GROUNDFISH SUBCOMMITTEE OF THE SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON METHODS FOR STANDARDIZING HOOK-AND-LINE SURVEY INDICES OF ABUNDANCE AND METHODOLOGY REVIEW OF THE SPECIES DISTRIBUTION MODEL IN TEMPLATE MODEL BUILDER

The Scientific and Statistical Committee's Groundfish Subcommittee (GFSC) met via webinar on June 21-23, 2022 with representatives from the Northwest and Southwest Fisheries Science Centers, State Agencies, Academia, and the public, with two goals. First, to develop methods and best practices for preparing hook-and-line survey data and using these data in stock assessments. Second, to complete a methodology review of the Species Distribution Model in Template Model Builder (sdmTMB) for developing relative biomass indices in future groundfish stock assessments. Recommendations from this meeting will inform the 2023 Accepted Practices Guidelines for Stock Assessments, which is a compilation of guidelines for groundfish and coastal pelagic species stock assessment scientists. Finally, future research recommendations developed herein for 2024 forward address outstanding issues. The GFSC thanks the presenters to this workshop for thorough and informative presentations. The meeting agenda is attached as Appendix A, and a list of participants is attached as Appendix B.

California Collaborative Fishery Research Program Hook-and-Line Survey

The GFSC received presentations on survey design and operations from Dr. Jenn Casselle (University of California Santa Barbara) and on current methods for data analysis and use of these data in recent assessments from Dr. Melissa Monk (SWFSC). The GFSC and workshop participants discussed issues raised in past assessment reviews, how analytical progress to date has addressed these issues, and future research needs.

Dr. Jenn Cassell presented the survey design for the California Collaborative Fisheries Research Program (CCFRP). The survey is currently a statewide project based in fishing communities and supported by contributions from multiple partners at six universities that provides nearshore fisheries data from rocky regions for use by resource managers. The program started in 2007 with Moss Landing Marine Lab and Cal Poly San Luis Obispo providing central coast data. In 2017, the program expanded to provide statewide coverage with Cal Poly Humboldt and University of California at Davis Bodega Marine Lab in the north as well as the University of California at Santa Barbara Marine Science Institute and University of California at San Diego Scripps Institution of Oceanography in the south.

The survey targets Marine Protected Area (MPA) sites, each of which is paired with a reference location with similar habitat characteristics that is open to fishing. The reference sites are geographically proximate and bathymetrically similar to the MPA sites. Sampling in some locations has been inconsistent due to funding limitations that may continue into the future; new sampling could be implemented with adequate funding or prioritization. The program's summary report provides data for both MPA and reference sites.

Approximately four grid cells are randomly sampled within an MPA and its reference location during a sampling event. Sampling consists of three 15-minute drifts in each grid cell, which allows for three drifts in different locations within the grid cell. Grid cell selection was stratified using benthic habitat maps available prior to the California Seafloor Mapping Project (CSMP) and in consultation with Commercial Passenger (CPFV) operators. The survey expanded in 2017 coastwide in California as funding became available. Some sites were selected to allow for comparisons with other ongoing surveys in each area. An MPA is sampled up to four times a year, resulting in up to 24 cells sampled in paired MPAs and reference sites each year.

Data collected on the three drifts in each cell include angler number (for most programs), terminal gear type, start and stop times, GPS coordinates, species, fish length and fish condition. Terminal fishing gear is standardized and provided by the survey; these gears include swimbait, lingcod bars, two dropper loop hooks baited with squid, shrimp flies with squid and shrimp flies without bait. The terminal gears used vary among university partners. The fishing rods and reels are provided either by individual anglers or by the vessel and are not standardized. Use of standardized terminal fishing gears differ latitudinally, but data from baited shrimp fly are consistently available statewide, and all sites use a consistent set of three, or in one case four, of the five terminal gear types. Each of the three to 15 anglers are assigned a terminal fishing gear type and a station on the vessel for the duration of the trip and fish are placed in water-filled bins for data collection by scientific staff. Pre-COVID, the average was 12 anglers per vessel, decreasing to eight anglers per vessel during COVID. Anglers are permitted to retrieve their gear as needed. Angler activity is monitored so that the time with gear out of the water can be deducted from each angler's total fishing time, although that is not current practice when analyzing these data. The time out of the water is recorded at the level of the gear group station. Efforts are made to minimize the time an angler has gear out of the water during a drift and anglers are given a new baited rod to fish if needed, i.e., their current line is snagged or tangled.

The survey maximizes survival by crimping all barbs and processing fish in less than two minutes. Condition codes are recorded (e.g., crystalized eyes, barotrauma etc.) and fish are released with a descending device. Fish are measured to the nearest centimeter. In most cases, fishing occurs in less than 120 ft to minimize discard mortality. Fish in good condition and those over 24 cm are tagged with Hallprint T bar tags prior to release. Catch data includes angler number, species, total length, fish condition, tag number, start and stop times on the drift and GPS location. Environmental data include depth, cloud cover, habitat relief, wind speed/direction, swell height/direction, sea temperature and how many seals and sea lions are present. The vessels must move on some drifts due to marine mammal interference.

The QA/QC and data handling takes place for each monitoring group in a Microsoft Access database template distributed to each monitoring group, though an SQL database is in development. A statewide coordinator cleans the data and plots the drifts for each, then addresses issues identified and merges data across monitoring groups. Tag data include time at liberty, net distance moved and adult spillover to areas outside MPAs. CCFRP has also been collecting otoliths outside the MPAs north of Point Conception as time allows until 2021 and will begin collecting between five and 50 individuals per species (north and south of Point Conception) beginning in 2022.

While the survey did not have a major recapture program due to the lack of rewards and advertising, tagged fish that were recaptured during the survey were noted. However, it was likely that many of the fish recaptured outside of the survey go unreported. The limited tagging recaptures indicated that fish were larger and more abundant in MPAs. Adult fish home ranges appeared to remain small across the times at liberty, and fishing pressure and length of the time the MPA was established were the most important metrics for understanding differences inside and outside of MPAs.

Discussion focused on understanding the sampling and data analyses from the CCFRP. First, the methods for calculating fishing time were clarified. Three 15 minute drifts occurred in each grid cell, with science crew recording if any anglers had gear out of the water for more than a minute. If gear was out of the water for more than one minute, this time was recorded and is available. CCFRP staff passed anglers a new set of gear as needed to ensure that fishing continued. Next, the purpose of the tagging project was explained, which was to qualitatively understand the scale of movement over MPA boundaries. These data are not currently used in mark-recapture models, though it potentially could be used that way.

The source of the fecundity estimates were clarified; these relationships are from published literature. The source of temperature data was clarified; all temperature data are measured at the surface, not at depth. Though the maximum survey depths sampled were restricted to 36 m to minimize discard mortality inside MPAs. Finally, the angler number was clarified to mean the actual angler fishing and their assigned location to fish on the vessel deck. The survey and data analyses to date did not address variation in angler ability, although it was noted that personal rod and reel gear is limited to conventional rather than spinning gear, and in some cases, vessels provide the rods.

Dr. Melissa Monk presented a review of analyses of the CCFRP survey index developed from the CCFRP data, and its use in the most recent stock assessments. The most recent analyses for vermillion/sunset rockfish north of Point Conception found that the relative CPUE was lower outside the closed areas. The CCFRP survey does not cover the entire range of vermilion/sunset; vermilion are less abundant in the shallowest depths, but abundances were similar through surveyed depths for mid and deeper depth bins. Southern California sites were not included in the assessment due to only four years of data being available and the population south of Point Conception was modeled separately. CPUE was higher inside MPAs than outside and increased through time.

Vermillion/sunset rockfish length distributions by 5 fm depth bins indicated a similar distribution of lengths inside and outside MPAs, though Point Lobos showed differences in length composition, with larger fish compared to its reference site, which is consistent with this being one of the oldest MPAs. The CCFRP index was used only in the assessment north of Point Conception. The final model employed a weighted Bayesian negative binomial model including year, site, inside/outside MPA, four depth bins and a year:inside/outside MPA interaction. Resulting trends were weighted by the percent of rocky habitat inside and outside the MPAs from habitat mapping work conducted at the SWFSC using the CSMP data. The CCFRP survey index for the vermillion/sunset rockfish was weighted by habitat such that a 20% weighting was applied to abundances inside the MPA. Time blocking selectivity in 2017 accounted for changes in length data due to the CCFRP survey expansion.

Length distributions from selected areas used in the 2019 gopher/black and yellow rockfish assessment resulted from 20,000 encounters with gopher rockfish and 199 black and yellow rockfish in the four MPA/reference site pairs used in the index, for which 78% of the drifts resulted in encounters. Negative binomial and delta-gamma models were evaluated, examining the relationship between CPUE and year, depth, site and MPA vs reference site for each of the sites. Additional variance was allowed within the model framework, providing more latitude in fitting the indices based on observed variability. Comparison of indices from various sources showed similar trends to the fishery dependent indices.

Recent habitat mapping has allowed for evaluation of the type of habitat being sampled within each of the three 15 minute drifts within each cell. This comparison is important because comparable habitats in MPA and reference sites were determined by the participating boat captains at the start of the survey. Some of the original cells have been dropped in recent data analyses due to a lack of rockfish habitat. Comparison of depths sampled is also helpful to ensure comparable sites inside and outside of MPAs. Drift is used as the unit, with effort in angler hours determined from start to the end of the drift. Time spent re-baiting has not been subtracted in calculating the total number of angler hours sampled during a drift. Drifts are excluded if they are not entirely within the cell or if the time fished is less than 5 minutes.

Discussion focused on the potential effect of modeling the data at the angler level, the effect of gear saturation, the different gear types deployed in the survey, and whether or not the MPAs have larger fish due to locations that include better habitat rather than, or in addition to, restrictions on fishing within MPAs. Drs. Monk and Casselle agreed that modeling the data at the angler level was unlikely to change the survey index of abundance significantly. In terms of the potential for gear saturation, it was noted that anglers can retrieve and redeploy their gear at will during each 15 minute drift, and though there still is a limit to how many fish they can catch in that time period, it is somewhat less of an issue than for the Northwest Fisheries Science Center (NWFSC) Hook-and-Line Survey. While each survey site is sampled using three or four gear types, only one gear type out of the five, baited shrimp fly, is used across all survey sites in California. It is unclear if latitudinal differences in the bait types deployed influences observed spatial patterns. Most MPAs are at least 15 years old and were selected based on a large amount of community input. Researchers at Cal Poly (in an Master's Thesis) looked at the impact of habitat quality using onboard fisheries-dependent data collected before and after the establishment of most MPAs. It was suggested that prior patterns of fishing pressure had the largest impact on the current size structure, rather than differences in habitat. Of note was Bodega Head, which had been essentially fished out prior to the designation of MPAs.

There was discussion of whether a time block to model the data is needed for survey catchability (q) to account for the addition of new areas in 2017, though such a time block was not implemented in these assessments. Including area in the assessment and having a time block for selectivity may be sufficient. Further examination of the effects of the five terminal fishing gears, was noted as a research need, as was any impact of gear saturation. In this survey, fishing time is lower when catch is higher as anglers are reeling up fish more frequently resulting in more time with the hooks being occupied or out of the water.

Site selection for MPAs and reference sites may affect the relative trends observed as some MPAs subsumed older protected areas or were subject to differing fishing effort prior to protection, affecting apparent initial differences compared to reference sites. Evaluations of differences between MPA and reference sites should take into account the site history, fishing history, and time since protection. Site history can affect the CPUE and length compositions inside MPAs, and further analysis is needed.

The CCFRP is a student-oriented program that has supported many undergraduate and Master's thesis projects and that the Oregon marine reserve hook and line program is modeled after the CCFRP. Future research could address research and data needs identified during the workshop. The GFSC and workshop participants discussed the following CCFRP specific issues raised in past assessment reviews and during this workshop.

- *Should survey selectivity and a survey q time block be modeled using a time block to account for the spatial expansion of the survey from central CA to the entire CA coast?*
  The consensus was that survey selectivity should use time blocks to account for changes in spatial coverage from the CCFRP, and that using a time block on survey q to model the data should be explored.

- *Should CCFRP index standardization models include a random site effect, or other random effects?*
  The consensus was that models including a random site effect, and perhaps other random effects as appropriate, should be explored as future research. Random effects can stabilize a model, and random effects for sites within each survey region are appropriate as sites are chosen randomly. The most recent vermillion/sunset rockfish assessment began to investigate implementing random effects. There are no accepted practices at this time.

- *Should CCFRP data be modeled at the drift level or the fisher level?*
  The consensus was that drift level modeling for the CCFRP is most appropriate.

- *What is the future of the CCFRP survey?*
  The GFSC supports the continuation of the CCFRP as these data fill a known gap in other sampling programs. The CCFRP survey is the only fishery-independent survey available for nearshore rockfish sampling the nearshore rocky reef habitats. Current funding from the California Ocean Protection Council extends through 2023, but future funding is uncertain. If additional funding were available, it may be possible to expand the survey beyond the current depth range in sampling areas outside of the MPAs to collect biological samples throughout the depth distribution of more species. The permitting process for biological sampling inside the MPAs is rigorous and may be permitted if targeted questions address specific MPAs. The GFSC supports the continued collection of biological samples from CCFRP, agreeing that a better understanding of age structure in and outside MPA was an important issue for many assessments. CCFRP biological sampling that began about four years ago provided up to 90% of data for a recent gopher rockfish project.

- *Is there any additional guidance for inclusion of CCFRP Hook-and-Line survey data for the 2023 assessment cycle, specifically for copper rockfish in Southern California?* Discussion focused around the very different species assemblages in Southern California, and the fact that copper rockfish are only in high abundance at one of the four MPAs sampled in southern California. The consensus was that these data are important to explore for the 2023 copper rockfish assessment.

Northwest Fisheries Science Center (NWFSC) Hook-and-Line Survey

The GFSC received presentations on the survey design and operations from Mr. James Benante (PSMFC) and Mr. John Harms (NWFSC) and on current methods for data analysis and use of these data in recent assessments from Mr. John Wallace (NWFSC) and Dr. Tanya Rogers (SWFSC). Dr. Peter Kuriyama (SWFSC) presented recent research on gear saturation and interspecies interactions. Dr. Owen Hamel (NWFSC) and Ms. Danni Shi (University of Washington) presented recent research on using survival analyses to produce indices of abundance using the NWFSC Hook-and-Line survey data. The GFSC and workshop participants discussed issues raised in past assessment reviews, how analytical progress to date has addressed these issues, and future research needs.

Mr. James Benante presented survey design and operations for the NWFSC hook-and-line survey and Mr. John Harms was available to answer questions. The NWFSC H&L survey was piloted in 2003 using stratified random sampling design targeting rocky habitat. However, nearly 50% of sites selected were on soft bottom and yielded zero structure-associated species. To improve site selection, a hybrid fixed/random station design was adopted in 2004, and ultimately a fixed-station-only design by 2007. Sites within the Cowcod conservation area (CCA) were added in 2014. The NWFSC Hook-and-Line survey deploys standardized rod and reel gears and fishing effort (number of anglers, hooks, fishing time).

Data from the NWFSC Hook-and-Line survey have been used in 18 stock assessments for 10 species since 2005 (the first assessment to include these data was the 2005 vermilion rockfish assessment that was not endorsed by the SSC for management use). Mr. John Wallace presented a current analytical approach and its application in the bocaccio and cowcod assessments. Survey presence and absence data were analyzed at the hook level using a GLM. Oceanographic environmental data, such as water temperature, salinity, dissolved oxygen, and turbidity were not available to be included as covariates in the GLM model. CTD data are in the process of being made available, which will allow for bottom water temperature to be evaluated in future models.

Dr. Tanya Rogers presented a case study on the treatment of the NWFSC Hook-and-Line Survey in the 2021 vermilion/sunset rockfish assessment. The presentation focused on the catch (abundance) data and index standardization methods. Analysts chose to model the data at the drop level (a drop comprises 3 lines and 15 hooks) and explored several error distributions (binomial, logit normal, negative binomial, and delta-gamma), which were evaluated using posterior predictive checks. Analysts chose several covariates to include (year, site, depth, and drop number), noting that covariates will only affect the year effects if sampling is biased across years, and using AIC to select covariates when sample sizes are large tends to select for complex models. Posterior predictive checks revealed that the logit normal distribution provided the best representation of the variance. The binomial distribution underestimated variance while the negative binomial and delta-gamma overestimated it. The mean value of the index in each year was highly consistent under different assumptions about the distribution of the variance, but the magnitude of the variance was sensitive to the distribution chosen. One unresolved issue identified was hook saturation, which may lead to CPUE of vermillion/sunset rockfish being affected by catch rates of other species. Dr. Rogers also noted that guidance is needed on how or whether to interpolate or extrapolate to unsampled sites before generating an index and whether spatial models should be explored in the future.

The GFSC supports the approaches used by the analysts to generate an index in this case study. In particular, using posterior predictive checks to explore the consequences of alternative choices of error distributions was revealing. The GFSC recommends this approach be explored for future assessments that use these data to generate an index, noting that different species may lead to different variance assumptions. The GFSC also discussed the potential role of aggregation and species interactions to affect the performance of the CPUE index. It was noted that the drift effect has been removed for some species to account for this type of variation, and this may warrant further investigation in future assessments.

Dr. Peter Kuriyama presented a simulation study he conducted that investigated the influence of three potential sources of bias in hook-and-line survey data: survey design, gear saturation, and multispecies interactions (Kuriyama et al. 2019). The structure of the simulation study was inspired by the design of the NWFSC Hook-and-Line Survey, but findings are applicable to hook-and-line surveys more generally. Simulations explored changing numbers and distribution of fish, the number of sites sampled, and whether sites were chosen at random or based on density. All simulations showed some evidence of hyperstability, where CPUE is less sensitive to changes in population sizes at large relative sizes compared with small relative sizes. Assuming a patchy distribution of fish, which was the closest approximation to the true distribution of most species sampled by the NWFSC Hook-and-Line Survey, resulted in the greatest degree of hyperstability. Sampling larger numbers of sites resulted in smaller relative error in CPUE but had little effect on hyperstability. Under a patchy distribution, random sampling resulted in underestimation of CPUE and density-based sampling resulted in overestimation of CPUE. The study conclusions were that hyperstability is likely to occur with a hook and line survey with a similar design to the NWFSC Hook-and-Line Survey due to gear saturation. Therefore, while changes in population size could be detected when relative population size is small, this methodology could not detect changes at high relative stock sizes or total rockfish abundance. Density-based sampling led to more hyperstability in CPUE, but also increased the ability to detect changes, and particularly declines, in population size.

The GFSC discussed the implication of these simulation results with respect to interpreting CPUE indices from the NWFSC Hook-and-Line Survey. It was noted that it seemed counterintuitive that increasing the number of hooks from 75 to 600 did not reduce the hyperstability in the study and Dr. Kuriyama postulated that, theoretically, the gear saturation effect could be eliminated if the number of hooks was adequately increased. However, during the development of the NWFSC

Hook-and-Line Survey there were concerns about the survey catch impacting the cowcod population, which limited the number of hooks deployed.

Dr. Owen Hamel presented an analysis conducted by Ms. Danni Shi with his guidance to use survival analysis, an approach from biomedical research, which could circumvent the challenges posed by hyperstability. The approach leads to a model that describes how fish are caught in each unit of time. The "survival" of hooks is modeled as a function of the "hazard rate", the rate of a hook catching a fish, given it has not yet caught a fish. The hazard rate could then be modeled as a function of one or more linear predictors. The analysis presented focused on bocaccio and used ridge regression to select covariates. It was noted that the index generated using survival analysis more closely matched trends in biomass from the 2017 fitted assessment model than did the index generated using the standard methods in for that assessment.

The GFSC supports further research using survival analysis as it appears to be a promising approach. Future work should consider using methods that demonstrate the significance or uncertainty of estimates of the regression coefficients and diagnostics of overall model fit. A simulation study to test the performance of this estimator based on an individual-based model would be a useful next step and would help in evaluating its potential to address the hyperstability.

The GFSC and workshop participants discussed the following issues with the NWFSC Hook-and-Line survey, which were raised in past assessment reviews and during this workshop.

Should Cowcod Conservation Area (CCA) sites be aggregated with other sites sampled since the survey's outset into a single index, or should these be two separate indices? Should this be done for all species in the survey?
The 2019 cowcod assessment explored interactions between inside and outside the CCAs for NWFSC hook-and-line indices, finding that for cowcod the difference in indices with and without CCAs was not large, so the assessment used one index based on all data. Stepwise AIC model selection identified a model with year, site, and hook number effects as the best model. The 79 CCA sites added to the sampling frame since 2014 contain a somewhat larger proportion of deep sites. The prevailing oceanography in the CCAs and the relative proportion of various habitat types is quite likely different among the CCA sites compared to the original sites and may support different segments of some species' life histories. There are also indications that relative population trends for some species are not always in synchrony inside and outside the CCAs. Approaches that combine the two areas into a single index should account for these issues.

The GFSC agreed that the ideal approach was to create a single index, although a first step would be to create separate indices for the sites inside and outside the CCAs. If the indices are similar, how they are combined should not impact the assessment results. However, if the trends for the indices differ, they should be combined by weighting the two indices by the best measures of habitat area (i.e., using CSMP data). It was recognized that estimates of habitat area will be more reliable for nearshore stocks and for areas north of Point Conception, and that in some cases the available habitat information may not support a combined index. In this case the GFSC suggests conducting stock assessment model sensitivities to each index and to alternative weighting approaches to combining the two indices.

How should survey selectivity be modeled, including the need to account for possible changes to selectivity with the addition of survey sites inside the CCA?

The 2019 cowcod assessment explored a selectivity time block for the period starting in 2014 through the model end year, 2018, with selectivities estimated using 3-parameters of a dome-shaped selectivity curve for both time periods, and estimated the size at peak selectivity, the slope of the ascending limb, and the slope of the descending limb. The "-999" option was used for terminal selectivity, estimating this quantity based on the decay rate of the (estimated) descending limb.

The GFSC agreed that the length-composition data for inside and outside the CCAs should be pooled in the same way as the index data and analyzed with a selectivity time block beginning in 2014 through the model end year.

How should overdispersion in the NWFSC Hook-and-Line index be accounted for?
The GFSC previously recommended that confidence intervals for predicted catch rate values be computed and included in plots of predicted vs observed catch rates to determine whether the 95% confidence intervals overlap the 1:1 line in 95% of the cases. This was to explore whether the statistical model, which assumes independent observations, is capturing overdispersion in the data.

The GFSC noted that 95% prediction intervals (maximum likelihood) or 95% posterior predictive intervals (Bayesian analysis) are more appropriate than confidence intervals when evaluating whether there is overdispersion and recommended that future analyses use them. The graphs provided by Mr. John Wallace suggested poor fits to the 2010 data, with the many points near the origin, making the evaluation of overdispersion difficult. It was noted that 2010 had the lowest catch rates of any survey year, with 28% of hooks having fish.

General discussion on modeling hook and line survey data

The GFSC and workshop participants discussed the following general modeling issues raised in past assessment reviews and during this workshop.

<u>*Modeling Approaches*</u>
Should hook and line data be modeled using a binomial model or a hurdle model? See binomial model implemented by John Wallace for the NWFSC Hook-and-Line. This topic was first discussed during a 2012 CIE Review.

Applying a hurdle model to CCFRP data for vermillion/sunset rockfish led to poor outcomes while the use of a negative binomial distribution for the entire CCFRP data set performed adequately. This is because the hurdle model needs to use the data at the angler level (drop with time on the water as an offset), which may not be appropriate given the CCFRP survey design. A hurdle model is possible for the NWFSC Hook-and-Line survey given that the data may be modeled at the hook level. Hurdle models and variants thereof that impose maxima on the positive catches should be explored for the NWFSC Hook-and-Line survey.

The GFSC suggests that hurdle models and several possible error models should be explored for the hook and line survey data sets, such as the binomial, negative binomial, delta gamma and logit normal. Irrespective of the error model chosen, the aim should be to minimize underestimation of uncertainty.

What level of data aggregation should be used to model hook and line data? For the NWFSC Hook-and-Line survey two approaches have been implemented, at the hook level (Mr. John Wallace approach) and the drop-level (Dr. E.J. Dick (SWFSC) approach). Though never used in an assessment, the NWFSC Hook-and-Line survey could be modeled at the site-level (all 75 hooks), which has also been proposed. The CCFRP Hook-and-Line survey data are modeled at the site level.

The catches by hook are correlated within each drop. Similarly, catches by drop are correlated within a site. The NWFSC Hook-and-Line index for vermillion/sunset rockfish is fairly robust to whether the data are analyzed at the hook vs drop level, but the variance is greater when the data are analyzed by drop, as expected given the pseudoreplication of hooks (even if the catch probability by species varies by hook position). Some of this is accounted for if additional variance is estimated within the stock assessment. Nevertheless, the GFSC recommends considering various models (e.g., by hook, by drop, and by site) for both hook and line surveys as well as estimating additional variance when conducting the assessment if the standardization model does not reproduce the observed variance in the data.

Should survival models be used to generate indices of abundance for hook and line data? See Ms. Danni Shi's 2018 internship final report. This approach uses soak time.
This is a promising approach, but further analysis and exploration is needed prior to its use in an assessment. The performance of this approach could be explored using an individual-based simulation of multiple species.

Should spatial models be used to generate indices for hook and line data? See Thorson et al., 2015, which uses a spatial Gompertz model for H&L survey data.
The assessment of 2021 vermillion/sunset rockfish discusses the use of spatio-temporal models to predict observations from stations not observed in a particular year and to incorporate the CCAs into the entire time-series. Advantages of spatial models include being able to predict beyond the fixed stations and to make smooth predictions for stations that have no samples. The GFSC encourages exploration of spatial models, recognizing the importance of exploring the regression diagnostics. The utility of spatial models for fixed-station survey designs (e.g., NWFSC Hook-and-Line, CalCOFI) should also be examined.

Model Covariates
How should soak time be modeled to generate indices for hook and line data? See the 2013 SSC review of data-moderate assessments and the survival analysis work from 2018. For several species, soak time (also referred to as fishing time) is the second-most significant explanatory variable after site effect. Identifying a defensible modeling approach that includes this variable may improve year-to-year resolution in abundance indices as well as increase the range of potential stock sizes the survey is able to effectively index.

Soak time could be addressed using survival models. The CCFRP is using a fixed amount of time (subject to the time taken to raise fish) but in the NWFSC Hook-and-Line survey soak time relates to the catch rate (i.e., is itself a response variable). The CIE review recommended, and the GFSC concurs that the soak time approach of Ward et al. (2004) should be explored.

How should gear/hook saturation be modeled to generate indices for hook and line data? See Noel Cadigan's 2012 CIE review (pp 9-23). See Dr. Peter Kuriyama's paper. See 2021 vermillion/sunset rockfish assessment.
See prior discussion of gear saturation. It was noted that the survival model could potentially address this.

Similarly, once water temperature from CTD casts are made available they can be analyzed to account for seasonal or spatial variability potentially affecting metabolic demand and catch rates.

<u>*Other Modeling Issues*</u>
How should model selection be done for hook and line survey data? Past methods used include AIC, and posterior predictive distributions.
Posterior predictive checks and regression diagnostics should be used to identify those models that provide adequate fits to the data. Metrics such as AIC (maximum likelihood) or WAIC (Bayesian methods) should be used to select among models given they provide an adequate fit to the data. With respect to spatial models, the standard two AIC units approach for distinguishing adequate from inadequate models is not necessarily as robust compared to non-spatial models so care should be taken when using AIC for spatio-temporal model selection.

What modeling methods best characterize the variance seen in the hook and line survey data sets?
See responses to questions under modeling approaches.

Current methods implicitly assume equal weighting for each survey site. Does this need to change, and, if yes, how?
Equal weight is currently given to all sites inside and outside of MPAs in the NWFSC Hook-and-Line Survey data analyses, whereas CCFRP data analyses are already weighted by habitat. The sites inside and outside the MPAs should be weighted using habitat data, but this is only possible if adequate habitat data are available. It was noted that previous analyses using CCFRP indicate that all rocky areas are not equal so detailed habitat information is preferable. Spatial models implicitly model sites and should use habitat as a covariate when modeling hook and line survey data.

Some of the abundance indices used in the assessment may not contribute to estimated stock status in a substantive way (raised in the 2015 bocaccio assessment). Is there an objective procedure for selection of abundance indices based on information content (or a need for one)? If the survey index agrees with other information, then it doesn't "contribute". If a survey index has a very high coefficient of variation (CV), then it doesn't contribute in a substantial way either, but what is the harm (unless none of the information from a survey contributes...)?
There may be value in evaluating an index for information context (and distinguish uninformative indices due to larger CVs from uninformative indices due to saturation). It was noted that some hook-and-line indices may be informative for some regions but uninformative for others.

Species Distribution Model in Template Model Builder (sdmTMB) Methodology Review

The GFSC received presentations on Species Distribution Model in Template Model Builder (sdmTMB) and contrasts between sdmTMB the currently approved Vector Autoregressive Spatial Temporal (VAST) tool from Dr. Eric Ward (NWFSC), and comparisons between survey data analyses for a suite of species using sdmTMB and VAST from Drs. Chantel Wetzel (NWFSC) and Kelli Johnson (NWFSC). The GFSC and workshop participants discussed the merits of sdmTMB as well as the species-specific comparisons between sdmTMB and VAST.

Dr. Eric Ward presented an overview of sdmTMB. Spatial modeling, in general, attempts to estimate spatial fields over complex surfaces given limited observations. A Gaussian Random Field (GRF) model is one approach to make inferences. At its heart, GRF models are linear mixed effects models. They have the benefit of being easily implemented in R but suffer from long computational times when dimensionality becomes large (>>50 dimensions). Stochastic Partial Differential Equation (SPDE) is an approach to deal with large dimensionality problems by estimating random effects at nodes. However, higher resolution requires increasing computational times.

Integrated Nested Laplace Approximation (INLA) is a Bayesian estimation of SPDE models via Laplace approximation. INLA requires a steep learning curve and, while faster than MCMC, run times are long with high dimensionality. VAST models have much faster run times and use marginal maximum likelihood estimation. There are multiple methods to implement spatial models (INLA/inlabru, mgcv, VAST, sdmTMB) and all can be cast as General Linear Mixed Models (GLMMs). These GLMMs can include main effects, random intercepts, spatial or temporal covariates, and offsets.

VAST and sdmTMB are both implementations of a spatial modeling framework that can produce identical results but also have different features and advantages. VAST allows multivariate responses. This feature could be added to sdmTMB but there are no current plans to do so. The absence of this feature will not limit use for West Coast stock assessments. Conversely, sdmTMB contains built-in routines for cross validation and model ensembling that could be advantageous when fitting many potential models to a dataset. Beyond differences in features, sdmTMB has several advantages over VAST. The programming for sdmTMB is more stable which should result in less time for model implementation than for VAST, which often requires significant coding changes between versions. Accessibility for sdmTMB should be much greater due to a familiar R syntax. Efficiency should be much greater because the workflow is broken into multiple pieces. This allows model fitting, which is generally fast, to be completed prior to prediction, which is often slow in a separate step. Diagnostics and plotting have many options to visualize model fits in sdmTMB.

Dr. Chantel Wetzel presented a spatiotemporal model comparison between VAST and sdmTMB to calculate indices of abundance for species collected by the NWFSC West Coast Bottom Trawl (WCGBT) survey. Comparisons from a total of eight species were conducted, with the results from three species (arrowtooth flounder, sablefish, and widow rockfish) presented for brevity. These species represent a broad range of life histories. Both VAST and sdmTMB are highly flexible modeling approaches and model parameterizations were identical. Three distributional assumptions were compared (delta-gamma, delta-lognormal, and tweedie). For the arrowtooth flounder model with a delta-gamma distribution, inclusion of a vessel-year random effect did not produce any differences between VAST and sdmTMB. Similarly, when no vessel-year random effect was included, there were no differences in model outputs between VAST and sdmTMB for arrowtooth flounder when a delta-gamma distribution was examined. An identical pattern where all parameters and confidence limits overlap was seen between VAST and sdmTMB when applied to arrowtooth flounder, sablefish, and widow rockfish with both delta-gamma and delta-lognormal distributions. Conversely, there was a slight but noticeable difference at the starting and ending values between model implementations in VAST and sdmTMB. This difference arises due to slight differences in model assumptions for the Tweedie distribution with sablefish. VAST assumes that effort affects the number of fish caught while sdmTMB assumes that effort affects the biomass of fish caught. This difference in assumption has been identified as an area of future research.

Three model implementations with sdmTMB were compared to a Bayesian binomial index standardization model for NWFSC Hook-and-Line survey data used in the recent vermillion/sunset rockfish assessment. The three sdmTMB model structures were (a) a negative binomial model with year and site fixed effects, (b) a negative binomial model with year and site fixed effects with an angler random effect, and (c) a delta-truncated negative binomial model with year and site fixed effects with an angler random effect. Both negative binomial models were nearly identical while the delta-truncated negative binomial produces marginally lower estimates. Each of these models showed a similar trend as the Bayesian binomial implementation in the assessment with the most notable differences occurring at the start and end of the data series. Inclusion of the best fitting model index, the delta-truncated negative binomial, had no impact on the vermillion/sunset rockfish assessment when substituted for the Bayesian logit model index (as described above in the Northwest Fisheries Science Center Hook-and-Line survey section from the analysis presented by Dr. Tanya Rogers).

At the time of the workshop, an appropriate extrapolation grid for the NWFSC Hook-and-Line survey area was unavailable. Ideally, an extrapolation grid would be available for creation of a spatial and or spatio-temporal index of abundance for the 2023 assessment cycle. However, existing habitat data (e.g., rocky reefs versus sandy bottom) that would be incorporated in an extrapolation grid are limited outside state waters south of Point Conception. It is important to note that an extrapolation grid is not needed to determine whether data support spatial models but will be needed to turn model estimates into an index.

One key advantage to sdmTMB is that the same analytical platform can be used to model data with varying complexity ranging from simple GLM to complex spatial and spatio-temporal analyses. This flexibility can allow a range of datasets to be modeled using sdmTMB rather than requiring users to move between modeling platforms (e.g., VAST, traditional GLMs).

The GFSC endorsed the use of sdmTMB for index standardization in 2023 assessments and beyond. The sdmTMB performed as expected with results similar to VAST, with the exception of the small differences in the Tweedie distribution, due to whether effort was assumed to affect biomass or numbers. Further examination of the differences for the Tweedie distribution was identified as an area for future research. Appropriate methods for estimating error distributions is also a subject for further development. Estimates of uncertainty around indices of abundance may not encompass the full extent of the uncertainty due to process error, particularly for hook-and-line data, so estimating additional variance within the stock assessment model may be necessary.

Composition standardization using VAST can be conducted in consultation with Dr. James Thorson (AFSC) and should be explored as a research topic after the 2023 assessments, including comparisons between model- and design-based composition data expansions. Model- based expansions of composition data would be more consistent with methods used to produce indices of abundance.

Accepted Practices

The GFSC discussed accepted practices with respect to hook and line surveys in general and for each of the surveys discussed during the workshop. With respect to the CCFRP survey, the GFSC recommends:

1. Time blocks in selectivity and survey *q* should be considered starting in 2017 to account for expansion of the survey area.
2. Drift level modeling for the CCFRP is most appropriate.
3. This survey can be explored for use in the next copper rockfish assessment in Southern California, though there is only one sampling site in that region.

General to both surveys and index standardization, the GFSC recommends:

1. Capture as much of the realistic uncertainty as possible in the index standardization approach, noting that an additional variance term will still need to be explored when including the index in assessments. The additional variance term should reflect variability in the index rather than poor fit of the model to index trend.
2. Where applicable, generate a single index that integrates habitat inside and outside of closed areas (such as the CCA) by weighting by the area of habitat inside and outside of closed areas. The GFSC notes that habitat quality differs across types of rocky habitat and the quality and availability of habitat data may differ across state and federal waters.
3. If habitat area is not available, create separate indices for inside and outside (currently or recently) closed areas. In that case, sensitivity analyses should be conducted in the assessment to characterize the relative influence of the two indices.
4. Pool length composition data (with appropriate weighting) across inside and outside closed areas and analyze with a selectivity time block when shifts in the areas covered occur (e.g., 2014 for the CCAs and 2017 for CCFRP). Note that CCAs will likely be open to fishing in the future so selectivity may need to change again.
5. Investigate and characterize overdispersion and the consequences of different assumptions about the error structure.
6. Use posterior predictive checks, in particular with respect to fitting Bayesian hurdle models.
7. Explore multiple error models, such as Binomial, Negative Binomial, Delta-gamma, logit normal, or others as appropriate. The GFSC supports exploring the use of hurdle models as well, noting they may not be appropriate or computationally feasible for all species.
8. Consider models that use alternative levels of data aggregation (e.g., hook, drop/drift, and site) to try to understand the consequences for the variances estimated using these approaches. Note that angler effect was included in the Bayesian binomial model (John Wallace's model) for the NWFSC Hook-and-Line survey and was influential for bocaccio.

The current recommendation was to not model CCFRP at the angler level, which would only be relevant if an individual angler were used as the effort. Furthermore, some programs do not track individual anglers (e.g., Humboldt).

The GFSC discussed accepted practices for sdmTMB and makes the following recommendation:

1. Endorse sdmTMB for use in index development.

Future Research Recommendations

The GFSC suggests the following areas for future research for hook and line survey data:

1. Explore the use of random effects in the model-based index standardization.
2. Survival models are a promising approach, but simulation studies are needed to better understand the performance of this estimator.
3. Apply the approach to accounting for soak time previously recommended in the 2012 CIE review of the NWFSC Hook-and-Line Survey.
4. Develop spatial model-based indices for hook and line survey data, including an examination of effectiveness for fixed-station vs random sampling designs.
5. Explore NWFSC Hook-and-Line Survey CTD data in standardizing indices once it is available, with a particular emphasis on water temperature.
6. Explore modeling the CCFRP data with random effects for the site, and perhaps other covariates.
7. Explore delta GLM/hurdle models.
8. Support continuing the CCFRP survey with long-term funding, the collection of biological samples, and involvement of undergraduate and Master's Thesis projects.

The GFSC discussed future research needs for sdmTMB and makes the following recommendations:

1. Explore the development of extrapolation grids and the quality of habitat data within the NWFSC Hook-and-Line survey area, as feasible.
2. Explore multivariate responses (e.g., similar to the existing implementation in VAST) in the NWFSC Hook-and-Line Survey data to better account for species interactions and to derive model based age and length compositions for stock assessments.
3. Explore the appropriateness of the Tweedie distribution assumptions of VAST and sdmTMB using numbers or biomass.
4. Develop an approach to standardize compositional data to match the indices developed using sdmTMB.

References

Ward, P., Myers, R.A., and Blanchard, W. (2004). Fish lost at sea: the effect of soak time on pelagic longline catches. Fish. Bull. 102: 179–195.

Appendix A – Meeting Agenda

SSC Groundfish Subcommittee

Online Meeting

June 21-23, 2022

Instructions for how to connect to the Scientific and Statistical Committee's (SSC) webinar will be posted on the Pacific Fishery Management Council's (Council's) website prior to the first day of the meeting.

SSC meetings are open to the public and public comment periods have been scheduled for each day. Additional public comments may be taken at the discretion of the Chair. Dates and times on this agenda are subject to change once the meeting begins. Committee member work assignments are noted in parentheses at the end of each agenda item. The first name listed is the discussion leader and the second, the rapporteur. Note, dates and times not specified for discussion and/or presentations will be allocated to drafting and reviewing of the workshop report.

Tuesday, June 21, 2022 – 8 AM

A. Administrative Matters

1. Roll Call, Introductions, Announcements, etc. — Melissa Haltuch
2. Review and Approve Agenda and Workshop Scope

B. CCFRP Hook and Line Survey

1. Survey design and operations — Jenn Casselle
   (8:30 a.m.; **Hamel, Budrick**)
2. Current analytical methods — Melissa Monk
   (8:55 a.m.; **Hamel, Budrick**)
3. Vermillion/Sunset Rockfish Assessment Case Study — Melissa Monk
   (9:20 a.m.; **Hamel, Field**)

BREAK (9:45 – 10:00 a.m.)

3. CCFRP specific discussion
   (10:00 a.m.; **Hamel, Field**)

C. NWFSC Hook and Line Survey

1. Survey design and operations — John Harms
   (10:45 a.m.; **Haltuch, Tsou**)
2. Current analytical methods — John Wallace
   (11:10 a.m.; **Haltuch, Tsou**)

3. Cowcod Rockfish Assessment Case Study — John Wallace
(11:35 a.m.; **Haltuch, Tsou**)

LUNCH (12:00 – 1:00 p.m.)

C. NWFSC Hook and Line Survey, Continued

4. Vermillion/Sunset Rockfish Assessment Case Study — Tanya Rogers
(1:00 p.m.; **Haltuch, Marshall**)

5. Gear saturation and interspecies interactions — Peter Kuriyama
(1:25 p.m.; **Haltuch, Marshall**)

6. Survival analysis — Danni Shi and Owen Hamel
(1:50 p.m.; **Haltuch, Marshall**)

7. NWFSC H&L specific discussion
(2:15 p.m.; **Haltuch, Punt**)

BREAK (3:00 – 3:15 p.m.)

8. Discussion of common H&L survey issues
(3:15 p.m.; **Hamel, Punt**)

9. Identify clarifying requests, continuing discussion items, and wrap-up
(4:15 p.m.; **Haltuch, Schaffler**)

PUBLIC COMMENT PERIOD
4:30 p.m. (or immediately following Agenda Item C.9)
Public comments are accepted at this time.

Wednesday, June 22, 2022 — 8 AM

D. Methodology Review Introduction

1. Roll Call, Introductions, Announcements, etc. — Owen Hamel
2. Review Agenda and Review Scope

E. sdmTMB Methodology Review

1. sdmTMB Overview — Eric Ward
(8:15 a.m.; **Hamel, Schaffler**)

2. Comparison of sdmTMB and VAST — Kelli Johnson and Chantel Wetzel
(9:00 a.m.; **Hamel, Schaffler**)

BREAK (9:45 – 10:00 a.m.)

3. Discussion — Owen Hamel
   (10:00 a.m.; **Hamel Budrick**)

LUNCH (12:00 – 1:00 p.m.)

C. Hook and Line Surveys, Continued

10. Review Clarifying Requests — Melissa Haltuch
    (1:00 p.m.; **Haltuch, Field**)

11. Discussion Topics from Day 1 — Melissa Haltuch
    (2:00 p.m.; **Haltuch, Tsou**)

A. Administrative Matters, Continued

3. Review Clarifying Requests
   (3:00 p.m.)

PUBLIC COMMENT PERIOD
3:30 p.m. (or immediately following Agenda Item A.3)
Public comments are accepted at this time.

Thursday, June 23, 2022 — 8 AM

1. Identify Accepted Practices and Future Research Needs — Owen Hamel
   (8:00 a.m.; **Hamel, Marshall**)

G. Outstanding items from Days 1 and 2

1. Presentations / Discussions — Melissa Haltuch
   (9:30 a.m.; **Haltuch, Punt**)

A. Administrative Matters, Continued

4. Workshop and Methodology Review Meeting Report Drafting
   (10:30 a.m.)

PUBLIC COMMENT PERIOD
11:30 a.m. (or immediately following Agenda Item A.4)
Public comments are accepted at this time.

Appendix B - Participants

Add participant list