



A discussion on estimating stock distribution and distributing catch for Pacific halibut fisheries

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PURPOSE

To determine definitions for stock distribution and catch distribution to create a clear delineation between science inputs and management procedures for distributing the TCEY across the coast.

BACKGROUND

Recommendations from the 93rd IPHC Annual Meeting (AM093) included the following related to distributing TCEY among the Regulatory Areas (IPHC 2017).

30. **NOTING** that the Commission has indicated its interest in clearer accounting for all mortality, and that Canada has put forward catch limit allocation principles proposing that catch limits include all sources of mortality for each regulatory area, the Commission **RECOMMENDED** that the presentation of harvest advice be changed to be based on the TCEY, which includes all O26 commercial, sport, personal use/subsistence, bycatch and wastage removals, for the 2018 Annual Meeting cycle, as a step towards more comprehensive and responsible management of the resource that will result in the negotiation of Regulatory Area-specific catch limits based on TCEYs.

38. **NOTING** that the term “apportionment” has connotations broader than stock distribution that are not reflective of its meaning in the IPHC context, the Commission **RECOMMENDED** that it be replaced with the terms “stock distribution” or “stock distribution model(ing)”.

39. The Commission **RECOMMENDED** that the IPHC Management Strategy Evaluation (MSE) process be accelerated so that more of the elements contained within the current Program of Work are delivered at the 94th Annual Meeting of the Commission in 2018. The IPHC Secretariat is directed to mobilise carryover funds from “core operations” to ensure the accelerated delivery schedule.

40. The Commission **REQUESTED** that the IPHC Secretariat initiate a process to develop alternative, biologically based stock distribution strategies for consideration by the Commission and its subsidiary bodies. This should also be incorporated into the MSE Program of Work.

There is an obvious interest in beginning evaluations of the distribution part of the updated harvest strategy (Figure 1). Compared to only evaluating the scale component, also evaluating the distribution component increases the complexity of the simulations, involves additional computer programming and debugging, and requires additional stakeholder guidance (i.e., MSAB meetings). The most difficult aspect of accelerating the timeline in the work plan is ensuring that the MSAB is providing the necessary feedback and guidance to the MSE process. There are many decisions to make and evaluations to consider, which would require additional meetings other than the two already scheduled annually. Regardless, it is beneficial to begin the conversation with the MSAB and to begin identifying management procedures related to distributing the TCEY among the Regulatory Areas.

This document summarizes the issue with apportionment as identified by the Commissioners at AM093, suggests terms and definitions to be used by the Commission when referring to distributing TCEY among Regulatory

Areas, and proposes some management procedures for distributing the TCEY across the coast. This information is provided to spur discussion with MSAB members in preparation for evaluating management procedures related to TCEY distribution in the future.

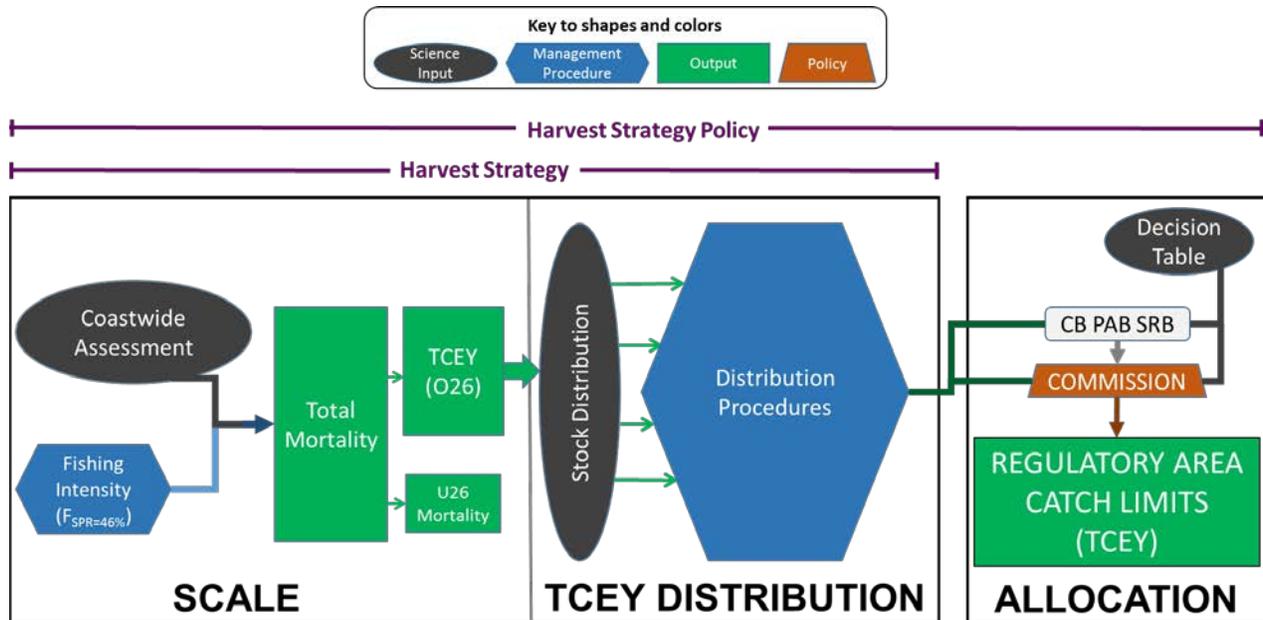


Figure 1: The current IPHC harvest strategy policy showing the separation of scale and TCEY distribution of fishing mortality. A constant fishing intensity is maintained, but a substantial change in the distribution for a given Total Mortality may result in a slight change to the calculated SPR.

A REQUIEM FOR APPORTIONMENT

The Merriam-Webster definition of apportion (<https://www.merriam-webster.com/dictionary/apportion>) is “to divide and share out according to a plan; *especially*: to make a proportionate division or distribution of.” The Merriam-Webster Law Dictionary further defines apportion as “to make a usually proportionate division or distribution of (an amount due) according to a plan.” The IPHC’s harvest strategy historically deemphasized the distinction between the estimation of stock distribution, and the subsequent application of harvest rates, the combination of which yielded staff catch advice. Beginning with the 2014 stock assessment results, apportionment was defined as the relative distribution of legal (O32) survey catch among regulatory areas (Webster and Stewart 2015), and the application of the harvest strategy was delineated to include the target harvest rates applied to the apportioned exploitable biomass estimates consistent with the policy at that time. Overall, this can be viewed as distributing the TCEY according to a management plan, with apportionment referring only to the component that determined the distribution of O32 biomass. These two concepts continued to be confused and referred to as apportionment, despite being reported as separate chapters in each year’s RARA. Therefore, it has become imperative to use new terms to describe and clearly separate the two concepts: 1) estimating the biological distribution of the stock, and 2) applying management protocols to distribute TCEY among Regulatory Areas. This new approach should provide a clearer distinction between a scientific concept (the former) and management procedures (latter).

DISTRIBUTION OF THE TCEY

Following the Commission's recommendation from AM093, we suggest the phrase **TCEY distribution** when referring to how the TCEY is distributed among Regulatory Areas, and the phrases **stock distribution** and **distribution procedures** referring to separate components determining the distribution of the TCEY. More specifically, these terms are defined as follows (also see Appendix A: Glossary).

TCEY DISTRIBUTION

TCEY distribution is the management procedure for distributing the TCEY among Regulatory Areas. This may be composed of the purely scientific component (stock distribution) and/or the management component of distributing harvest (distribution procedures), with an outcome of harvest strategy determined catch limits in each Regulatory Area. The adopted catch limits include an additional allocation/decision step that is typically determined at the Annual Meeting (Figure 1).

The ultimate goal is to set catch limits for each Regulatory Area, and the harvest strategy typically defines a procedure to do so. However, the harvest strategy may be focused on an alternative area definition that is broader than the Regulatory Areas. For example, the harvest strategy may distribute TCEY to Regional Areas composed of multiple Regulatory Areas, and distributing or allocating the TCEY to individual Regulatory Areas could be a management procedure or a management decision/negotiation (Figure 2).

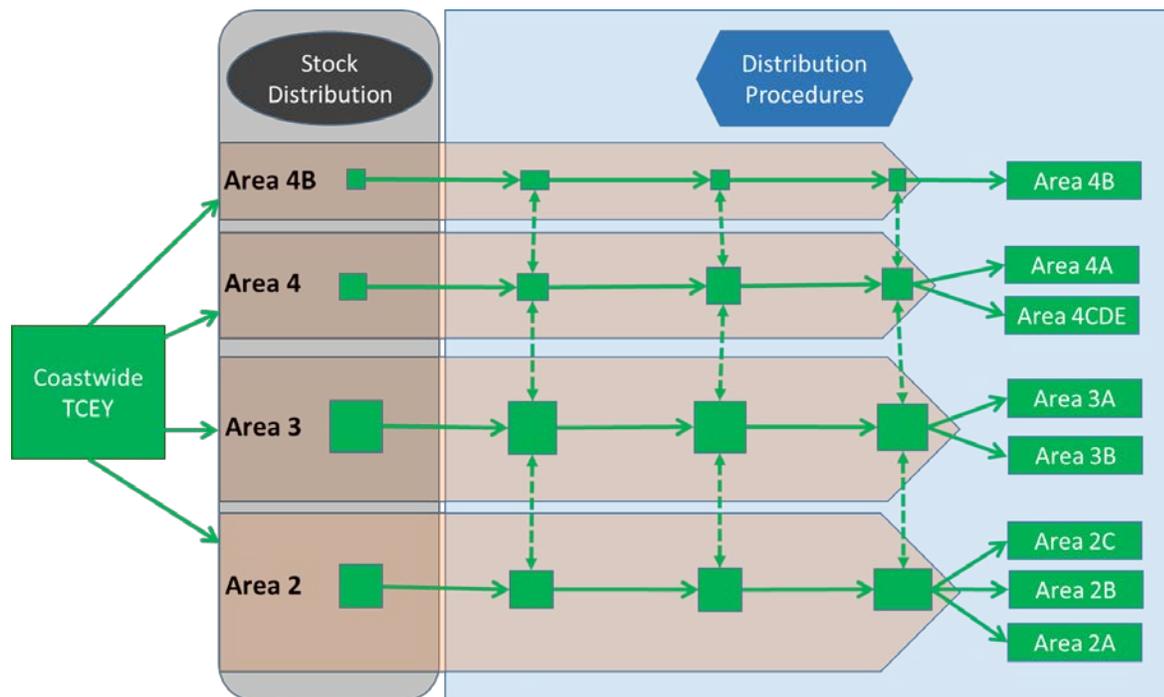


Figure 2: The process of distributing the TCEY to Regulatory Areas from the coastwide TCEY. The first step is to distribute the TCEY to regional areas based on the estimate of stock distribution. Following this, a series of adjustments may be made based on observations or social, economic, and other considerations. Finally, the adjusted regional TCEY's are allocated to Regulatory Areas. The allocation to Regulatory Areas may occur at any point after stock distribution and may also be external to the procedures and instead an allocation step (see Figure 1).

STOCK DISTRIBUTION

Stock distribution is the analytical process of estimating the proportion of biomass in defined areas of the coast relative to the coastwide biomass. This is a science product and the outcome does not need to specifically align with Regulatory Areas. Distributing the TCEY based on the stock distribution will often be the first step in the process (Figure 2).

Currently (and in the previous harvest strategy) stock distribution is estimated using the O32 results from the annual IPHC fisheries-independent setline survey. Stock distribution is based on the space-time model introduced in 2016, and includes all corrections for: survey timing, hook competition, expansion regions, as well as incorporating calibrated observations from other surveys. The survey results are not estimated in absolute biomass, but provide a relative proportion among Regulatory Areas (Webster and Stewart 2017).

Stock distribution may play a role in distributing the TCEY if there is an objective of maintaining a diversity in the population across space. It has been shown that maintaining a diverse portfolio of stocks in salmon populations (e.g., Schindler et al. 2010) has resulted in better resilience to environmental changes and regime shifts, resulting in more sustainable fisheries. Little is known about the exact interplay between geographic regions within the Pacific halibut population, but there may be subtle genetic differences (Drinan et al. 2016), and it may be beneficial to distribute harvest across all the population instead of potentially over-exploiting one component. This appears to be an objective for the previous harvest strategy, which spread effort across all Regulatory Areas.

The Regulatory Areas are management areas and do not necessarily have a biological basis. For example, Area 4A includes south and north of the Aleutian Islands, which may provide some separation and slow movement between the northern and southern areas. However, the stock is managed by Regulatory Area, which must be preserved when determining biologically-based areas.

Our proposal is to estimate the stock distribution among regions, after which management-related protocols and decisions can be used to further distribute the TCEY into Regulatory Areas. Given the current understanding of Pacific halibut, four biologically relevant regions that meet management needs are: Area 2, Area 3, Area 4ACDE (simply called Area 4), and Area 4B (Figure 3).

These four biologically-based regions capture the broad spatial and productivity domains of the population. Distributing the TCEY among them would continue to protect the geographic life-history variability and possible biodiversity in the Pacific halibut population, but would not force arbitrary delineation among areas with evidence of strong stock mixing. Further distributing the TCEY to Regulatory Areas would be done through the Distribution Procedures component (Figure 2).

DISTRIBUTION PROCEDURES

Distribution Procedures is the process of further modifying the distribution of the TCEY among regions and then distributing the TCEY among Regulatory Areas within geographic regions based on management procedures defined by the harvest strategy. For example, modifications at the region level may be based on differences in production between areas. Distributing the TCEY to Regulatory Areas from regions could be based on observations in each area relative to other areas (e.g., WPUE), uncertainty of data or mortality in each area, and may also be based on defined allocations.

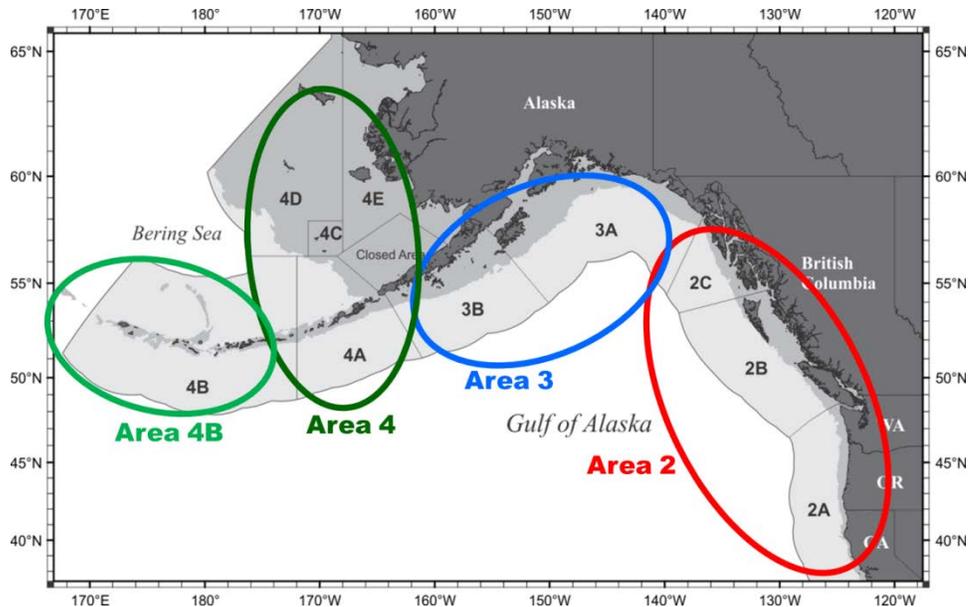


Figure 3: Proposed biological stock distribution regions.

The previous harvest strategy included harvest rates that were lower in the western Regulatory Areas (16.125% in 3B and 4) than in the eastern Areas (21.5% in 2 and 3A). The updated harvest strategy approaches management of the Pacific halibut stock from the viewpoint of the coastwide stock by setting an overall fishing intensity, and then distributing the coastwide TCEY (Figure 1). Therefore, only relative harvest rates among regions are necessary, which maintains the overall fishing intensity. Specific differences in harvest rates among Regulatory Areas can be used, but are not required, to then determine Regulatory Area catch limits. The regional information can be largely based on scientific analyses (e.g., Yield-Per-Recruit or YPR), but the area-specific decisions involve management objectives related to local stock and fishery trends/performance as well as other considerations. YPR for each region may be used to guide the relative harvest rates, but other measures of average production may also be useful. For example, the long-term average surplus production in each region can provide insights; or annual observations of surplus production could be used to adjust harvest rates on a short-term basis. Surplus production can be measured as the biomass that can be removed from a region and maintain the biomass in that region at the same value as in the previous year, noting that it incorporates natural production, movement, and exploitation rates, all of which are difficult to estimate and would be confounded.

Other data may be used as indicators of stock trends in each region or Area, and are included in the Distribution Procedures component because they may be subject to certain biases and include factors that may be unrelated to biomass in that Area. Commercial weight-per-unit-effort (WPUE) is a popular source of data used to indicate trends in a population, but may not always be proportional to biomass. Regardless, if WPUE is increasing in one region and declining in all other regions, that may be an indication that more fish are available in that region and the population in that region may be able to sustain a higher exploitation rate than other regions. This could also apply to distributing catch to Regulatory Areas within a region. A rule could be created to inform or adjust the distribution of TCEY based on survey or fishery catch rates or catch-rate trends. This is one of many examples of how an auxiliary source of data could be used to inform the distribution of TCEY. Other alternatives could be WPUE minimums, targets, or WPUE-based control rules. Furthermore, other types of data may also be used, such as survey observations (not necessarily the setline survey), age-compositions, size-at-age, and possibly even environmental observations.

A final step in the distribution of TCEY may be to simply make further discretionary adjustments, or to simply allocate the TCEY from regional areas to Regulatory Areas. This is entirely based on management decisions (Allocation box in Figure 1) that takes social, economic, national, and other factors into consideration. The final distribution of TCEY among Regulatory Areas would be input into the stock assessment to determine the adopted SPR and coastwide fishing intensity, which may differ from the harvest strategy SPR due to these final management decisions.

MANAGEMENT PROCEDURES FOR DISTRIBUTING TCEY ACROSS THE COAST

In the MSE simulations, the process of distributing the TCEY always begins with the coastwide TCEY determined from the stock assessment and fishing intensity (Figure 1). Distributing the TCEY among regions always includes stock distribution based on estimates from the setline survey, but also includes adjustments by region and Regulatory Area based on management procedures. Adjustments from management procedures may include using relative harvest rates, using observations from the fishery (e.g., WPUE, average size, etc.), and incorporating socio-economic concerns. The key to these adjustments is that they are relative adjustments such that the overall fishing intensity is maintained (i.e., a zero sum game). For example, distributing the TCEY based on stock distribution, and then increasing the TCEY in all Areas would result in a higher fishing intensity. This may be a desired outcome for a particular year (short-term, tactical decision making based on current trends estimated in the stock assessment), but would deviate from the harvest strategy and the long-term management objectives. The goal of a harvest strategy is to provide a method to determine catch levels that if implemented for many years would produce desirable results. Deviations from that harvest strategy may result in undesirable outcomes, but could also take advantage of current situations.

POTENTIAL MANAGEMENT PROCEDURES FOR DISTRIBUTING THE TCEY

Some management procedures are described below for distributing the TCEY which can be evaluated as part of the MSE process. It begins with a procedure similar to the past harvest strategy, and progresses to more complex procedures. We propose to include the first two procedures in the evaluation, and some additional examples are provided to illustrate how MSAB members may devise additional procedures to be simulation tested and evaluated as part of the MSE process.

Pseudo-previous harvest strategy (status quo)

Similar to the previous harvest strategy, this example distributes the TCEY to Regulatory Areas based on stock distribution and relative harvest rates for each Regulatory Area. Previously, harvest rates of 21.5% for Areas 2 and 3A and 16.125% for Areas 3B and 4 were used to calculate the TCEY. Replicating the previous harvest strategy with the current harvest strategy dependent on a coastwide fishing intensity (Figure 1) is not straightforward, though.

The previous harvest strategy applied area-specific harvest rates to apportioned biomass, thus the coastwide harvest rate was dependent on the distribution of biomass. With area-specific harvest rates ranging from 16.125% to 21.5%, the coastwide harvest rate could theoretically also cover this same range, depending on where the biomass was distributed. In 2017, the coastwide harvest rate was 19.6%, and has been near that value since 2013. Conversely, the current harvest strategy maintains a constant coastwide fishing intensity, from which the TCEY is distributed.

In this alternative, distributing the TCEY to Regulatory Area A is done as follows.

$$TCEY = f(FI) \quad (1)$$

$$TCEY_A = TCEY \frac{\rho_A \times F_A}{\sum_A \rho_A \times F_A} \quad (2)$$

The term FI refers to fishing intensity and the TCEY is a function of that fishing intensity and calculated in the stock assessment. The TCEY in Regulatory Area A is then determined from the proportion of the stock in Area A (ρ_A), which is noted with a Greek symbol because it is an estimated quantity from the setline survey data, and F_A , which is the relative fishing intensity for Area A . The division by the summation of the product of ρ_A and F_A is done to ensure that the sum of the area-specific TCEYs is equal to the coastwide TCEY¹.

$$\sum_{all A} TCEY_A = TCEY \frac{\sum_{all A} \rho_A \times F_A}{\sum_{all A} \rho_A \times F_A} = TCEY$$

Forcing the TCEY to remain constant guarantees that the fishing intensity will remain constant, and ρ_A and F_A may take on any value (although ρ_A is typically a proportion). We propose to make F_A relative to Area 3B, which means that F_A for Areas 2 and 3A would equal 1 and F_A for Areas 3B and 4 would be 0.75. These are not necessarily the optimal relative harvest rates, and relative harvest rates that best meet the Pacific halibut fishery and management objectives would be determined in the MSE process.

The final step of adjusting the TCEY based on other considerations would occur at the Annual Meeting and would not be a specific part of the harvest strategy. Equation (2) would determine the TCEY in each Regulatory Area, but the MSE simulations could include “management variability” that would account for this final step.

Regional distribution

Regulatory Areas are on a finer spatial scale than is necessary to preserve biocomplexity because the stock moves among areas and discernable genetic differentiation has not been observed. However, as mentioned earlier, it may be an objective to preserve biocomplexity as a precautionary measure for what we currently do not understand. Distributing the TCEY using regional estimates of stock distribution based on biological boundaries (Figure 3) may meet the objective of distributing effort to maintain stock diversity. Furthermore, incorporating relative harvest rates to alter that distribution among regions before further distributing, or allocating, the TCEY to Regulatory Areas would maintain some aspects of the past harvest strategy, but use a more biologically supported set of regions. The final allocation step would be entirely management based and could have defined allocation percentages, introduce national shares, or use some type of data to inform the distribution of TCEY to Regulatory Area within region.

As with the status quo alternative, the equation for distributing the TCEY to regions is similar, with an additional step to further allocate the TCEY to Regulatory Area.

¹ A change in the distribution of the TCEY will result in slight changes to total mortality from wastage and catch sharing plans, which feeds back to the total fishing intensity calculation. The change in fishing intensity would be very small even with abrupt changes to the distribution of TCEY, but does highlight the iterative process of ensuring that the TCEY and total mortality do indeed result in the expected fishing intensity.

$$TCEY_R = TCEY \frac{\rho_R \times F_R}{\sum_A \rho_R \times F_R} \quad (3)$$

$$TCEY_A = TCEY_R \times P_{A|R}$$

The coastwide TCEY is calculated as in Equation (1) and the division by the summation of the product of ρ_A and F_A is done to ensure that the sum of the regional TCEYs is equal to the coastwide TCEY. The regional TCEY is then multiplied by area-specific parameters, $P_{A|R}$, that sum to 1 for the areas within region R (which is why the notation includes $A|R$, which is read as ‘A given R ’). The allocation to Area, indicated by the parameter $P_{A|R}$, can simply be a specified allocation, or may be a complex algorithm that incorporates data from each area along with other specifications. It is critical that the $P_{A|R}$ within each region is one to maintain the coastwide TCEY (see previous footnote¹) and thus fishing intensity.

Areas 3A and 3B are in the same region, but used different harvest rates in the previous harvest strategy. They would have the same relative harvest rate in this alternative, but additional adjustments in the allocations from the region to the two areas could account for differences in exploitation between the two areas. We propose to make all regional harvest levels relative to region 3.

Additional management procedures

There are many other management procedures that would be worth evaluating as part of the Management Strategy Evaluation. However, we suggest using the regional framework described above and to focus on the adjustments and relative harvest rates (F_A) rather than the stock distribution (ρ_A) when developing additional management procedures. For example, it is possible to

- use additional data, other than the fishery-independent data used to estimate stock distribution, to inform additional adjustments to the distribution of the TCEY to regions or Areas within a region.
- Assign a specific allocation when distributing the TCEY to Areas within a region.
- Annually negotiate the allocation to Areas within a region (although this would be difficult to simulate, but could be evaluated against regional objectives).

TIMELINE FOR EVALUATION AND DECISION POINTS

Simulating these management procedures and evaluating them against spatial objectives requires a multi-area model that is currently in development. Therefore, specific recommendations informed by MSE simulations is not possible for the 2018 Annual Meeting (AM094). However, this is a start to the conversation and there are many notes and recommendations that can be provided to the Commission at AM094. At the May and October 2017 MSAB meetings, as well as the June and September SRB meetings, the following is expected to be considered and discussed.

- The pseudo-status quo management procedure as an alternative to evaluate.
- The regional management procedure for distributing the TCEY, as explained above, as an alternative to evaluate.
- Discuss additional ideas such as incorporating fishery observations, defining static allocations, and, time periods of fixed distribution.
- Develop additional alternatives to evaluate using these ideas.

RECOMMENDATION/S

That the Scientific Review Board:

- 1) **NOTE** paper IPHC-2017-SRB10-10 which begins a discussion about alternatives to distribute the TCEY in the current harvest strategy policy to address the task assigned to IPHC Secretariat and the MSAB at the 2017 Annual Meeting (AM093) to initiate a process to develop alternative, biologically based stock distribution strategies for consideration by the Commission and its subsidiary bodies.
- 2) **CONSIDER** the definitions and terms used to describe TCEY distribution.
- 3) **CONSIDER** the proposal for stock distribution to operate on the regions defined in this paper.
- 4) **CONSIDER** the proposed alternatives for distributing the TCEY (pseudo-status quo and regional distribution) to evaluate in the future using the MSE framework.

ADDITIONAL DOCUMENTATION / REFERENCES

- Drinan, D. P., Galindo, H. M., Loher, T. and Hauser, L. (2016), Subtle genetic population structure in Pacific halibut *Hippoglossus stenolepis*. *J Fish Biol*, 89: 2571–2594. doi:10.1111/jfb.13148
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APPENDIX A: GLOSSARY: DRAFT

This appendix contains definitions of some important terms and is in development. Any suggestions are appreciated. The [glossary on the IPHC website](#) may be an additional useful resource.

Adopted SPR: The SPR calculated from the adopted catch limits for a particular year. This may differ from the default SPR due to final management decisions to increase or decrease the TCEY in certain Regulatory Areas.

Default SPR: the SPR that used in the harvest strategy policy. This will be determined as part of the MSE process. Currently, the default SPR is a “staus quo” or “interim” SPR of 46%.

Distribution Procedures: the process of distributing the TCEY among Regulatory Areas that is based on management decisions. This may be based on differences in production between areas or data (e.g., WPUE) in each area relative to other areas (not necessarily Regulatory Areas).

Fishing Intensity (FI): A measure of the total fishing mortality on all sizes and through all sources. An example is $F_{SPR=XX\%}$ which indicates a level of fishing that would result in an SPR of XX%.

Harvest rate: The proportion of a specific component (exploitable) of the population that is harvested. This is commonly used for individual fisheries, but is difficult to compare among fisheries or combine across fisheries because the specific components typically differ between fisheries.

Harvest Strategy: The science input and management procedures that result in the determination of Regulatory Area TCEY’s, but does not include the final Commission decision making process. The harvest strategy can be programmed and evaluated with MSE.

Harvest Strategy Policy: The harvest strategy plus the final step involving Commission decisions, which may depart from the harvest strategy evaluated with MSE.

Regions: Broad areas that encompass Regulatory Areas and are supported by current understanding of the biology and life-history of Pacific Halibut.

Regulatory Areas: Eight management units for which the IPHC sets annual catch limits: 2A, 2B, 2C, 3A, 3B, 4A, 4B, and 4CDE (which includes the Closed Area).

Spawning Potential Ratio (SPR): A commonly used metric of fishing intensity. SPR is the ratio of the equilibrium spawning biomass per recruit given some level of fishing and the equilibrium spawning biomass per recruit in the absence of fishing. An SPR equal to 100% implies no fishing, and lower SPR values indicate higher fishing intensities.

Status Quo (Interim) SPR: An SPR of 46%, corresponding to a Fishing Intensity of $F_{SPR=46\%}$, which is currently used in the interim harvest strategy.

Stock Distribution: the analytical process of estimating the proportion of biomass in defined areas of the coast relative to the coastwide biomass. This is a science product which may not specifically align with Regulatory Areas.

TCEY Distribution the management procedure for distributing the TCEY among Regulatory Areas. This may be composed of the purely scientific component (stock distribution) and the possibly science and/or management component of distributing harvest (management distribution).

Total Constant Exploitation Yield (TCEY): The amount of yield of halibut greater than 26 inches in length from all sources.

Total mortality/removals: Mortality or removals of all sizes and from all sources. This includes directed fishery, sport fisheries, bycatch, O26, U26, and everything else resulting in fishing mortality of Pacific halibut.