Ideas on estimating stock distribution and distributing catch for Pacific halibut fisheries

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1 PURPOSE

To update the Management Strategy Advisory Board (MSAB) on discussions and ideas related to science inputs and management procedures for distributing the Total Constant Exploitation Yield (TCEY) across the IPHC Convention Area.

2 BACKGROUND

The report from the 94th Session of the IPHC Annual Meeting (AM094) included the following text related to distributing TCEY among the Regulatory Areas (IPHC-2018-AM094-R):

*37. The Commission **REQUESTED** that the objectives related to distributing the TCEY, as detailed in Circular IPHC-2017-CR022, be presented at MSAB11 for further stakeholder feedback.*

*38. The Commission **REQUESTED** that the proposed TCEY distribution methodology of the Harvest Strategy Policy reflect an understanding of both stock distribution and fishery management distribution procedures.*

*39. The Commission **RECOMMENDED** that the IPHC Secretariat consider the survey WPUE grid across the fishery as well as other biological factors (e.g. habitat configuration, size distribution in the region etc.) and provide alternatives to the current management areas (e.g. biological regions), and that the MSAB consider additional ways to incorporate biological information into TCEY distribution procedures.*

*40. The Commission **NOTED** that the current procedure to distribute the TCEY could be replaced by an interim procedure to be developed in the near term while the MSAB completes their Program of Work to deliver guidance in 2021 on scale and TCEY distribution.*

*41, The Commission **AGREED** to meet via an inter-sessional electronic meeting (soon after the AM094), along with the IPHC Secretariat, to discuss TCEY distribution procedures to use in the interim while long-term distribution procedures are being developed by the MSAB. MSAB representatives and the IPHC Secretariat will inform the Commission of what guidance the MSAB may be able to provide to help develop an interim distribution strategy, and how the development of an interim harvest procedure may affect the MSAB's current Program of Work.*

*42. The Commission **AGREED** that distributing the TCEY to regions does not necessarily need to be the first step of the TCEY distribution procedure, and other biological factors, such as habitat and size distribution, be considered.*

*43. The Commission **NOTED** that the work the MSAB has already completed on distribution procedures may help to inform the development of an interim distribution strategy. MSAB representatives and the IPHC Secretariat will advise the Commission of how this may affect their current Program of Work, and what guidance they may be able to provide to help develop an interim distribution strategy.*

The report from the 10th meeting of the Management Strategy Advisory Board (MSAB) in October 2017 included the following related to distributing the TCEY:

37. ***NOTING*** *the order of operations in the proposed TCEY distribution procedure, the MSAB AGREED that the order of stock distribution and TCEY distribution procedures is a management choice that could be evaluated.*
38. *The MSAB* ***NOTED*** *that the order of operations in the proposed TCEY distribution procedure will be subject to review at future MSAB meetings and that the specific components require further definition.*
39. *The MSAB* ***AGREED*** *that the output of the TCEY distribution procedure should be a catch table describing mortality in each IPHC Regulatory Area.*

This document expands on previous MSAB meeting papers IPHC-2017-MSAB09-09 and IPHC-2017-MSAB10-10, to report progress on the topic of distributing the TCEY.

3 DEFINITIONS AND A DESCRIPTION OF THE PROPOSED IPHC HARVEST STRATEGY POLICY

A considerable amount of discussion related to a description of the harvest strategy policy occurred at previous MSAB meetings. Figure 1 shows an updated depiction of the harvest strategy policy with terms describing the various components. These terms are defined in the IPHC glossary[1], but of note for this paper are TCEY distribution, stock distribution, and distribution procedures. The management procedure is the sequence of elements including the assessment, fishing intensity, stock distribution, and distribution procedures. The goal of the MSAB is to define a management procedure that will be used to output O26 mortality limits for each Regulatory Area that meet the long-term objectives of managers and stakeholders. The "decision" step on the right of Figure 1 is where a deviation from the management procedure may occur due to input from other sources and decisions of the Commissioners that may reflect current biological, environmental, social, and economic conditions.

4 A BACKGROUND ON THE DISTRIBUTION OF THE TCEY

As tasked by the Commission, an evaluation of the previous IPHC informal 'harvest policy' was undertaken and presented at MSAB08. That harvest policy used a procedure that took the coastwide stock assessment as an input, and output 1) the coastwide Total Constant Exploitation Yield (TCEY) (across all Regulatory Areas), and 2) the TCEY and Fishery Constant Exploitation Yield (FCEY) for each Regulatory Area. The integral input to that harvest policy was the coastwide stock assessment. The scaling of catch for that harvest policy revolved around the concept of exploitable biomass (EBio) and defined harvest rates. EBio was based on numbers-at-age, weight-at-age, and externally derived selectivity-at-age.

Given the complex but static definition of EBio, there was a divergence between EBio and the assessment which updated selectivity each year, and later allowed it to vary over time. In other words, EBio was not representative of the stock assessment results because the selectivity curves used to define EBio were out of date. It is difficult to exactly characterize what EBio is because it is a single value meant to describe a

[1] https://iphc.int/the-commission/glossary-of-terms-and-abbreviations

complex amalgamation of fleets, areas, stock size, and size-at-age. Ebio was not the biomass of fish over 26 inches (O26, 66 cm) or 32 inches (O32, 81 cm), and it was not the biomass of the stock that is encountered by the fisheries.

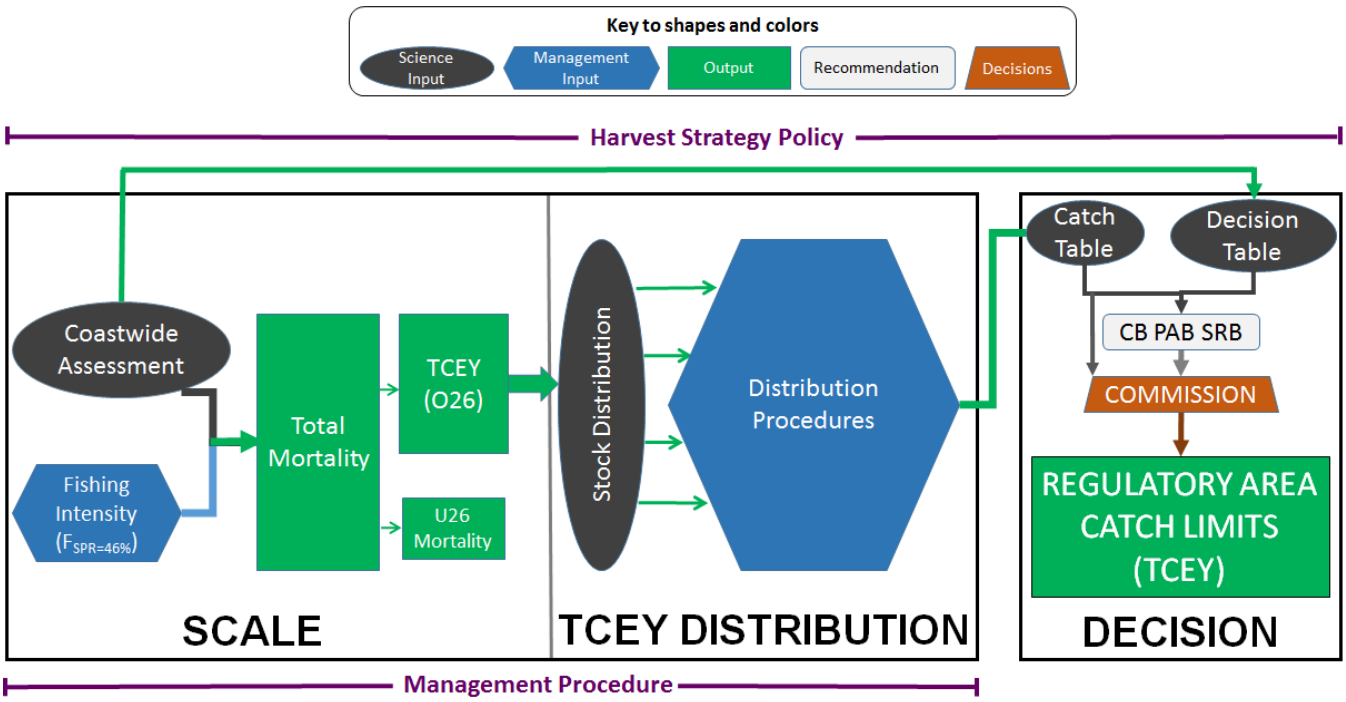

Figure 1: A revised harvest strategy policy showing the separation of scale and distribution of fishing mortality. The decision step is when policy (not a procedure) influences the final outcome.

Ebio was apportioned to IPHC Regulatory Areas using the estimated distribution of O32 biomass from the setline survey. Then, IPHC Regulatory Area-specific catch levels (TCEY) were calculated from defined harvest rates. A harvest rate of 16.125% was used for western areas (3B, 4A, 4B, and 4CDE) and 21.5% for eastern areas (3A, 2C, 2B, and 2A). These harvest rates were based on the selection of O26 fish for TCEY (Hare 2011) and were converted from values originally based on O32 fish, reflecting the size limit (Clark and Hare 2006). They were lower in the west due to the presence of small fish, a lower estimated yield-per-recruit, and greater uncertainty in historical analyses. These harvest rates were explicitly linked to EBio.

In 2017, the Commission agreed to move to an SPR-based management procedure to account for the mortality of all sizes and from all fisheries. The procedure uses a coastwide fishing intensity based on spawning potential ratio (SPR), which defines the "scale" of the coastwide catch. This eliminates the use of EBio and area-specific absolute harvest rates. Therefore, there are currently two inputs to the current management procedure for distributing the TCEY among IPHC Regulatory Areas: 1) the current estimated stock distribution and 2) relative target harvest rates.

4.1 A BACKGROUND ON STOCK DISTRIBUTION

The IPHC uses a space-time model to estimate annual Weight-Per-Unit-Effort (WPUE) for use in estimating the annual stock distribution of Pacific halibut (Webster 2018). Briefly, observed WPUE is fitted with a model that accounts for correlation between setline survey stations over time (years) and space (within Regulatory Areas). Competition for hooks by Pacific halibut and other species, the timing of the setline survey relative to annual fishery mortality, and observations from other fishery-independent surveys are also accounted for in the approach. This fitted model is then used to predict WPUE (relative density) of Pacific halibut for every setline survey station in the design (including all setline survey expansion stations), regardless of whether it was fished in a particular year. These predictions are then averaged within each IPHC Regulatory Area, and combined among IPHC Regulatory Areas, weighting by the 'geographic extent' (calculated area within the survey design depth range) of each IPHC Regulatory Area. It is important to note that this produces relative indices of abundance and biomass, but does not produce an absolute measure of abundance or biomass because it is weight-per-unit-effort scaled by the geographic extent of each IPHC Regulatory Area. These indices are useful for determining trends in stock numbers and biomass, and are also useful to estimate the geographic distribution of the stock.

This method for estimating the stock distribution has been used (first with a design-based estimator from 2008–2016, and subsequently with the space-time model in 2016 and 2017) since 2008, following the adoption of a coastwide stock assessment. There have been several workshops and reviews dedicated to evaluating the use of fishery-independent data for estimating stock distribution (IPHC 2008, 2009, 2010), with the most recent review by the IPHC's Scientific Review Board (SRB) in September 2013 (Cox et al. 2014). That review concluded that the method was imperfect, but should be unbiased, when responding to whether it represented a "scientifically objective" estimate of stock distribution. They further noted that selection of catch targets other than those based purely on biology "involves choices and trade-offs that are beyond the scope of purely science-based decision-making".

For 2018 harvest advice (IPHC-2018-AM094-11 Rev_1), the estimated stock distribution was based on the IPHC space-time model output of O32 Pacific halibut WPUE and provided an estimate of the proportion of the O32 portion of the stock in each IPHC Regulatory Area. These proportions were revised from 2016 estimates (Figure 2), indicating a larger proportion of the coastwide stock in Regulatory Areas 2C, 3A, 4A, 4B, and 4CDE in 2017 and a smaller proportion in 2A, 2B, and 3B (Table A1, Appendix A). The estimated stock distribution (proportions in each IPHC Regulatory Area) was then used to distribute the TCEY in accordance with the estimated distribution of the stock.

4.2 USING RELATIVE HARVEST RATES

The distribution of the TCEY for 2018 was shifted from the estimated stock distribution to account for additional factors related to productivity and paucity of data in each IPHC Regulatory Area. Previously, this was accomplished by applying different harvest rates in western areas (16.125% in IPHC Regulatory Areas 3B, 4A, 4B, and 4CDE)) and eastern areas (21.5% in IPHC Regulatory Areas 2A, 2B, 2C, and 3A). However, with the elimination of EBio and the use of SPR-based fishing intensity to determine the coastwide scale, the TCEY, rather than the esoteric concept of exploitable biomass was distributed. Therefore, an absolute measure of harvest rate is not necessary, but it may still be desired to shift the

distribution of the TCEY away from the estimated stock distribution to account for other factors. Consistent with the previous approach, relative harvest rates were used with a ratio of 1.00:0.75, being equal to the ratio between 21.5% and 16.125%. This application shifted the target TCEY distribution away from the stock distribution by moving more TCEY into IPHC Regulatory Areas 2A, 2B, 2C, and 3A and less TCEY from IPHC Regulatory Areas 3B, 4A, 4B, and 4CDE (Table 1), thus harvesting at a higher rate in eastern IPHC Regulatory Areas.

Table 1: IPHC Regulatory Area stock distribution estimated from the 2017 space-time model O32 WPUE, IPHC Regulatory Area-specific relative target harvest rates, and resulting 2018 target TCEY distribution based on the IPHC's 2018 interim management procedure (reproduced from Table 1 in IPHC-2018-AM094-11 Rev_1).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
O32 stock distribution	1.7%	11.3%	16.6%	35.6%	10.0%	6.6%	4.8%	13.3%	100.0%
Relative harvest rates	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.75	--
Target TCEY Distribution	1.9%	12.4%	18.2%	38.9%	8.2%	5.4%	3.9%	10.9%	100.0%

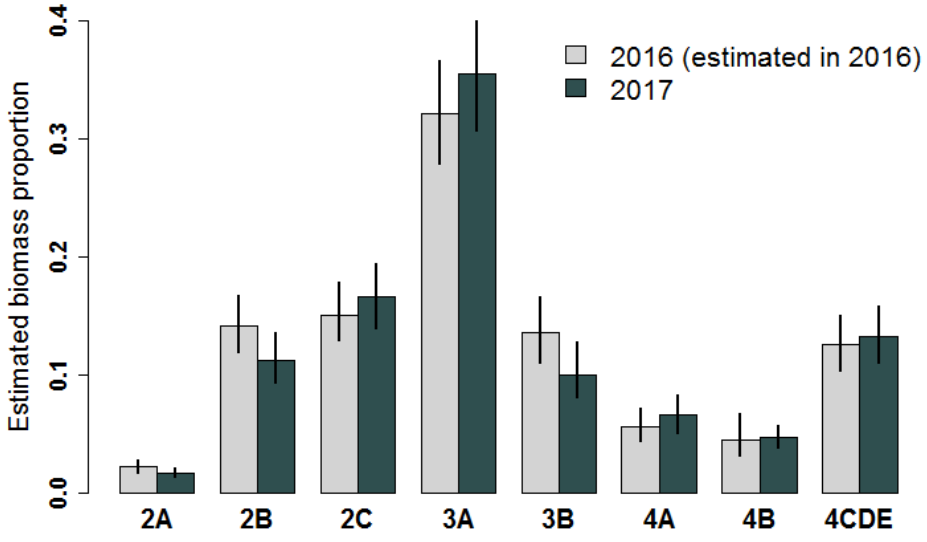

Figure 2: Estimated stock distribution based on setline survey catch of O32 Pacific halibut as estimated in 2016, and as estimated in 2017. Vertical lines indicate 95% credible intervals.

5 REDEFINING THE TCEY DISTRIBUTION PROCEDURE

TCEY distribution is the part of the management procedure for distributing the TCEY among Regulatory Areas and is composed of a purely scientific component to distribute the TCEY in proportion to its estimated biomass in each area (stock distribution) and steps to further modify the distribution of the TCEY based on additional considerations (distribution procedures). Those two components are described below.

5.1 REDEFINING STOCK DISTRIBUTION

Emerging understanding of biocomplexity across the geographic range of the Pacific halibut stock indicates that IPHC Regulatory Areas should only be considered as management units and do not represent relevant sub-populations (Seitz et al. 2017). Balancing the removals against the current stock distribution is likely to protect against localized depletion of spatial and demographic components of the stock that may produce differential recruitment success under changing environmental and ecological conditions. This concept of distributing harvest in proportion to stock distribution is widely recognized in fisheries management, particularly among salmon stocks (*portfolio effect*: Hilborn et al 2003; Schindler et al 2010). This approach provides an additional precautionary buffer against spatial recruitment overfishing and may maintain sub-population structure that is not completely understood, but important to the long-term health of the coastwide population.

The structure of two of the four current Pacific halibut stock assessment models are developed around identifying portions of the data (fishery-independent and fishery-dependent data) that correspond to differing biological and population processes within the larger Pacific halibut stock. This approach, referred to as 'Areas-As-Fleets' is commonly used in stock assessments (Waterhouse et al. 2014), and was a recommended model to include in the ensemble during the SRB review of models developed in 2014 (Cox et al. 2016, Stewart and Martell 2015, 2016).

Biological Regions were defined with boundaries that matched some of the IPHC Regulatory Area boundaries for the following reasons. First, data (particularly historical data) for stock assessment and other analyses are most often reported at the IPHC Regulatory Area scale and are largely unavailable for sub-Regulatory Area evaluation. Particularly for historical sources, there is little information to partition data to a portion of a Regulatory Area. Second, it is necessary to distribute TCEY to IPHC Regulatory Area for quota management. If a Region is not defined by boundaries of IPHC Regulatory Areas (i.e. a single IPHC Regulatory Area is in multiple Regions) it will be difficult to create a distribution procedure that accounts for biological stock distribution and distribution of the TCEY to Regulatory Areas for management purposes. It is unlikely that there is a set of Regions that accurately delineates the stock biologically since different aspects of the stock differ over varying scales, and movement occurs among Biological Regions. However, if the goal is to preserve biocomplexity across the entire range of the Pacific halibut stock, Biological Regions are considered by the IPHC Secretariat to be the best option for biologically-based areas to meet management needs.

Each Biological Region has some qualities that identified it as being separate, to a certain degree, biologically from adjacent Biological Regions, despite evidence from tagging studies of movement by

Pacific halibut among all IPHC Regulatory Areas at some point in its life-cycle (Valero and Webster 2012; Webster et al 2013). These qualities include sex ratios, age composition, size-at-age, and historical trends in those data that could be indicative of biological diversity within the greater Pacific halibut population. The four Regions are labeled as follows and composed of the listed IPHC Regulatory Areas (Figure 3):

Region 2: 2A, 2B, and 2C
Region 3: 3A and 3B
Region 4: 4A and 4CDE
Region 4B: 4B

Trends over the last five years (2013–2017) indicate that population distribution, measured either via O32 or all sizes estimated WPUE of Pacific halibut from the space-time model, have been relatively stable (Figure 4 and Appendix A). However, over the time-period 1993–2017 (setline survey data prior to 1993 is insufficient to provide stock distribution estimates) there has been an increasing proportion of the coastwide stock occurring in Region 2 and a decreasing proportion occurring in Region 3. It is unknown to what degree either of these periods corresponds to historical distributions from the mid-1900s or to the average distribution likely to occur in the absence of fishing mortality.

In summary, the overall conservation goal for Pacific halibut is to maintain a healthy coastwide stock. However, given the wide geographic range of the Pacific halibut stock, there likely is stock structure that we do not fully understand and this stock structure may be important to coastwide stock health. Therefore, conservation objectives relate to where harvesting occurs, with an objective to retain viable spawning activity in all portions of the stock. One method for addressing this objective is to distribute the fishing mortality relative to the distribution of observed stock biomass. This requires defining appropriate areas for which the distribution is to be conserved. Splitting the coast into many small areas for conservation objectives can result in complications including being cumbersome to determine if conservation objectives are met, being difficult to accurately determine the proportion of the stock in that area, being subject to inter-annual variability in estimates of the proportion, forcing arbitrary delineation among areas with evidence of strong stock mixing, and not being representative of biological importance. Therefore, Biological Regions represent the most logical scale over which to consider conservation objectives related to distribution of the fishing mortality. Adjusting the distribution of the TCEY among Biological Regions to account for additional considerations, and further distributing the TCEY to IPHC Regulatory Areas would be done through steps defined in the Distribution Procedures component (Figure 5).

In addition to using Biological Regions for stock distribution, the “all sizes” WPUE from the space-time model (Table A2, Appendix A), which is largely composed of O26 Pacific halibut (due to selectivity of the setline gear), is more congruent with the TCEY (O26 catch levels) than O32 WPUE. Therefore, when distributing the TCEY to Biological Regions, the estimated proportion of “all sizes” WPUE from the space-time model should be used for consistency.

5.2 DISTRIBUTION PROCEDURES

Distribution Procedures contains the steps of further modifying the distribution of the TCEY among Biological Regions and then distributing the TCEY among IPHC Regulatory Areas within Biological Regions (Figure 5). For example, modifications at the Biological Region or IPHC Regulatory Area level may be based on differences in production between areas, observations in each area relative to other areas (e.g., WPUE), uncertainty of data or mortality in each area, defined allocations, or national shares. Data may be used as indicators of stock trends in each Region or IPHC Regulatory 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 Biological Region or IPHC Regulatory Area. For example, commercial WPUE is a popular source of data used to indicate trends in a population, but may not always be proportional to biomass. Types of data may be used include fishery WPUE, survey observations (not necessarily the IPHC fishery-independent setline survey), age-compositions, size-at-age, and environmental observations.

The steps in the Distribution Procedures may consider conservation objectives, but they will mainly be developed with respect to fishery objectives. Yield and stability in catch levels are two important fishery objectives that often contradict each other (i.e. higher yield often results in less stability). Additionally, area-specific fishery objectives may be in conflict across IPHC Regulatory Areas. Pacific halibut catch levels are defined for each IPHC Regulatory Area and quota is accounted for by those Regulatory Areas. Therefore, IPHC Regulatory Areas are the appropriate scale to consider fishery objectives.

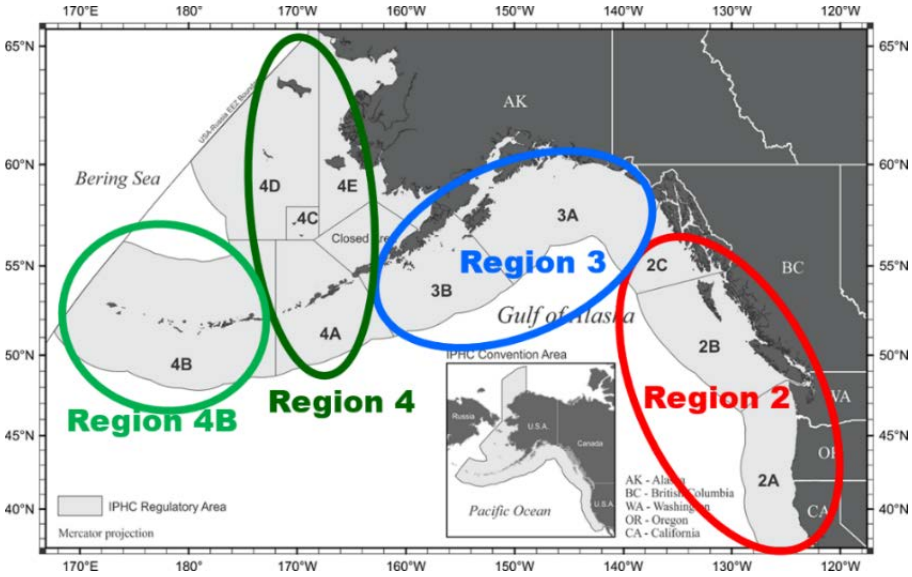

Figure 3: Biological Regions overlaid on IPHC Regulatory Areas with Region 2 comprised of 2A, 2B, and 2C, Region 3 comprised of 3A and 3B, Region 4 comprised of 4A and 4CDE, and Region 4B comprised solely of 4B.

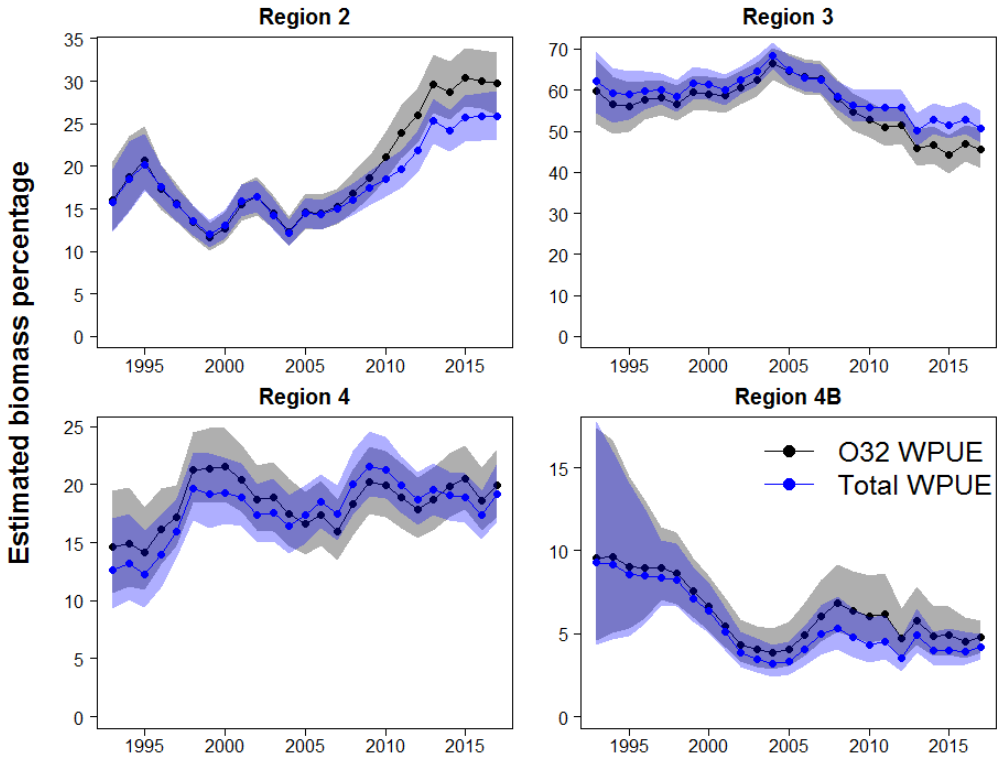

Figure 4: Estimated stock distribution (1993-2017) based on estimate WPUE from the space-time model of O32 (black series) and all sizes (blue series) of Pacific halibut. Shaded zones indicate 95% credible intervals.

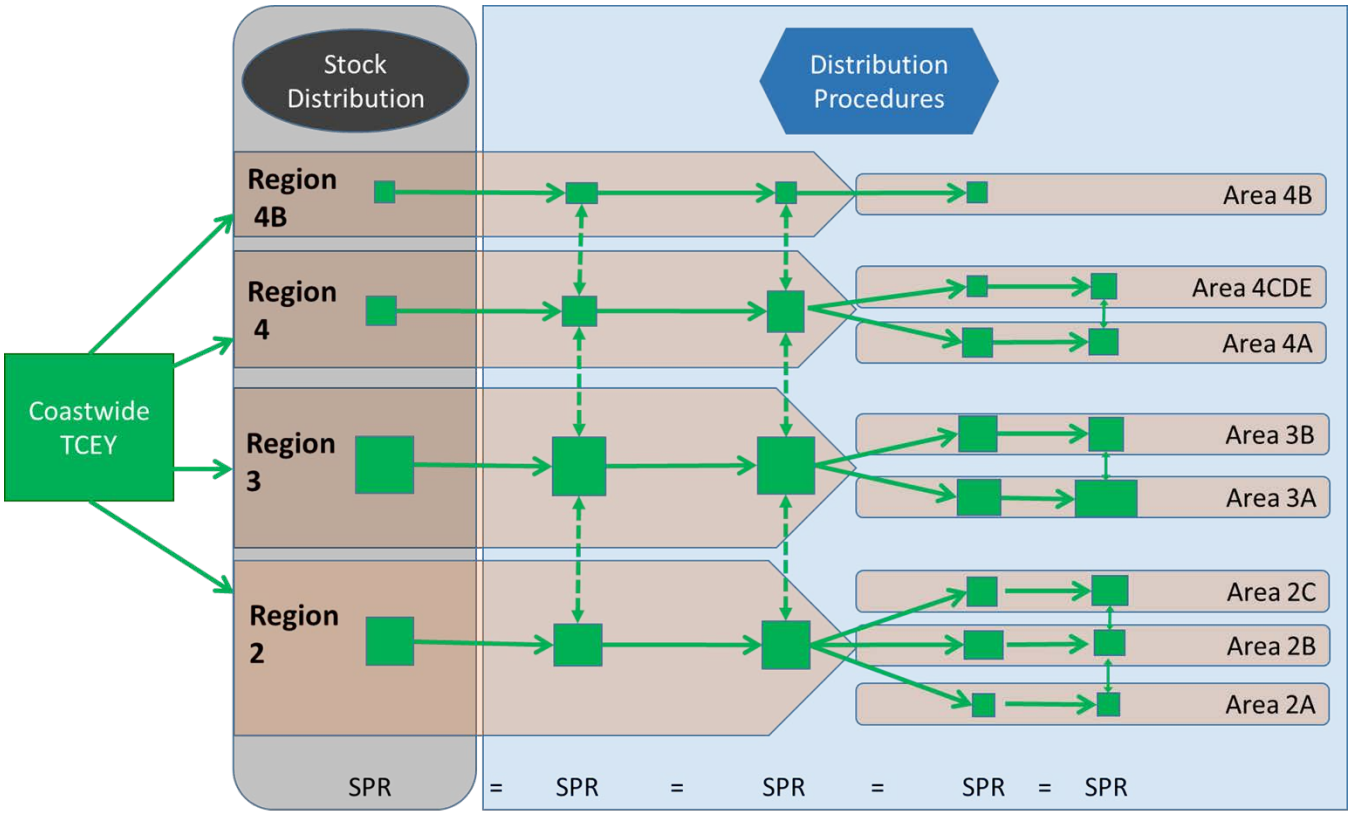

Figure 5: The process of distributing the TCEY to Regulatory Areas from the coastwide TCEY. The first step is to distribute the TCEY to Biological Regions based on the estimate of stock distribution. Following this, a series of adjustments may be made based on observations or social, economic, and other considerations. Finally, the adjusted regional TCEY's are allocated to IPHC Regulatory Areas. The allocation to IPHC Regulatory Areas may occur at any point after regional stock distribution. The dashed arrows represent balancing that is required to maintain a constant coastwide SPR.

6 A SUMMARY OF THE MANAGEMENT PROCEDURE FOR DISTRIBUTING TCEY ACROSS THE COAST

The harvest strategy policy begins with the coastwide TCEY determined from the stock assessment and fishing intensity determined from a target SPR (Figure 1). When distributing the TCEY among regions, stock distribution occurs first to distribute the harvest in proportion to biomass and satisfy conservation objectives, and then is followed by adjustments across Regions and Regulatory Area based on distribution procedures to further encompass conservation objectives and consider fishery objectives. The key to these adjustments is that they are relative adjustments such that the overall fishing intensity (target SPR) is maintained (i.e., a zero sum game). Otherwise, the procedure is broken and it is uncertain if the defined objectives will be met.

A framework for a management procedure that ends with the TCEY distributed among IPHC Regulatory Areas and would encompass conservation and fishery objectives is described below.

1. **Coastwide Target Fishing Intensity:** Determine the coastwide total mortality using a target SPR that is most consistent with IPHC objectives defined by the Commission. Separate the total mortality in ≥26 inches (O26) and under 26 inches (U26) components. The O26 component is the coastwide TCEY.
   1.1. Target SPR is scheduled for evaluation at the 2019 Annual Meeting. The current interim target SPR is 46%.
2. **Regional Stock Distribution:** Distribute the coastwide TCEY to four (4) biologically-based Regions using the proportion of the stock estimated in each Biological Region for all sizes of Pacific halibut using information from the IPHC setline survey and the IPHC space-time model.
   2.1. Four Regions (2, 3, 4, and 4B) are defined above (Figure 3).
3. **Regional Allocation Adjustment:** Adjust the distribution of the TCEY among Biological Regions to account for other factors.
   3.1. For example, relative target harvest rates are part of a management/policy decision that may be informed by data and observations. This may include evaluation of recent trends in estimated quantities (such as fishery-independent WPUE), inspection of historical trends in fishing intensity, recent or historical fishery performance, and biological characteristics of the Pacific halibut observed in each Biological Region. The IPHC Secretariat may be able to provide Yield-Per-Recruit (YPR) and/or surplus production calculations as further supplementary information for this discussion. The regional relative harvest rates may also be determined through negotiation, which is simply an allocation agreement for further Regional adjustment of the TCEY.
4. **Regulatory Area Allocation:** Apply IPHC Regulatory Area allocation percentages within each Biological Region to distribute the Region-specific TCEY's to Regulatory Areas.
   4.1. This part represents a management/policy decision, and may be informed by data, based on past or current observations, or defined by an allocation agreement. For example, recent trends in estimated all sizes WPUE from the setline survey or fishery, age composition, or size composition may be used to distribute the TCEY to IPHC Regulatory Areas. Inspection of historical trends in fishing intensity or catches by IPHC Regulatory Area may also be used. Finally, agreed upon percentages are also an option. This allocation to IPHC Regulatory Areas may be a procedure with multiple adjustments using different data, observations, or agreements

The four steps described above would be contained within the IPHC Harvest Strategy Policy as part of the Management Procedure, and are pre-determined steps that have a predictable outcome. The decision making process would then occur (Figure 1).

5. **Seasonal Regulatory Area Adjustment**: Adjust individual Regulatory Area TCEY limits to account for other factors as needed. This is the policy part of the harvest strategy policy and occurs as a final step where other objectives are considered (e.g. economic, social, etc.).
   5.1. Departing from the target SPR 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 management procedure and the long-term management objectives. Departures from the

management procedure may result in unpredictable outcomes, but could also take advantage of current situations.

7 RECOMMENDATION/S

That the Management Strategy Advisory Board:

1) **NOTE** paper IPHC-2018-MSAB011-09 which describes the distribution of the TCEY component of a harvest strategy policy and continues a discussion about a framework and alternatives to distribute the TCEY.
2) **CONSIDER** the potential definitions and terms used to describe the harvest strategy policy, and in particular the TCEY distribution component containing the separation of stock distribution and distribution procedures.
3) **CONSIDER** how the TCEY distribution framework could meet conservation objectives, particularly the objective of maintaining a healthy coastwide stock.
4) **CONSIDER** how the TCEY distribution framework could meet fishery objectives, particularly the objective to maintain an economically sufficient level of catch across regulatory areas.

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Appendix A
Time-Series of Estimated Stock Distribution

Table A1: Time-series of stock distribution based on O32 WPUE estimated from the space-time model by IPHC Regulatory Area (net lb/skate).

Year	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1993	1.6%	7.0%	7.4%	35.1%	24.7%	9.1%	9.5%	5.5%	100.0%
1994	1.5%	8.8%	8.6%	31.7%	25.0%	9.6%	9.6%	5.3%	100.0%
1995	1.3%	10.1%	9.3%	31.2%	24.9%	9.1%	9.0%	5.1%	100.0%
1996	1.3%	8.1%	8.0%	30.2%	27.4%	10.0%	9.0%	6.1%	100.0%
1997	1.3%	6.2%	8.1%	33.4%	24.8%	10.9%	9.0%	6.3%	100.0%
1998	1.4%	5.2%	6.9%	27.0%	29.7%	13.6%	8.6%	7.6%	100.0%
1999	1.4%	4.4%	5.8%	26.0%	33.4%	13.3%	7.5%	8.1%	100.0%
2000	1.4%	5.3%	6.1%	30.8%	28.3%	13.0%	6.6%	8.6%	100.0%
2001	1.4%	6.7%	7.5%	33.0%	25.6%	11.2%	5.4%	9.2%	100.0%
2002	1.1%	6.8%	8.5%	39.0%	21.6%	10.4%	4.3%	8.3%	100.0%
2003	1.1%	5.5%	7.8%	37.9%	24.7%	10.1%	4.0%	8.8%	100.0%
2004	1.3%	5.3%	5.7%	45.0%	21.4%	9.2%	3.8%	8.3%	100.0%
2005	1.5%	6.1%	7.1%	46.1%	18.6%	9.0%	4.1%	7.5%	100.0%
2006	1.3%	6.2%	7.0%	42.7%	20.5%	8.3%	4.9%	9.1%	100.0%
2007	1.2%	6.8%	7.2%	42.0%	20.8%	7.7%	6.0%	8.2%	100.0%
2008	1.3%	7.9%	7.6%	39.6%	18.4%	9.1%	6.8%	9.2%	100.0%
2009	1.1%	10.0%	7.5%	35.5%	19.3%	9.4%	6.4%	10.8%	100.0%
2010	1.6%	11.2%	8.3%	36.0%	16.8%	8.6%	6.1%	11.3%	100.0%
2011	2.0%	11.6%	10.4%	36.1%	14.8%	8.1%	6.2%	10.8%	100.0%
2012	1.7%	12.1%	12.1%	38.1%	13.4%	7.4%	4.7%	10.5%	100.0%
2013	1.9%	13.6%	14.2%	32.9%	13.0%	6.8%	5.8%	11.9%	100.0%
2014	2.0%	12.9%	13.9%	34.2%	12.3%	7.0%	4.9%	12.8%	100.0%
2015	2.4%	14.1%	13.9%	31.1%	13.1%	6.8%	4.9%	13.7%	100.0%
2016	2.0%	13.2%	14.8%	33.5%	13.3%	6.0%	4.5%	12.6%	100.0%
2017	1.7%	11.3%	16.6%	35.6%	10.0%	6.6%	4.8%	13.3%	100.0%

Table A2: Time-series of stock distribution based on all-sizes WPUE estimated from the space-time model by IPHC Regulatory Area (net lb/skate)

Year	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1993	1.7%	7.0%	7.0%	36.9%	25.4%	5.9%	9.3%	6.8%	100.0%
1994	1.6%	8.8%	8.0%	33.7%	25.5%	6.6%	9.2%	6.6%	100.0%
1995	1.5%	10.3%	8.5%	33.7%	25.3%	6.7%	8.6%	5.6%	100.0%
1996	1.4%	8.3%	7.9%	32.2%	27.7%	8.3%	8.5%	5.6%	100.0%
1997	1.3%	6.2%	8.0%	35.2%	25.0%	10.8%	8.3%	5.2%	100.0%
1998	1.4%	5.3%	6.9%	28.0%	30.5%	13.4%	8.2%	6.3%	100.0%
1999	1.4%	4.7%	6.0%	27.1%	34.5%	12.6%	7.1%	6.5%	100.0%
2000	1.3%	5.4%	6.3%	32.6%	28.7%	12.3%	6.3%	6.9%	100.0%
2001	1.4%	6.8%	7.7%	34.2%	25.9%	11.4%	5.1%	7.5%	100.0%
2002	1.1%	6.8%	8.5%	40.2%	22.2%	10.3%	3.9%	7.0%	100.0%
2003	1.0%	5.5%	7.7%	38.0%	26.6%	9.8%	3.5%	7.8%	100.0%
2004	1.1%	5.2%	5.8%	44.5%	23.8%	8.9%	3.2%	7.5%	100.0%
2005	1.3%	6.2%	7.0%	44.9%	19.9%	9.0%	3.3%	8.4%	100.0%
2006	1.1%	6.2%	7.0%	41.4%	21.7%	8.1%	4.0%	10.4%	100.0%
2007	1.0%	7.0%	7.1%	40.3%	22.2%	7.8%	5.0%	9.7%	100.0%
2008	1.1%	7.7%	7.3%	37.5%	21.1%	9.6%	5.3%	10.4%	100.0%
2009	0.9%	9.3%	7.3%	34.7%	21.5%	10.1%	4.8%	11.5%	100.0%
2010	1.2%	9.7%	7.6%	36.0%	19.9%	9.0%	4.3%	12.3%	100.0%
2011	1.5%	9.4%	8.8%	37.5%	18.3%	8.1%	4.5%	11.9%	100.0%
2012	1.4%	10.3%	10.2%	39.4%	16.5%	7.6%	3.5%	11.1%	100.0%
2013	1.5%	11.9%	11.9%	34.3%	15.8%	6.9%	4.9%	12.8%	100.0%
2014	1.5%	11.2%	11.5%	37.6%	15.1%	6.8%	4.0%	12.3%	100.0%
2015	1.9%	12.1%	11.7%	36.3%	15.1%	6.6%	4.0%	12.2%	100.0%
2016	1.7%	11.8%	12.4%	36.6%	16.2%	5.8%	3.9%	11.6%	100.0%
2017	1.4%	9.9%	14.6%	38.1%	12.6%	7.0%	4.2%	12.3%	100.0%