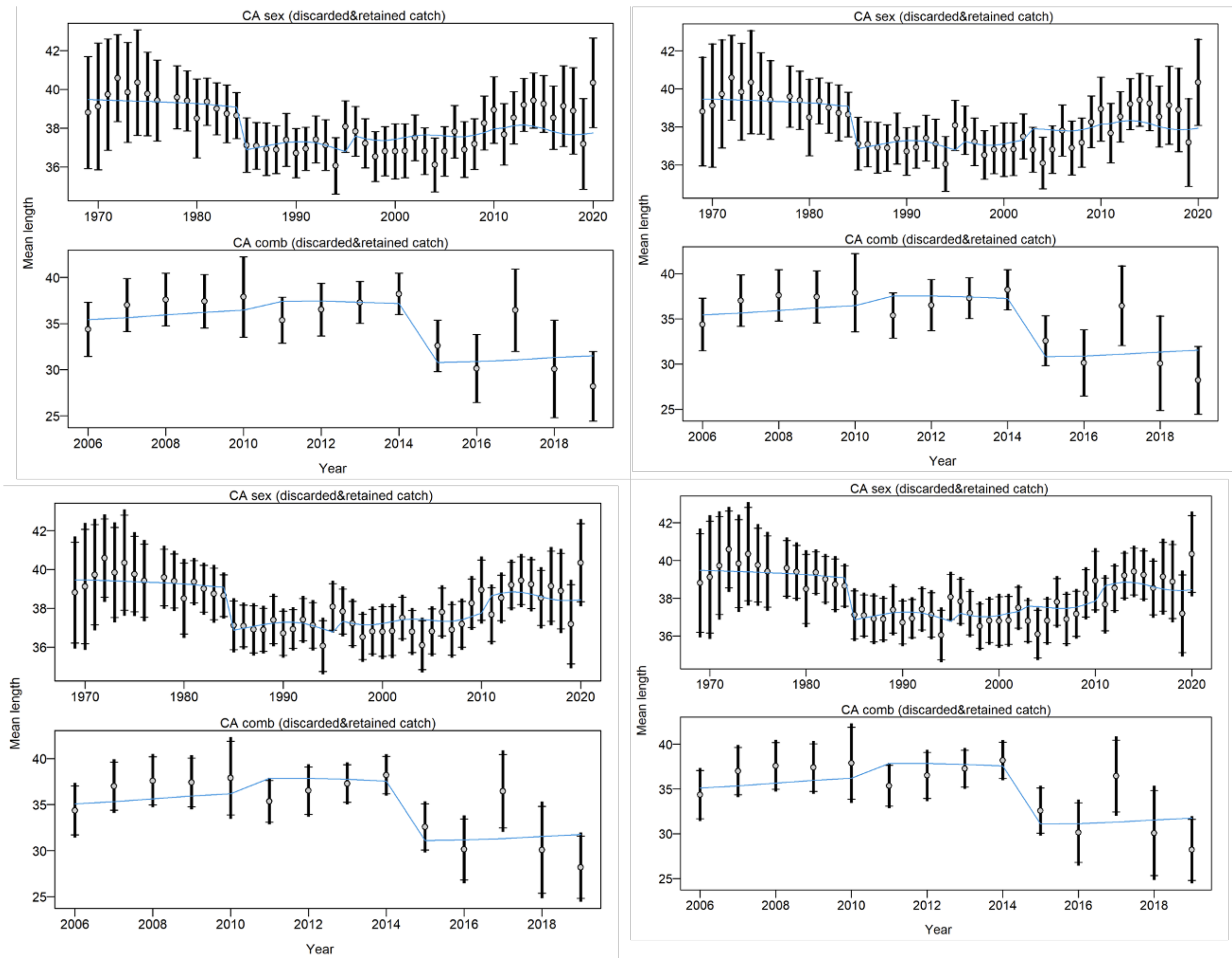

Figure 2 Observed mean length by year for the California fleet (points) and the model expected mean length (blue line). The top right panel is the base model, top left is the sensitivity with a block from 2003 - 2020, bottom left is the sensitivity with a block from 2011 - 2020, and the bottom right is the sensitivity with a block from 2003 - 2010 and 2011 - 2020.

The Pearson residuals for each of the sensitivities are shown in Figure 3 below. Similar to the mean length figures, the sensitivities that included a block from 2011 - 2020 appeared to decrease the pattern of model expectations exceeding the observations (open circles) at the end of the time series for fish less than 30 cm.

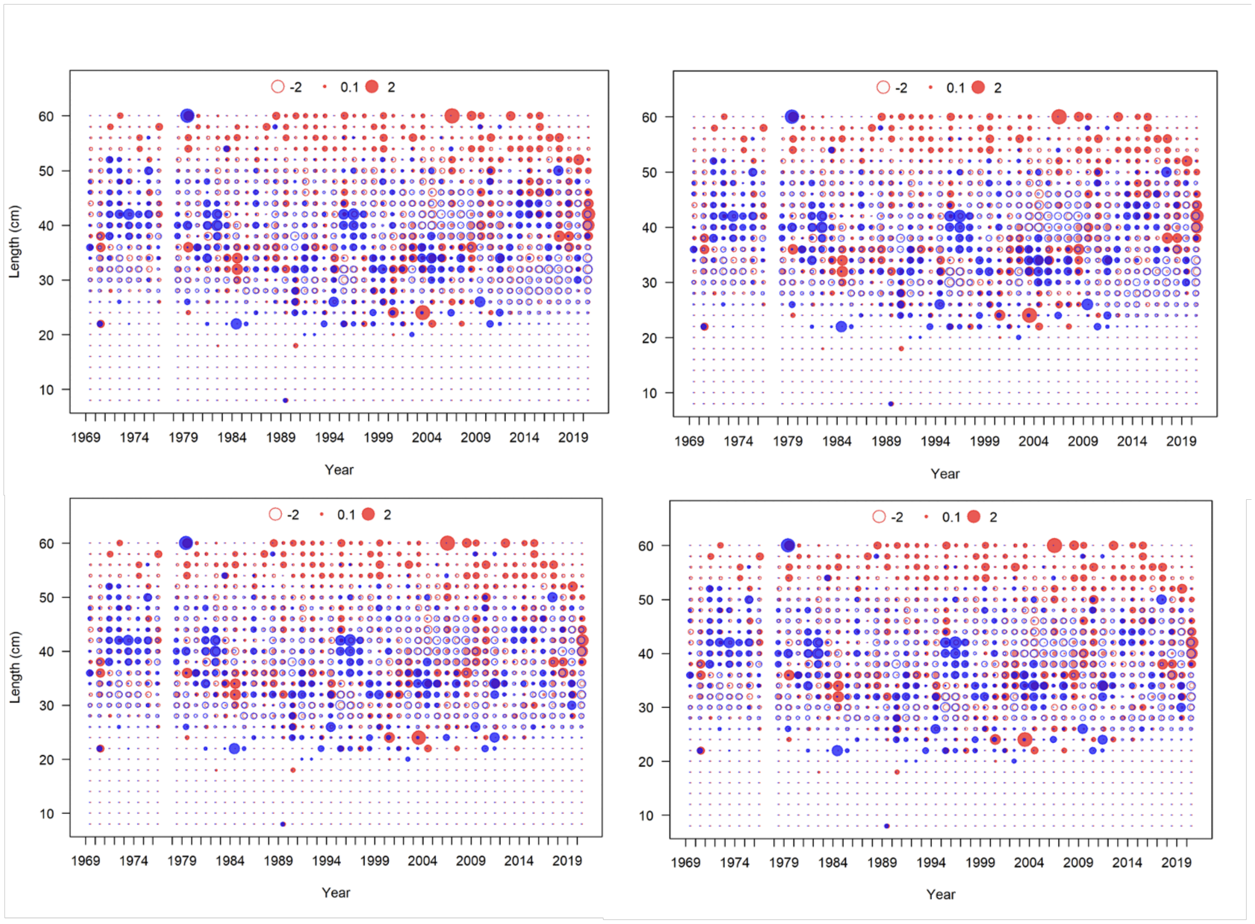

Figure 3 Pearson residuals of length data by year for the California fleet. The top-right panel is the base model, top-left is the sensitivity with a block from 2003 - 2020, bottom-left is the sensitivity with a block from 2011 - 2020, and the bottom-right is the sensitivity with a block from 2003 - 2010 and 2011 - 2020.

The estimates of spawning biomass and fraction unfished across the selectivity block sensitivities and the base model are shown in Figures 4 and 5. The estimated spawning biomass and fraction unfished were similar across sensitivity runs. The change in the negative-log-likelihoods (*NLL*) relative to the base model are shown in Table 2. The sensitivity that added a block for 2011 - 2020 had the lowest *NLL*, approximately 5 units lower than the base model but this improved fit to the data required two additional selectivity parameters.

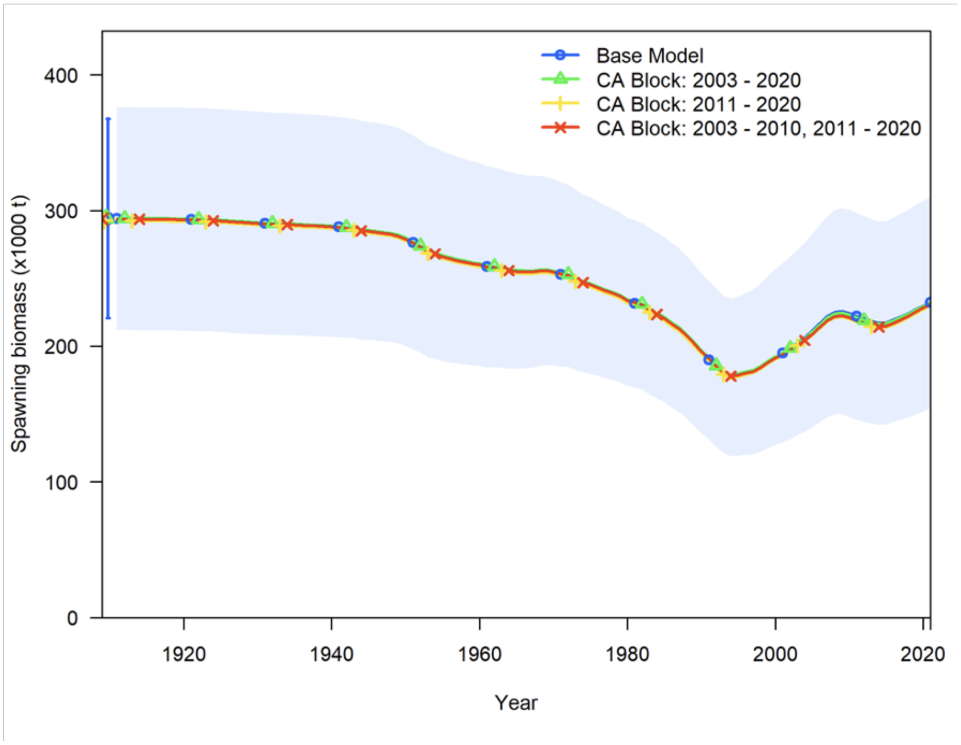

Figure 4 Spawning biomass estimated across selectivity block sensitivities.

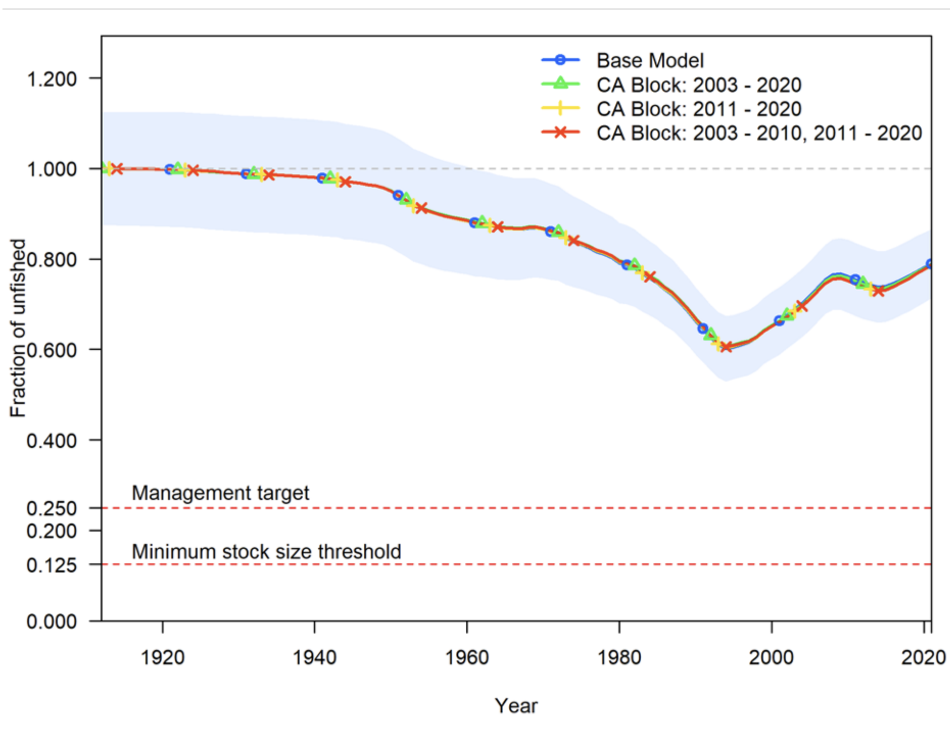

Figure 5 Fraction unfished estimated across selectivity block sensitivities.

Table 2 Table of likelihoods and estimates across each of the block sensitivities.

	Base Model	CA Block: 2003 - 2020	CA Block: 2011 - 2020	CA Block: 2003 - 2010, 2011 - 2020
Change in NLL	**0**	**1.94**	**5.21**	**5.12**
Total Likelihood	1028.95	1027.01	1023.74	1023.83
Survey Likelihood	-49.59	-49.65	-49.83	-49.82
Length Likelihood	338.18	337.88	334.86	335.11
California	*149.93*	*148.30*	*143.45*	*143.31*
OR/WA	*165.95*	*166.14*	*165.73*	*165.76*
AFSC Slope	*28.41*	*28.51*	*28.49*	*28.48*
Triennial	*23.68*	*23.73*	*23.67*	*23.69*
NWFSC Slope	*11.31*	*11.41*	*11.35*	*11.38*
NWFSC WCGBT	*116.84*	*117.01*	*116.76*	*117.04*
Age Likelihood	909.45	908.18	908.88	908.74
Recruitment Likelihood	-15.67	-15.78	-15.87	-15.88
Forecast Recruitment Likelihood	0	0	0	0
Parameter Priors Likelihood	0.04	0.04	0.04	0.05
log(R0)	12.27	12.27	12.27	12.27
SB Virgin	294070	294299	292524	293626
SB 2020	232065	231982	229959	230935
Fraction Unfished 2021	0.79	0.79	0.79	0.79

Panel Conclusions:

While the new 2011-2020 selectivity block produced a significantly better fit (i.e., $2 \times 5.21 = 10.42\ \chi^2_2$ units; $Pr(\chi^2_2 > 10.42) = 0.0055$), adding it did not result in a change in the estimated stock size and status. It was unclear to the STAT what may have driven a shift in selectivity in the California fishery during this period (the introduction of the IFQ in 2011 is captured via a shift in retention) and a similar shift in selectivity was not observed in the Oregon/Washington fleet. Recent length sample sizes (i.e., since 2017) from the California fleet have been low and thus this needs to be further explored as well. There is a potential that the discrepancy in the model fit is related to a sampling process rather than a real change in fishery selectivity. The STAT and panel agreed to not adopt the 2011-2020 selectivity block and to highlight this issue for future research (see below).

Request No. 3: Evaluate the sensitivity runs for the WCGBTS to see what may be driving the poor fit at the end of the time series.

Rationale: To understand what is causing the poor fit.

STAT Response: The STAT went through 1) all sensitivity model runs that were provided in the assessment document, 2) many of the other sensitivity runs that were performed during robustness trial examinations of the draft base model, and 3) many of the model runs that were conducted during development of the base model. In general, the STAT did not identify any model structural assumptions that, when evaluated in isolation, led to an improved fit in the mean age for the WCGBTS (Table 3).

Table 3. Main list of general model types that were 'visually' examined for improved fit to the mean age data for the WCGBTS relative to the base model. This list is not exhaustive of all models examined but is representative of general findings.

Better Fit	Little to No Difference	Worse Fit
Severely upweight WCGBTS age data	• 2011 maturity • Alternative *M* fix/estimate • Alternative weighting methods • NWFSCslope_female selectivity asymptote at 1 • Ageing error assumptions • Increase growth CVs • Remove recruitment deviations • Parameter offset methods • Other selectivity sensitivities not mentioned elsewhere • All other data source sensitivities not mentioned elsewhere	• 2011 fishery selectivities • 2011 survey selectivities • Mirror commercial selectivities • Remove WCGBTS ages

Models resulting in the largest change in fit to WCGBTS mean age included severely (and artificially) up-weighting these data relative to other data sources (lambda = 10.0, or a 10-fold increase in relative weight) as compared to the base model (Figure 6) and removing these data altogether (Figure 7). Clearly, there is a tradeoff between fitting WCGBTS length data versus age data in this model, and this is the case in general as well as by specific parameters (e.g., see profile plots for key parameters, Figures 153-164 in the draft assessment document). In general, input sample sizes were specified as 3.09 * number of tows for WCGBTS length data and was specified as the number of fish for WCGBTS conditional age-at-length data (CAAL; further details at the top of page 12 in draft assessment document). The range of input sample sizes for length across the WCGBTS was 402 (2004) to 1829 (2018), and 1 fish to 78 fish per year-sex-length bin for CAAL. The Francis data weighting approach used in the base model resulted in a 4-fold higher relative weighting of input sample sizes for lengths as compared to ages (i.e., Francis weight of 0.41 compared to 0.11 for WCGBTS lengths and ages, respectively).

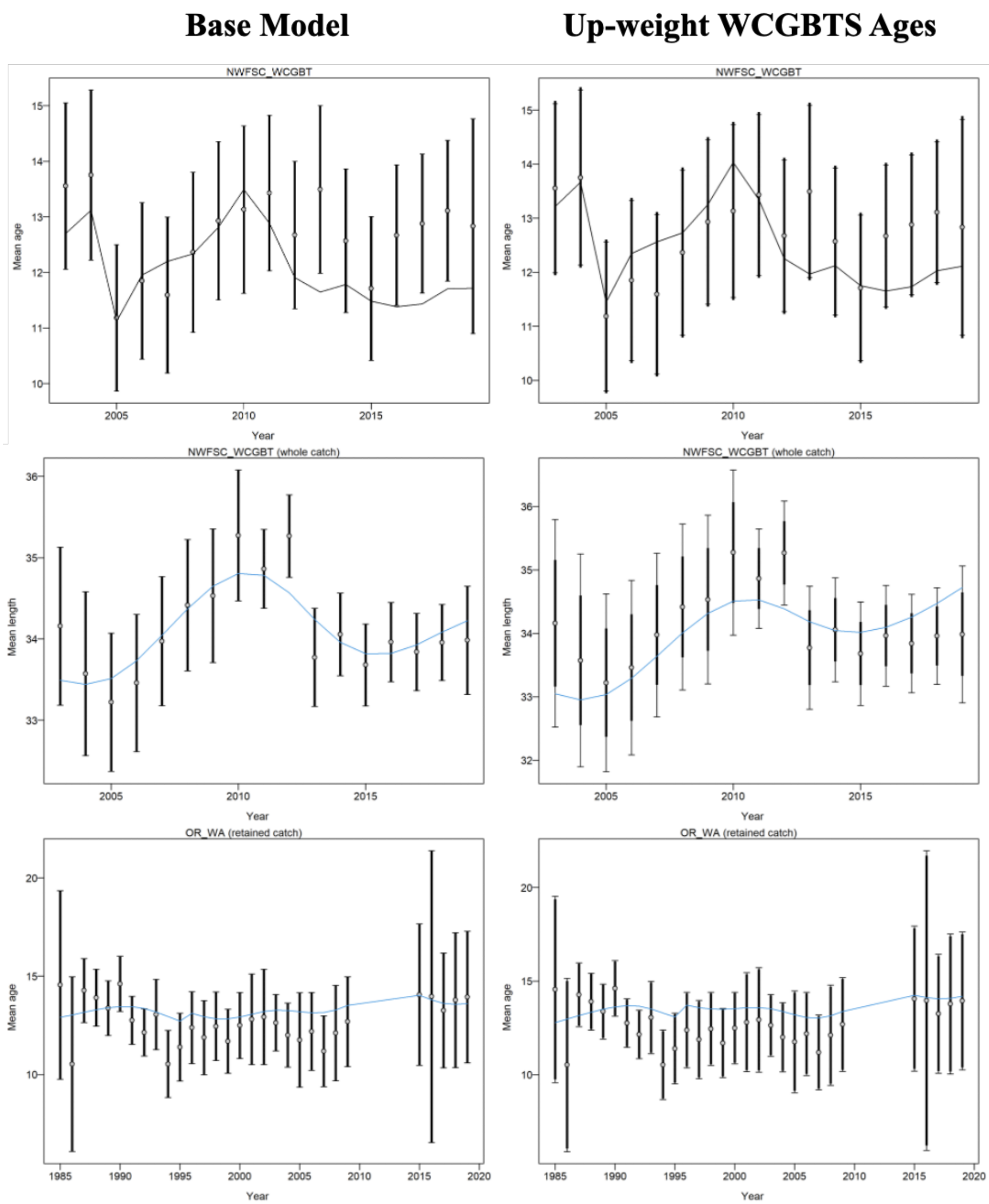

Figure 6. Fits to WCGBTS mean age for a model that severely up-weighted these data (top right) relative to other data sources (lambda = 10.0, or a 10-fold increase in relative weight) as compared to the base model weight for this data source (top left). Fits to WCGBTS mean length and OR_WA mean age are also shown for comparison.

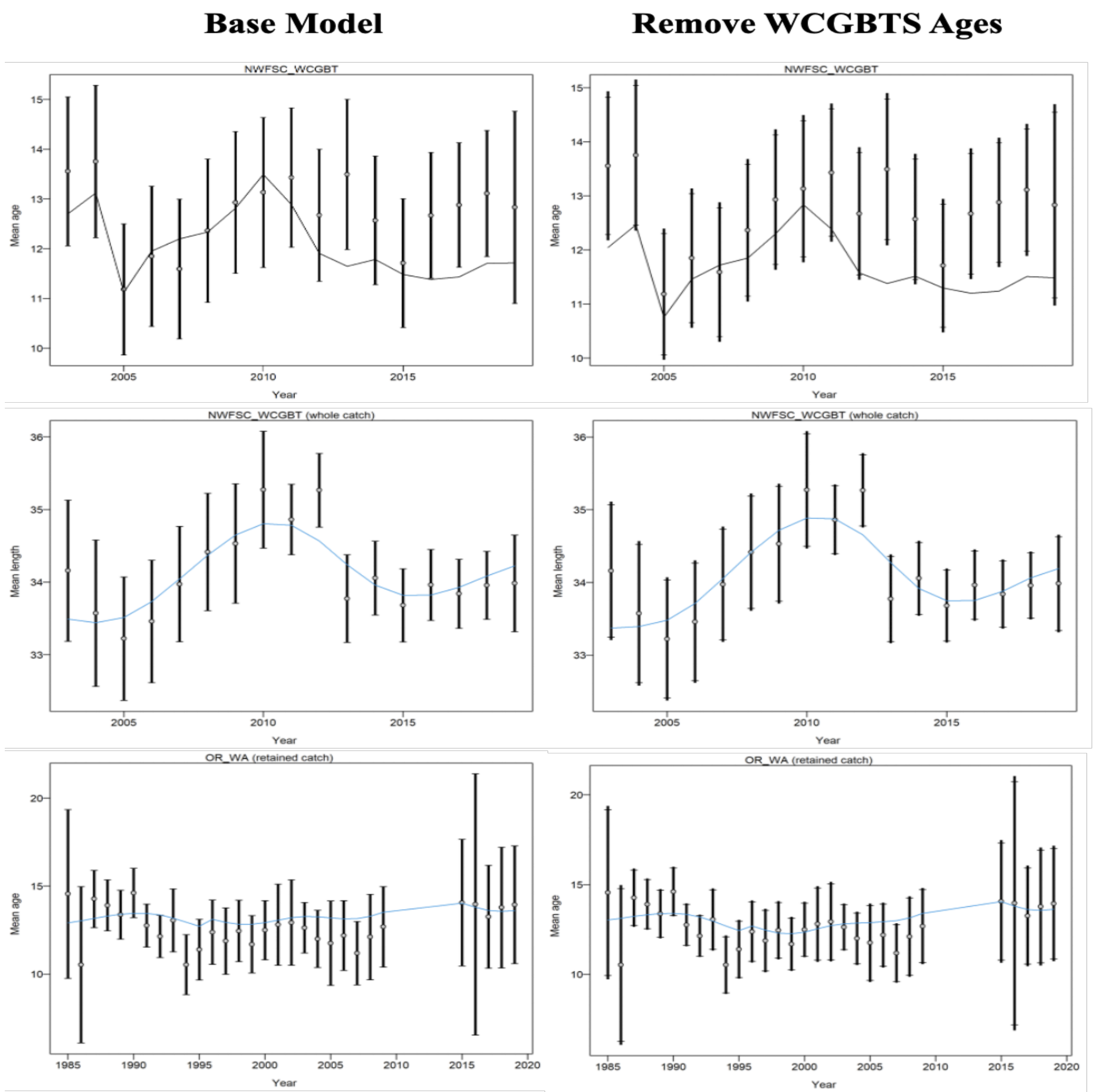

Figure 7. Fits to WCGBTS mean age for a model that removed these data (top right) as compared to the base model (top left). Fits to WCGBTS mean length and OR_WA mean age are also shown for comparison.

In general, the base model fits the WCGBTS mean length data well at the expense of not fitting the WCGBTS age data as well. When the model is forced to fit the WCGBTS age data more so than in the base model, the fit of length data becomes worse (Figure 6) as does recent fits to the WCGBTS index (Figure 8). This change also results in an *a priori* unexpected stock trajectory and the undesirable property of autocorrelation in early recruitment deviations (Figure 8). The base model attempts to balance WCGBTS length and age data. Ideally, an assessment model would provide unbiased and risk-neutral estimates (i.e., equal likelihood of being above or below the true state). The Pacific Fishery Management Council applies a precautionary approach when adopting Annual Catch Limits in order to avoid exceeding the true and unknown Overfishing Limit (OFL) of the stock. Forcing the model to fit the WCGBTS age data results in a dramatic shift in the estimated stock size and status and would result in large changes of the estimated OFL and Acceptable Biological Catch (ABC) relative to the base model. Hence, the under-fitting of the age data in the base model results in a de-facto precautionary approach compared to forcing the model to fix the mean age of the WCGBTS (i.e., the estimated OFLs and ABCs from the base model would be well below those estimated from this alternative model).

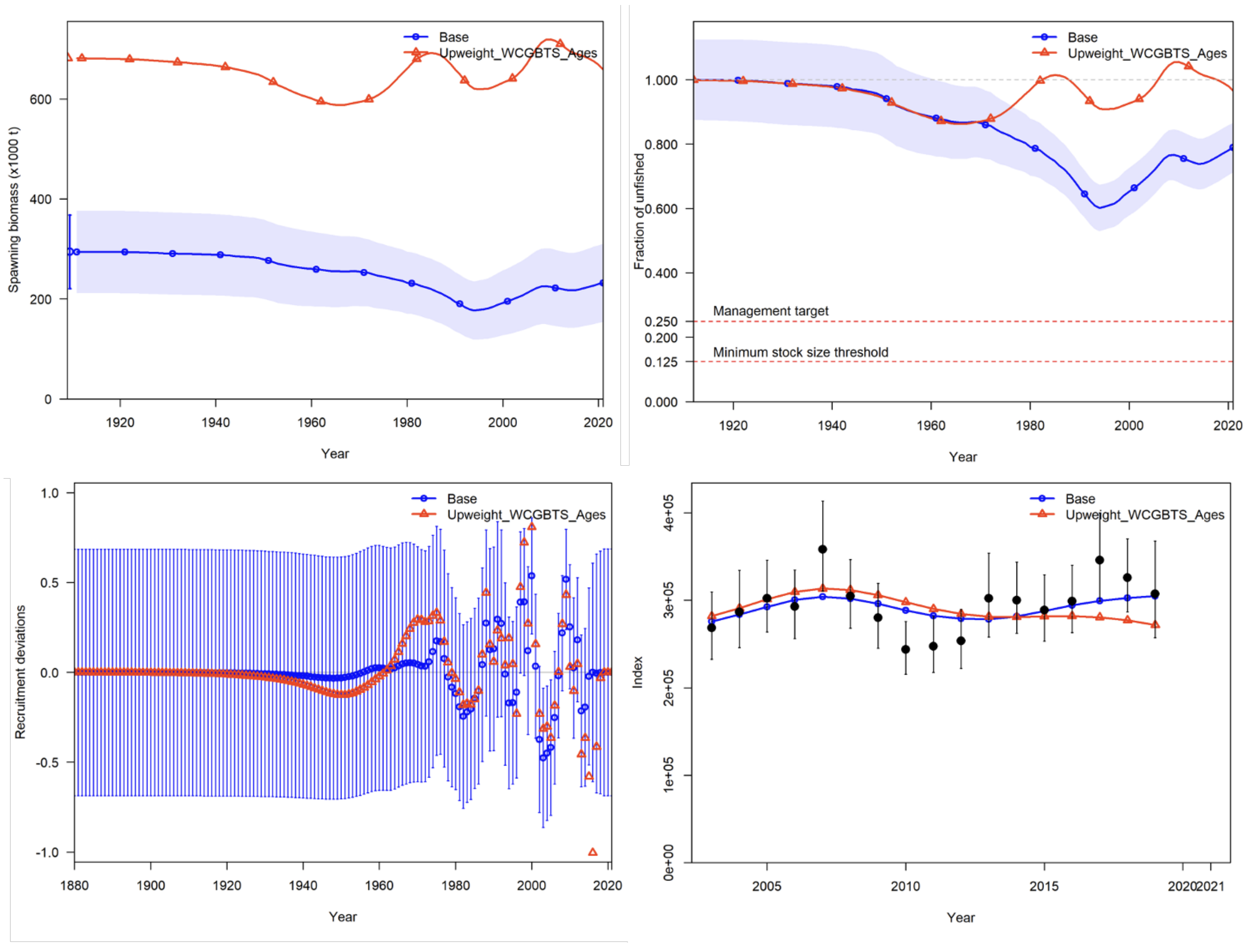

Figure 8. Comparison of spawning biomass (top left), stock status (top right), recruitment (lower left), and the fit to the WCGBTS index (lower right) for the base model and the sensitivity model where the WCGBTS mean age data are forced to fit better than in the base model.

Panel Conclusions:

Both the STAT and the panel agreed that these results did not provide evidence to support a change in model formulation. A possible mechanism for the lack of fit is a change in growth rates and size-at-age. Annual estimates of mean length-at-age were examined, and substantial differences were not evident. However, a small change in growth rates may be enough to account for the lack of fit to the WCGBTS age and length data. This issue requires future research (see below).

Request No. 4: Provide a likelihood profile of M including the priors in the base model.

Rationale: To explore a range of *M* estimates for states of nature in the decision table.

STAT Response: Since request 4 and 5 are closely linked, we will respond to each request in a single response.

Request No. 5: Provide an alternative run with M estimated with a tight prior (SE = 0.219).

Rationale: To explore a range of *M* estimates for states of nature in the decision table.

STAT Response: Since requests 4 and 5 are closely linked, we will respond to each request in a single response. The West Coast groundfish Terms of Reference (TOR) requests that decision tables identify the low and high states using one of the following options:

"One method bases uncertainty in management quantities for the decision table on the asymptotic standard deviation for the current year spawning biomass from the base model. Specifically, the current year spawning biomass for the high and low states of nature are given by the base model mean plus or minus 1.15 standard deviations (i.e., the 12.5th and 87.5th percentiles). A search across fixed values of R_0 are then used to attain the current year spawning biomass values for the high and low states of nature. Another method to provide reasonable alternative models uses the 12.5% and 87.5% quantiles of the likelihood profile of an estimated parameter (the value of 0.66 reflects the chi-square distribution with one degree of freedom) to determine the major axis of uncertainty. Expert judgment may also be used as long as it is fully explained, justified and documented."

Prior to the meeting the STAT explored the viability of defining low and high states for a potential decision table based on either the base model uncertainty or the profile across values of female natural mortality rate (*M*). Request 4 and 5 attempt to provide information to select *M* values to create the low and high state of nature in the decision table. Below is a table of changes in the total negative-log-likelihood (*NLL*) across values of female *M* around the median of the prior (0.108 per year):

Table 4. Changes in the negative-log-likelihood across female *M* values using either no-prior likelihood contribution, prior likelihood contributions from the default prior or a tighter prior (*SE* = 0.219) on female *M*.

Base Model: Profile across natural mortality with the prior likelihood excluded:							
	M = 0.07	*M* = 0.08	*M* = 0.09	*M* = 0.10	*M* = 0.108	*M* = 0.11	*M* = 0.12
NLL	1024.14	1021.75	1022.54	1025.44	1028.96	1029.98	1035.9
Δ Base	-4.82	-7.21	-6.42	-3.52	0	1.02	6.94
Request 4: Change in *NLL* with the prior likelihood included (Default Prior SE)							
	M = 0.102	*M* = 0.104	*M* = 0.106	*M* = 0.108	*M* = 0.110	*M* = 0.112	*M* = 0.114
NLL	1026.23	1027.08	1027.98	1028.96	1029.99	1031.07	1032.21
Prior	0.033	0.033	0.034	0.036	0.040	0.045	0.050
Δ Base	-2.73	-1.88	-0.98	0	1.03	2.11	3.25
Request 5: Change in *NLL* with the prior likelihood included with a tighter SE							
	M = 0.102	*M* = 0.104	*M* = 0.106	*M* = 0.108	*M* = 0.110	*M* = 0.112	*M* = 0.114
NLL	1026.26	1027.09	1027.99	1028.96	1029.99	1031.08	1032.24
Prior	0.060	0.044	0.037	0.036	0.043	0.056	0.075
Δ Base	-2.7	-1.87	-0.97	0	1.03	2.12	3.28

In initial explorations of the original profile (Base without prior contribution) the change in *NLL* across values of *M* resulted in a relatively steep profile where small changes in *M* resulted in changes in the *NLL* that would quickly exceed the 12.5% and 87.5% intervals around the base model (0.66 reflects the chi square distribution with one degree of freedom). Low and high states of nature based on M profiles did not seem to capture the range of structural uncertainties in the model, as evidenced through sensitivity analyses.

An alternative method presented in the TOR for defining low and high states of nature would be to identify the 12.5% and 87.5% quantiles around the final year spawning biomass. Using the asymptotic standard deviation for the current year spawning biomass from the base model the range of low and high spawning biomass in 2021 would range from 186,336 - 277,794 mt around the base model value of 232,065 mt, which corresponds to female M of 0.093 and 0.1144 per year. The guidance in the TOR clearly states that the low and high states should be identified using the asymptotic standard deviation from the base model. However, an alternative approach that could allow one to capture a larger uncertainty interval for models with low estimated model uncertainty would be to use the default category 1 sigma value of 0.50 to identify the 12.5% and 87.5% quantiles. Using this higher level of uncertainty, the range of low and high spawning biomass values in 2021 would range from 130,584 - 412,410 mt, corresponding to female M values of 0.084 and 0.126 per year. The spawning biomass and fraction-unfished trajectories from both approaches are shown below relative to the base model.

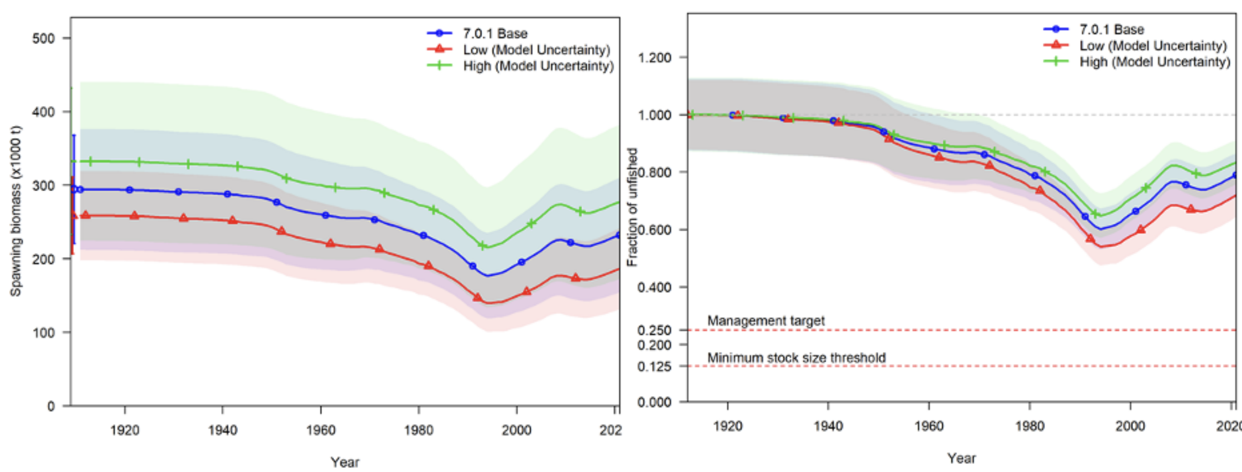

Figure 9. The estimated spawning biomass and fraction unfished from the base model and low and high states of nature determined based on the 12.5% and 87.5% quantile from the uncertainty around spawning biomass in 2021 from the base model.

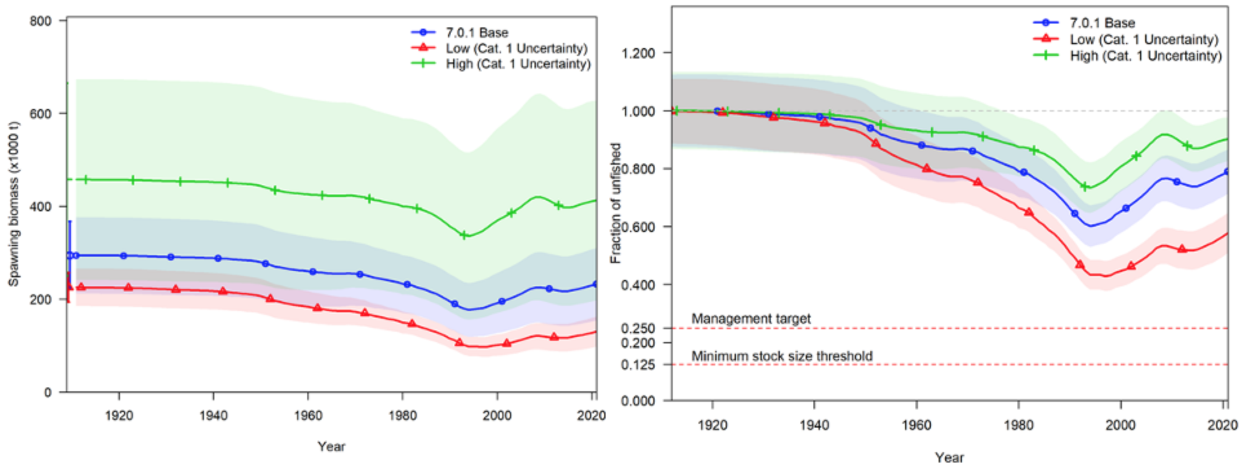

Figure 10. The estimated spawning biomass and fraction unfished from the base model and low and high states of nature determined based on the 12.5% and 87.5% quantile from the category 1 default sigma value of 0.5.

Panel Conclusions:
The STAT and panel agreed that the low and high states of nature in Figure 9 reflected the range of structural uncertainties in the model, as evidenced through sensitivity analyses. The WCGBTS catchability parameter estimate for the Low run was about 1.98, and the catchability (q) estimate for the High run was about 0.56. This range of q values seems plausible. The STAT and panel agreed that the female M values used to produce the Low and High runs in Figure 9 will be used to define low and high states of nature for the decision table.

Description of the Base Model and Alternative Models used to Bracket Uncertainty

The final ***base model*** incorporated the following specifications:

Model Structure	Base Model
Starting year	1911
Population characteristics	
Maximum age	60
Gender	2
Population lengths	5-60 cm by 1 cm bins
Summary biomass (mt)	Age 3+
Data characteristics	
Data lengths	8-60 cm by 2 cm bins
Data ages	1-60 ages
Minimum age for growth calculations	1
Maximum age for growth calculations	60
First mature age	0
Starting year of estimated recruitment in main period	1975
Fishery characteristics	
Fishing mortality method	Hybrid F
Maximum F	3.5
Catchability	Analytical estimate
CA Trawl Selectivity	Double Normal, Female Offset
OR/WA Trawl Selectivity	Double Normal, Female Offset
AFSC Slope Survey	Cubic Spline, Male Offset
Triennial Survey	Double Normal, Female Offset
NWFSC Slope Survey	Cubic Spline, Male Offset
NWFSC WCGBT Survey	Double Normal, Female Offset
Fishery time blocks	
CA Trawl Selectivity	1911-1984, 1985-1995, 1996-2020
CA Trawl Retention	1911-1947, 1948-2010, 2011-2014, 2015-2020
OR/WA Trawl Selectivity	1911-1984, 1985-1995, 1996-2020
OR/WA Trawl Retention	1911-2001, 2002-2010, 2011-2020

Alternative models to bracket uncertainty were based on the 12.5% and 87.5% quantiles around the final year spawning biomass. Values for female *M* were chosen so that model estimates of final year spawning output matched the 12.5% and 87.5% quantiles. These runs are illustrated in Figure 9.

Technical Merits of the Assessment

The STAR panel commends the STAT for their systematic and thorough documentation of the assessment data and model specifications, and their documentation of assessment model diagnostics and sensitivity analyses. Technical merits of the assessment model can be summarized as a size-structured model that integrates almost all relevant data about the productivity dynamics for the Dover Sole stock as a whole. Model fit diagnostics were good overall, as were model convergence diagnostics.

The STAT responses to the 2011 STAR panel Recommendations seemed thorough and were mostly complete (see Recommendations).

Technical Deficiencies of the Assessment

There were limited new fishery age data since 2010 available for use in this assessment. No otoliths collected in CA after 2009 were read, and limited otoliths collected in OR and WA were read. The number of otoliths collected and read/aged from WCGBTS was reduced by about 50% in 2019 (2 vessels versus the 4 vessels in earlier years) and was not conducted in 2020 due to the COVID-19 pandemic.

Areas of Disagreement Regarding STAR Panel Recommendations

There were no areas of disagreement between the STAT Team and the STAR panel, nor among the STAR panel members (including GAP, GMT, and PFMC representatives).

Management, Data, or Fishery Issues raised by the GMT or GAP Representatives During the STAR Panel Meeting

None.

Unresolved Problems and Major Uncertainties

Unresolved Problems

There is a potential that the low estimate of *M* (natural mortality rate) the model produces indicates some other model mis-specification. *M* for females was fixed at 0.108, the median of the Hamel prior, while *M* for males was estimated as an offset parameter relative to the female value. However, the model was highly informative about female *M* because a likelihood profile indicated a lower value (*NLL* minimized at 0.082 with a range between 0.07-0.095 all being less than 2 *NLL* units from the minimum), and the fixed value in the model had a significantly higher profile value. There were, though, some conflicting signals among various data sources. For example, the model estimate of *M* was 0.082 which seemed low given knowledge about the life-span of Dover Sole.

There is also some lack of fit to CA fishery length compositions during 2000-2020 (see Request

No. 2) and WCGBTS age compositions since 2010 (see Request No. 3).

Major Uncertainties

There are ontogenetic changes in the spatial distribution of Dover Sole that are different for males and females. The assessment estimates that females at large sizes are never fully selected by surveys or fisheries. Therefore, the assessment model has substantial cryptic biomass, especially for large female Dover Sole, that is not available to surveys or the fishery. There is also evidence that Dover Sole are distributed to the offshore edge of the WCGBTS (see Figure 11). The veracity of the cryptic biomass is a major uncertainty.

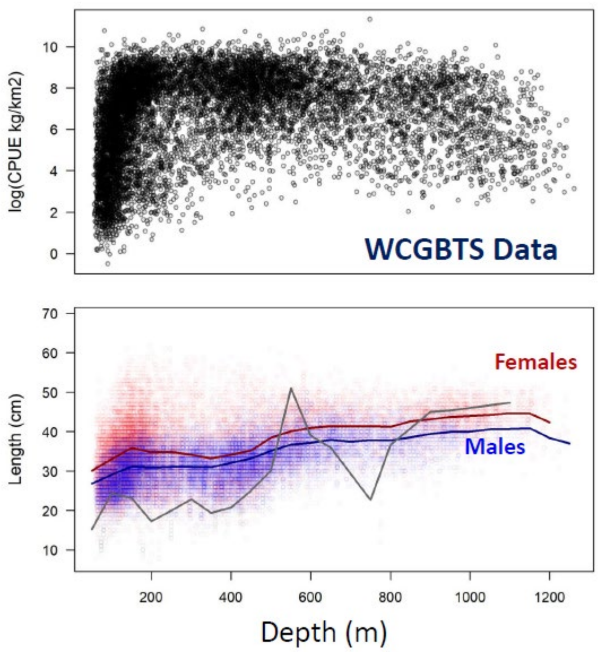

Figure 11. WCGBTS log catch-per-unit-effort (CPUE) by depth (top panel) and the mean length by sex (females - red, males - blue, unsexed - grey; bottom panel) across depths.

Uncertainty about the level of natural mortality rates translates into uncertain estimates of both status and sustainable fishing levels for Dover Sole.

Stock structure and spatial productivity dynamics are not well understood. Historical tagging studies conducted between 1948 - 1979 found limited adult movement in recaptured tagged fish, indicating that there is the potential for spatial variation in various productivity processes (recruitment, growth, maturation, and mortality rates). Some evidence of this was presented for maturation rates. However, there is the potential for substantial larval mixing during their long pelagic life. The WCGBTS index-of-abundance time-series did not differ substantially between CA, OR, and WA regions.

Recommendations for Future Research and Data Collection

Higher priority

Consider studies to verify the magnitude of the cryptic biomass.

Improve understanding of survey catchability, which could be provided via trawl escapement and herding studies. This is linked to a 2011 recommendation.

Improve size and age fishery sampling south of Pt. Reyes to investigate possible differences in age, size, and sex structure by depth and latitude. More generally, increase collection and reading of age compositions for the fishery to improve the application of an age structured assessment model.

Investigate the spatial and temporal dynamics, seasonality, and ontogenetic movement that could help to capture what is happening with Dover Sole regarding the distribution of ages in the bottom trawl survey. Investigate whether there are seasonal or annual environmental factors that could potentially change distribution patterns, and how those pattern changes overlap with the bottom trawl survey.

Lower priority

Consider using the AFSC Slope Survey age data as conditional age-at-lengths.

Conduct spatiotemporal analysis of maturity-at-length and length-at-age and examine if trends are significantly different. This is linked to a 2011 recommendation.

Conduct additional genetic and tagging studies to examine stock structure and connectivity of the stock across its whole range.

Consider if existing tagging information provides useful assessment information about growth and/or mortality rates.

Acknowledgements

The STAR panel thanks the public attendees, STAT, GMT, GAP, and Council representatives. The panel also thanks Jim Hastie for providing guidance on conducting virtual assessment review and Council staff for providing technical support.

References

Francis, R. I. C. Chris, and R. Hilborn. 2011. “Data Weighting in Statistical Fisheries Stock Assessment Models.” Canadian Journal of Fisheries and Aquatic Sciences 68 (6): 1124–38. https://doi.org/10.1139/f2011-025.

Hamel, Owen S. 2015. “A Method for Calculating a Meta-Analytical Prior for the Natural Mortality Rate Using Multiple Life History Correlates.” ICES Journal of Marine Science: Journal Du Conseil 72 (1): 62–69. https://doi.org/10.1093/icesjms/fsu131.

PFMC (2020) Terms of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2021 - 2022.