Review of the IPHC method for apportioning halibut exploitable biomass among regulatory areas

IPHC Scientific Review Board, Meeting 1

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SCIENTIFIC DEFINITION OF THE IPHC APPORTIONMENT METHOD

This report provides a scientific review of the current International Pacific Halibut Commission (IPHC) Biomass Apportionment Method. We base the review on a 1-day meeting at IPHC offices in Seattle, WA where IPHC staff and the Canadian scientific advisor to the Commissioners presented material explaining the current approach, as well as the basis for various criticisms. In reviewing this material we were reminded to focus on the scientific basis for apportionment rather than on the science-policy interdependencies.

The review is divided into three parts. In the first part, we provide a scientific definition of the apportionment method that clearly identifies the components we intend to review. Parts 2 and 3 address two general classes of questions set out by IPHC staff and Commissioners: (1) scientific objectivity of the apportionment method and (2) the roles of science and policy in contemporary fisheries management and how this can be used to guide future management of the Pacific halibut fishery.

The halibut biomass apportionment method

A simple representation of the IPHC formula for apportioning halibut biomass among regulatory areas was kindly presented by the Scientific Advisor to the Canadian Commissioners, Dr Robyn Forrest, (slightly modified here to be consistent with review notation):

Area Proportion$_a$ = (Biomass Unit$_a$) / (sum of all Biomass Units)

where the "Biomass Unit$_a$" in regulatory area a is computed as

Biomass Unit$_a$ = (Survey WPUE$_a$) x (Bottom Area$_a$) x (Adjustment Factors$_a$).

We translated this word equation into a formula for which we can identify data, parameters, rules, and analytical procedures that may affect the bias and variability of biomass apportionment. The proportion of the stock in regulatory area *a* in year *y* is

$$p_{a,y} = b_{a,y} \Big/ \sum_{j=1}^{J} b_{j,y} \qquad \text{Eq (1)}$$

where $b_{a,y}$ is the biomass unit in area a in year *y*, given by

$$b_{a,y} = s\left(I_{a,y}^{O32}, I_{a,y-1}^{O32}, I_{a,y-2}^{O32}, f_{a,y}^{H}, f_{a,y-1}^{H}, f_{a,y-2}^{H}, f_{a,y}^{T}, f_{a,y-1}^{T}, f_{a,y-2}^{T}, w_y, w_{y-1}, w_{y-2} \right) A_a \quad \text{Eq (2).}$$

The terms on the right hand side of Eq (2) are:

$s()$ - Smoothing function applied to annual regulatory area WPUE values. This smoother is used to reduce the effect of "chasing the most recent survey data point" in which random noise in current survey indices has large impact on biomass apportionment.

$I_{a,y}^{O32}$ - Average survey weight-per-unit-effort (O32 WPUE) for halibut 32-inches and larger in area *a* in year *y*;

w_y, w_{y-1}, w_{y-2} - Weights defining how much influence each of the most recent 3 survey indices has on the smoothing function. The current weighting scheme is: $w_y = 0.75, w_{y-1} = 0.20, w_{y-2} = 0.05$; that is, the current year survey contributes 75%, the previous year 20%, and two years ago 5%.

A_a - The total bottom area encompassed by the 0 – 400 fathom depth range in regulatory area *a*, including inlets and estuaries.

$f_{a,y}^{H}$ Multiplicative adjustment for the expected number of baits available during the survey in regulatory area *a* in year *y*. Webster et al. (2011) provide details on the hook competition adjustment method that is used to compute this factor for each regulatory area and year. This is actually a more complicated function than we present here.

This adjustment for each area is made by dividing the coastwide average number of baits remaining after a survey set by the regulatory area average according to:

$$f_{a,y}^{H} = \left(\frac{1 - e^{-Z_{CW,y}}}{Z_{CW,y}} \right) \left(\frac{Z_{j,y}}{1 - e^{-Z_{j,y}}} \right) \qquad \text{Eq (3)}$$

where $Z_{CW,y}$ is the coastwide average bait removal rate and $Z_{j,y}$ is the regulatory area average. The coastwide average is used here to take into account that if a regulatory are has the same bait removal rate as the coastwide average, the adjustment is equal to one.

$f_{a,y}^{T}$ - Multiplicative adjustment for the amount of catch removed from regulatory area *a* prior to the survey in year *y*. Like the hook competition adjustment, this one is standardized to a predetermined average.

1. Comments on the current approach (IPHC questions are italicized)

a. Does the current method achieve a <u>scientifically objective</u> apportionment of coastwide biomass?

We interpret "scientific objectivity" to mean that Eq (1) generates $p_{a,y}$ values that are unbiased with respect to the true proportion of O32 halibut biomass in each regulatory area, independent of the management consequences of applying this approach.

Given the challenges of determining the spatial distribution of biomass across such a large and heterogeneous ocean environment, our answer is a cautious yes.

The apportionment approach is unbiased, conditional on the factors contributing to $b_{a,y}$ each being unbiased, or having biases cancel each other out. Here we comment on the existing steps that have been taken to remove known potential biases associated with hook competition and survey timing. We also provide suggestions for analyses that could improve the scientific basis for apportionment and possibly providing better transparency.

Habitat area - The 0-400 fathom depth range serves as a proxy for halibut habitat area. This may be reasonable, but it does assume a uniform effect of depth across the entire northeast Pacific and some of the Bering Sea. Some research could be allocated to investigating the validity of this assumption. For example, formal species distribution modeling approaches (e.g., reviewed in Planque et al. 2010) could better incorporate halibut biology and habitat preferences into area calculations.

Smoothing - The smoothing of survey WPUE is done over time, yet the formula is intended to apportion biomass over space and time. Temporal smoothing alone could cause adjacent areas to become more different than they really are. A combined spatio-temporal smoothing applied to each year could help to retain spatial consistency in smoothed WPUE across regulatory areas (e.g., Cressie and Wikle 2011; Banerjee et al. 2004). In preliminary discussions, IPHC staff noted that this is an area of research, but is challenged by difficulties associated with complex coastlines and large sample sizes. We suggest conditional autoregressive models as a possible solution to spatio-temporal smoothing of survey catch rates for these situations. These models do not rely on Euclidean distances, do not compute covariance matrices, and can incorporate a generalized linear model component to model local covariate effects such as depth, tide, bait removal, etc.

A spatial smoothing analysis may also allow assessment of differential catchability among areas by comparing survey WPUE near regulatory area borders with smoothed estimates. Smoothers involving generalized linear models may also be able to account for local habitat effects on catchability that should remain constant from year to year. We recognize that there are immediate practical difficulties of implementing spatial smoothing in the apportionment procedure, so we are not recommending an immediate change of approach. However, it may be worthwhile allocating some future research to investigating the effects of temporal vs spatio-temporal smoothing.

Hook competition - The Z values used in the hook competition formula are random variables and probably not normally distributed. Therefore, the non-linear transformation in Eq (3) requires a bias correction. The extent of bias caused by ignoring it might not be large given the range of variability within a regulatory area. To improve transparency, the expected frequency and magnitude of random errors in apportioning biomass should be summarized and reported.

Survey timing adjustment – The survey timing adjustment involves the harvest rate in an area, and is therefore a function of the exploitable biomass (i.e., EBio) assigned to each regulatory area. Because this is done using the apportionment method in Eq (1), it is somewhat circular.

Our discussions with IPHC colleagues indicated that this adjustment is becoming less important as regulatory area "realized" harvest rates approach their intended targets. To aid transparency, this adjustment could probably be phased out.

b. Is the current method consistent with apportionment methods used for other fisheries?

Yes and No.

The biomass apportionment method for halibut is similar to some apportionment methods in other fisheries and dissimilar to others.

Sablefish biomass in the Gulf of Alaska is apportioned similar to Eq (1). Commercial fishery CPUE is also used there because it is believed that the fishery reflects a distribution of sablefish over a longer period than the time taken to complete the survey. From a biological perspective, annual biomass apportionment for GOA sablefish is considered less critical since they appear to be highly mobile.

In contrast, less mobile Pacific ocean perch fisheries are given area-specific catch allocations to mitigate smaller-scale population structuring that would be expensive to accommodate more precisely (i.e., with separate discrete assessments).

Fixed percentages are used to allocate Pacific hake TACs between the US and Canada as well as some European stocks among EU countries based on negotiated agreements. However, fixed percentage approaches mix biomass apportionment and catch allocation, so it is not clear how relevant these are to the halibut context.

On the east coast of North America, sharing of George's Bank cod, haddock, and yellowtail flounder between the US and Canada is currently done by resource distribution as measured by annual bottom trawl surveys. Smoothers are applied in the final stage of the apportionment algorithm to keep the process as "transparent" as possible. The Transboundary Management Guidance Committee established to develop the algorithm also noted sensitivity to choices about smoothing parameters.

c. *Are the data and adjustments used for apportionment appropriate and reliable for the purpose?*

See above comments on hook competition adjustments. The data appear to be appropriate for the calculation in Eq (1), but reliability has not been fully assessed. This could easily be tested by simulation and we encourage the IPHC to follow-up, either in house or with an external contract.

d. *Is the apportionment method consistent with the achievement of regulatory-area harvest objectives?*

There is some difficulty in assessing this question because the apportionment method and the consistency with regulatory area targets cannot be easily separated. First, apportionment is used to compute "realized" regulatory area harvest rates, and then TACs are recommended to bring these harvest rates toward their intended targets. So, the question could be true by its own definition.

Furthermore, it is unclear that application of the apportionment method has been specifically responsible for "realized" harvest rates approaching their targets. Is it true that there has been opposition to apportionment that caused deviations between target TACs and actual TACs? If that is the case, then the answer would be no, apportionment is actually a barrier to achieving the objectives, at least on a reasonably short time scale. Over the longer term, ad hoc reductions in TACs may make it look like apportionment was ultimately successful.

e. *Are there particular changes or improvements that need to be made in the short term?*

In addition to suggestions made above:

Compute area adjustments based on depths actually fished in each region (rather than 0-400 fathoms) as a sensitivity. Note that this might be most appropriate for allocation considerations rather than ensuring balanced spatial harvest rates.

f. *Are there research questions or alternative apportionment methods that could be investigated in order to inform potential future changes to the method?*

IPHC has examined a wide range of apportionment options, including most of those listed in question 2b. Some of these could be re-examined in the context of a Management Strategy Evaluation .

As IPHC scientists have previously proposed (and are presently working on), we suggest that treating each regulatory area as a separate fleet in the stock assessment model could help to incorporate regulatory area differences in selectivity into the assessment. This will also help to better define a coastwise selectivity function that is more consistent with the actual fisheries than the one currently used in the EBio calculation. It could also be used to conduct a sensitivity analysis of yield outcomes that result from alternative objective function definitions.

We support expanding the survey where necessary to include the area used to define halibut habitat.

2. Comments on the management and/or policy aspects of the current approach.

a. Is a science-based approach appropriate for Pacific halibut?

A purely science-based approach must use a biological rationale for biomass and catch targets. Choosing targets other than B_{MSY} and MSY (or F_{MSY}), as well as including precautionary adjustments in the computations leading up to total allowable catch (e.g., "slow up fast down"), involves choices and trade-offs that are beyond the scope of purely science-based decision-making.

It is important to clearly delineate the roles of science and policy in halibut fishery management. The role of science is to generate plausible hypotheses and assessments of halibut stock dynamics, while policy generates the suite of objectives and feasible regulatory options for achieving both short- and long-term goals. A science-based approach then develops plausible operating models and methods to examine the consequences of applying each regulatory option. Ultimately, the success of the science-based approach occurs through a continuous cycle of hypotheses – policy options – evaluation. We consider that the cycle and feedback between science and policy analysis is central to the Management Strategy Evaluation paradigm.

b. What are the relative merits of adopting alternative methods that include management and/or policy considerations explicitly?

The main advantage of adopting a Management Strategy Evaluation (MSE) approach as described in 2a is the roles of science and policy are made explicit and that all procedures used in decision-making area transparent. Transparency is needed both in the process of generating advice from assessments (e.g., understanding the elements of apportionment in Eq 1), but also in the expected suite of outcomes from applying the harvest strategy repeatedly over time. It seems safe to say that the latter is unknown for this fishery.

Another benefit of adopting the MSE approach is an ability to prioritize research into science (e.g., movement, spawning distribution, spatial analyses, etc) and policy (e.g., costs of maintaining or expanding surveys, bycatch regulations, catch allocation) needs.

References

Banerjee, S. Carlin, B.P., and A.E. Gelfand. 2004. Hierarchical modeling and analysis for spatial data. Chapman & Hall/CRC Press.

Cressie, N. and C.K. Wikle. 2011. Statistics for spatio-temporal data. Wiley & Sons, NJ.

Planque, B. Loots, C., Petitgas, P., Lindstrøm, U., & Vaz, S. 2010. Understanding what controls the spatial distribution of fish populations using a multi-model approach. *Fisheries Oceanography*, *20*(1), 1–17.

Appendix A. SRB meeting main questions and agenda.

SRB Meeting: August 30th, 2013

Topic: Apportionment

Apportionment of the estimated coastwide exploitable biomass (and therefore catch) among IPHC regulatory areas has been necessary since the adoption of a coastwide stock assessment model for Pacific halibut in 2006. Since that time, there have been a number of analyses and working papers summarizing the evolution of the goals and methods currently applied. The process was investigated in two specific workshops held in 2008 and 2009, and has been the subject of considerable debate at annual meetings each year.

As the first task of the Scientific Review Board, the IPHC staff request a review of the following:

1. Comment on the scientific basis for the current approach. Specifically:
    a. Does the current method achieve a scientifically objective apportionment of coastwide biomass?
    b. Is the current method consistent with apportionment methods used for other fisheries?
    c. Are the data and adjustments used for apportionment appropriate and reliable for the purpose?
    d. Is the apportionment method consistent with the achievement of regulatory-area harvest objectives?
    e. Are there particular changes or improvements that need to be made in the short term?
    f. Are there research questions or alternative apportionment methods which could be investigated in order to inform potential future changes to the method?
2. Comment on the management and/or policy aspects of the current approach. Specifically:
    a. Is a science-based approach appropriate for Pacific halibut?
    b. What are the relative merits of adopting alternative methods which include management and/or policy considerations explicitly?

The IPHC staff request that a short statement summarizing the meeting discussions and conclusions reached be prepared for the Commission to consider during the 2013 Interim and Annual meetings.

Agenda
8:00 AM: Introductions (Bruce Leaman, all attendees)
8:15 AM: SRB Motivation and mission statement (Bruce Leaman)

- Summary of upcoming meetings and SRB roles
- Desired SRB work products during the 2013 process

8:45 AM: Administrative tasks (SRB)

- Identify a chairperson
- Clarify rapporteur needs

9:15 AM: Overview of apportionment history and method (Ray Webster, Bruce Leaman, Ian Stewart)
10:15 AM: Break
10:30 AM: Overview of U.S. and Canadian positions on apportionment (Loh-Lee Low, Robyn Forrest)
11:30 AM: Questions and discussion
12:00 PM: Lunch
1:30 PM: Discussion (SRB Chair)
3:00 PM: Break
3:15 PM: Further discussion and statement writing (SRB Chair)
5:00 PM: Adjourn

Anticipated attendees
SRB members: James Ianelli (NOAA-AFSC), Marc Mangel (UCSC), Sean Cox (SFU)
IPHC Staff: Bruce Leaman, Steve Martell, Ian Stewart, Ray Webster
IPHC Science Advisors: Robyn Forrest, Loh-Lee Low (absent)

<u>Selected apportionment references</u> (.pdf files provided as background material):

IPHC. 2008. IPHC Apportionment Workshop Summary. 7 p.

Hare, S. R., R. A. Webster, J. L. Valero and B. M. Leaman. 2008. Questions and significant comments arising at apportionment workshop - September 2008. 33 p.

IPHC. 2009a. Apportionment workshop 2009 minutes. 12 p.

IPHC. 2009b. Questions and significant issues arising at BAW II. 9 p.

Valero, J. L., S. R. Hare, and B. M. Leaman. Draft document. Considerations for a proposed method to apportion halibut yield. 6 p.

Webster, R. A., S. R. Hare, J. L. Valero, and B. M. Leaman. 2011. Notes on the IPHC setline survey design, alternatives for estimating biomass distribution, and the hook competition adjustment. IPHC Report of Assessment and Research Activities 2010. p. 229-240.

Halibut Strategic Working Group. 2011. Halibut science workshop Meeting summary and minutes, 104 p.

Webster, R. A., and I. J. Stewart. 2013. Apportionment and regulatory area harvest calculations. IPHC Report of Assessment and Research Activities 2012. p.187-206.