Identifying Benchmarks and Assessing Status of CUs Under the Wild Salmon Policy: Converging on Consistent Methods.

Summary of Progress Meeting

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V9T 6N7

2012

Canadian Technical Report of Fisheries and Aquatic Sciences 3019

Fisheries and Oceans Canada   Pêches et Océans Canada

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Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. No. Fs 97-6/3019E ISSN 0706-6457

Correct citation for this publication:

Holt, C.A. 2012. Identifying benchmarks and assessing status of CUs under the Wild Salmon Policy: Converging on consistent methods. Summary of progress meeting. Can. Tech. Rep. Fish. Aquat. Sci. 3019: v + 23 p.

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ABSTRACT

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Metrics and benchmarks of status for Pacific salmon Conservation Units (CUs) have been developed under Strategy 1 of the Wild Salmon Policy (WSP). A progress meeting was held at the Pacific Biological Station 18-19 October 2012 with the goals to explore differences in CU assessments that have occurred (or may occur), understand the rationale for those differences, and identify a consistent way forward, where appropriate. The outcomes of the meeting were: (1) updated information from Area staff on CU assessments, (2) a list of methods requiring further analysis and/or review by the Canadian Science Advisory Secretariat, and (3) a revised list of candidate benchmarks and metrics. A revised process for reviewing CU assessments was presented, but further discussions are required to identify a process for identifying priority CUs for assessment and evaluating those assessments.

RÉSUMÉ

Holt, C.A. 2012. Identifying benchmarks and assessing status of CUs under the Wild Salmon Policy: Converging on consistent methods. Summary of Progress Meeting. Can. Tech. Rep. Fish. Aquat. Sci. 3019: v + 23p.

Les mesures et les points de référence relatifs au statut des unités de conservation (UC) du saumon du Pacifique ont été élaborés dans le cadre de la Stratégie 1 de la Politique concernant le saumon sauvage. Une rencontre sur l'avancement s'est tenue à la Station biologique du pacifique les 18 et 19 octobre 2012 afin d'explorer les différences actuelles ou éventuelles dans l'évaluation des UC, de comprendre le pourquoi de ces différences, et, le cas échéant, de déterminer la voie à suivre pour tous. Les résultats de cette rencontre ont été : 1) la communication de renseignements à jour sur l'évaluation des UC par le personnel local; 2) l'établissement d'une liste des méthodes qui doivent être analysées ou examinées plus en détail par le Secrétariat canadien de consultation scientifique; 3) la révision de la liste des mesures et des points de référence potentiels. Un processus révisé d'examen des évaluations d'UC a été présenté, mais il faudra tenir des discussions supplémentaires pour déterminer un processus d'établissement des priorités et d'examen des évaluations d'UC.

1. INTRODUCTION

Metrics and benchmarks of status for Pacific salmon Conservation Units (CUs) were developed by Holt et al. (2009) under Strategy 1 of the Wild Salmon Policy (WSP). In practice, the ways in which those methods have been implemented have differed among Areas, and some gaps in methodology have been identified. A progress meeting was held at the Pacific Biological Station 18-19 October 2012 with the goals to explore differences in CU assessments that have occurred (or may occur), understand the rationale for those differences, and identify a consistent way forward, where appropriate. The proposed outcomes were:

(1) Updates from Area staff on CU assessments
(2) List of methods requiring further analysis and/or review by CSAS
(3) Process to reviewing CU assessments (Canadian Science Advisory Secretariat, CSAS, process, or otherwise)
(4) Revised list of candidate benchmarks and metrics

The meeting was attended by 23 DFO Staff involved in technical assessments of CU status, from Core Science, Stock Assessment in the Areas, and Resource Management (see Appendix for participant list, Agenda, and Terms of Reference). Additional DFO staff were invited, but declined.

Significant progress was made on outcomes (1), (2), and (4). Further discussion is required to come to consensus on a process for reviewing CU assessments (outcome 3), though one option is outlined here. This document also summarizes the progress to-date by Area staff on CU assessments, and discussions on the proposed synoptic survey, data treatment (including enhancement), and revised/additional metrics and benchmarks.

2. SUMMARY OF PROGRESS FROM AREAS

2.1. Fraser River sockeye salmon (Sue Grant)

Status assessments under Wild Salmon Policy Strategy 1 for Fraser River Sockeye Salmon CUs have been recently completed through two CSAS processes: (1) identification of uncertainty in Fraser Sockeye CU status (Grant et al. 2011) and (2) integration of statuses across both individual metrics and the uncertainty in status within metrics (Grant and Pestal 2012).

For the first CSAS review process, Fraser Sockeye CU status evaluations built upon foundational WSP publications, which start with Holtby and Ciruna’s (2007) identification of CUs. Specifically, this first CU list for Fraser Sockeye was updated through discussions between B. Holtby and Fraser Sockeye CU experts. Subsequently, to evaluate Fraser Sockeye CU status, a status evaluation toolkit developed by Holt et al. (2009), and the evaluation of relative performance of 20+ trends in abundance metrics in identifying true status conducted by Porszt (2009), were used to guide metric selection and status evaluation. Given there are four classes of indicators (abundance, trends in abundance, fishing mortality, and distribution), and for each class of indicator, a large number of possible metrics, the selection of appropriate metrics for each CU involved considerations of Fraser Sockeye CU data availability and data properties to select the final suite of metrics evaluated (i.e. one relative abundance metric and three trends in abundance metric). In addition, given uncertainty in stock-recruitment data, we also decided to present relative-abundance metric benchmarks and associated status across all probability levels and also across different model forms. Model forms used to estimate abundance metric benchmarks specifically includes the standard Ricker model that assumes constant productivity across the time series and also, since most Fraser Sockeye CUs have exhibited multi-decadal systematic decreases in productivity, Ricker model forms that consider time varying intrinsic CU productivity. The estimation of abundance benchmarks using model forms that consider cycle line interactions for highly cyclic Fraser Sockeye CUs remains and outstanding analytical challenge.

To complete the Fraser Sockeye CU status evaluation process, a status integration CSAS workshop was conducted. This was required since Fraser Sockeye CU status across different metrics, and different model forms and probability levels for the relative abundance metric, indicated for particular CUs different WSP status zones from Red (poor status) to Green (healthy status). In cases where metric information is contradictory, provision of this metric-specific status information alone would not provide complete scientific advice to fisheries management. Therefore, for Fraser Sockeye CUs, status integration was evaluated during a three day technical workshop, which included the development of both final integrated status for each Fraser Sockeye CU (which include one or more WSP status zones) and commentaries on the information used to assess status. For the workshop, two page standardized data summaries (WSP status information and other biological information relevant to their interpretation) were produced for each Fraser Sockeye CU case study. Case studies were evaluated ‘blind’, with generic labels rather than CU names. Each CU case study was evaluated first in small group sessions (four to six participants per group) and, subsequently, in plenary sessions (all 34 workshop participants). On the final day of the workshop, the integrated status for each CU, developed in the previous days’ plenary sessions, were re-visited with the goal to narrow down a CU’s status to a final single status zone (where possible), and to fine tune commentaries. Also on the final day of the workshop, CU names were revealed to provide participants with the opportunity to introduce any specific supplementary information that might support a change in integrated status designation or that could be added to the CU status commentaries. Integrated status results from this workshop complete WSP status determinations for Fraser Sockeye, which follows up on the recently published exploration of uncertainty in WSP status metrics for these CUs.

2.1.1 Discussion points

While it is not possible to identify an algorithm that integrates status from all metrics into a single status, it may be possible to develop rough guidelines that describe a subset of the decision steps used in integration (e.g., for relatively straight forward CUs). Grant and Pestal (2012) provides a starting point for these guidelines. The final status will require expert opinion to combine the dimensions and context not captured in formal metrics.

For management and planning, the detailed CU assessments on the suite of benchmarks are as, or more important than the final overall status that integrates those metrics. The overall status may be valuable when prioritizing resources for further assessment and management activities, and for reporting out to senior management, stakeholders, and the public.

2.2. North coast Skeena (lake-type) sockeye salmon (Steve Cox-Rogers)

Most North Coast/Central Coast CU's are data limited. The large number of CUs and their diverse distribution makes regular assessments of status difficult. Indicator CUs (those that are regularly monitored) comprise about 25%-30% of all North Coast CUs. Data sets of production proxies (imputed escapement series, age-structure, and recruitment time-series) have been reconstructed for most CUs using a wide range of catch (where available) and estimated exploitation histories (all species). However, CU data quality is highly variable and there is concern that many assumptions being used to estimate the production series could be introducing time-varying biases that are difficult to detect when developing benchmarks. To date, trial sockeye benchmarks for Skeena CUs have been developed from these data, with plans to extend the analyses to other species and watersheds. Sensitivity analyses of the production data sets are being planned. In addition to Holt et al. (2009) stock-recruit benchmark approaches, habitat-based benchmarks (proportions of maximum recruitment, R_{MAX}; spawner abundances at R_{MAX}, S_{MAX}; and spawner abundances at capacity, S_{cap}) are also being evaluated for Skeena sockeye and possibly other species.

2.3. West Coast of Vancouver Island (Diana Dobson)

One of the three regional WSP pilot is taking place on the WCVI. The objective of the WCVI pilot is to implement strategies 1 to 5 of the WSP for Area 23 salmon (i.e. those originating from Barkley Sound and Alberni Inlet). Many aspects of WSP implementation, such as establishing benchmarks and fishery reference points, are required for Marine Stewardship Council (MSC) certification, and also for implementation of both the Maanulth First Nation Treaty and the 2008 Pacific Salmon Treaty. Therefore, there is strong motivation on the part of South Coast area staff to complete this work.

There does not appear to be timely resolution on some of the technical issues regarding "Strategy 1" evaluation; however our assessments are proceeding regardless. For the most part, we are trying to apply methods as they have been applied elsewhere – i.e. use benchmarks as defined in Holt et al. (2009) and use similar interpolation, extrapolation and aggregation methods applied by B. Holtby in the regional synoptic survey. However, there are some key gaps for data limited CUs and for these we are applying other methods for establishing abundance-based benchmarks. For data poor CUs, such as Henderson Lake sockeye or SWVI chinook, alternate abundance metrics based on habitat carrying capacity models are being applied (e.g. those of Parken et al. (2006) for chinook or K. Hyatt's sockeye carrying capacity model for oligotrophic lakes (pers. comm.)). If assessment data do not support the application of a benchmark (e.g. a data poor or inconsistent time series), then we do exclude it from the analysis.

In the experience of the Barkley Pilot which has so far focused on sockeye, "Strategy 1" assessments have been informative, but a small and less problematic portion of the overall implementation. This may reflect the fact that the assessment results for the relevant CUs were not particularly controversial with stakeholders. It also reflects the fact the fishery reference points they established were much higher than the abundance-based biological benchmarks. As we move into the chinook phase of the pilot, we expect that the "Strategy 1" assessments may be more problematic. There does not appear to be a regional standard on outstanding issues such as those related to interpolation or aggregation of data within a CU or consensus on how to assess wild versus hatchery contribution to a CU. Also, unlike sockeye, the abundances of many of the contributing chinook populations are likely below their upper biological benchmark. Therefore, the assessment results may be more controversial.

Regardless, in the pilot, Strategy 4 implementation – i.e. the development of the "management plan" with objectives, performance indicators, etc. – has been significantly more time consuming than Strategy 1 implementation. We maintain the development of a sound "management plan" is the most important aspect of the pilot as at lays out the path to long-term conservation of the populations within the CUs. Strategy 1, 2 and 3 serve to inform the development of the integrated plan and potentially other integrated plans (e.g. a land-use planning process for a regional district). We suggest there should be more emphasis placed in these discussions/workshops on how and why the Strategy 1 assessments inform management and how the information is communicated. For management and plenary purposes, the simple assessment of status relative to a benchmark is less informative than understanding the factors contributing to the current status. We also suggest that there needs to be more consideration of the utility of the various benchmarks/indicators in the context of declining stock assessment resources.

2.4. Southern BC chinook (Gayle Brown)

Declining trends in abundance have been observed over the past decade for a number of Chinook salmon populations originating from various watersheds in southern BC. Growing concerns about the declines led to the creation of the 'Southern BC Chinook Strategic Planning Initiative' with the first meeting convened on 21 July 2011 to initiate a collaborative process between First Nations, DFO and other stakeholders. The longer term objective of this initiative is to devise a comprehensive and transparent framework for managing Chinook salmon. Initial work by the Technical Working Group will be to carry out a status assessment for the 35 Chinook CUs south of Cape Caution along the BC coast. The assessment process will be based on both COSEWIC and Wild Salmon Policy Strategy I metrics and benchmarks and results will be presented for peer review at a CSAP meeting in Feb 2013. The populations comprising each of the CUs are currently being reviewed for completeness and correct association, relevant types of data are being assembled and reviewed, and the process for calculating the suite of metrics is under development. A crucial step in this early phase of the status review task will be to identify all those populations which have had substantial supplementation from hatchery-origin fish, both from hatchery rearing of fish native to the watershed or from transplants from other watersheds. The treatment of enhanced (i.e., supplemented) populations under the WSP and according to the COSEWIC guidelines on manipulated populations is under review as the choice of approach will affect the composition of CUs as well as the outcome of the status assessments.

2.5. Yukon (Marc Labelle)

Twenty-one CUs have been identified for Yukon (12 chinook, 8 chum, and 1 coho). Marc Labelle provided a summary of assessment methods used on Yukon and Trans-boundary systems, and highlighted the enormous challenges for enumerating this diverse set of geographically extensive CUs.

3. SYNOPTIC SURVEY (BLAIR HOLTBY)

Summary adapted from Holtby (2012)

A methodological framework is presented that provides a synoptic assessment of the conservation status of CUs. The approach uses data that are readily available for most CUs and established qualitative and quantitative criteria for determining conservation status. Although related to the assessment of biological production status as described by the Wild Salmon Policy, this framework deals with the assessment of conservation status and should be considered as complimentary to the WSP. The framework was designed to be part of the annual cycle of planning for stock assessment of Pacific salmon and reporting on status as required by the WSP.

A criteria-based method is described employing metrics of abundance, both absolute and relative, current and historical trends in abundance, and productivity. In addition, a variety of composite scoring tools are explored to assist in summary descriptions of status. The metrics include analogs of those used by COSEWIC to determine extinction risk. The method is applied to Fraser River sockeye and to southern BC chinook and the results compared to status profiles based on expert consensus (Fraser sockeye) or expert opinion (chinook).

The principal findings are that criteria-based approaches like the one presented as well as that of COSEWIC are unlikely to provide definitive statements of status but, instead, are useful as the starting points for discussions leading to expert consensus. While criteria-based methods were able to identify CUs that were clearly at-risk or clearly not at-risk, the majority of CUs presented with conflicting evidence that could only be resolved through structured discussion within a consensus building process.

3.1. Discussion points

Several methods for identifying conservation status were identified by Holtby (2012) using a variety of types of data (abundances, decline rates, productivity, and fishing mortality). The method based on COSEWIC criteria (abundances and decline rates) was suggested as an appropriate starting point for the assessment as it provided the fewest false-positives. Identifying conservation status requires expert opinion to integrate information on productivity, exploitation history, and other relevant factors not included in COSEWIC criteria.

In addition to spawning escapement data by CU from NuSEDS, the synoptic survey requires expansion factors for escapement time-series, the mean age composition of spawners, harvest rates, a database of hatchery and enhancement activities, and amplification factors for recruitment of hatchery-origin fish. Without that supplementary information, results may be inaccurate or biased.

There was consensus among the group that, once approved by CSAS, the synoptic survey methodology should be adopted by SACC, and used annually (possibly at the November meeting) as a starting point to identify conservation status on each CU incorporating expert opinion from within SACC. Where more detailed WSP assessments have been completed, those results will replace outputs from the synoptic survey. Further discussions on the process for identifying conservation status (how expertise within SACC is integrated with synoptic survey output) and the final use of the statuses (e.g., for internal prioritization of assessment and management resources, reporting out publicly, and/or otherwise) are required. The outputs of the synoptic survey would not require further CSAS review.

In addition, a process for updating the list of CUs is currently under development by B. Holtby, and will be provided to SACC who will be responsible for its maintenance. This process will include the development of profiles for each CU that describe the composite populations, why and when it was identified as a CU, a history of revisions, among other types of information.

4. DATA TREATMENT

4.1. Enhancement[1]

The Wild Salmon Policy states that wild salmon are salmon that "have spent their entire life cycle in the wild and originate from parents that were also produced by natural spawning and continuously lived in the wild" (DFO 2005). One of the goals of the WSP is to provide healthy, diverse, and abundant *wild salmon populations* for future generations (emphasis added). However, the explicit definition of a wild salmon population is not provided, and possible working definitions (e.g., those that consider the proportion of naturally spawning vs. hatchery-origin fish) are difficult or impossible to implement because not all hatchery fish are marked and there is no way of identifying fish that spawned in the wild from parents that originated from hatcheries. Even if it were possible to differentiate wild and hatchery-origin fish, there may be no reason to do so. Long-term supplementation practices often involve integration of wild and hatchery fish so that the two types of fish are indistinguishable. Although in those circumstances, fish spawning in the wild may suffer lower productivity than their hatchery-origin counterparts, differences in productivity will be difficult to evaluate.

Several approaches for considering enhancement in CU assessments were identified. Holtby et al. (2007) excluded certain populations with major hatchery contributions when defining CUs (e.g., hatchery production on Robertson Creek chinook salmon on the west coast of Vancouver Island are excluded from neighbouring CUs), though not all. Populations that are comprised of both naturally spawning and hatchery-origin fish were included despite non-wild components. When assessing status of CUs, Holt et al. (2009) suggested removing first generation hatchery-origin fish from recruitment time series, but this option may not be biologically reasonable given the integration of wild and hatchery-origin fish that has occurred under long-term supplementation practices. Another option is to exclude all populations that have been enhanced beyond Salmon Enhancement Program (SEP) guidelines for ensuring genetic integrity. However, SEP guidelines may not provide appropriate guidance to determine whether an enhanced population can be considered 'wild' or not. Furthermore, this could exclude groups of naturally spawning fish that are associated with hatchery populations from CUs and WSP status assessments, even though they provide important biodiversity and are of assessment interest.

Alternatively, it may be appropriate to identify status of CUs (as currently defined) despite hatchery contributions, while recognizing that these CUs differ from those containing purely wild salmon (e.g., by providing a category in the CU profile that characterizes the hatchery contribution, with additional descriptions as required). These categories could differentiate CUs with significant hatchery contribution from major, long-standing major SEP facilities, from CUs with smaller supplementation facilities from Community Development Economic Programs or Public Involvement Projects. Notwithstanding, a few key principles in assessing status of these CUs were identified:

(1) transparency in the extent of hatchery production and natural spawning within CUs is critical (including the contribution of hatchery to the run in which it is contained, and contribution of the hatchery system to the entire CU)
(2) long-term supplementation practices often result in hatchery-origin and naturally spawning fish being genetically indistinguishable and the degree to which the population can be considered wild or hatchery-origin is (and will likely remain) unclear.
(3) fish spawning in the wild may suffer lower productivity than their hatchery-origin counterparts (and may in fact, not be self reproducing), but differences in productivity will be difficult to evaluate

Given upcoming challenges of assessing status of CUs with significant hatchery input for Southern BC chinook, the Chinook Technical Working Group will work with B.Holtby to categorize CUs in a scheme (adapted from the 4-category scheme used by Grant and Pestal (2012)) that differentiates CUs based on the occurrence of, and type and characteristics of supplementation, considering the principles listed above.

[1]Discussion with contributions from Ruth Withler (PBS, Molecular Genetics section)

4.2. Data quality

The quality of data will affect how it can be used to assess status. C. Holt presented a 3-tiered approach for ranking data quality (adapted from English et al. 2012), and aligned rankings with the metrics that can be applied. For example, data of very poor quality (e.g., where the enumeration method is not well document or provides unreliable estimates because of inappropriate timing or location of surveys, rank 1) should be excluded entirely, or used for metrics of distribution based on presence/absence when zero entries are reliable indications of absences. Caution should be used when using data of low quality (rank 2) to assess status on abundance or trends in abundance. Methods for aggregating data from sites within a CU that dampen variability, including variability due to observation errors, may be warranted (e.g., methods that calculate time-series for the average stream) (e.g., Irvine et al. 1999; Holtby 2012). Further work will be required to quantitatively investigate this characteristic of data aggregation. Data of moderate and high quality (where uncertainties are <30-50%, derived from AUC estimates, mark-recapture, or fences without large breaches, rank 3) may be used for metrics on abundances, trends in abundance, and distribution.

Participants outlined numerous additional challenges when processing data prior to analysis. When methods for enumeration change over time, careful site-specific calibration is required to standardize abundances to a common scale, but guidelines on appropriate methods to do this do not exist. In addition, calibration of indices of abundances to absolute numbers is required when comparing against capacity-derived benchmarks. Development of calibration guidelines based on best available science would ensure that methods are technically sound and are consistent among areas and CUs. Similarly, participants expressed uncertainty in how representative indicators sites were of an entire CU. If data on indicator sites were calibrated to total escapement, one option would be to calculate a metric on the % that indicator sites represent of the total escapement (e.g., English et al. 2012).

The aggregation of data from sites that have different qualities of data (due to, e.g., different enumeration methods) presents another challenge. One approach is to sum abundances from each site but exclude those of very poor or poor quality. Clearly, this approach tends to down-weight populations of low abundance, which are often sites of poor quality. Alternatively, sites with data with differing qualities may be aggregated using an "average-stream" analysis, which tends to minimize the effects of observation errors from poor quality data (e.g., Irvine et al. 1999). This approach weights all sites equally despite differences in total abundances, and therefore places more emphasis on weak populations than the previous method. It may be appropriate to provide data and resulting status using both approaches (summing and average-stream) considering the different emphasis that each provides.

4.3. Data interpolation

4.3.1 Simulation modelling evaluation of methods (Michael Folkes)

A substantial proportion of escapement time series stored in the NuSEDS database are interspersed with data gaps, both within and at the series extremes. Ignoring these numerical shortfalls can lead to significant underestimates of total CU escapement resulting in biased and imprecise benchmark estimates. A simulation tool has been developed to allow for a quantitative comparison of methods used to impute values for missing data. While some imputation methods are insensitive to attributes of the data series (e.g. trends and correlation), others rely on multiple, correlated data series to find optimal solutions for all missing data. This tool evaluates the performance of each imputation function given known attributes of simulated data series. The goal of this project is to suggest the best imputation methods given the structure and attributes of the data available. Results from this evaluation of interpolation methods are expected Jan. 2013. These results will form the basis for data interpolation guidelines for CU assessments.

4.3.2 Empirical evaluation of methods (Blair Hotlby)

In a case study on Fraser River sockeye salmon and Southern BC chinook salmon CUs, Holtby (2012) compared conservation status for two analytical approaches to interpolation and aggregation, one where spawner abundance data were summed across sites and interpolated using a contingency table method, the “summing method”, and a second where data were averaged across sites without explicit interpolation, the *Z*-score method. The summing method was less sensitive to the inclusion of zero-abundance values than the *Z*-score method, and was suggested for further use. Holtby (2012) further suggested including zero abundance values in the analysis instead of omitting them to reduce the probability of false negatives in status assessments (i.e., not detecting a conservation concern when one exists), and including non-indicator sites to allow for more robust comparisons with absolute abundance benchmarks (e.g., those used by COSEWIC).

5. METRICS AND BENCHMARKS: REVISIONS AND ADDITIONS

Holt et al. (2009) described a suite of metrics and benchmarks to evaluate CU status based on four dimensions: abundances, trends in abundance over time, distribution of spawners, and fishing mortality relative to productivity. Discussion focused on suggested revisions and additions to that list.

One revision was suggested for benchmarks based on the ratio of the mean of abundances in the current generation to the historical mean. Holt et al. (2009) identified lower and upper benchmarks at 0.25 and 0.5 (respectively) derived from Pestal and Cass (2009) who used expert opinion to select 0.25 as a boundary between very low and low status and 0.5 as a boundary between low and moderate status. Grant et al. (2011) revised the lower and upper benchmarks to ratios of 0.5 and 0.75 respectively, because those values represented the boundaries between low and moderate status (0.5), and moderate and high status (0.75) in the scheme of Pestal and Cass (2009). Although based entirely on expert opinion, the revised benchmarks are reasonable as they are more closely aligned with the language describing boundaries between red, amber, and green in the WSP.

Two additional sets of benchmarks on abundances were suggested based on maximum recruitment (adult or smolts), R_{MAX}, and absolute number of spawners. The first set of benchmarks was derived from the theoretical relationship between S_{MSY} and adult R_{MAX}[1]. For CUs of moderate productivity (Ricker 0.5< a <2), lower and upper benchmarks were provisionally identified at 18% and 35% of R_{MAX}, corresponding to ~40% and 80% S_{MSY}. Assuming density-dependent survival in freshwater and a linear relationship between smolts abundances and adult recruits, benchmarks on adult recruits may also be applied to juvenile smolts. Further analysis is required to investigate the relationship between the lower benchmark on R_{MAX} and S_{gen}, and to evaluate the performance of R_{MAX} benchmarks in simulation.

In addition, lower benchmarks on absolute abundances relative to COSEWIC criterion D1 (1000 spawners) and criterion C (10,000 spawners, when accompanied by a decline in abundances) were suggested. Two challenges in identifying these benchmarks are the choice of a buffer between the lower benchmark and the level of abundances that would trigger listing by COSEWIC, and uncertainty about if and how COSEWIC will use criterion C to assess status of Pacific salmon given the large number of apparently self-sustaining CUs with abundances < 10,000 and recent declines >10%.

Spawning escapement goals have been established for some chum salmon stocks in BC and Alaska (Eggers 2008; Van Will 2009; Hilborn et al. 2012) using escapement time-series and 25th and 75th percentiles as limit and target reference points. Several participants suggested that these could be adopted as lower and upper benchmarks of CU status. That method assumes that if populations have recovered from relatively low levels in the past (25th percentile), they will again in the future

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[1] For the Ricker model formulation $R = Se^{a\left(1-\frac{S}{b}\right)}$, $S_{MSY}=b(0.5-0.07a)$ and $R_{MAX}=b\cdot\frac{e^{(a-1)}}{a}$.

assuming that conditions have and will remain constant over time. Although similar in concept and data requirements to the metric defined by Holt et al. (2009) on the ratio of current abundances to historical mean, these metrics may differ in their sensitivity to missing years of data and short time-series. Further analyses are required to compare and evaluate these benchmarks in simulation.

Although metrics of distribution have been developed (Holt et al. 2009), underlying distributional objectives that these metrics address have not been explicitly stated. Participants identified at least four reasons for assessing status on distributional metrics: (1) to determine when populations within a CU display divergent temporal patterns suggesting that they should be considered separate CUs, (2) to determine when CUs approach a status that would result in a COSEWIC listing under area or extent of occupancy, (3) to identify the vulnerability of CUs to spatially defined threats (e.g., threats at ocean entry or in-river migration), and (4) to identify changes in spatially mediated processes that are important for long-term sustainability of the CU (e.g., dispersal among populations within a CU). Further work is required to prioritize objectives for assessing distribution, align distributional metrics with those objectives, and provide guidelines for interpreting the metrics. An additional metric on the number of ocean entry points per CU was suggested as a proxy for vulnerability of a CU to threats during migration. Distributional metrics related to the area and extent of freshwater occupancy were also identified, with benchmarks derived from COSEWIC criteria B and D (but see discussion above on challenges in applying benchmarks related to COSEWIC criteria).

Fishing mortality relative to lower and upper and benchmarks, F_{MSY} and 70% of F_{MSY}, respectively, was identified as a secondary metric of status because it is more closely aligned with threats to a CU (instead of a characteristic of the population) than metrics on abundances, trends in abundance, and distribution. Despite obvious problems with using exploitation rates as an index of relative abundance, some participants suggested that this metric could be useful in cases where there is no information on current abundances, but information on exploitation rates and productivity exist from meta-analyses. This issue remains unresolved as consensus was not reached.

Additional metrics and benchmarks on current productivity and trends in productivity were suggested based on the recent assessment of Fraser River sockeye salmon CUs (Grant and Pestal 2012). The replacement level of recruits/spawner (=1) was suggested as a lower benchmark. An upper benchmark was not identified as the choice was presumed to be arbitrary given the large range of intrinsic productivities observed for apparently self-sustaining populations (Dorner et al. 2008). Time trends in productivity were highlighted by Grant and Pestal (2012) as an important consideration in status assessments. Although no formal benchmarks were identified, these could be developed. For example, a CU could be considered below the lower benchmark if there is a persistent decline in productivity (as inferred from residuals of a stock-recruitment model, Ricker *a* parameter, or an index of marine survival) over multiple (≥2) generations that extends to present, or stabilizes at low levels. Likewise, a CU could be considered below the upper benchmark (but above the lower benchmark) if there is a persistent decline in productivity over ≥2 generations that is reversed in the current generation, or there is a persistent decline over <2 generations to present or that stabilizes. Further work is required to formalize benchmarks, though metrics on productivity have been, and can be used qualitatively in status assessments (e.g., Grant and Pestal 2012).

Similar metrics have been applied to the synoptic survey of conservation status (Holtby 2012), but thresholds delineating status differ. Both Holt et al. (2009) methods (including the revisions suggested here) and the synoptic survey include metrics on current abundances, ratio of current to historic abundances, short-term trends in abundances, productivity, and fishing mortality. However, the synoptic survey also includes metrics on the ratio of the current abundances to the mean of the previous 5 generations, short-term trends in abundances iterated over the entire time series, and spawner abundances relative to S_{MSY}. The synoptic survey does not include a metric on spawner abundances relative to S_{gen} or metrics on distribution[2]. Instead of identifying three zones of status, red, amber, and green (as in Holt et al. 2009), the synoptic survey identifies 6 categories of risk characterization: very high risk, high risk, moderate risk, of concern, low risk, and least risk. Although the categories of risk characterization are, for the most part, not aligned with zones of biological status under the WSP, they could be in future iterations. These differences have arisen in part because biological benchmarks derived for the WSP are intended to delineate status based on biological production and conservation (in so far as COSEWIC listing should be avoided), whereas the synoptic survey focuses primarily on conservation status and therefore “should be viewed as complimentary to WSP status determination” (Holtby 2012, p.5). Indeed, the methodology “is intended to be a useful prioritization tool” instead of providing a definitive assessment of status (Holtby 2012, p.6).

5.1. Meta-analyses

Meta-analyses can be used to estimate parameters of interest (e.g., productivity) in a data-poor CU by borrowing information from neighbouring data-rich systems. One example used for sockeye salmon on the North Coast is hierarchical Bayesian analysis that combines information on stock-recruitment parameters across CUs with informative priors on capacity. Parameter and benchmarks can then be estimated for CUs with little or no data. The primary assumption in these analyses is exchangeability of parameters among CUs (i.e., parameters from all CUs are assumed to be drawn from the same distribution). In another example, habitat-based benchmarks were derived from a meta-analysis for chinook populations.

5.1.1 Using accessible watershed size to predict benchmarks for chinook salmon CUs: a Bayesian hierarchical modelling approach (Chuck Parken)

Summary adapted from Liermann et al. (2010)

Escapement goals for Chinook salmon populations tend to be highly uncertain due to variability in, and in some cases complete absence of, spawner-recruit data. A previous study of 25 populations from Oregon to Alaska demonstrated that watershed size is a good predictor of unfished equilibrium population size. This relationship was further developed by evaluating a series of Bayesian hierarchical models of increasing complexity. The model that performed best included a temporal random walk to account for patterns in the spawner-recruit residuals and life history-specific distributions for the productivity parameter.

[2] Metrics on distribution were included in previous iterations of the synoptic survey but were omitted from the final version

6. PROCESSES FOR ASSESSING AND REVIEWING CUS

Two tiers of status assessment were identified, synoptic surveys of conservation status and more detailed CU assessments (e.g., Grant et al. 2011; Grant and Pestal 2012), which require different processes for implementation and types of review. Once accepted by CSAS (revisions currently under review), the methodology for synoptic surveys will be maintained by SACC and applied annually (possibly in conjugation with fall Outlook reports). As described in a previous section, the development of conservation status will require expert opinion contained in SACC to interpret the synoptic survey output and integrate it with information on productivity, fishing mortality, and other relevant metrics. The annual conservation status determined by SACC would not require further CSAS review.

The results of the synoptic survey, combined with management commitments such as those for MSC certification, will inform a prioritization scheme for more detailed CU assessments. CSAS review is recommended for these detailed assessments to ensure data are treated appropriately, methods are applied consistently among species and CUs, the interpretation of status is clear and transparent, and the results are formally documented. It was recommended that peer reviews focus on area- and theme-specific expertise (instead of the entire salmon CSAP sub-committee) to increase the efficiency of the process and reduce burden on authors and reviewers. Further discussion is required to identify criteria for initiating a detailed CU assessment, and to adapt the current CSAS process to review those assessments.

6.1. Stakeholder engagement

Status assessment requires consultation of stakeholders in a technical capacity. The recent assessment on Fraser River sockeye salmon demonstrated the successful engagement of expertise from a diverse group of First Nations, commercial and recreational fisheries, NGOs, and provincial and federal scientists when integrating status on a suite of metrics and corresponding benchmarks and uncertainties (Grant and Pestal 2012). Stakeholders evaluated uncertainty in assessments based on different model assumptions and probability distributions on benchmarks, and assigned overall status according to risk tolerance. In the assessment process, participants were asked to provide objective, technical advice on status. Socio-economic values were excluded from the process, and are intended for inclusion in the strategic planning process under Strategy 4 of the WSP.

7. RECOMMENDATIONS FOR FUTURE WORK

(1) Development of a process for defining and revising CUs, including the creation of CU profiles to record revision histories (in progress, B. Holtby). The official list of CUs is to be maintained by SACC. This process should include updating of tables defining CUs in DFO databases (e.g., NuSEDS, PADS, EPADS, MRP).

(2) Further scrutiny of CU definitions by Area staff (Holtby and Ciruna 2007, updated v3). This work is currently underway for Southern BC chinook salmon.

(3) Development and/or maintenance of databases of CU-specific spawner age-structures, escapement expansion factors, time-series of harvest rates, SEP activities, and hatchery amplifications to be used as inputs in the synoptic survey.

(4) Development of processes for data provision, execution, maintenance, reporting, and end use of synoptic survey (maintained by SACC).

(5) Simulation evaluation of interpolation methods (in progress, M. Folkes).

(6) Guidelines for calibration of time-series and development of expansion factors.

(7) Publication of an updated list of metrics and benchmarks in a Technical Report (possibly in conjunction with updated software on benchmark identification) (C. Holt).

(8) Evaluation of new abundance metrics and comparison with those identified in Holt et al. (2009): benchmarks based on R_{MAX} and percentiles of escapement time-series (C.Holt).

(9) Development of habitat-based benchmarks (similar to those developed by Parken et al. for chinook salmon) for other species (e.g., coho) (proposal submitted for funding, A. Tompkins).

(10) Distribution metrics: initiate a working group to develop a consistent list of distributional metrics aligned with the various goals for assessing distribution (C.Holt, R.Bailey, G.Brown, S.Grant).

(11) Development of a template for data summaries adapted from Grant and Pestal (2012) for status integration (C. Holt)

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APPENDIX A: AGENDA

Agenda: Progress Meeting

Identifying benchmarks and assessing status of CUs:
Converging on consistent methods
Oct. 18-19, 2012
PBS Seminar Room

Day 1: Progress updates on CU assessments

9:00	Introductions, logistics, and policy context	Carrie Holt
9:20	Fraser River sockeye salmon: successes and further challenges	Sue Grant
10:30	Break	
10:45	Skeena lake sockeye: developing benchmarks using hierarchical Bayesian models and habitat capacity Progress on CU assessments of all species in the Skeena watershed	Steve Cox-Rogers
11:30	Discussion, and follow-up questions	Group
12:00	Lunch	
1:00	WCVI assessments: Progress on Barkley sockeye and chinook and beyond	Diana Dobson
2:00	Break	
2:15	Southern BC Chinook: challenges for upcoming assessment	Gayle Brown
2:45	Group discussion ▪ Progress in other areas/species ▪ Identify common challenges/topics that require further scientific advice/review ▪ Brainstorm methods and timelines for reviewing CU assessments (e.g., through CSAS, a technical working group, etc...)	Group
3:00	Synoptic Survey- update, followed by discussion	Blair Holtby
4:00	Wrap-up	

Day 2: Developing consistent methods, with emphasis on data-poor CUs

9:00	Data treatment, with emphasis on data-poor CUs: ▪ considering enhancement ▪ interpolation of missing data (contributions from M. Folkes) ▪ aggregating data across sites ▪ dealing with data of differing qualities	Carrie Holt to lead discussions
10:00	Break	
10:15	Overview of metrics: Holt et al. (2009). When are they appropriate, and when should others be considered? Additional approaches/benchmarks, with emphasis data-poor CUs ▪ Benchmarks on abundances and trends: suggested revisions and additions (including habitat-based benchmarks) ▪ Metrics on productivity (and metrics on time-trends) ▪ Metrics on distribution and linkages to COSEWIC criteria ▪ Metrics on fishing mortality: when to apply? ▪ Meta-analyses that borrow information from neighbouring CUs (e.g., hierarchical Bayesian models)	
12:00	Lunch	
1:00	Follow-up discussion on morning discussion on metrics, benchmarks, and approaches to assessments. Identify topics that require further scientific analysis and/or review ▪ Note, Call for Scientific Advice will be posted by CSAS Oct. 2012.	
2:00	Break	
2:15	Data summaries: developing a consistent template for CU assessments ▪ Would a common template be useful for status integration across metrics? ▪ Brainstorm information to include and format Develop advice for frequency of re-assessments. ▪ Integrating CU assessments with synoptic survey and stock assessment framework	
4:00	Wrap-up	

APPENDIX B: PARTICIPANT LIST

Velez-Espino, Antonio
Dobson, Diana
Grant, Sue
Brown, Gayle
Parken, Chuck
Baillie, Steve
Cox-Rogers, Steven
Huang, Ann-Marie
Labelle, Marc
Bailey, Richard
Tompkins, Arlene
Patten, Bruce
Van Will, Pieter
Ritchie, Lynda
O'Brien, David
Tompkins, Arlene
Tadey, Joe
Kadowaki, Ron
Holbty, Blair
Irvine, James
Saunders, Mark
Luedke, Wilf
Cass, Al
Folkes, Michael (absent, but sent presentation)

APPENDIX C: TERMS OF REFERENCE

Terms of Reference: Progress Meeting

Identifying benchmarks and assessing status of CUs: Converging on consistent methods

Holt et al. (2009) provided a template for identifying benchmarks and assessing CUs under Strategy 1 of the Wild Salmon Policy. Progress has been made applying these methods, but assessments have diverged from those described by Holt et al. (2009) due to: (1) poor-quality data available for assessments, (2) better understanding of characteristics of benchmarks (e.g., degree of precaution they provide, practicality of estimation) once put into practice, (3) information missing from the published suite of metrics required to make informed decisions about assessments, and (4) divergent methods for handling data prior to assessments, not specified by Holt et al. (2009), among other factors. Recommendations from a recent assessment of Fraser River sockeye salmon CUs and upcoming assessments of southern BC chinook salmon and Skeena watershed sockeye salmon, among others, provide further incentives for a progress update.

The overall goal of this meeting is to facilitate convergence on a consistent, robust methodology for assessing status of CUs by exploring differences that have occurred, understanding rationale for those differences, and identifying a consistent way forward, where appropriate. The meeting will focus on biological status of CUs based on biological information instead of management approaches or requirements, which require fisheries objectives and stakeholder input not provided here. See section on Policy Context below for information on how this work relates to other policy initiatives.

Discussion Topics:

(1) Updates from Area staff on progress on estimating benchmarks and evaluating status of CUs.

- Are methods consistent with Holt et al. (2009)? How have they diverged? What are the obstacles to assessments? What information/methodologies are required for further progress?

(2) Update on how methods have been applied to CUs with poor quality or limited data. Possible approaches include:

- infilling and extrapolation where data exist but are incomplete (but consistency among CUs and species is desired)
- meta-analyses that borrow information from neighbouring sites within a CU or neighbouring CUs (e.g., hierarchical stock-recruitment models)
- time-series estimation of stock-recruitment parameters (assuming shared environmental anomalies among neighbouring CUs, as suggested by C.Walters)
- inclusion of freshwater habitat information

Develop consensus on when a CU can be listed as "data deficient".

***Note, we will not evaluate these methods here, but will compile a list of possible approaches and highlight those that require additional scientific analysis and/or review**

(3) Discussion of proposed/revised metrics of status and/or benchmarks, such as:

- Metrics and benchmarks based on juvenile data
- Metrics on absolute abundance criteria with benchmarks related to criterion D1 of COSEWIC (criterion related to very small population sizes ~1000 mature individuals)

- Metrics on distribution related to those used by COSEWIC, and/or others (e.g., those used by McElhany et al. (2006)).
- Metrics based on fishing mortality. When and how should these be applied?
- Metrics on spawner abundances and trends in spawner abundances: should abundances always by log-transformed?

***Again, we will not solve all these issues here, but will instead highlight those that require additional scientific analysis and/or review**

(4) Develop a common dashboard of assessment outputs ('data summary'). This dashboard could include:

- metrics and benchmarks described in Holt et al. (2009), and additional metrics covered at this meeting
- information on model fit, when models are used to estimate benchmarks
- time series of productivity (recruits/spawner and Ricker "a" parameter)
- time series of fishing mortality
- text on history of CU including spawning channels/enhancement.
- information on data quality

Grant et al. (2012) provides an example of such a dashboard, which could be adapted to provide a more generic template for CUs with different types and/or qualities of data.

(5) Develop guidelines for how CU assessments should be reviewed and provide input on how often CUs should be assessed.

- In which cases should assessments be reviewed by CSAS?
- Could a technical working review assessments, or review preliminary steps involving technical details of data used to generate time-series for assessments?
- What resources would be required to establish such a technical working group? Who would be involved?

(6) What scientific information is missing and required to move forward on implementation of Strategy 1 of the Wild Salmon Policy. Does this science require (or would it benefit from) CSAS review? (Note, a call for Scientific Advice will be posted by CSAS in Oct. 2012).

- Examples include: evaluation of methods for assessing data-limited CUs, evaluation of habitat-based benchmarks, and review of additional metrics, especially those for distribution.

Proposed Outcomes:

a) Updated timeline on proposed CU assessments.
b) Description of possible methods for assessing data-poor CUs. Identify how, where, and when these methods will be implemented and reviewed.
c) Revised list of metrics, benchmarks, and additional information to be included in dashboard of assessment outputs.
d) Guidelines on how and when CU assessments should be reviewed (through CSAS and/or a technical working group). Scientific input on how often CUs should be assessed.
e) Submission to CSAS for upcoming Calls for Scientific Advice.

Participants: Area Chiefs and Area staff involved with stock assessments, Science staff involved with stock assessments.

Timing: Two days in October. Day1 will cover progress updates from Area staff. Day 2 will cover discussion topics 2-6 and outcomes b)-e).

Format:

- Brief questionnaire to participants prior to meeting to facilitate brainstorming
- Presentation at meeting from Areas to provided updates on CU assessments and obstacles for future assessment work
- Group discussion of topics listed above, facilitated by C. Holt.

Policy context:
Assessment of CUs under Strategy 1 of the Wild Salmon Policy can be placed in the context of numerous other ongoing initiatives. Although critical for an understanding of how benchmarks relate to other work at DFO, we will not talk in detail about these topics at the proposed meeting due to time constraints.

A methodology for a synoptic survey on the conservation status of CUs has recently been developed by B. Holtby (in draft form, waiting approval by CSAS). That methodology has been applied to Fraser River sockeye salmon and Southern BC Chinook salmon to identify CUs of high conservation priority that require further, more detailed assessments under Strategy 1 of the Wild Salmon Policy (Holtby 2012).

The Marine Stewardship Council (MSC) certification of sockeye, pink, and chum salmon fisheries requires the development of fisheries reference points for management and they (provisionally) considers these to be equivalent to WSP benchmarks, despite concerns from DFO Science. A recent national DFO initiative to identify reference points under the Precautionary Approach (DFO 2009) resulted in the development of a guidance document for salmonids (Chaput et al. 2011).

Operationally, CU assessments will be prioritized, in part, based on new Stock Assessment Framework being developed in DFO (Pacific region) by R. Kadowaki and others. This prioritization will be in the context of recent budget reductions for assessments, and limited access to resources to meet assessment and fisheries objectives.

The Cohen Commission will submit its final report this fall, which will make recommendations for improving the future sustainability of the sockeye salmon fishery in the Fraser River, including, as required, any changes to the policies, practices and procedures of DFO, possibly including recommendations for WSP implementation.

In addition, biological assessment of CUs under Strategy 1 of the Wild Salmon Policy will be integrated with habitat status, ecosystem values, and socio-economic factors through Strategies 2, 3, and 4. A case study in Barkley Sound by K.Hyatt and others will provide guidance on an application of this integration to other regions. Recent progress on Strategy 4 has identified provisional planning units for the Pacific Region, which are groups of CUs in a geographic location that are subject to common risk factors and where socio-economic factors are given full consideration.

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