SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON ASSESSMENT METHODOLOGY REVIEW – FINAL ACTION

The Scientific and Statistical Committee (SSC) discussed reports and recommendations for 1) the further review of length-based assessment methods held on October 23, 2020 (Supplemental SSC Groundfish Subcommittee Report 2 appended to this report), 2) the proposed language in the Terms of Reference (TOR) for Groundfish and Coastal Pelagic Species Stock Assessments (SSC Groundfish Subcommittee Report 1), 3) the workshop on data-limited assessment methods and the potential use of the Data-Limited Tool (DLMtool) developed by researchers at the University of British Columbia for use in Pacific Fishery Management Council (PFMC) stock assessments (Supplemental SSC Groundfish Subcommittee Report 3 appended to this report), and 4) future plans for evaluating alternative elasmobranch harvest control rules.

Review of the Length-based Assessment Methods

At the September 2020 meeting, the SSC reviewed three proposed length-based assessment methods (Length-based Integrated Mixed Effects, LIME; Stock Synthesis with Catches and Lengths, SS-CL; and Stock Synthesis with Catches and Lengths informed with one or more fishery-independent abundance indices, SS-CL+Index). The SSC concluded that further development for the LIME method is needed and did not endorse the method to be used for PFMC stock assessments. The SSC recommended a list of short-term tasks to be completed before adopting the SS-CL or SS-CL+Index methods, which are detailed in section 6 of the Length-based Assessment Methods Methodology Review Panel report provided in September (Agenda Item D.4, Attachment 2, September 2020).

Dr. André Punt (University of Washington) briefed the SSC on the progress of the short-term research recommendations that was reviewed by the SSC Groundfish Subcommittee on October 23. The SSC agrees with the Subcommittee that these short-term recommendations were adequately addressed and, thus, endorses the SS-CL and SS-CL+Index methods for use in the 2021 stock assessments.

The SSC also concurs with the long-term research requests as outlined on page 3 of Supplemental SSC Groundfish Committee Report 2 but recommends extending the range of years for finding a breakpoint beyond 10 years. It was agreed that these requests should be completed in time to be discussed at the post-assessment cycle review meeting ("post-mortem") to be held in December of 2021 or January of 2022.

Adopt Proposed Terms of Reference (TOR)

There are three minor changes to the proposed TOR:

- On page 4. Guidance on the use of sex data associated with lengths when sexually dimorphic species are assessed.
- On page 5. Addition of language classifying stocks with less than 10 years of length data as Category 3 assessments. This does not affect the current assessments and will be subject

to long-term analyses to be provided at the post-mortem review of the stock assessment process in Winter of 2021.

- A change on page 2, line 6, of the SSC Groundfish Subcommittee Report 1 in reference to data-moderate assessments that can be considered category 1 stocks, replacing SS-CL with SS-CL+Index.
- One TOR revision unassociated with length-based assessments, regarding how residuals are estimated in the Vector Autoregressive Spatial Temporal (VAST) model, changing Pearson residual to residuals.

The SSC recommends adoption of the TOR language for the PFMC 2021 Groundfish and Coastal Pelagic Species stock assessments in SSC Groundfish Subcommittee Report 1 reflecting the first two changes, with the addition of the last two revisions.

Data-Limited Methods Workshop

A Data-Moderate and Data-Limited Methods Workshop was held on May 12-13, 2020. Dr. André Punt briefed the SSC on the workshop discussions and recommendations (Supplemental SSC Groundfish Subcommittee Report 3 appended to this statement). The topics considered during the workshop were:

- Potential refinements of data-moderate and data-limited assessment methods already approved for use in Pacific Fishery Management Council (PFMC) stock assessments.
- Additional data-moderate and data-limited assessment methods that could be considered for review and adoption.
- Potential use of the Data-Limited Method (DLM) Tool for use in groundfish stock assessments.

The workshop report documents short descriptions of various methods and their potential use for PFMC stock assessments. The SSC concurs with the Workshop conclusions and research recommendation detailed in section 3 of the workshop report.

The SSC agrees with the workshop that review of an MSE tool such as DLM tool would ideally involve a technical review of the mathematical specifications of the operating model, along with the results of applying the DLM tool to address a problem that is currently of interest to the Council. The SSC notes the DLM tool could be used to inform groundfish management and possibly highly migratory species, but not likely to be informative for short-lived species like coastal pelagic species and salmon.

Evaluation of Alternative Elasmobranch Harvest Control Rules

The SSC Groundfish Subcommittee held planning meetings on September 2 and October 23, 2020 to scope the issue and determine if sufficient information is available to inform a revised harvest control rule (HCR) for elasmobranchs. Dr. John Budrick briefed the SSC on the discussions and recommendations from the meetings. There is not much additional data available from similar species/stocks to be added to Dr. Martin Dorn's meta-analysis, which informed the current elasmobranch HCRs. The SSC notes that the 50 percent spawning potential ratio target is likely to lead to declines in abundance for elasmobranchs to levels below the estimated B_{MSY} over multi-decadal time scales. Consequently, it may be advisable to maintain harvest limits at or below the maximum sustainable yield (MSY) equilibrium level estimated in elasmobranch assessments until

a more sustainable proxy is developed. The SSC recommends this topic for future research and/or a methodology review.

PFMC
11/16/20

THE SCIENTIFIC AND STATISTICAL COMMITTEE'S GROUNDFISH SUBCOMMITTEE REPORT ON ASSESSMENT METHODOLOGY REVIEW OF LENGTH-BASED ASSESSMENT METHODS: REVIEW OF SHORT-TERM REQUESTS

Pacific Fishery Management Council
Via Webinar

October 23, 2020

SSC Groundfish Subcommittee Members Present

Dr. André Punt, University of Washington, Seattle, WA (Chair of the Methodology Review)
Dr. John Budrick, California Department of Fish and Wildlife, Belmont, CA
Dr. Fabio Prior Caltabellotta, Oregon State University, Corvallis, OR
Dr. John Field, SSC Chair, National Marine Fisheries Service Southwest Fisheries Science Center, Santa Cruz, CA
Dr. Melissa Haltuch, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA
Dr. Owen Hamel, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA
Dr. Kristin Marshall, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA
Dr. Jason Schaffler, Muckelshoot Indian Tribe, Auburn, WA
Dr. Tien-Shui Tsou, Washington Department of Fish and Wildlife, Olympia, WA
Dr. Will White, Oregon State University, Corvallis, Oregon

Methodology Proponents Present

Dr. Jason Cope, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA
Dr. Merrill Rudd, Scaleability LLC
Dr. Chantel Wetzel, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA

Others Present

Ms. Alison D. Whitman, Oregon Department of Fish and Wildlife, Newport, OR
Dr. Vladlena Gertseva, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA
Dr. Jim Hastie, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle,

WA
Ms. Lynn Mattes, Oregon Department of Fish and Wildlife, Newport, OR, GMT
Mr. Mike Okieniewski, Pacific Seafoods, Woodland, WA, CPSAS
Ms. Whitney Roberts, Washington Department of Fish and Wildlife, Olympia, WA, GMT
Dr. Ian Taylor, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA
Ms. Lynn Walton

A Methodology Review Panel reviewed two length-based assessment methods (SS-CL and LIME) during May 12th – 14th, 2020. The Panel agreed that the LIME method should not be adopted at this time, although it could be further developed for future consideration. It also recommended that SS-CL could be adopted once four short-term tasks had been undertaken. The SSC concurred with the Panel recommendations at its September 2020 meeting. Dr. Merrill Rudd has since conducted additional analyses to address three of the four short-term requests.

The SSC Groundfish Subcommittee (SSCGFSC) met by webinar on 23 October 2020 to discuss progress on the short-term recommendations and to review the set of long-term recommendations. The SSCGFSC also reviewed the proposed changes to the Terms of Reference (TOR) for Groundfish and Coastal Pelagic Species Stock Assessments (SSC Groundfish Subcommittee report 1, Agenda Item G.5.a, November 2020). This report documents the deliberations and recommendations related to the short- and long-term recommendations for SS-CL.

A. Review of Responses to Short-Term requests from the Methodology Review Panel for Stock Synthesis with Catches and Length

Further investigation by Dr. Rudd focusing on the perfect data-rich simulation scenario found that population parameters were estimated without bias when recruitment deviations were turned off during the operating model burn-in. The previously reviewed work showed operating model runs with the recruitment deviations turned on during the burn-in period, which led to unexpected bias. Current model runs have the operating model recruitment deviations set to zero during the burn-in and the estimation model estimates recruitment deviations during this period. The SSCGFSC discussed the need to conduct simulation runs that both generate recruitment deviations during the operating model burn-in period and estimate recruitment deviations during the burn-in period of the estimation model. The SSCGFSC notes that the bias correction for these runs needs to be documented and checked.

Previously reviewed simulation results showed unexpected results when L_∞ is set to a value larger than the (true) operating model value. Investigations of the simulations presented at the Review Panel found that increasing the number of length bins and ensuring model convergence produced results as expected. All previously presented analyses have been rerun without recruitment deviations turned on during the operating model burn-in and with a larger number of length bins. All results use a standardized set of plots showing simulation performance for several model-estimated parameters.

Assessments meeting the Review Panel criteria of uninformative length data were not available for further data moderate model runs. Sablefish was considered, but lengths are excluded from the assessment due to data conflicts rather than being uninformative. Thus, the SSCGFSC developed an exploratory long-term request to evaluate the difference in outcomes between the age-centric benchmarks and SS-CL (see below).

The SSCGFSC thanks Dr. Rudd for addressing the short-term requests and recommends the adoption of SS-CL for the 2021 stock assessment cycle.

B. Long-term requests from the SSC for Stock Synthesis with Catches and Lengths

The SSCGFSC discussed longer-term requests in support of future use of SS-CL assessments, as well as the timeline. The sub-committee agreed to five requests as follows:

1. Provide a table of possible stocks (including those that are done already) with length-composition sample sizes and temporal coverage.
    a. Consider addition of the presence of sexual dimorphism and availability of sex data.
2. Potential additional long-term analyses for consideration:
    a. Compare results of the simulated "perfect" data or a benchmark assessment with and without sex data and sex-specific growth rates for species with sexual dimorphism and selection of both males and females in the fishery. If no sex data are associated with lengths, this can increase the variance in the length-at-age, leading to issues for data-moderate as well as full assessments. This analysis would inform future TOR and considerations surrounding prioritization.
3. Implement a set of SS-CL runs similar to those presented during the May 2020 review, applying the Appendix 4 flow chart from the review report, for sablefish with fixed life history parameters for *M*, *h*, and growth based on the 2019 stock assessment.

4. Implement a set of SS-CL runs with various number of years of data (between 1 and 10) to look for a pattern or break point in the number of years of data that provides adequate information for assessment using SS-CL. Consideration of life-history factors is encouraged, but not necessary.
5. Set up the operating model with recruitment deviations during the burn-in phase, ensuring that the bias-correction is set up correctly, so that the evaluation of bias and variability in assessment outcomes can include recruitment deviations during the burn-in phase in both the operating and estimation models to better represent reality. Document the issue that resulted in biased results when recruitment deviations were previously turned on during the burn-in phase of the operating model. The current fix of turning off recruitment deviations in the operating model provides adequate information on which make a recommendation regarding the use of SS-CL at present.

It was agreed that these requests should be completed in time to be discussed at the post-assessment cycle wrap-up meeting ("post-mortem") to be held in December of 2021 or January of 2022. The primary responsibility for completing this work falls to the Northwest Fisheries Science Center.

Agenda Item G.5.a
Supplemental SSC Groundfish Subcommittee Report 3
November 2020

Report on the Data-Moderate and Data-Limited Methods Workshop

The workshop on data-moderate and data-limited methods was held in conjunction with the methodology review for length-based assessment methods. The workshop was chaired by Dr. Andre Punt (SSC, University of Washington). Appendix 1 lists the participants.

The topics considered during the workshop were:

- Potential refinements of data-moderate and data-limited assessment methods already approved for use in Pacific Fishery Management Council (PFMC) stock assessments.
- Additional data-moderate and data-limited assessment methods that could be considered for review and adoption.
- Potential use of the Data-Limited Method (DLM) Tool for use in groundfish stock assessments.

Dr. Punt thanked the participants for their contributions to what he considered a very successful workshop, which should help the Council in applying the best available science given data-limited situations. He particularly thanked Drs. Carruthers and Hordyk for their presentation on DLMtool.

1. Data-moderate and data-limited assessment methods

1.1 Potential refinements of data-moderate and data-limited assessment methods already approved for use in PFMC stock assessments

Several data-moderate and data-limited assessment methods are already approved for use in groundfish stock assessments for the PFMC. These methods, and any others proposed for consideration, must comply with the requirements of the Magnuson-Stevens Act (MSA) and the Council Process. Dr. Budrick presented the requirements for assessment methods, and Dr. Dick presented data-limited and data-moderate stock assessment methods already approved for use, and some potential improvements to those methods.

1.1.1 Requirements of Magnuson-Stevens Act and the Council Process

Dr. Budrick presented the requirements for groundfish stock assessment methods in the PFMC and MSA. The goal of this talk was to provide the context and requirements for any new proposed assessment methods that may emerge from this workshop.

The Magnuson-Stevens Act and its National Standard (NS) Guidelines 1 and 2 provide the context for federal requirements of assessment methods. NS1 goals are to prevent overfishing and achieve maximum benefit to the nation by achieving Optimal Yield. In the context of data-limited assessment methods, NS1 requires that in the absence of setting reference points, the rationale for choosing alternative approaches for Status Determination Criteria (SDC) and how they relate to

the reproductive potential of the stock must be provided. NS2 requires the Best Scientific Information Available, explicitly recognizes data limitations, and endorses using appropriate methods for the data available.

Within the PFMC, requirements for assessment methods are described in Fishery Management Plans (FMPs) and Terms of Reference (TORs) for Stock Assessments, Council Operating Procedure 25 (COP25), the TOR for the Methodology Review Process, and TOR developed for a specific stock assessment methodology review. The Groundfish FMP states that stock assessments are to provide information to aid in determination of overfishing limits (OFLs) and Annual Catch Limits (ACLs), including estimates of current biomass, precision of those estimates, the fishing mortality rate and biomass corresponding to Maximum Sustainable Yield, MSY (F_{MSY} and B_{MSY}) or their proxies, unfished biomass, a precautionary threshold, and an overfished threshold. The stock assessment TORs define the process and reporting requirements for assessments, and are updated every two years, which allows for flexibility in the adoption of new methods. COP25 and the TOR for methodology reviews describe the process through which any new proposed assessment methodology would be reviewed before it would be endorsed for use in PFMC stock assessments.

The discussion on requirements for stock assessment methods focused on a recent NMFS NS1 working group (with multiple representatives from the participants of this workshop) that is currently exploring how an updated NS1 could affect how SDCs operate and are interpreted. For example, potential methods are being explored for situations in which biomass- or abundance-based catch limits cannot be implemented. Guidance from this working group is expected in 2021.

1.1.2 Potential refinements of data-moderate and data-limited assessment methods already approved for use in PFMC stock assessments

Dr. Dick reviewed three depletion-based methods (Depletion-Corrected Average Catch [DCAC], Depletion-Based Stock Reduction Analysis [DB-SRA], and Extended Depletion-Based Stock Reduction Analysis [XDB-SRA]) and proposed ideas for potential improvements. DCAC (MacCall, 2009) and DB-SRA (Dick and MacCall, 2011) were inspired by the 2011 MSA deadline for implementing ACLs. Both methods estimate sustainable yield as a function of four input parameters (M, F_{MSY}/M, B_{MSY}/B_0, relative stock status) and historical catches. If data are available to inform changes in abundance, they can be incorporated into XDB-SRA. This method is a Bayesian surplus production model that updates the four prior distributions in DB-SRA, and generates posterior distributions of unfished biomass, *MSY*, F_{MSY} and OFL in a manner consistent with NS1 guidelines.

DCAC was recommended as a one-time calculation that is best treated as a stop-gap measure until better, data-driven management becomes possible. Annual updating of DCAC parameters (i.e., stock status) in Management Strategy Evaluations (MSE) was not recommended. Providing the model with annual updates to stock status is not consistent with a truly data-poor scenario and using the same depletion over time has the effect of "moving the goalpost." Simulation studies could be useful to understand what factors determine when DCAC yields become 'stale,' i.e., provide a timeline to prioritize future data collection efforts. DCAC may also be useful to complement data-rich assessments, providing estimates of yield for adjacent, data-poor regions by using the data-rich assessment to inform the DCAC parameters.

Discussion of DB-SRA included the frequency and nature of updates to OFLs. Simulation testing could help determine how performance varies between fixing the OFL at the terminal value, projecting forward using the model, or some other rule. Similar to DCAC, updating the estimate of depletion on a regular basis is not considered practical for most data-poor scenarios and should be avoided in MSEs. It was noted that the length-based methods proposed in the methodology review provide information about stock status and are therefore not subject to the same concerns.

Potential improvements for XDB-SRA suggested in the presentation included 1) use of the Deriso-Schnute model for the population dynamics, allowing fits to abundance and size data, 2) performance testing of filters (e.g., based on oscillations, $B > B_0$), 3) sensitivity of data-weighting to priors on additive variance parameters, and 4) propagating uncertainty in catch into model outputs.

Dr. Cope briefly updated participants on two methods that he and Dr. Wetzel continue to develop in the Stock Synthesis framework: Simple Stock Synthesis (SSS) and Extended Simple Stock Synthesis (XSSS). Both SSS and XSSS are available as R packages via github and a Shiny application being developed as a tool that encompasses a range of data-limited assessment methods. The Shiny application will provide results from a set of those methods, depending on the data provided by the user (e.g., catch, index, length). It will run and output plots and diagnostics, such as likelihood profiles. Dr. Cope is intending to implement a Bayesian version of this approach that would apply to scenarios with a single year of composition data.

1.1.3 Discussion and Conclusions

Workshop participants agreed that DCAC and DB-SRA continue to be a suitable stop-gap approaches to inform setting catch limits in data-limited settings until more data are available.

DCAC and DB-SRA may be particularly useful for stocks with spatial structure where data are not equally available for all assessed regions (e.g., 2019 assessment of cowcod). However, these methods require strong assumptions in the absence of data. A length-based method would be preferable if sufficient representative length data were available. Updating OFLs using these methods is not recommended. However, currently there are no guidelines for how long OFLs set with these methods should stay in place.

1.2 Additional data-moderate and data-limited assessment methods that could be considered for review and adoption

Several data-limited and length-based assessment methods are used in other Fishery Management Councils in the U.S., but those methods have not yet been employed in the PFMC or considered by the PFMC SSC. Given the interest in the PFMC for expanded capabilities for data-limited situations and the greater availability and ease of collection of length data over age data leads to a need to consider evaluating alternative or additional approaches. This portion of the workshop comprised a discussion of these alternative methods, their potential benefits, and how they should be prioritized for future review and evaluation by the SSC.

Dr. Budrick began the session with a presentation titled "Data-moderate and data-poor assessment methods applied in other Councils." He summarized the frequency with which data-limited, data-poor, and length-based methods are used by other Councils to set OFLs and ABCs, based on Newman et al.'s (2015) review. The PFMC has the largest number of both data-rich and data-poor

stocks, including 1/3 of data-poor assignments nationally. Several other regions have used or are considering some new data-limited methods that the PFMC SSC should be aware of. These include length-based spawning potential ratio (LB-SPR) in the Western Pacific and the Data-Limited Method (DLM) package in the Caribbean (Sagarese et al., 2018; see Item 2 below). The New England Fishery Management Council has made use of a method named An Index Method (AIM) for data-moderate stocks; this could be a topic for future discussion and consideration, but the workshop participants were not familiar with the method.

Dr. Budrick summarized a series of methods for consideration, which the workshop discussed in terms of pros and cons for future consideration and evaluation. The workshop noted that there are many potential methods used at the state and international level. A useful resource is the FishPath project (https://www.scienceforconservation.org/science-in-action/fishpath), which catalogues a list of data-limited methods, what data are required for each method, and their documentation.

Dr. Punt provided an oral report based on a document that summarized international stock assessment methods that could be considered by the PFMC. There are essentially five packages that are well-documented and widely used internationally: 1) Stock Synthesis (used by the PFMC); 2) SAM (a data rich method with the advantage of integrating over the random effects), 3) MULTIFAN (widely used for tuna and billfish stocks, though with decreasing frequency); 4) CASAL (used in New Zealand; advantages include scalability from data-rich to data-poor, length-structured modeling, and fast Bayesian integration); and 5) GADGET (used in Iceland; a multi-species, multi-area, multi-fleet approach). Most other data-limited methods used internationally are not suitable for applying control rules that would be acceptable for groundfish management in the PFMC, and they perform poorly in MSE simulations.

1.2.1 Data-limited methods for possible consideration

1.2.1.1 Surplus production models

There is a lineage of this model type including the early model A Stock-production Model Incorporating Covariates [ASPIC; Prager, 1994] and the state-space Bayesian Surplus Production 2 (BSP2, McAllister, 2014) that included process error. The more recently developed Just Another Bayesian Biomass Assessment (JABBA; Winker et al., 2018) and JABBA-Select (Winker et al., 2020) are more worthy of PFMC consideration. Advantages of JABBA-Select include that it splits spawning biomass and exploitable biomass; unlike the earlier JABBA it includes life history parameters (including steepness) and fishery selectivity. In simulations it has performed well in comparison to age-structured assessments, though the workshop was unsure how that could be the case if JABBA-Select does not include age-structured dynamics in some form. JABBA-Select is available as an R package so it is readily available and straightforward to implement for a R user. The workshop noted that XSSS and XDB-SRA are also surplus production methods (placing a prior on recent relative stock status rather than unfished biomass) and have some of the same advantages as JABBA.

1.2.1.2. LB-SPR

Length-based Spawning Potential Ratio (LB-SPR; Nadon, 2017) is a length-based method to estimate the ratio of current to unfished spawning potential (spawning potential ratio; SPR). It is limited by the assumptions of constant recruitment and fishing mortality over time; the former is

particularly problematic for most PFMC groundfish stocks. A further limitation is that it requires an estimate of scale (i.e., biomass from surveys) to generate catch limits. Absent that, the method would not comply with MSA. This is a serious limitation. However, LB-SPR has been used in data-limited assessments as way to generate priors for some biological parameters. This was done for the 2019 Washington state cabezon assessment (Cope et al., 2019), for example. The workshop agreed that the degree of utility was helpful.

1.2.1.3 CC-SRA

Catch-curve Stock Reduction Analysis (CC-SRA; Thorson and Cope, 2015) is a modification of DB-SRA that incorporates at least one year of length- or age- composition. The key advantage is that CC-SRA is approximately unbiased if life history parameters are unbiased and recruitment variability (σ_R) is not too great (performance is adequate for σ_R values up to at least 0.9), whereas DB-SRA can yield biased estimates of fishing mortality if recent estimates of spawning biomass are mis-specified. It produces estimates of catch, stock status, and fishing mortality, so could be a useful method. A downside noted by the workshop is that the method's outputs may be somewhat biased if only one sample of length composition (rather than age composition) is available. Dr. Cope and colleagues continue to explore the potential for implementation of this method.

1.2.1.4. ORCS

The Only Reliable Catch Stocks method (Berkson et al., 2011) depends on a 14-question 'Table of Attributes' that requires several subjective decisions by experts to implement. The workshop agreed that this degree of subjectivity is undesirable and that existing data-limited methods used by the PFMC are superior.

1.2.1.5. CASAL

The C++ Algorithmic Stock Assessment Laboratory (CASAL; Bull et al., 2012) is a potentially useful tool as it appears to have faster runtimes for Bayesian analyses than Stock Synthesis. Another advantage is that it can implement length-based models (rather than age models translated into length). A new version, Casal2, may be available soon. However, the workshop noted that this method is unlikely to be advanced in the PFMC because the source code is not publicly available and because of the lack of growth increment data for many species.

1.2.1.6. Other methods

Dr. Budrick reported that Dr. Mark Maunder is developing a method that would estimate MSY based on abundance and production indices. However, this would require a user decision on the link between an indicator and ACLs, and it is unclear how that relationship could be demonstrated to be sufficiently reliable for assessment purposes under the MSA. The workshop noted that the optimal control literature has shown this type of control rule to be highly sensitive to observation error.

Another set of approaches are the so-called "Robin Hood" methods for jointly targeted species complexes (e.g., Punt et al., 2011). Essentially if the trajectory of fishing mortality is similar for ≥ 2 species in a complex, that trend in fishing mortality could be used as a prior for other species

in the complex. This approach is promising, and already possible to implement in CASAL (though see above for problems with that package).

1.3 Discussion and conclusions

The workshop participants agreed that JABBA-Select and CC-SRA have promise for use in the PFMC and should be investigated further. Of the methods considered during the workshop (1.2.1.1 – 1.2.1.5), the workshop agreed that ORCS was considered but rejected as a potential method, given its limitations (i.e., it requires several subjective decisions by experts to implement), and availability of alternatives. In addition, CASAL (and Casal2) was discussed as possibly beneficial because of its computational advantages but the inaccessibility of source code is problematical for its use in the PFMC processes.

2. Use of the Data-Limited Tool (DLMtool) for groundfish stock assessments

2.1 Introduction to the Data-Limited Tool

Drs. Tom Carruthers and Adrian Hordyk provided the background to the Data-Limited Tool (DLMtool; https://www.datalimitedtoolkit.org/; Carruthers and Hordyk, 2018). Most of the world's fish stocks and many U.S. fish stocks are considered to be data-limited. This has led to the development of a variety of data-limited and data-moderate methods of stock assessment / management strategies. However, methods are often developed and adopted for use in management without adequate testing. In particular, effective and thorough testing based on closed loop simulations (aka MSE) is often absent, and evaluation of estimation performance is not a suitable way to infer management performance. DLMtool attempts to fill this gap by providing a framework within which to test combinations of assessment methods and harvest control rules. The DLMtool and the associated MSE tool have been used in a variety of fisheries worldwide, including some in California.

DLMtool is a R package that provides a standardized testing framework for developing, evaluating, and applying candidate archetype assessment and management strategies (aka "management procedures"). DLMtool hence allows identification of the strengths and weaknesses of alternative management strategies in terms of achieving management goals, as well as when they are likely to perform poorly. As such, DLMtool can be used to identify a management strategy for a particular case as well as triage candidate management strategies. The results of the testing also clarify the value of the information content of various data types. The development using an R package provides the facility for the application of MSE in data-limited contexts. DLMtool currently includes 110 data-limited management strategies, most of which produce catch limits.

MSEtool is an MSE package in R that includes multiple data-rich management strategies. The package includes four delay-difference models, three statistical catch-at-age analysis methods, and three surplus production models, as well as the ability to link the assessment to harvest control rules. The package also includes the ability to condition the operating model to available data.

The operating model (OM) underlying DLMtool (and hence MSEtool) represents the stock and fleet dynamics as well as how data are generated and implementation error (Total Allowable Catch [TAC] and effort and size-regulation over- and underages) impacts removals. The underlying operating model is age-structured, and parametrization is flexible. The operating model can

generate a variety of data sources, including catch-at-age and catch-at-length data for a single fleet (but not for multiple fleets). In addition to many of the features included in previous Council MSE's, the operating model underlying DLMtool includes spatial structure, considerable flexibility in terms of representing fishery and population dynamics processes, and several sources for parameter and process uncertainty. A current development relates to driving effort in the operating model using a bio-economic model. The results of the MSE projections can be summarized in terms of time-trajectories of biomass, catch (total and TAC), effort, and fishing mortality, with results expressed relative to MSY reference points. The package includes diagnostics to check that sufficient simulations have been conducted and produces generic MSE outputs, including trade-off plots. OM objects can be easily shared and MSE results replicated without having to learn custom ('one-off') software.

Management in DLMtool can be based on any combination of catch limits, effort limits, spatial closures, changes to selectivity- and retention-at-length, and changes to discard mortality. Dr. Carruthers outlined the set of data-poor, data-moderate, and information rich (requires input from a survey) management strategies. He illustrated the performances of management strategies, including some that use length data, for canary rockfish-like, arrowtooth flounder-like and capelin-like situations. The management strategies based on some length-based assessment methods that use limited length data performed poorly for the canary rockfish-like situation, and all management strategies performed well for arrowtooth flounder-like situation. Performance varied among management strategies for capelin-like situation, although Dr. Carruthers noted that generally there was more variation in performance metrics due to the operating models than the management strategies within broad classes. The workshop noted that the DB-SRA implemented in the example analyses provided estimates of depletion, which is not how DB-SRA, DCAC, or SSS are applied for Council decision making. It was noted that errors in productivity will impact performance as well as errors in estimating depletion, but the latter are generally more impactful.

Dr. Carruthers also mention two additional packages:

- SRA_scope - highly flexible OM conditioning function in Template Model Builder with full 'assessment style' reporting produces diagnostics as well as the details of the sampling process.
- Method Evaluation and Risk Assessment (MERA) – an online tool for quickly drafting operating models and testing prototype management strategies.

Dr. Carruthers highlighted that:

- Technical measures (input controls) can improve performance when combined with catch-limit management of data-limited fisheries.
- Stocks with productivity shifts are often better suited to calibrated index-based management strategies than index target management strategies or model-based management strategies such as SS-CL that rely on assumptions of non-stationarity.

In discussion, it was noted that DLMtool is currently tailored primarily to species with a maximum age of greater than four years and would not be ideal as the basis for salmon MSEs. One identified advantage of DLMtool over alternative MSE tools is that it is not necessary to tie the operating model to the structure of the current assessment model, allowing the consequences of model mis-

specification on management performance to be evaluated. Methods such as DLMtool provide analysts with an impression of the likely performance of management strategies in various scenarios, and hence heuristics for which methods will perform adequately or poorly given uncertainties.

Dr. Carruthers noted that DLMtool was continually being updated based on user requests, but that requests for major changes may be require financial support.

2.2 Next steps and future analyses using the DLM tool

Dr. Budrick provided an overview of the methodology review process for groundfish stocks, noting that the original idea for a future review would have focused on the tool itself, to allow review of its inner workings, process, statistical methods, biases and assumptions. Such a review could be conducted in spring 2022, assuming that a proposal for a methodology review was submitted in September 2021.

The workshop noted that other generic MSE tools exist, including Fisheries Library for R (FLR; Kell et al., 2007) and the SSMSE package being developed by a group led by Kathryn Doering of the NWFSC and Nathan Vaughan of the SEFSC. The workshop noted that technical documentation is available for DLMtool (see, for example, the supplementary material to Carruthers and Hordyk, 2018), although Dr. Carruthers stated that the package is under continual development so that the documentation may not include all features.

The workshop agreed that review of an MSE tool such as DLMtool would ideally involve a technical review of the mathematical specifications of the operating model, along with the results of applying DLMtool to address a problem that is currently of interest to the Council. The latter would both address an issue relevant to the Council and also allow an evaluation of how easy it would be to apply DLMtool to a new problem. The workshop agreed that testing and applying methods already available in DLMtool was not a high priority in the absence of a targeted question. Possible questions that could be addressed in such a review would include:

- How long can OFLs based on DCAC / DB-SRA be used before risk becomes excessive (DCAC/ DB-SRA were originally developed as stop-gap methods and not as long-term approaches for setting OFLs)?
- What levels of sigma are needed for category 2 and 3 stocks to have the same level of risk of overfishing as category 1 stocks?
- How well do management strategies based on SS-CL and SS-CL+Index perform, and is this performance a function of life history and/or the quality/quantity of available length data?
- Can alternative harvest control rules better achieve the Council's management goals?

3. Conclusions and Research Recommendations

3.1 Data-moderate and data-limited assessment methods

- DCAC may also be useful to complement data-rich assessments, providing estimates of yield for adjacent, data-poor regions by using a data-rich assessment to inform the DCAC

parameters. If sufficient length data are available for the adjacent regions, then length-based methods should also be considered in this context.

- Simulation studies could be useful to understand (a) what factors determine when OFLs from data-limited methods become 'stale,' i.e., provide a timeline to prioritize future data collection efforts, and (b) how performance varies between fixing the OFL at the terminal value using data-limited methods, projecting forward using the model, or some other rule.
- Of the potential refinements suggested, workshop participants prioritized two for the XDB-SRA approach. First, developing a Deriso-Schnute model as an alternative to the current model for the population dynamics is high priority because it would allow for fitting some age or length data and would allow for process error in recruitment. Second, exploring the propagation of uncertainty in catches into model results is also high priority. In particular, it may be important to investigate the consequences of variable bias and precision in catch data.
- Further research is needed to explore how and when to move from data-poor methods (i.e., DB-SRA or DCAC) to the length-based methods reviewed during the methodology review. Simulation studies (MSEs) could explore how to set expiration dates for OFLs set using these methods. The length-based assessment methodology review may be able to inform how many years of length data (for a given quantity/effective sample size per year, selectivity for the length data source, and given the life history characteristics of the stock in question) are needed to move to a length-based method.
- JABBA-Select and CC-SRA have promise for use in the PFMC and should be investigated further.
- ORCS was considered but rejected as a potential method due to subjectivity in expert judgement used in parameterizing the model and availability of better data-poor methods such as DCAC and DB-SRA.
- CASAL (or Casal2) was discussed as possibly beneficial because of its computational advantages but the inaccessibility of the source code is problematic to its use in PFMC processes.
- Methods relying on length data could be integrated with depletion-based approaches in a Bayesian framework (i.e., placing a prior on depletion and fitting to length composition data).

3.2. Data-Limited Tool

- DLMtool is a viable platform for evaluating management strategies, in particular identifying management strategies that are unlikely to perform adequately. The tool is well-documented and has been published in the peer-reviewed literature.
- The primary value of DLMtool is its ability to conduct MSE using a generic operating model that is easily replicated and its ability to be tailored to new assessment methods and harvest strategies.
- The assessment methods and harvest control rules included in DLMtool will need to be expanded to allow testing of methods used by the PFMC.
- Any review of an MSE tool such as DLMtool would ideally involve a technical review of the mathematical specifications of the operating model, along with the results of applying DLMtool to address a problem that is currently of interest to the Council.

5. References

Berkson, J., Barbieri, L., Cadrin, S., Cass-Calay, S.L., Crone, P., Dorn, M., Friess, C., Kobayashi, D., Miller, T.J., Patrick, W.S., Pautzke, S., Ralston, S. and M. Trianni. 2011. Calculating Acceptable Biological Catch for Stocks That Have Reliable Catch Data Only (Only Reliable Catch Stocks – ORCS). NOAA Technical Memorandum NMFS-SEFSC-616, 56 p.

Bull, B., Dunn, A., McKenzie, A., Gilbert, D.J., Smith, M.H., Bian, R. and D. Fu. 2012. CASAL (C++ algorithmic stock assessment laboratory) User Manual v2.30-2012/03/21. NIWA Technical Report 135. National Institute of Water and Atmospheric Research, Wellington, 280 p.

Carruthers, T.R. and A.R. Hordyk. 2018. The Data-Limited Methods Toolkit (DLMtool): An R package for informing management of data-limited populations. *Methods in Ecology and Evolution* 9: 2388-2395.

Cope, J.M., Berger, A.M., Whitman, A.D., Budrick, J.E., Bosley, K.M., Tsou, T.S., Niles, C.B., Privitera-Johnson, K., Hillier, L.K., Hinton, K.E. and W.N. Wilson. 2019. Assessing cabezon (*Scorpaenichthys marmoratus*) stocks in waters off of California and Oregon, with catch limit estimation for Washington state. Pacific Fishery Management Council, Portland, OR.

Dick, E.J. and A.D. MacCall. 2011. Depletion-Based Stock Reduction Analysis: A catch-based method for determining sustainable yields for data-poor fish stocks. *Fisheries Research* 110: 331–341.

Kell, L.T., Mosqueira, I., Grosjean, P., Fromentin, J.M., Garcia, D., Hillary, R., Jardim, E., Mardle, S., Pastoors, M.A., Poos, J.J. Scott, F. and R.D. Scott. 2007. FLR: An open-source framework for the evaluation and development of management strategies. *ICES Journal of Marine Science* 64: 640–646.

MacCall, A.D. 2009. Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. *ICES Journal of Marine Science* 66: 2267–2271.

McAllister, M.K. 2014. A generalized Bayesian surplus production stock assessment software. *Collected. Volume of Scientific Papers ICCAT* 70: 1725–1757.

Nadon, M.O. 2017. Stock assessment of the coral reef fishes of Hawaii, 2016. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-60, 212 p

Newman D., Berkson, J. and L. Suatoni. 2015. Current methods for setting catch limits for data-limited fish stocks in the United States. *Fisheries Research* 164: 86-93.

Prager, M.H. 1994. A suite of extensions to a nonequilibrium surplus-production model. *Fishery Bulletin* 92: 374–389.

Punt, A.E., Smith, D.C. and A.D.M. Smith. 2011. Among-stock comparisons for improving stock assessments of data-poor stocks – the "Robin Hood" approach. *ICES Journal of Marine Science* 68, 972–981.

Sagarese, S.R., Rios, A.B., Cass-Calay, S.L. and N.J. Cummings. 2018. Working towards a framework for stock evaluations in data-limited fisheries. *North American Journal of Fisheries Management* 38: 507– 537.

Thorson, J.T. and J.M. Cope. 2015. Catch curve stock-reduction analysis: An alternative solution to the catch equations. *Fisheries Research* 171: 33-41.

Winker, H., Carvalho, F., Thorson, J.T., Kell, L.T., Parker, D., Kapur, M., Sharma, R. Booth, A.J. and S.E. Kerwath. 2020. JABBA-Select: Incorporating life history and fisheries' selectivity into surplus production models. *Fisheries Research*. 222: 105355.

Winker, H., Carvalho, F. and M. Kapur. 2018. JABBA: Just Another Bayesian Biomass Assessment. *Fisheries Research* 204: 275-288.

Appendix 1: Participants

Tuesday, May 12

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