INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC–2021–SRB019–00
Last Update: 20 August 2021

19th Session of the IPHC Scientific Review Board (SRB019) – *Compendium of meeting documents*

21 – 23 September 2021, Seattle, WA, USA

Commissioners

Canada	United States of America
Paul Ryall	Glenn Merrill
Neil Davis	Robert Alverson
Peter DeGreef	Richard Yamada

Executive Director

David T. Wilson, Ph.D.

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Report of the 19th Session of the IPHC Scientific Review Board (SRB019)

Meeting held electronically, 21-23 September 2021

Commissioners

Canada	United States of America
Paul Ryall	Chris Oliver
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IPHC Secretariat

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ACRONYMS

AM	Annual Meeting
COVID-19	Novel Coronavirus 2019
CPUE	Catch Per Unit Effort
DMR	Discard Mortality Rate
FISS	Fishery-Independent Setline Survey
IPHC	International Pacific Halibut Commission
MP	Management Procedure
MSAB	Management Strategy Advisory Board
MSE	Management Strategy Evaluation
OM	Operating Model
PCR	Polymerase Chain Reaction
PDO	Pacific Decadal Oscillation
PHMEIA	Pacific Halibut Multiregional Economic Impact Assessment
SRB	Scientific Review Board
TCEY	Total Constant Exploitable Yield
U.S.A.	United States of America
WPUE	Weight-Per-Unit-Effort

DEFINITIONS

A set of working definitions are provided in the IPHC Glossary of Terms and abbreviations: https://www.iphc.int/the-commission/glossary-of-terms-and-abbreviations

HOW TO INTERPRET TERMINOLOGY CONTAINED IN THIS REPORT

This report has been written using the following terms and associated definitions so as to remove ambiguity surrounding how particular paragraphs should be interpreted.

Level 1: **RECOMMENDED**; **RECOMMENDATION; ADOPTED** (formal); **REQUESTED; ENDORSED** (informal): A conclusion for an action to be undertaken, by a Contracting Party, a subsidiary (advisory) body of the Commission and/or the IPHC Secretariat.

Level 2: **AGREED**: Any point of discussion from a meeting which the Commission considers to be an agreed course of action covered by its mandate, which has not already been dealt with under Level 1 above; a general point of agreement among delegations/participants of a meeting which does not need to be elevated in the Commission's reporting structure.

Level 3: **NOTED/NOTING**; **CONSIDERED**; **URGED**; **ACKNOWLEDGED**: General terms to be used for consistency. Any point of discussion from a meeting which the Commission considers to be important enough to record in a meeting report for future reference. Any other term may be used to highlight to the reader of an IPHC report, the importance of the relevant paragraph. Other terms may be used but will be considered for explanatory/informational purposes only and shall have no higher rating within the reporting terminology hierarchy than Level 3.

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EXECUTIVE SUMMARY

The 19th Session of the International Pacific Halibut Commission (IPHC) Scientific Review Board (SRB019) was held electronically from 21 to 23 September 2021. The meeting was opened by the Chairperson, Dr Sean Cox (Canada).

The following are a subset of the complete recommendations/requests for action from the SRB019, which are provided in full at Appendix V.

RECOMMENDATIONS

2022-24 IPHC Fishery-independent setline survey (FISS) design evaluation

SRB019–Rec.01 (para. 13) The SRB **RECOMMENDED** that the Commission note the SRB018 endorsement of the proposed 2022 design and provisional endorsement of the proposed 2023-24 designs, as provided at Appendix IV, recognizing that the designs for 2023-24 will be reviewed again at subsequent SRB meetings.

SRB019–Rec.02 (para. 14) **NOTING** the presentation of three alternative 2022 sampling designs (Figs. 1, 2, and 3) that optimize the SRB018-endorsed proposed 2022 design for cost, thereby meeting the goals of long-term revenue neutrality (Secondary Objective), without compromising the scientific goals of the FISS (Primary Objective), the SRB **RECOMMENDED** that the Secretariat prioritize 2022 sampling designs that include IPHC Regulatory Area 4CDE despite the relatively low contribution of this area to overall biomass and variance. This region is an important area to monitor for future range shifts and biological samples collected here are likely to be important for understanding the biology of Pacific halibut at their leading range edge.

Modelling of IPHC length-weight data

SRB019–Rec.03 (para. 18) The SRB **RECOMMENDED** that the IPHC provide a revised length-net weight relationship for each IPHC Regulatory Area based on modelling of combined FISS and commercial sample data to be used for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected, for 2021 and until further notice.

Management Strategy Evaluation: Update

SRB019–Rec.05 (para. 34) The SRB **RECOMMENDED** the investigation of empirical procedures to inform mortality limits in non-assessment years of a multi-year assessment MP.

SRB019–Rec.06 (para. 35) **NOTING** the inclusion of uncertainty stemming from implementation ***uncertainty***, the SRB **RECOMMENDED** that the IPHC Secretariat develop, for presentation at SRB020, alternative scenarios that represent implementation ***bias***, i.e. the potential for quota reductions called for by the management procedure to be less likely implemented than quota increases.

IPHC Secretariat MSE Program of Work (2021-23)

SRB019–Rec.07 (para. 38) The SRB **RECOMMENDED** that the initial management procedure be evaluated on the basis of the current operating model.

SRB019–Rec.08 (para. 39) The SRB **RECOMMENDED** that the IPHC Secretariat develop alternative OMs from various hypotheses related to population processes or environmental covariates for implementation in the MSE framework, noting paragraph 38, and that tasks leading to the adoption of a well-defined MP should be prioritized.

1. OPENING OF THE SESSION

1. The 19th Session of the International Pacific Halibut Commission (IPHC) Scientific Review Board (SRB019) was held electronically from 21 to 23 September 2021. The list of participants is provided at Appendix I. The meeting was opened by the Chairperson, Dr Sean Cox (Canada).

2. The SRB **RECALLED** its mandate, as detailed in Appendix VIII, Sect. I, para. 1-3 of the IPHC Rules of Procedure (2021):

   1. *The Scientific Review Board (SRB) shall provide an independent scientific peer review of Commission science/research proposals, programs, and products, including but not limited to:*
      a. *Data collection;*
      b. *Historical data sets;*
      c. *Stock assessment;*
      d. *Management Strategy Evaluation;*
      e. *Migration;*
      f. *Reproduction;*
      g. *Growth;*
      h. *Discard survival;*
      i. *Genetics and Genomics.*
   2. *Undertake periodic reviews of science/research strategy, progress, and overall performance.*
   3. *Review the recommendations arising from the MSAB and the RAB.*

2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION

3. The SRB **ADOPTED** the Agenda as provided at Appendix II. The documents provided to the SRB are listed in Appendix III. Participants were reminded that all documents for the meeting were published on the IPHC website, 30 days prior to the Session: https://www.iphc.int/venues/details/19th-session-of-the-iphc-scientific-review-board-srb019.

3. IPHC PROCESS

3.1 SRB annual workflow

4. The SRB **RECALLED** that the core purpose of the SRB019 is to review progress on the IPHC science and research program, including specific products, and to provide guidance for the delivery of products to the Commission at its Interim Meeting in November 2021, and Annual Meeting in January 2022.

3.2 Update on the actions arising from the 18th Session of the SRB (SRB018)

5. The SRB **NOTED** paper IPHC-2021-SRB019-03, which provided the SRB with an opportunity to consider the progress made during the intersessional period, on the recommendations/requests arising from the SRB018.

6. The SRB **NOTED** that most actions from SRB018 remain either 'In Progress' or 'Pending'.

7. The SRB **AGREED** to consider and revise the actions as necessary, and to combine them with any new actions arising from SRB019 into a consolidated list for future reporting.

8. The SRB **RECALLED** three actions for delivery at SRB020 as follows:

   a) SRB018–Req.1 (para. 13) IPHC Fishery-independent setline survey (FISS): 2022-24 FISS design evaluation. The SRB **REQUESTED** plots by survey area of WPUE vs. depth from both FISS and commercial fisheries to help understand if there is part of the Pacific halibut stock in deeper waters not covered by the FISS.

b) SRB018–Req.2 (para. 14) The SRB **REQUESTED** that the IPHC Secretariat conduct a preliminary comparison, to be presented at SRB020, between male, female, and sex-aggregated analysis of the FISS data using the spatial-temporal model.

c) SRB018–Req.14 (para. 52) The SRB **NOTED** that, without a clearer understanding of the Commissions purpose for future use of this work, it is difficult to provide guidance on prioritising model development (e.g. improve spatial resolution, incorporate dynamic / predictive processes, adding more detail on subsistence and recreational fisheries, including uncertainty in the assessment). The SRB therefore **REQUESTED** specific guidance and clarification from the Commission on the objectives and intended use of this study.

3.3 Outcomes of the 97th Session of the IPHC Annual Meeting (AM097)

9. The SRB **NOTED** paper IPHC-2021-SRB018-04 which detailed the outcomes of the 97th Session of the IPHC Annual Meeting (AM097), relevant to the mandate of the SRB, and **AGREED** to consider how best to provide the Commission with the information it has requested, throughout the course of the current SRB meeting.

3.4 Observer updates

10. The SRB **NOTED** updates from the two science advisors, who provided context that may help with SRB discussions/deliberations. These included, but were not limited to: 1) linking the 5-year plan to information provided to Commissioners; 2) How economic analysis will be implemented into advice; 3) How to improve communication within MSE process; 4) Whether a three-year schedule for a full stock assessment still makes sense; 5) How is climate change effecting Pacific halibut biology and assessment and what are the implications for management; and 6) What stakeholder advisory boards in the MSE processes, or the MSAB itself, have (or haven't) been able to accomplish.

4. IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS) AND COMMERCIAL DATA MODELLING

4.1 2022-24 FISS design evaluation

11. The SRB **NOTED** paper IPHC-2021-SRB019-05, which provided an opportunity to further review the 2022-24 FISS designs presented at SRB018 and endorsed by the Scientific Review Board (SRB) at that meeting.

12. The SRB **NOTED** and applauded the IPHC Secretariat, field staff (Setline Survey Specialists), and contracted vessels for successfully executing the 2021 FISS under the continuing and potentially overwhelming circumstances of the COVID-19 pandemic. Despite such challenges, the FISS was still able to achieve the intended range of precision set in the FISS Objectives. This achievement speaks to both the dedication of the entire IPHC Secretariat and the flexibility of the spatio-temporal analysis framework to accommodate changes in FISS design.

13. The SRB **RECOMMENDED** that the Commission note the SRB018 endorsement of the proposed 2022 design and provisional endorsement of the proposed 2023-24 designs, as provided at Appendix IV, recognizing that the designs for 2023-24 will be reviewed again at subsequent SRB meetings.

14. **NOTING** the presentation of three alternative 2022 sampling designs (Figs. 1, 2, and 3) that optimize the SRB018-endorsed proposed 2022 design for cost, thereby meeting the goals of long-term revenue neutrality (Secondary Objective), without compromising the scientific goals of the FISS (Primary Objective), the SRB **RECOMMENDED** that the Secretariat prioritize 2022 sampling designs that include IPHC Regulatory Area 4CDE despite the relatively low contribution of this area to overall biomass and variance. This region is an important area to monitor for future range shifts and biological samples collected here are likely to be important for understanding the biology of Pacific halibut at their leading range edge.

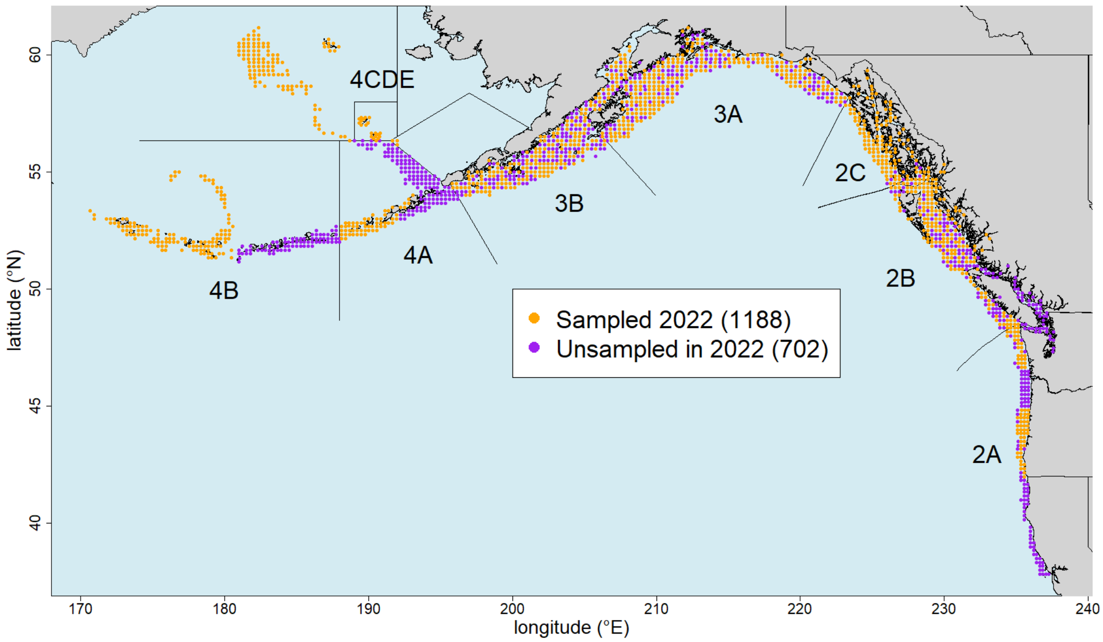

Fig. 1. Potential optimized FISS design for 2022, with original design endorsed at SRB018 augmented with additional stations in IPHC Regulatory Areas 2B, 2C, 3A, and 3B in order to help achieve the secondary objective of long-term revenue neutrality.

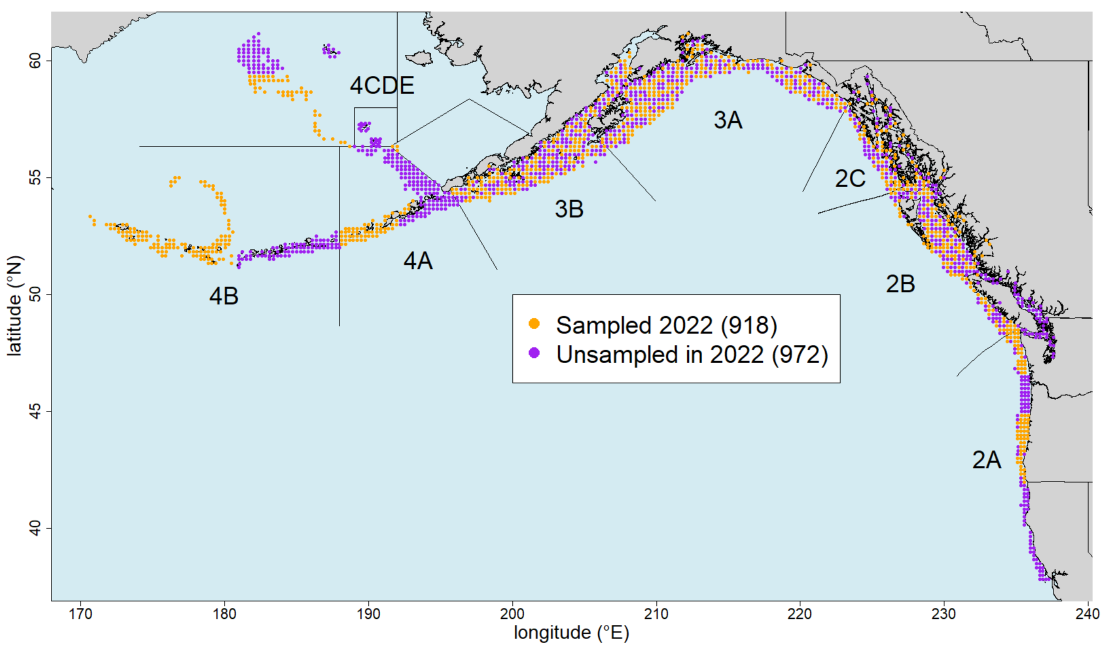

Fig. 2. Potential FISS design for 2022, with original design endorsed at SRB018 modified to remove northern Bering Sea shelf edge stations fished in 2021 to help achieve the secondary objective of long-term revenue neutrality.

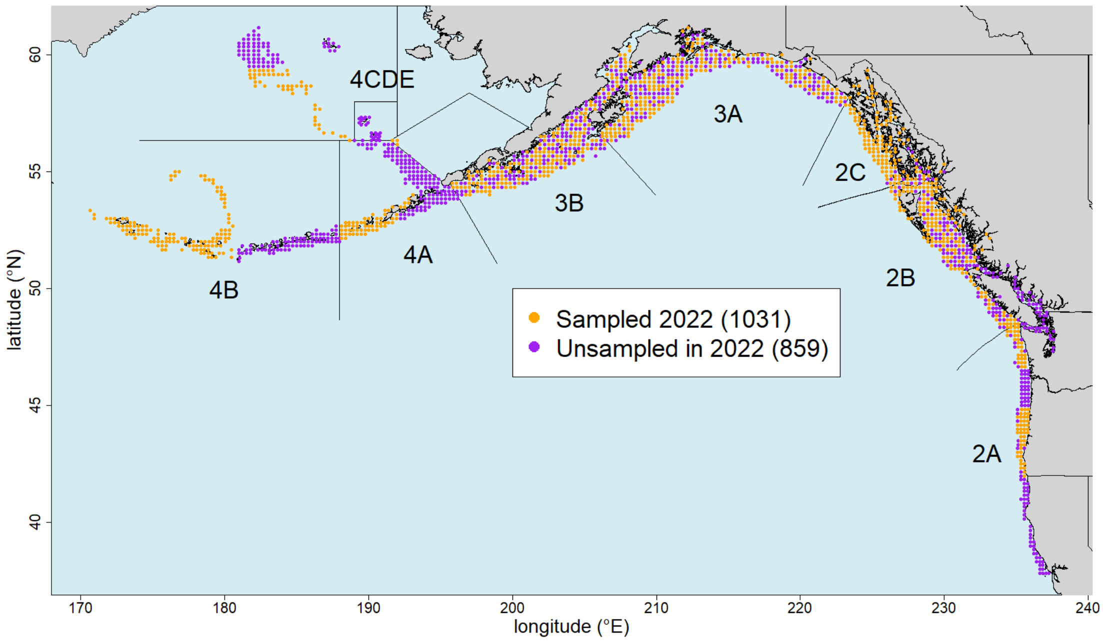

Fig. 3. Potential optimized FISS design for 2022, with original design endorsed at SRB018 modified to remove northern Bering Sea shelf edge stations fished in 2021 augmented with additional stations in IPHC Regulatory Areas 2B, 2C, 3A, and 3B in order to help achieve the secondary objective of long-term revenue neutrality.

4.2 Modelling of IPHC length-weight data

15. The SRB **NOTED** paper IPHC-2021-SRB019-05.2 that presented methods for revised the length-net weight relationships from FISS and commercial sampling data.
16. The SRB **NOTED** that such length-weight relationships may vary with sex, and that changes over time may be affected by changes in environmental variables including temperature.
17. The SRB **NOTED** that any revised length-weight relationship will affect the estimates of a high proportion of overall Pacific halibut mortality that results from recreational catch and Pacific halibut discards.
18. The SRB **RECOMMENDED** that the IPHC provide a revised length-net weight relationship for each IPHC Regulatory Area based on modelling of combined FISS and commercial sample data to be used for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected, for 2021 and until further notice.
19. **NOTING** the emerging difference between length-weight regressions based on historical vs. recent data, the SRB **REQUESTED** further investigation of the underlying processes (whether in the observation process - e.g. timing of sample collection - or biological changes - e.g. changes in somatic growth) driving these differences. While the suggested solution provides a numerical solution it also annually requires significant sampling and analysis efforts which could potentially be reduced through a better understanding of the processes involved.

4.3 Review of IPHC hook competition standardization

20. The SRB **NOTED** paper IPHC-2021-SRB019-05.3 that presented an overview of the IPHC standardization for hook competition on FISS sets.
21. The SRB **NOTED** that such a standardization is not applied to commercial CPUE, but would in any case be of limited value given the weighting of commercial CPUE in IPHC stock assessment.

22. **NOTING** the presentation of methods used for hook competition standardization, the SRB **REQUESTED** continued analysis of this phenomenon and incorporation of these corrections in the FISS data analysis, including potential use of hook timer studies if the technology permits.

4.4 Accounting for the effects of whale depredation on the FISS

23. The SRB **NOTED** paper IPHC-2021-SRB019-05.4 that presented an approach to accounting for the effects of whale interactions on FISS catch rates through the space-time modelling.
24. **NOTING** the presentation of methods used for accounting for whale depredation, and the limited impact of the correction at this point, the SRB **REQUESTED** that the IPHC Secretariat continue to monitor the influence of whale depredation on the FISS and the stock assessment. If the whale depredation correction becomes more important in the future, it will become important to conduct a broader investigation of ways that this phenomenon could be described and accounted for, if at all, in the FISS. Also, the impact / treatment of the associated compositions should be better explained within the stock assessment.. While the SRB generally supports the idea to use all possible data there is a question as to whether the simple time covariate approach risks introducing bias through changes in density of Pacific halibut and / or whales and through ignoring possible depredation selectivity by size and sex.

5. PACIFIC HALIBUT STOCK ASSESSMENT: 2021

5.1 Modelling updates

25. The SRB **NOTED** paper IPHC-2021-SRB019-06, which provided a summary of stock assessment development, including responses to previous SRB requests and an update on data sources and planning for the final 2021 stock assessment.
26. The SRB **NOTED** that:
    a) the 2021 stock assessment represents an update to the 2020 stock assessment with no changes to model structure or primary sources of data;
    b) preliminary trends in the time-series of commercial fishery sex ratio-at-age, that now includes 2020, the 4th year of consecutive data.
27. The SRB **AGREED** that the final 2021 stock assessment would include new data and updated data for all standard data sources, including:
    a) 2021 FISS results: modelled trends and biological data (ages, lengths, weights, weight-at-age);
    b) 2020 Commercial fishery sex ratios-at-age and 2021 logbook and biological sampling;
    c) Biological information from other sources (non-directed commercial and recreational);
    d) Mortality estimates for 2021 and updates to 2020 where necessary.
28. The SRB **NOTED** and appreciated the thorough and informative response to the SRB018 (Req.04) providing five ways in which surplus production could be considered in the Pacific halibut assessment and highlighting that three of these have been previously evaluated (fitting surplus production models directly, reporting the '3-year surplus' in the decision table, and the standard reporting of empirical harvest rates).
29. The SRB **NOTED** that the FISS index-based analysis of relative harvest rates among regions (option 5 of the 5 analyses of surplus production presented in IPHC-2021-SRB019-06) could be considered as a potential metric for defining "Exceptional Circumstances" in the management procedures evaluated in the MSE.
30. **NOTING** that the surplus production analysis revealed a recent pattern of harvest exceeding surplus production despite current biomass being below the target biomass, the SRB **RECOMMENDED** that the IPHC Secretariat continue to report on surplus production in addition to trends and scale of surplus production and fishing intensity as part of the annual assessment.

31. The SRB **REQUESTED** that the IPHC Secretariat consider the following topics for inclusion in the 2022 full stock assessment and presentation for SRB evaluation at SRB020 in June 2022:
    a) Sensitivity analysis of the assessment to processes being investigated by the Biological and Ecosystem Research Program, e.g. spatiotemporal differences in maturity schedules, discard mortality, and length-weight relationships;
    b) Continued exploration of data weighting;
    c) Evaluation of treatment of commercial sex ratio;
    d) Use of the Pacific Decadal Oscillation (PDO) and other environmental covariates to predict recruitment;
    e) Estimation of whale depredation mortality for potential explicit inclusion in the assessment model; and
    f) Other factors discussed since the last stock assessment.
32. The SRB **AGREED** that the IPHC Secretariat should continue on a three-year schedule for conducting a full stock assessment.

6. MANAGEMENT STRATEGY EVALUATION: UPDATE

33. The SRB **NOTED** paper IPHC-2021-SRB019-07 describing the MSE Program or Work for 2021–23, sources of variability in the MSE framework, and results from simulations with a biennial mortality limit specification.

6.1 A summary of the MSE outcomes to date

34. The SRB **RECOMMENDED** the investigation of empirical procedures to inform mortality limits in non-assessment years of a multi-year assessment MP.
35. **NOTING** the inclusion of uncertainty stemming from implementation ***uncertainty***, the SRB **RECOMMENDED** that the IPHC Secretariat develop, for presentation at SRB020, alternative scenarios that represent implementation ***bias***, i.e. the potential for quota reductions called for by the management procedure to be less likely implemented than quota increases.
36. The SRB **NOTED** that the primary coastwide objectives do not specify the short to medium-term risk of low mortality limits, and that reporting lower quantiles of TCEY, such as the 5^{th} percentile, may be informative to distinguish between MPs.

6.2 IPHC Secretariat MSE Program of Work (2021-23)

37. The SRB **NOTED** that tasks for the MSE Program of Work prioritize the adoption of a well-defined management procedure, taking into account interdependencies among tasks and that exploration and development of alternative OMs is likely to compete with the simulation and evaluation of MPs, potentially delaying the adoption of a well-defined management procedure.
38. The SRB **RECOMMENDED** that the initial management procedure be evaluated on the basis of the current operating model.
39. The SRB **RECOMMENDED** that the IPHC Secretariat develop alternative OMs from various hypotheses related to population processes or environmental covariates for implementation in the MSE framework, noting paragraph 38, and that tasks leading to the adoption of a well-defined MP should be prioritized.

7. BIOLOGICAL AND ECOSYSTEM SCIENCE RESEARCH

7.1 IPHC 5-Year biological and ecosystem science research plan (2017-21)

40. The SRB **NOTED** paper IPHC-2021-SRB019-08 which provided the SRB with an update on progress on IPHC's five-year Biological and Ecosystem Sciences Research Plan (2017-21).

41. The SRB **NOTED** and commended the IPHC Secretariat for their continued attention to place current and future Biological and Ecosystem Science Research activities into the context of Stock Assessment (SA) and Management Strategy Evaluation (MSE) data needs. Information provided in Appendices I, II, III, and IV of IPHC-2021-SRB019-08 integrated components across areas of the IPHC research, monitoring, and assessment portfolios. This effort was greatly appreciated, and will foster greater appreciation of the impacts of the IPHC research program on Pacific halibut management.

42. The SRB **NOTED** that:

    a) in previous SRB meetings, conclusions from the reproduction focal area were based on data from a single region collected from a relatively small sample size in a single year;

    b) the IPHC-2021-SRB019-08 document lacked many of the forward-looking planning the SRB had requested during previous meetings;

    c) the plans described by the IPHC Secretariat during the SRB019 oral presentations regarding the expanded spatial and temporal sampling design to collect samples during the 2022 FISS to produce histologically-based maturity ogives by biological region. The SRB **ACKNOWLEDGED** that this effort is needed before information from the existing data can be integrated into a formalized effort to inform the SA and MSE.

43. The SRB **RECOMMENDED** that the Secretariat consider the value of other opportunistically collected samples that would facilitate further downstream analyses in a cost effective manner.

7.2 Progress on ongoing research projects

7.2.1 Reproduction

44. The SRB **NOTED** the completion of studies in one location, which provide information on the seasonal characteristics of reproductive development in female Pacific halibut. This is one step toward the intended goal of providing maturation schedules based on samples from across the species range.

45. The SRB **NOTED** the plans described by the IPHC Secretariat for the sampling design to collect samples during the 2022 FISS to produce histologically-based maturity schedules by biological region. The SRB is pleased to see the detailed practical and scientific considerations that have gone into the development of the plan to ensure the best possible chance of success in addressing the objectives of this study. However, the SRB also **NOTED** that the conclusion that July-August is an acceptable sampling period is based on an analysis from a single location (Portlock, region 3) which may or may not represent seasonal reproductive timing in other regions.

46. The SRB **NOTED** that the IPHC Secretariat is finalising a proposed sampling design for the collection of ovaries in the 2023 FISS, for providing precise estimates of fecundity and **REQUESTED** for SRB020 in June 2022, more detail on the considerations taken to ensure the sampling maximises the opportunity to address the objectives.

7.2.2 Growth and Physiological Condition

47. The SRB **NOTED** ongoing studies aimed at characterizing previously-identified physiological growth genetic gene expression markers as potentially useful indicators of growth patterns in Pacific halibut that could also assist in understanding growth variation at a genomic level.

48. The SRB **ACKNOWLEDGED**:

    a) that there are multiple sources of variability in physiological condition that can affect growth;

    b) progress in development of quantitative (q)PCR assays to quantify expression levels of genes that have been demonstrated by the IPHC Secretariat as associated with Pacific halibut body size.

49. The SRB **NOTED** the information on associations of wild-caught age-4 Pacific halibut body size and gene expression patterns characterized by the IPHC Secretariat under experimental conditions.

50. The SRB **REQUESTED** that the IPHC Secretariat pause further pursuit of this research until it can articulate specifically how this approach will inform the stock assessment or MSE and why this approach is preferable to investigation of age-length-weight information which is available at a much broader geographic and temporal scale.

7.2.3 Discard Mortality Rates (DMRs) and Survival

51. The SRB **NOTED** ongoing studies aimed at providing updated estimates of DMRs in both the commercial longline and recreational fisheries. Of interest is the apparently low (approaching natural mortality) and very delayed mortality of longline discarded fish.

7.2.4 Genetics and Genomics

52. The SRB **NOTED** ongoing studies aimed at describing the genetic structure of the Pacific halibut population by low-coverage whole genome resequencing with particular emphasis on stock structure in IPHC Regulatory Area 4B.
53. The SRB **ACKNOWLEDGED** progress made in the area of low-coverage whole genome resequencing and the promising preliminary data showing discrimination among spawning aggregations. Less clear is how sampling at other times of the year would allow estimation of the spawning site contribution to catches, when likely not all spawning sites have been included. This may hamper the development of a complete picture of the stock structure and migration patterns.
54. The SRB **NOTED** that the IPHC Secretariat would benefit from further consultation with the SRB regarding additional analyses that attempt to characterize spatial structure and applications of this information.

7.3 Research integration

55. The SRB **NOTED** that the IPHC Secretariat have embraced past SRB recommendations to integrate the research program with stock assessment and MSE information needs.
56. The SRB **RECOMMENDED** that the IPHC Secretariat identify those research areas with uncertainty and indicate research questions that would require the SRB to provide input and/or decision in future documentation and presentations provided to the SRB.

8. PACIFIC HALIBUT FISHERY ECONOMICS UPDATE

57. The SRB **NOTED** paper IPHC-2021-SRB019-09 which provides the SRB with an update on the development of the Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA), including the addition of the recreational sector, and responds to comments made during the SRB018 (IPHC-2021-SRB018-R).
58. The SRB **NOTED** the long-term objectives of the Fishery Economics program presented in Section 5.3: "*To provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource in Canada and the United States of America.*"
59. The SRB **NOTED** that substantial uncertainties surround our understanding of recreational fishing effort dynamics (e.g. the expected change in effort with changes in season length or size limits and the availability of alternative target species such as Pacific salmon) and **REQUESTED** that the IPHC Secretariat assess and present at SRB020, the feasibility and value of various stated preference (e.g. a discrete choice experiment) and revealed preference (e.g. time series analysis of fishing effort patterns with respect to regulatory changes) approaches to understanding recreational effort dynamics.
60. The SRB **REQUESTED** that the IPHC Secretariat assess and present at SRB020, the potential of using data from the Guided Angler Fish Program (USA) and Pacific Region Experimental Recreational Halibut Program (Canada) as inputs to the economic analysis of Pacific halibut, particularly the trade-offs between the commercial and the recreational sector.

61. The SRB **REQUESTED** further information (e.g. inverse demand curves), to be presented at SRB020, on the regional supply-price relationships for commercial landings, as well as localized importance of the Pacific halibut fishery to communities.

9. International Pacific Halibut Commission 5-year program of integrated science and research (2021-26)

62. The SRB **NOTED** paper IPHC-2021-SRB019-10 which described research priorities, integration across programs, and performance metrics for 2022-26 and applauded the progress toward integration across core areas.

63. The SRB **REQUESTED** that the IPHC Secretariat consider the following changes (in no particular order) to this document by SRB2020:

a) Add an Executive Summary;

b) Change the title, the overall statement of purpose section, and Fig. 4 to better reflect the goals and intent of the research program;

c) Enhance stock assessment section to reflect research in this area including some of the priorities from the external review etc.;

d) Include the intent to use the MSE to provide research direction and prioritisation (feedback) to the biological research program;

e) Keep monitoring section separate as is, but demonstrate the linkage to the research through resource sharing etc.;

f) Add a performance metric related to the provisioning of high-quality management advice that meets the Commission's needs;

g) Include specific subsections on implications for integration with other core areas and relevance to management;

h) Draft the section on climate change.

10. Review of the draft and adoption of the report of the 19th Session of the IPHC Scientific Review Board (SRB019)

64. The SRB **THANKED** outgoing board member, Dr Sven Kupschus, for his service to the IPHC over the past years and wished him well in his future endeavours.

65. The report of the 19th Session of the IPHC Scientific Review Board (IPHC-2021-SRB019-R) was **ADOPTED** on 23 September 2021, including the consolidated set of recommendations and/or requests arising from SRB019, provided at Appendix V.

APPENDIX I
LIST OF PARTICIPANTS FOR THE 19TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

SRB Members

Dr Sean **Cox**:	spcox@sfu.ca; Professor, School of Resource and Environmental Management, Simon Fraser University, 8888 University Dr., Burnaby, B.C., Canada V5A 1S6
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Observers

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	Anna **Henry**, anna.henry@noaa.gov
	Sarah **Webster**, sara.webster@noaa.gov

IPHC Secretariat

Name	**Position and email**
Dr David **Wilson**	Executive Director, david.wilson@iphc.int
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Ms Tara **Coluccio**	Administrative Specialist/Communications, tara.coluccio@iphc.int

APPENDIX II
AGENDA FOR THE 19TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

Date: 21-23 September 2021
Location: Electronic Meeting
Venue: Adobe Connect
Time: 12:00-17:00 (21st), 09:00-17:00 (22-23)
Chairperson: Dr Sean Cox (Simon Fraser University)
Vice-Chairperson: Nil

1. OPENING OF THE SESSION

2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION
- IPHC-2021-SRB019-01: Agenda & Schedule for the 19th Session of the Scientific Review Board (SRB019)
- IPHC-2021-SRB019-02: List of Documents for the 19th Session of the Scientific Review Board (SRB019)

3. IPHC PROCESS

3.1. SRB annual workflow (D. Wilson)

3.2. Update on the actions arising from the 18th Session of the SRB (SRB018) (D. Wilson)
- IPHC-2021-SRB019-03: Update on the actions arising from the 18th Session of the SRB (SRB018) (IPHC Secretariat)

3.3. Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) (D. Wilson)
- IPHC-2021-SRB019-04: Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) (D. Wilson)

3.4. Observer updates (e.g. Science Advisors)

4. IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS) AND COMMERICAL DATA MODELLING

4.1. 2022-24 FISS design evaluation (R. Webster)

4.2. Modelling of IPHC length-weight data (R. Webster)

4.3. Review of IPHC hook competition standardization (R. Webster)

4.4. Accounting for the effects of whale depredation on the FISS (R. Webster)
- IPHC-2021-SRB019-05: IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling (R. Webster)

5. PACIFIC HALIBUT STOCK ASSESSMENT: 2021

5.1. Modelling updates (I. Stewart)
- IPHC-2021-SRB019-06: Update on the development of the 2021 stock assessment: Development (I. Stewart & A. Hicks)

6. MANAGEMENT STRATEGY EVALUATION: UPDATE
- IPHC-2021-SRB019-07: IPHC Secretariat MSE Program of Work (2021–2023) and an update on progress (A. Hicks & I. Stewart)

6.1. A summary of the MSE outcomes to date (A. Hicks)

6.2. IPHC Secretariat MSE Program of Work (2021-23) (A. Hicks)

7. BIOLOGICAL AND ECOSYSTEM SCIENCES RESEARCH

- IPHC-2021-SRB019-08: Report on current and future biological research activities (J. Planas)

7.1. IPHC 5-Year biological and ecosystem science research plan (2017-21) (J. Planas)
7.2. Progress on ongoing research projects (J. Planas)

8. PACIFIC HALIBUT FISHERY ECONOMICS UPDATE

- IPHC-2021-SRB019-09: Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA): summary of progress (B. Hutniczak)

9. INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED SCIENCE AND RESEARCH (2021-26)

- IPHC-2021-SRB019-10: International Pacific Halibut Commission 5-Year program of integrated science and research (2021-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, B. Hutniczak, & R. Webster)

10. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 19TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

APPENDIX III
LIST OF DOCUMENTS FOR THE 19TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

Document	Title	Availability
IPHC-2021-SRB019-01	Agenda & Schedule for the 19th Session of the Scientific Review Board (SRB019)	✓ 19 Aug 2021
IPHC-2021-SRB019-02	List of Documents for the 19th Session of the Scientific Review Board (SRB019)	✓ 19 Aug 2021
IPHC-2021-SRB019-03	Update on the actions arising from the 18th Session of the SRB (SRB018) (IPHC Secretariat)	✓ 19 Aug 2021
IPHC-2021-SRB019-04	Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) (D. Wilson)	✓ 19 Aug 2021
IPHC-2021-SRB019-05	IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling (R. Webster)	✓ 21 Aug 2021
IPHC-2021-SRB019-06	Update on the development of the 2021 stock assessment (I. Stewart & A. Hicks)	✓ 19 Aug 2021
IPHC-2021-SRB019-07	IPHC Secretariat MSE Program of Work (2021–2023) and an update on progress (A. Hicks & I. Stewart)	✓ 19 Aug 2021
IPHC-2021-SRB019-08	Report on current and future biological and ecosystem science research activities (J. Planas)	✓ 20 Aug 2021
IPHC-2021-SRB019-09	Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA): update for SRB019 (B. Hutniczak)	✓ 19 Aug 2021
IPHC-2021-SRB019-10	International Pacific Halibut Commission 5-Year program of integrated science and research (2021-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, R. Webster, B. Hutniczak)	✓ 19 Aug 2021
Information papers		
Nil to-date	Nil to-date	-

APPENDIX IV

IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS) DESIGN PROPOSED FOR 2022, AND TENTATIVELY PROPOSED FOR 2023-24

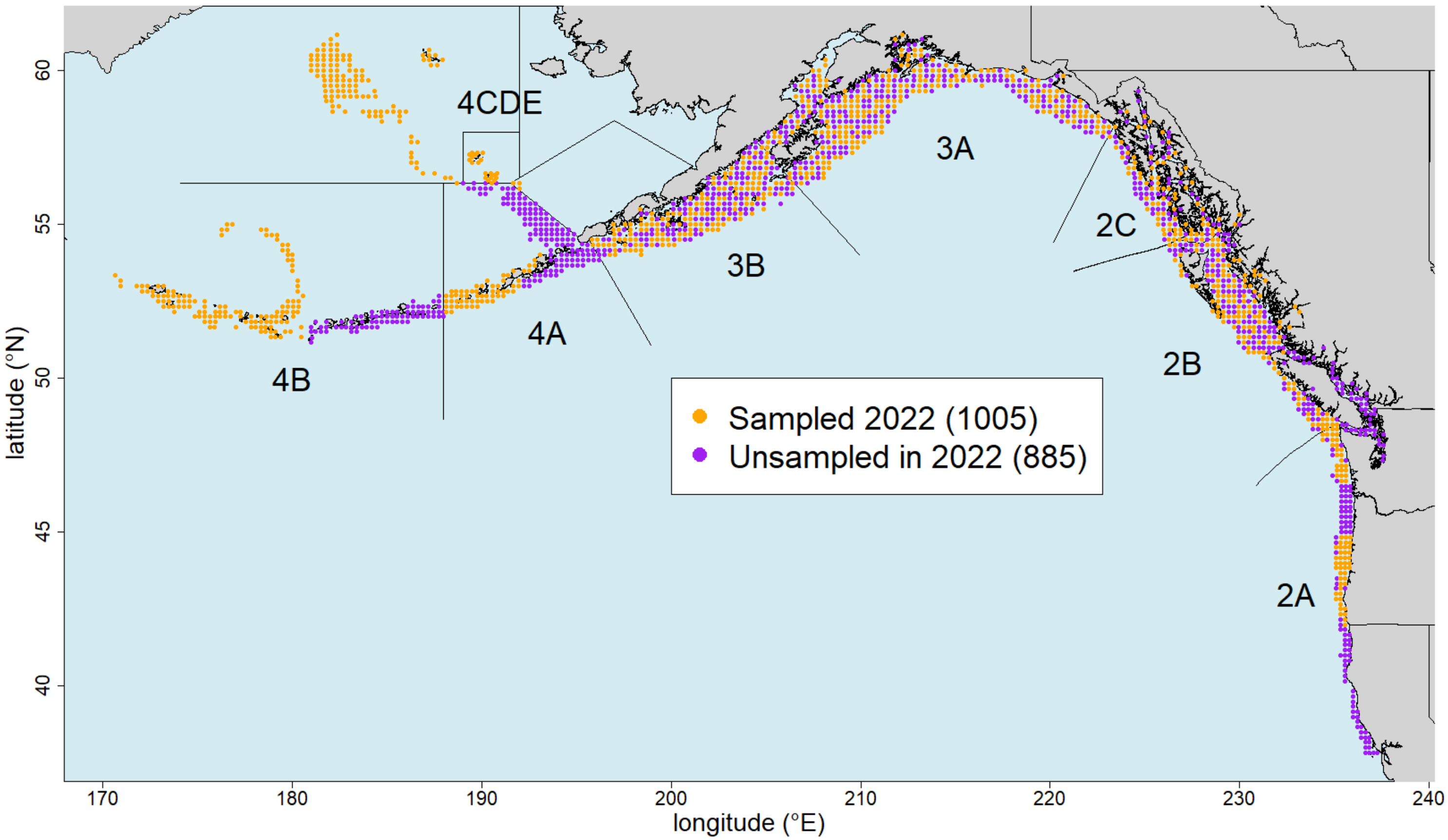

Fig.1. Proposed minimum FISS design in 2022 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

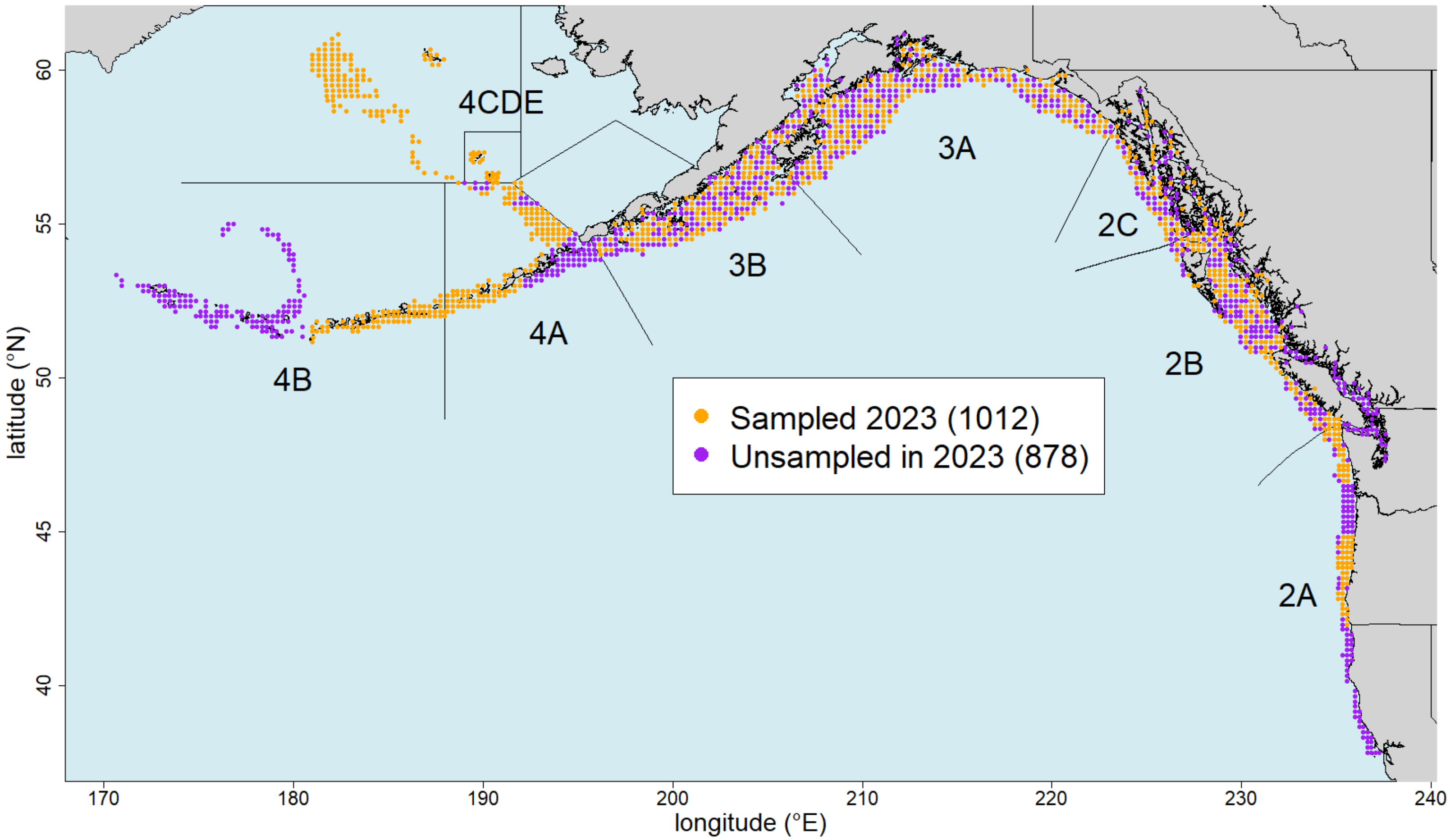

Fig. 2. Proposed minimum FISS design in 2023 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

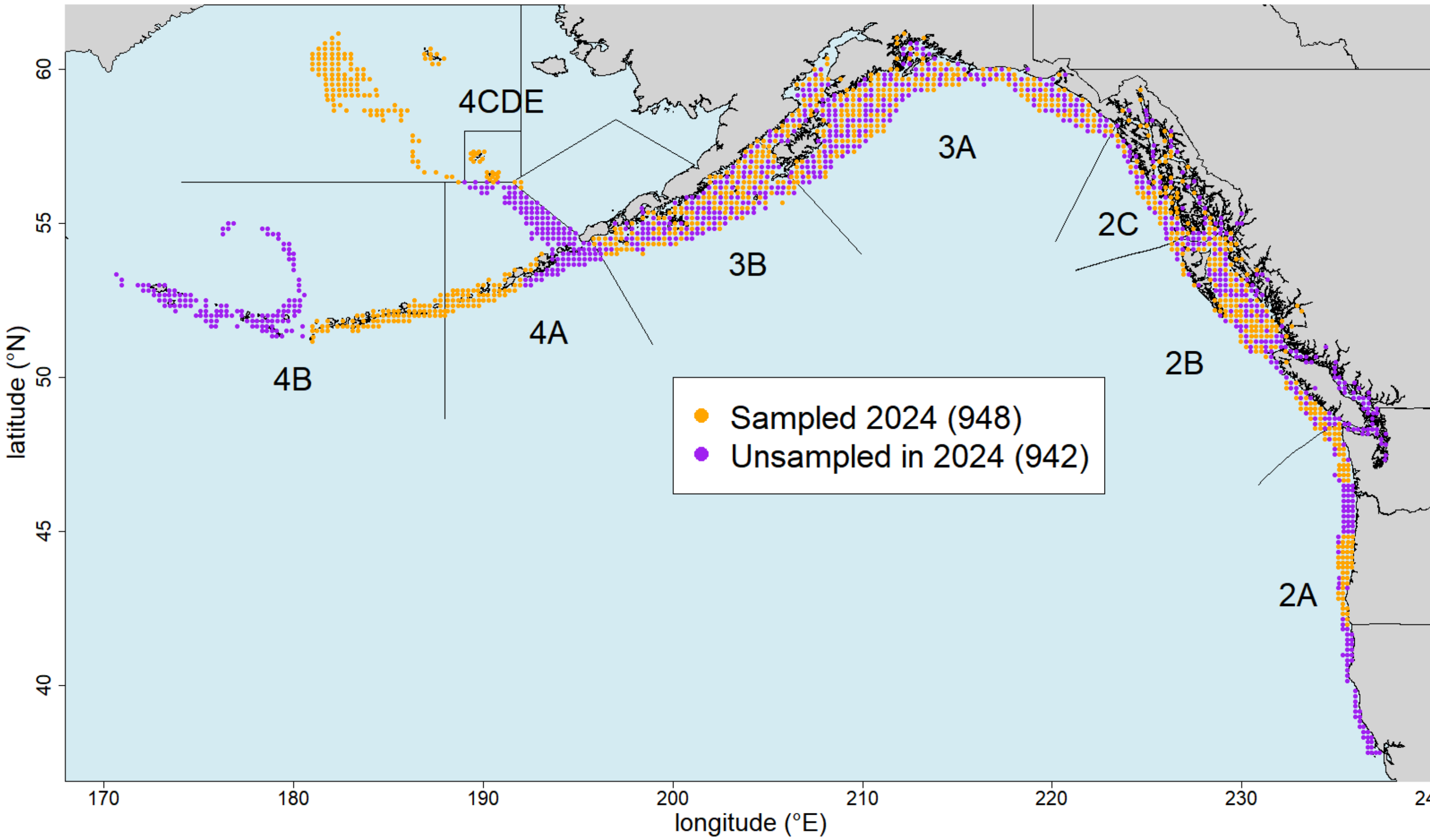

Fig. 3. Proposed minimum FISS design in 2024 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

APPENDIX V
CONSOLIDATED SET OF RECOMMENDATIONS AND REQUESTS OF THE 19TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

RECOMMENDATIONS

2022-24 IPHC Fishery-independent setline survey (FISS) design evaluation

SRB019–Rec.01 (para. 13) The SRB **RECOMMENDED** that the Commission note the SRB018 endorsement of the proposed 2022 design and provisional endorsement of the proposed 2023-24 designs, as provided at Appendix IV, recognizing that the designs for 2023-24 will be reviewed again at subsequent SRB meetings.

SRB019–Rec.02 (para. 14) **NOTING** the presentation of three alternative 2022 sampling designs (Figs. 1, 2, and 3) that optimize the SRB018-endorsed proposed 2022 design for cost, thereby meeting the goals of long-term revenue neutrality (Secondary Objective), without compromising the scientific goals of the FISS (Primary Objective), the SRB **RECOMMENDED** that the Secretariat prioritize 2022 sampling designs that include IPHC Regulatory Area 4CDE despite the relatively low contribution of this area to overall biomass and variance. This region is an important area to monitor for future range shifts and biological samples collected here are likely to be important for understanding the biology of Pacific halibut at their leading range edge.

Modelling of IPHC length-weight data

SRB019–Rec.03 (para. 18) The SRB **RECOMMENDED** that the IPHC provide a revised length-net weight relationship for each IPHC Regulatory Area based on modelling of combined FISS and commercial sample data to be used for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected, for 2021 and until further notice.

Pacific halibut stock assessment: 2021 - Modelling updates

SRB019–Rec.04 (para. 30) **NOTING** that the surplus production analysis revealed a recent pattern of harvest exceeding surplus production despite current biomass being below the target biomass, the SRB **RECOMMENDED** that the IPHC Secretariat continue to report on surplus production in addition to trends and scale of surplus production and fishing intensity as part of the annual assessment.

Management Strategy Evaluation: Update

SRB019–Rec.05 (para. 34) The SRB **RECOMMENDED** the investigation of empirical procedures to inform mortality limits in non-assessment years of a multi-year assessment MP.

SRB019–Rec.06 (para. 35) **NOTING** the inclusion of uncertainty stemming from implementation ***uncertainty***, the SRB **RECOMMENDED** that the IPHC Secretariat develop, for presentation at SRB020, alternative scenarios that represent implementation ***bias***, i.e. the potential for quota reductions called for by the management procedure to be less likely implemented than quota increases.

IPHC Secretariat MSE Program of Work (2021-23)

SRB019–Rec.07 (para. 38) The SRB **RECOMMENDED** that the initial management procedure be evaluated on the basis of the current operating model.

SRB019–Rec.08 (para. 39) The SRB **RECOMMENDED** that the IPHC Secretariat develop alternative OMs from various hypotheses related to population processes or environmental covariates for implementation in the MSE framework, noting paragraph 38, and that tasks leading to the adoption of a well-defined MP should be prioritized.

IPHC 5-Year biological and ecosystem science research plan (2017-21)

SRB019–Rec.09 (para. 43) The SRB **RECOMMENDED** that the Secretariat consider the value of other opportunistically collected samples that would facilitate further downstream analyses in a cost effective manner.

Research integration

SRB019–Rec.10 (para. 56) The SRB **RECOMMENDED** that the IPHC Secretariat identify those research areas with uncertainty and indicate research questions that would require the SRB to provide input and/or decision in future documentation and presentations provided to the SRB.

REQUESTS

Update on the actions arising from the 18th Session of the SRB (SRB018)

SRB019–Req.01 (para. 8) The SRB **RECALLED** three actions for delivery at SRB020 as follows:

a) SRB018–Req.1 (para. 13) IPHC Fishery-independent setline survey (FISS): 2022-24 FISS design evaluation. The SRB **REQUESTED** plots by survey area of WPUE vs. depth from both FISS and commercial fisheries to help understand if there is part of the Pacific halibut stock in deeper waters not covered by the FISS.

b) SRB018–Req.2 (para. 14) The SRB **REQUESTED** that the IPHC Secretariat conduct a preliminary comparison, to be presented at SRB020, between male, female, and sex-aggregated analysis of the FISS data using the spatial-temporal model.

c) SRB018–Req.14 (para. 52) The SRB **NOTED** that, without a clearer understanding of the Commissions purpose for future use of this work, it is difficult to provide guidance on prioritising model development (e.g. improve spatial resolution, incorporate dynamic / predictive processes, adding more detail on subsistence and recreational fisheries, including uncertainty in the assessment). The SRB therefore **REQUESTED** specific guidance and clarification from the Commission on the objectives and intended use of this study.

Modelling of IPHC length-weight data

SRB019–Req.02 (para. 19) **NOTING** the emerging difference between length-weight regressions based on historical vs. recent data, the SRB **REQUESTED** further investigation of the underlying processes (whether in the observation process - e.g. timing of sample collection - or biological changes - e.g. changes in somatic growth) driving these differences. While the suggested solution provides a numerical solution it also annually requires significant sampling and analysis efforts which could potentially be reduced through a better understanding of the processes involved.

Review of IPHC hook competition standardization

SRB019–Req.03 (para. 22) **NOTING** the presentation of methods used for hook competition standardization, the SRB **REQUESTED** continued analysis of this phenomenon and incorporation of these corrections in the FISS data analysis, including potential use of hook timer studies if the technology permits.

Accounting for the effects of whale depredation on the FISS

SRB019–Req.04 (para. 24) **NOTING** the presentation of methods used for accounting for whale depredation, and the limited impact of the correction at this point, the SRB **REQUESTED** that the IPHC Secretariat continue to monitor the influence of whale depredation on the FISS and the stock assessment. If the whale depredation correction becomes more important in the future, it will become important to conduct a broader investigation of ways that this phenomenon could be described and accounted for, if at all, in the FISS. Also, the impact / treatment of the associated compositions should be better explained within the stock assessment.. While the SRB generally supports the idea to use all possible data there is a question as to whether the simple time covariate approach risks introducing bias through changes in density of Pacific halibut and / or whales and through ignoring possible depredation selectivity by size and sex.

Pacific halibut stock assessment: 2021 - Modelling updates

SRB019–Req.05 (para. 31) The SRB **REQUESTED** that the IPHC Secretariat consider the following topics for inclusion in the 2022 full stock assessment and presentation for SRB evaluation at SRB020 in June 2022:

a) Sensitivity analysis of the assessment to processes being investigated by the Biological and Ecosystem Research Program, e.g. spatiotemporal differences in maturity schedules, discard mortality, and length-weight relationships;

b) Continued exploration of data weighting;

c) Evaluation of treatment of commercial sex ratio;

d) Use of the Pacific Decadal Oscillation (PDO) and other environmental covariates to predict recruitment;

e) Estimation of whale depredation mortality for potential explicit inclusion in the assessment model; and

f) Other factors discussed since the last stock assessment.

Biological and ecosystem science research

Reproduction

SRB019–Req.06 (para. 46) The SRB **NOTED** that the IPHC Secretariat is finalising a proposed sampling design for the collection of ovaries in the 2023 FISS, for providing precise estimates of fecundity and **REQUESTED** for SRB020 in June 2022, more detail on the considerations taken to ensure the sampling maximises the opportunity to address the objectives.

Growth and Physiological Condition

SRB019–Req.07 (para. 50) The SRB **REQUESTED** that the IPHC Secretariat pause further pursuit of this research until it can articulate specifically how this approach will inform the stock assessment or MSE and why this approach is preferable to investigation of age-length-weight information which is available at a much broader geographic and temporal scale.

Pacific halibut fishery economics update

SRB019–Req.08 (para. 59) The SRB **NOTED** that substantial uncertainties surround our understanding of recreational fishing effort dynamics (e.g. the expected change in effort with changes in season length or size limits and the availability of alternative target species such as Pacific salmon) and **REQUESTED** that the IPHC Secretariat assess and present at SRB020, the feasibility and value of various stated preference (e.g. a discrete choice experiment) and revealed preference (e.g. time series analysis of fishing effort patterns with respect to regulatory changes) approaches to understanding recreational effort dynamics.

SRB019–Req.09 (para. 60) The SRB **REQUESTED** that the IPHC Secretariat assess and present at SRB020, the potential of using data from the Guided Angler Fish Program (USA) and Pacific Region Experimental Recreational Halibut Program (Canada) as inputs to the economic analysis of

Pacific halibut, particularly the trade-offs between the commercial and the recreational sector.

SRB019–Req.10 (para. 61) The SRB **REQUESTED** further information (e.g. inverse demand curves), to be presented at SRB020, on the regional supply-price relationships for commercial landings, as well as localized importance of the Pacific halibut fishery to communities.

International Pacific Halibut Commission 5-year program of integrated science and research (2021-26)

SRB019–Req.11 (para. 63) The SRB **REQUESTED** that the IPHC Secretariat consider the following changes (in no particular order) to this document by SRB2020:

a) Add an Executive Summary;

b) Change the title, the overall statement of purpose section, and Fig. 4 to better reflect the goals and intent of the research program;

c) Enhance stock assessment section to reflect research in this area including some of the priorities from the external review etc.;

d) Include the intent to use the MSE to provide research direction and prioritisation (feedback) to the biological research program;

e) Keep monitoring section separate as is, but demonstrate the linkage to the research through resource sharing etc.;

f) Add a performance metric related to the provisioning of high-quality management advice that meets the Commission's needs;

g) Include specific subsections on implications for integration with other core areas and relevance to management;

h) Draft the section on climate change.

AGENDA & SCHEDULE FOR THE 19th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

Date: 21-23 September 2021
Location: Electronic Meeting
Venue: Adobe Connect
Time: 12:00-17:00 (21st), 09:00-17:00 (22-23)
Chairperson: Dr Sean Cox (Simon Fraser University)
Vice-Chairperson: Nil

1. OPENING OF THE SESSION

2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION

- *IPHC-2021-SRB019-01: Agenda & Schedule for the 19th Session of the Scientific Review Board (SRB019)*
- *IPHC-2021-SRB019-02: List of Documents for the 19th Session of the Scientific Review Board (SRB019)*

3. IPHC PROCESS

3.1. SRB annual workflow (D. Wilson)

3.2. Update on the actions arising from the 18th Session of the SRB (SRB018) (D. Wilson)
- *IPHC-2021-SRB019-03: Update on the actions arising from the 18th Session of the SRB (SRB018) (IPHC Secretariat)*

3.3. Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) (D. Wilson)
- *IPHC-2021-SRB019-04: Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) (D. Wilson)*

3.4. Observer updates (e.g. Science Advisors)

4. IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS) AND COMMERICAL DATA MODELLING

4.1. 2022-24 FISS design evaluation (R. Webster)

4.2. Modelling of IPHC length-weight data (R. Webster)

4.3. Review of IPHC hook competition standardization (R. Webster)

4.4. Accounting for the effects of whale depredation on the FISS (R. Webster)
- *IPHC-2021-SRB019-05: IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling (R. Webster)*

5. PACIFIC HALIBUT STOCK ASSESSMENT: 2021

5.1. Modelling updates (I. Stewart)
- *IPHC-2021-SRB019-06: Update on the development of the 2021 stock assessment: Development (I. Stewart & A. Hicks)*

6. MANAGEMENT STRATEGY EVALUATION: UPDATE

- *IPHC-2021-SRB019-07: IPHC Secretariat MSE Program of Work (2021–2023) and an update on progress (A. Hicks & I. Stewart)*

6.1. A summary of the MSE outcomes to date (A. Hicks)

6.2. IPHC Secretariat MSE Program of Work (2021-23) (A. Hicks)

7. BIOLOGICAL AND ECOSYSTEM SCIENCES RESEARCH

- *IPHC-2021-SRB019-08: Report on current and future biological research activities (J. Planas)*

7.1. IPHC 5-Year biological and ecosystem science research plan (2017-21) (J. Planas)
7.2. Progress on ongoing research projects (J. Planas)

8. PACIFIC HALIBUT FISHERY ECONOMICS UPDATE

- *IPHC-2021-SRB019-09: Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA): summary of progress (B. Hutniczak)*

9. INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED SCIENCE AND RESEARCH (2021-26)

- *IPHC-2021-SRB019-10: International Pacific Halibut Commission 5-Year program of integrated science and research (2021-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, B. Hutniczak, & R. Webster)*

10. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 19TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

SCHEDULE FOR THE 18th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB018)

Tuesday, 21 September 2021

Time	**Agenda item**	**Lead**
12:00-12:30	Adobe Connect - Participants encouraged to call in and test connection early	
12:30-12:45	1. OPENING OF THE SESSION 2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION	S. Cox & D. Wilson
12:45-13:30	3. IPHC PROCESS 3.1 SRB annual workflow (D. Wilson) 3.2 Update on the actions arising from the 18th Session of the SRB (SRB018) 3.3 Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) 3.4 Observer updates (e.g. Science Advisors)	D. Wilson
13:30-14:45	4. IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS) AND COMMERICAL DATA MODELLING 4.1 2022-24 FISS design evaluation 4.2 Modelling of IPHC length-weight data 4.3 Review of IPHC hook competition standardization 4.4 Accounting for the effects of whale depredation on the FISS	R. Webster
14:45-15:30	5. PACIFIC HALIBUT STOCK ASSESSMENT: 2021 5.1 Modelling updates	I. Stewart
15:30-15:45	Break	
15:45-16:30	5. PACIFIC HALIBUT STOCK ASSESSMENT: 2021 (cont.)	I. Stewart
16:30-17:00	SRB drafting session	SRB members

Wednesday, 22 September 2021

Time	**Agenda item**	**Lead**
09:00-10:00	Review of Day 1 and discussion of SRB Recommendations from Day 1	Chairperson

10:00-10:30	6. MANAGEMENT STRATEGY EVALUATION: UPDATE 6.1 A summary of the MSE outcomes to date 6.2 IPHC Secretariat MSE Program of Work (2021-23)	A. Hicks
10:30-10:45	Break	
10:45-11:45	6. (Cont.) MANAGEMENT STRATEGY EVALUATION: UPDATE	A. Hicks
11:45-12:30	7. BIOLOGICAL AND ECOSYSTEM SCIENCES RESEARCH 7.1 IPHC 5-Year biological and ecosystem science research plan (2017-21) 7.2 Progress on ongoing research projects	J. Planas
12:30-13:30	Lunch	
13:30-14:30	7. BIOLOGICAL AND ECOSYSTEM SCIENCES RESEARCH (Cont.)	
14:40-15:30	8. PACIFIC HALIBUT FISHERY ECONOMICS UPDATE	B. Hutniczak
15:30-15:45	Break	
15:45-17:00	SRB drafting session	SRB members
Thursday, 23 September 2021		
Time	**Agenda item**	**Lead**
09:00-10:00	Review of Day 2 and discussion of SRB Recommendations from Day 2	Chairperson
10:00-12:30	9. INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED SCIENCE AND RESEARCH (2021-26)	D. Wilson et al.
12:30-13:30	Lunch	
13:30-14:30	SRB drafting session	SRB members
14:30-17:00	10. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 19th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)	S. Cox

LIST OF DOCUMENTS FOR THE 19th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB019)

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IPHC-2021-SRB019-10	International Pacific Halibut Commission 5-Year program of integrated science and research (2021-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, R. Webster, B. Hutniczak)	✓ 19 Aug 2021
Information papers		
Nil to-date	Nil to-date	-

UPDATE ON THE ACTIONS ARISING FROM THE 18TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB018)

PREPARED BY: IPHC SECRETARIAT (19 AUGUST 2021)

PURPOSE

To provide the Scientific Review Board (SRB) with an opportunity to consider the progress made during the intersessional period, on the recommendations/requests arising from the SRB018.

BACKGROUND

At the SRB018, the members recommended/requested a series of actions to be taken by the IPHC Secretariat, as detailed in the SRB018 meeting report (IPHC-2021-SRB018-R) available from the IPHC website, and as provided in Appendix A.

DISCUSSION

During the 19th Session of the SRB (SRB019), efforts will be made to ensure that any recommendations/requests for action are carefully constructed so that each contains the following elements:

1) a specific action to be undertaken (deliverable);
2) clear responsibility for the action to be undertaken (such as the IPHC Staff or SRB officers);
3) a desired time frame for delivery of the action (such as by the next session of the SRB or by some other specified date).

RECOMMENDATION/S

That the SRB:

1) **NOTE** paper IPHC-2021-SRB019-03, which provided the SRB with an opportunity to consider the progress made during the inter-sessional period, in relation to the consolidated list of recommendations/requests arising from the previous SRB meeting (SRB018).
2) **AGREE** to consider and revise the actions as necessary, and to combine them with any new actions arising from SRB019.

APPENDICES

Appendix A: Update on actions arising from the 18th Session of the IPHC Scientific Review Board (SRB018)

APPENDIX A
Update on actions arising from the 18th Session of the IPHC Scientific Review Board (SRB018)

RECOMMENDATIONS

(para. 4) ***NOTING*** *that the core purpose of the SRB018 is to review progress on the IPHC science program, and to provide guidance for the delivery of products to the SRB019 in September 2021, the SRB* ***RECALLED*** *that formal recommendations to the Commission would not be developed at the present meeting, but rather, these would be developed at the SRB019.*

REQUESTS

Action No.	Description	Update
SRB018–Req.1 (para. 13)	***IPHC Fishery-independent setline survey (FISS): 2022-24 FISS design evaluation*** The SRB **REQUESTED** plots by survey area of WPUE vs. depth from both FISS and commercial fisheries to help understand if there is part of the Pacific halibut stock in deeper waters not covered by the FISS.	**Pending**: Task for SRB020 in 2022
SRB018–Req.2 (para. 14)	The SRB **REQUESTED** that the IPHC Secretariat conduct a preliminary comparison, to be presented at SRB020, between male, female, and sex-aggregated analysis of the FISS data using the spatial-temporal model.	**Pending**: Task for SRB020 in 2022
SRB018–Req.3 (para. 15)	The SRB **REQUESTED** that the shiny-tool to investigate data and model outputs for the FISS be made available to the SRB by SRB019.	**Completed**: See paper IPHC-2021-SRB019-05
SRB018–Req.4 (para. 24)	***Pacific halibut stock assessment: 2021*** The SRB **REQUESTED** an analysis of annual surplus production and the fraction of that production harvested.	**Completed**: See paper IPHC-2021-SRB019-06
SRB018–Req.5 (para. 30)	***Management Strategy Evaluation: update*** The SRB **REQUESTED** that the IPHC Secretariat present a revised system diagram of the MSE, showing components of variability and their implementation within MSE.	**Completed**: See paper IPHC-2021-SRB019-07
SRB018–Req.6 (para. 32)	The SRB **REQUESTED** that the Secretariat review potential indicators for use in defining ECs.	**Ongoing**: The Secretariat will continue working on this request and

Action No.	Description	Update
		report outcomes at SRB020 after discussions with the MSAB and Commission.
SRB018–Req.7 (para. 36)	The SRB **REQUESTED** that the IPHC Secretariat prioritize tasks for the MSE Program of Work that lead to adoption of a well-defined management procedure, taking into account interdependencies among tasks and presenting tasks as linked sets.	**Ongoing**: See paper IPHC-2021-SRB019-07
SRB018–Req.8 (para. 39)	***Biological and ecosystem sciences research*** The SRB **REQUESTED** that the IPHC Secretariat focus future reproductive biology studies on the development of updated regulatory area-specific maturity ogives (schedules of percent maturity by age).	**Ongoing**: See paper IPHC-2021-SRB019-10
SRB018–Req.9 (para. 40)	The SRB **REQUESTED** that the IPHC Secretariat provide information on the age distribution of all females collected to characterize reproductive development throughout the annual cycle in order to refine efforts to identify potential skip-spawning females.	**Completed**: See paper IPHC-2021-SRB019-08
SRB018–Req.10 (para. 41)	The SRB **REQUESTED** that planned studies on fecundity assessment are prioritized and that the sampling design be developed in coordination with the SA to ensure that the results are as informative as possible for assessment purposes. Effective sample stratification along age, weight and length gradients that maximise the contrast in the effect of these variables will be key to precise estimates of fecundity. Oocyte diameter in contrast may be a important covariate to provide but cannot be used in stratification. The primary goal of the fecundity research should be to estimate the exponent of the fecundity vs. weight relationship for incorporation in the SA.	**Ongoing**: See paper IPHC-2021-SRB019-10
SRB018–Req.11 (para. 42)	The SRB **NOTED** that growth marker genes identified in transcriptomic profiling studies can be informative in future genome scans. However, the SRB **REQUESTED** that the Secretariat explicitly describe how the gene regions identified as ‘over’ or ‘under’	**Ongoing**: See paper IPHC-2021-SRB019-08

Action No.	Description	Update
	expressed would be used. For example, research has yet to determine mechanisms for transcriptional differences other than there is over- or under-representation of mRNA transcripts associated with different treatment groups (e.g. warm vs. cool water) from a heterogeneous set of individuals collected from a single location. The Secretariat has not yet established that results can be generalized to other regions in the species range. Neither has the transcriptional patterns been generalized to individuals of different size/age. These questions should be investigated.	
SRB018–Req.12 (para. 43)	The SRB **REQUESTED** that the Secretariat use these gene regions and align sequences to the whole genome sequence data. Specifically, the Secretariat should investigate whether there is sequence variability within gene coding regions or in regions around gene coding regions that may be transcriptional modifiers (e.g. promoters). If genetic variation exists in or near these genes, these variable base pair position(s) (i.e. single nucleotide polymorphisms or SNPs) should be incorporated in other aspects of the Secretariat research; for example for research activities under the Migration and Population Dynamics Research area.	**Completed**: See paper IPHC-2021-SRB019-08
SRB018–Req.13 (para. 44)	The SRB **REQUESTED** that the analysis of seasonal patterns in gonad development be explicitly tied to the development/improvement of the maturity ogive (the vector of proportion mature at age that SA requires).	**Completed**: See paper IPHC-2021-SRB019-08
SRB018–Req.14 (para. 52)	***Pacific halibut fishery economics update*** The SRB **NOTED** that, without a clearer understanding of the Commissions purpose for future use of this work, it is difficult to provide guidance on prioritising model development (e.g. improve spatial resolution, incorporate dynamic / predictive processes, adding more detail on subsistence and recreational fisheries, including uncertainty in the assessment). The SRB therefore **REQUESTED** specific guidance and clarification from the Commission on the objectives and intended use of this study.	Ongoing: See paper IPHC-2021-SRB019-09 and 10

Action No.	Description	Update
SRB018–Req.15 (para. 57)	***International Pacific Halibut Commission 5-year program of integrated science and research (2021-26)*** The SRB **REQUESTED** that the forward-looking document on future integrated science and research priorities (IPHC-2021-SRB018-10) incorporate the following elements: a) Previous research priorities of stock assessment; b) How the Biological Division of the IPHC prioritized their research agenda in the previous 5-year plan to produce data to meet stock assessment needs; c) Introspective assessment of the success of the previous 5-year plan; d) Changing/New needs for stock assessment and MSE; e) Direction of new 5-year plan to continue unfinished objectives of the previous 5-yr plan and justification for goals and objectives of the proposed 5-year plan.	**Ongoing**: See paper IPHC-2021-SRB019-10
SRB018–Req.16 (para. 58)	The SRB **REQUESTED** that Measures of Success (sub-section 5 of IPHC-2021-SRB018-10) be cast in metrics of quantifiable improvements to MSE and SA performance, particularly subsections 5.1 and 5.2.	**Ongoing**: See paper IPHC-2021-SRB019-10

Action No.	Description	Update
SRB018–Req.17 (para. 59)	The SRB **REQUESTED** that the Secretariat provide explicit statements of the direction of external funding grant requests and the justification based on MSE and SA needs. For example: a) What is the IPHC contributing to the Biological and Ecosystem Science Branch budget? b) What is needed in terms of additional resources and personnel and in which areas to support the proposed direction stated in the next 5-year plan? c) What are the grant priorities, what are the targeted granting agencies, who will be tasked to write the grants, what intellectual resources are needed to be successful (i.e. research agency or academic partners with desired technical and/or analytical skills)? d) Where could the SA and MSE analytical staff provide analytical support to the Biological Sciences section?	**Ongoing**: See paper IPHC-2021-SRB019-10

INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC-2021-SRB019-04

OUTCOMES OF THE 97TH SESSION OF THE IPHC ANNUAL MEETING (AM097)

PREPARED BY: IPHC SECRETARIAT (D. WILSON, 19 AUGUST 2021)

PURPOSE

To provide the SRB with the outcomes of the 97th Session of the IPHC Annual Meeting (AM097) relevant to the mandate of the SRB.

BACKGROUND

The agenda of the Commission's Annual Meeting (AM097) included several agenda items relevant to the SRB:

5. STOCK STATUS OF PACIFIC HALIBUT (2020) & HARVEST DECISION TABLE (2021)
    - 5.1 IPHC Fishery-Independent Setline Survey (FISS) (2020) (L. Erikson)
    - 5.2 Space-time modelling of survey data and FISS designs for 2021-23 (R. Webster)
    - 5.3 Stock Assessment: Data overview and stock assessment (2020), and harvest decision table (2021) (I. Stewart)
    - 5.4 Pacific halibut mortality projections using the IPHC mortality projection tool (2021) (I. Stewart)
    - 5.5 Size limit review (I. Stewart)

6. IPHC SCIENCE AND RESEARCH
    - 6.1 IPHC 5-year Biological and Ecosystem Science Research Plan (2017-21): update (J. Planas)

7. REPORT OF THE 21st SESSION OF THE IPHC RESEARCH ADVISORY BOARD (RAB020) (J. Planas)

8. REPORTS OF THE IPHC SCIENTIFIC REVIEW BOARD (S. Cox)

9. MANAGEMENT STRATEGY EVALUATION
    - 9.1 IPHC Management Strategy Evaluation: update (A. Hicks)
    - 9.2 Reports of the IPHC Management Strategy Advisory Board (A. Kaiser, R. Baker)

6. *STOCK STATUS OF PACIFIC HALIBUT (2019) & HARVEST DECISION TABLE (2020)*
   - 6.1 *IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2019*
   - 6.2 *Space-time modelling of IPHC Fishery-Independent Setline Survey (FISS) data*
   - 6.3 *Stock Assessment: Independent peer review of the Pacific halibut stock assessment*
   - 6.4 *Stock Assessment: Data overview and stock assessment (2019), and harvest decision table (2020)*
   - 6.5 *Pacific halibut mortality projections using the IPHC mortality projection tool*
7. *IPHC 5-YEAR RESEARCH PROGRAM*
   - 7.1 *IPHC 5-year Biological & Ecosystem Science Research Plan: update*
8. *REPORT OF THE 20TH SESSION OF THE IPHC RESEARCH ADVISORY BOARD (RAB020)*
9. *REPORTS OF THE 14th AND 15TH SESSIONS OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB014; SRB015)*
10. *MANAGEMENT STRATEGY EVALUATION*
    - 10.1 *IPHC Management Strategy Evaluation: update*
    - 10.2 *Reports of the 13th and 14th Sessions of the IPHC Management Strategy Advisory Board (MSAB013; MSAB014)*

DISCUSSION

During the course of the 97th Session of the IPHC Annual Meeting (AM097) the Commission made a number of specific recommendations and requests for action regarding the stock assessment, MSE process, and 5-year research program. Relevant sections from the report of the meeting are provided in Appendix A for the SRB's consideration.

RECOMMENDATION

That the SRB:

1) **NOTE** paper IPHC-2021-SRB019-04 which details the outcomes of the 97th Session of the IPHC Annual Meeting (AM097) relevant to the mandate of the SRB.

APPENDICES

Appendix A: Excerpts from the 97th Session of the IPHC Annual Meeting (AM097) Report (IPHC-2021-AM097-R).

APPENDIX A
Excerpt from the 97th Session of the IPHC Annual Meeting (AM097) Report (IPHC-2021-AM097-R)

RECOMMENDATIONS

Nil.

REQUESTS

Management Strategy Evaluation

*AM097–Req.02 (para. 70) The Commission **REQUESTED** that the IPHC Secretariat consider and develop a draft MSE Program of Work for review by the Commission. The MSE Program of Work should describe technical versus policy-oriented issues, linkages between/among specific work products, and sequencing considerations between/among items. The MSE Program of Work should describe the resources required to complete items.*

Pacific halibut fishery economics update

*AM097–Req.04 (para. 94) The Commission **REQUESTED** that the IPHC Secretariat develop and distribute a Media Release on the Fishery economic project and the associated economic survey for industry to complete.*

IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling

PREPARED BY: IPHC SECRETARIAT (R. WEBSTER; 21 AUGUST 2021)

Part 1: 2022-24 FISS design evaluation

PURPOSE

To review the 2022-24 FISS designs presented at SRB018 and endorsed by the Scientific Review Board (SRB) at that meeting.

BACKGROUND

At SRB018, Secretariat staff presented proposed FISS designs for 2022-24 together with an evaluation of those designs (Webster 2021). Based on the evaluation, it is expected that the proposed designs would lead to estimated indices of density that would meet bias and precision criteria. In their report (IPHC-2021-SRB018-R, paragraph 16) the SRB stated:

> *The SRB **ENDORSED** the final 2022 FISS design as presented in Fig. 2, and provisionally **ENDORSED** the 2023-24 designs (Figs. 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.*

PROPOSED DESIGNS FOR 2022-24

The designs proposed for 2022-24 (Figures 1.1 to 1.3) use efficient subarea sampling in IPHC Regulatory Areas 2A, 4A and 4B, and incorporate a randomized subsampling of FISS stations in IPHC Regulatory Areas 2B, 2C, 3A and 3B (except for the near-zero catch rate inside waters around Vancouver Island), with a sampling rate chosen to keep the sample size close to 1000 stations in an average year. This was also used to generate the designs originally proposed for 2020 (but modified as a result of the impact of COVID19 and cost considerations), and for those proposed and approved for 2021. In 2020, designs for 2022-23 were also approved subject to revision. We are proposing one change from that 2022 design, bringing forward by one year (from 2023 to 2022) the sampling of the central and western subareas of IPHC Regulatory Area 4B to reduce the risk of bias in estimates from that area. Thus, we propose that:

- In 2022 the lower-density western and central subareas of IPHC Regulatory Area 4B in sampled, followed by the higher-density eastern subarea in 2023-24
- The higher-density western subarea of IPHC Regulatory Area 4A be sampled in all three years, with the medium-density northern shelf edge subarea added in 2023 only
- The highest-density waters of IPHC Regulatory 2A in northern Washington and central/southern Oregon are proposed for sampling in each year of the 2022-24 period
- The near-zero density waters of the Salish Sea in IPHC Regulatory 2B are not proposed for sampling in 2022-24

Following this three-year period, it is expected that the remaining subareas will be included during the subsequent 3-5 years. These include the southeastern subarea of IPHC Regulatory 4A, and lower-density waters of IPHC Regulatory 2A (see below).

The design proposals again include full sampling of the standard FISS grid in IPHC Regulatory Area 4CDE. The Pacific halibut distribution in this area continues to be of particular interest, as it is a highly dynamic region with an apparently northward-shifting distribution of Pacific halibut, and increasing uncertainty regarding connectivity with populations adjacent to and within Russian waters.

RECOMMENDATION

That the Scientific Review Board:

1) **RECOMMEND** that the Commission note the SRB endorsement of the proposed 2022 design (Figure 1.1) and provisional endorsement of the proposed 2023-24 designs (Figures 1.2 and 1.3).

References

IPHC 2021. Report of the 18th Session of the IPHC Scientific Review Board (SRB) IPHC-2021-SRB18-R.

Webster, R. A. 2021. 2022-24 FISS design evaluation. IPHC-2021-SRB018-05 Rev_1.

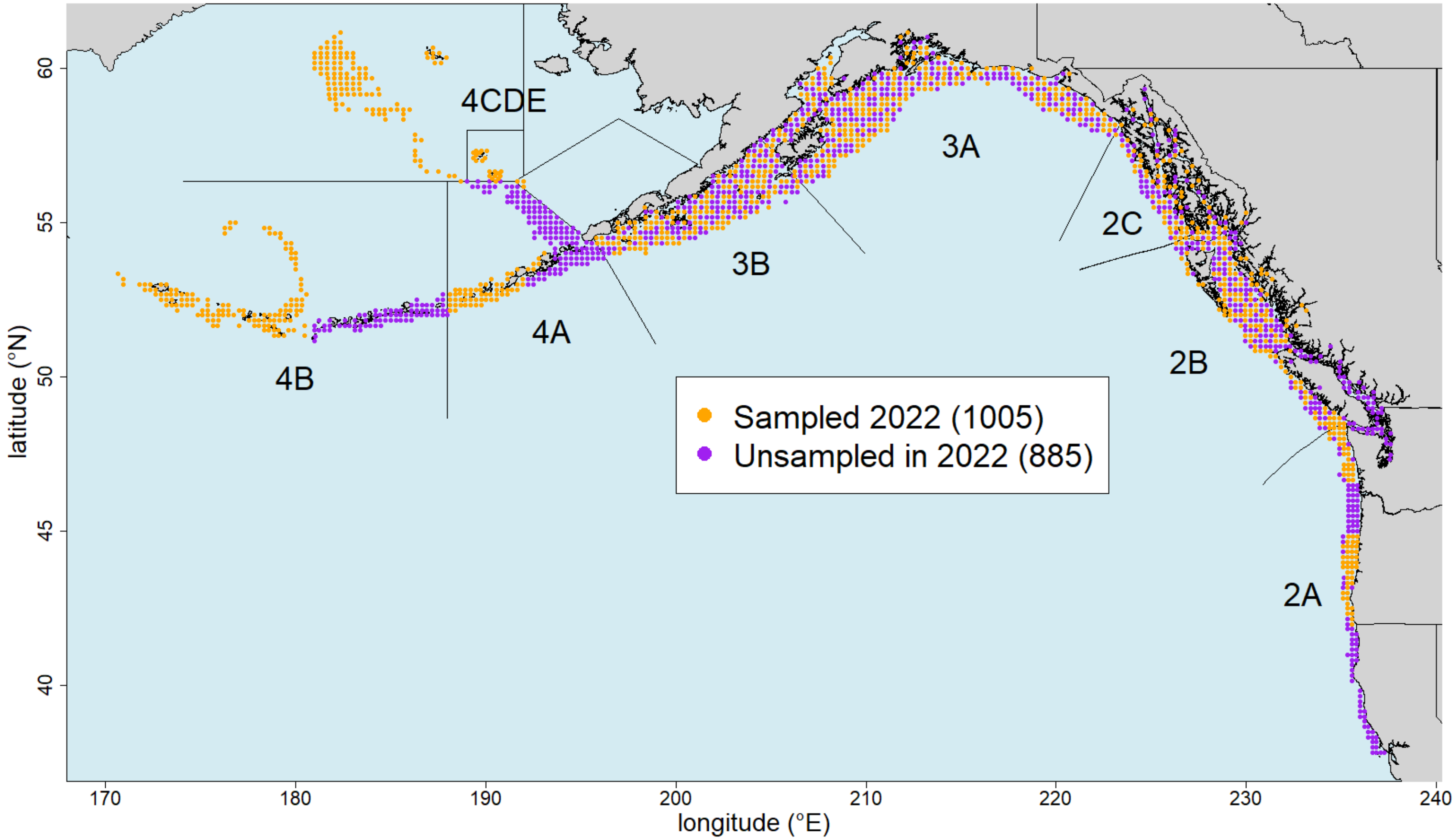

Figure 1.1. Proposed minimum FISS design in 2022 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

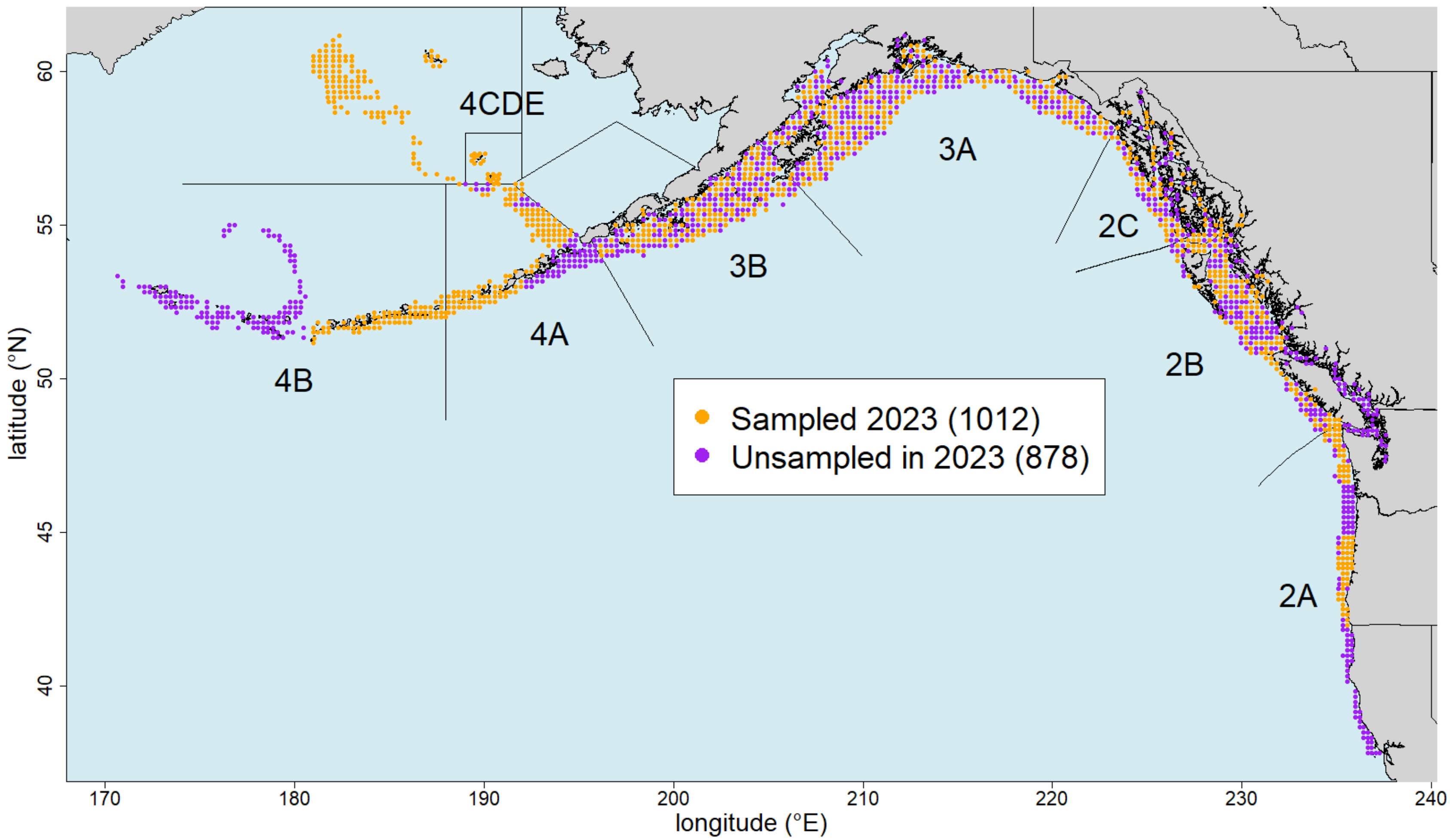

Figure 1.2. Proposed minimum FISS design in 2023 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

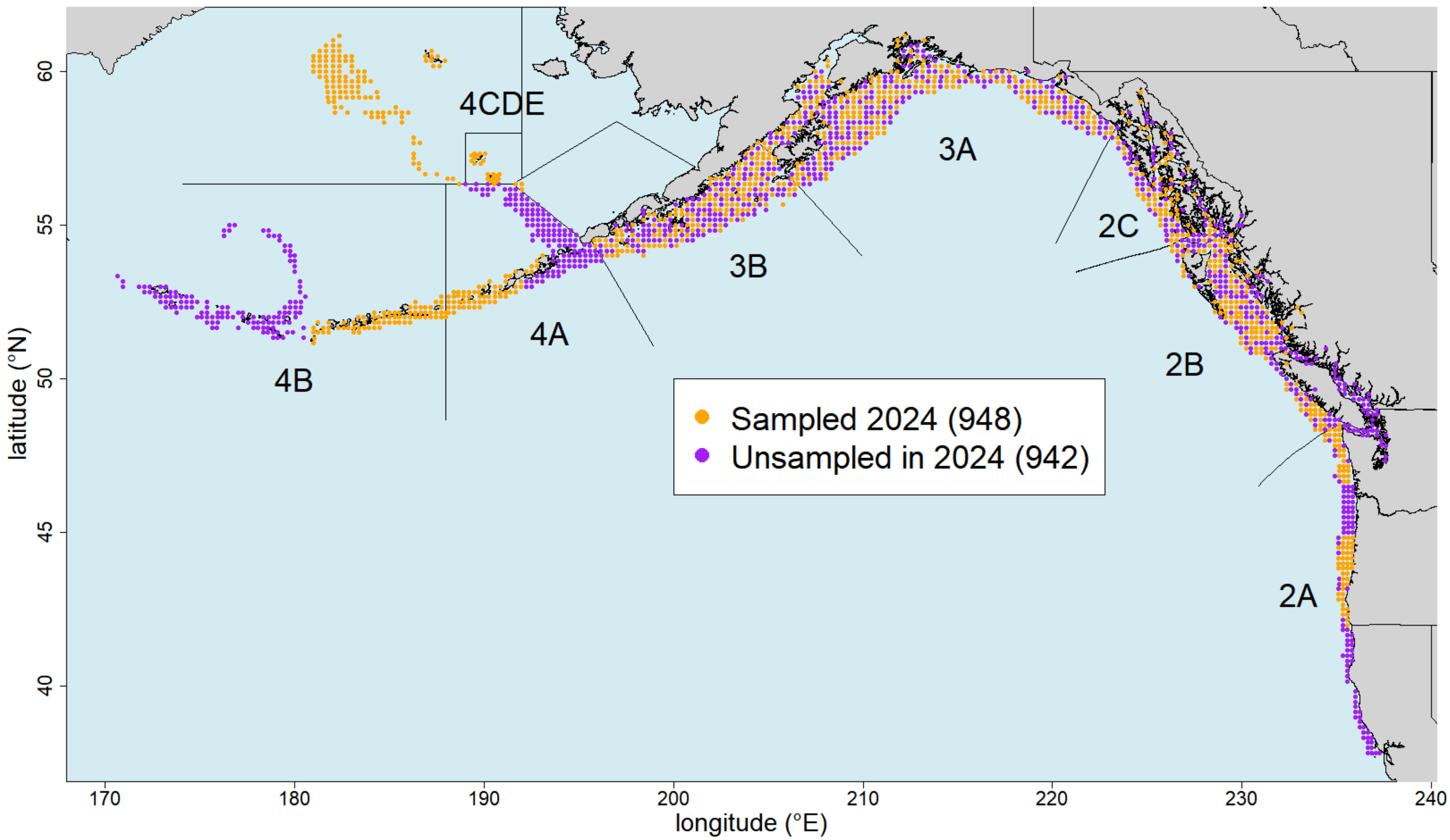

Figure 1.3. Proposed minimum FISS design in 2024 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

Part 2: Modelling of IPHC length-weight data

PURPOSE

To present results of fitting models to IPHC length-weight data from FISS and commercial sampling, and make recommendations of revised length-net weight relationships for applications to non-IPHC data sources.

BACKGROUND/INTRODUCTION

Historical length-weight curve

The IPHC's standard length to net weight relationship was used in all commission work to convert length to net weight of halibut until 2015, when individual weights were added to standard commercial data collections. More recently, the IPHC's Fishery Independent Setline Survey (FISS) began collecting individual weights in 2017, and made such collections comprehensive in 2019. The parameters of this relationship were estimated in 1926 based on a relatively small sample of Pacific halibut (454 fish) collected off Masset in IPHC Regulatory Area 2B. Using 1989 data, Clark (1992) re-estimated the relationship's parameters and found good agreement with the earlier curve, and no changes to the historical IPHC relationship were made. While it was recognized that such a calculated relationship will not be consistently accurate when computing total or mean weights from small numbers of Pacific halibut, it was assumed that predictions should be accurate when data come from larger samples of fish (Clark 1992). However, when Courcelles (2012) estimated the relationship from data collected in 2011, she found significant differences between her estimated curve and that derived from the 1989 data, although inference was limited to a relatively small part of Area 3A and to the time of the FISS. Reports from staff working on the FISS, along with other anecdotal reports, suggested that the historical length-net weight relationship has been overestimating the weight of Pacific halibut on average in recent years.

Adjustments and conversion factors

Various adjustment and conversion factors have been used to account for Pacific halibut measured at different stages of processing following capture (Table 2.1).

Table 2.1 Definitions of types of weight measures used by the IPHC and multipliers used to convert to net weight.

Weight	Definition	Multiplier to convert to net weight	Notes
Round	Head-on, not gutted, no ice and slime	0.75	
Gross (vessel weight)	Head-on, gutted, with ice and slime	0.8624	Assumes 10% head weight and 2% shrinkage, or 12% head, and 2% ice and slime
Dressed (vessel weight)	Head-on, gutted, no ice and slime	0.88	Assumes 10% head weight and 2% shrinkage, or 12% head only
Gross (dock weight)	Head-on, gutted, with ice and slime	0.882 or 0.88	Assumes 10% head weight and 2% ice and slime; deductions either additive (10+2=12% in 2A and 2B) or multiplicative (1-0.9*0.98=0.118 or 11.8% in Alaska)
Dressed (dock weight)	Head-on, no ice and slime (washed)	0.9	Assumes 10% head weight
Net	Head-off, gutted, no ice and slime (washed)	1	

The historical relationship between fork length and net weight includes adjustments for the weight of the head, and of ice and slime (I/S): gross landed weight (gutted, with head, ice and slime) was assumed to include a proportion of 0.12 head weight and 0.02 ice and slime, which combine to give a multiplier of 0.8624 to convert gross to net weight. Clark (1992) noted that subsequent studies showed the head weighed less than 0.12 of gross weight, but that the adjustment factor worked well anyway, possibly because of additional shrinkage of fish after being weighed at sea (as they were in the 1926 study in which the relationship was estimated). In practice, combined deductions of 0.12 in Areas 2A and 2B, and 0.118 in Alaska, were applied to commercial landings to convert from gross to net weight. These both include the 0.02 deduction for ice and slime assumed in the IPHC length-net weight relationship, but use 0.1 as the proportion for the head. This head deduction has been required as part of IPHC regulations since 2008 (Leaman and Gilroy 2008, Gilroy et al. 2008). The way the two deductions are combined differs among areas. In Areas 2A and 2B, these deductions are simply added (0.1+0.02=0.12), while in Alaska, the corresponding multipliers (1 minus the deduction) are multiplied, leading to a multiplier of 0.882, and a deduction of 0.118.

Estimating and comparing length-net weight curves

The commercial sampling program and the FISS weight sampling provide us with two independent data sources to use in re-estimating length-net weight relationships. For estimating the relationship between fork length and net weight, only head-on fish (with the same standard head and I/S deductions assumed in the standard IPHC relationship, 0.10 and 0.02 respectively) are used to ensure a consistent comparison due to the high spatial variability in the proportion of the weight removed when cutting heads (see below). Function parameters are estimated by fitting linear models (on the log scale) using least squares. Let *L* be the fork length of a halibut in centimetres, and *W* be its net weight in pounds. The standard IPHC length-net weight relationship is

$$W = 6.921 \times 10^{-6} L^{3.24} \quad (1)$$

More generally, the relationship between length and weight is assumed to have the following form

$$W = \alpha L^{\beta}$$

While this can be fitted as a non-linear model, it is somewhat easier to linearise the equation by taking logs of both sides, giving

$$\log(W) = a + \beta \log(L)$$

where $a = \log(\alpha)$. For the standard IPHC model, *a* = −11.88, or -12.57 if weights in kg are used as we do in the analyses below. Now suppose we have *N* halibut in our sample, and each is indexed by *i*, *i* = 1, …, *N*. Then the model we fit is

$$\log(W_i) = a + \beta \log(L_i) + \varepsilon_i \quad (2)$$

where $\varepsilon_i \sim N\left(0, \sigma^2\right)$.

For both FISS and commercial data, several observations appeared to be extreme outliers. Such outliers were likely the result of errors (e.g., incorrect conversion to or from metric or imperial units), and to avoid the most extreme values influencing the estimated relationships, observations with measured weight more than twice or less than half the value predicted by the historical length-weight curve were excluded from the statistical analyses. These amounted to just 21 out of over 62,000 commercial samples from 2015-20, and 22 out of over 83,000 FISS samples from 2019-20.

Commercial catch sampling

In 2015, collection of weight data by IPHC staff began on randomly sampled fish in commercial landings. Sample weights were measured in all ports except Dutch Harbor and St Paul, which were added the following year. In 2017, weighing of fish was expanded to include all Pacific halibut selected for biological sampling (length measurement, fin clip for genetic analysis, and otolith collection). The addition of recording fish weights to commercial sampling was motivated by a desire for more accurate estimation of commercial landings, validation of adjustments for head weights and the weight of ice and slime, and validation or revision of the IPHC historical length-net weight relationship. Sample sizes by year and IPHC Regulatory Area are given in Table 2.2.

Table 2.2. Sample sizes of weighed commercial Pacific halibut by year and IPHC Regulatory Area.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE
2015	32	801	1431	1538	1133	798	192	147
2016	303	1943	1673	1470	1492	1574	1466	1270
2017	1118	1376	1367	1453	1381	997	1816	1632
2018	2253	1421	1612	1676	808	925	1307	1494
2019	1731	1076	1573	1751	1751	1322	968	960
2020	1318	1694	1717	1608	1606	937	1264	905

Head weight

Head weight was estimated from a subset of Pacific halibut that were weighed twice, before and after the head was cut in the plant. Data showed that head cuts were highly variable (Webster and Erikson 2017), and the proportion of the fish removed varied greatly among ports and plants. Because the head cut was so variable, the IPHC regulations were changed in 2018 (?) to require all catch to be offloaded and weighed with the head on to ensure consistent treatment of fish across ports and plants, and accurate accounting for the mortality in stock assessment and management analyses. Following the regulation change, commercial sampling for head weight was discontinued, and the 10% deduction for head is applied to all offloaded Pacific halibut as a standard part of the conversion to net weight. (With the requirement to land fish head on, the accuracy of that 10% adjustment became moot – it is simply part of the IPHC definition of net weight.)

Ice and slime

It was hoped that commercial sampling would yield estimates of the weight of ice and slime through the comparison of fish weight twice, before and after washing. Plant operations have not allowed for the collecting of such data, and therefore it has not been possible to validate the assumed 2% adjustment for ice and slime. In the absence of any updated information, that adjustment remains in use. The Commission considers this adjustment to be applicable only in the absence of any water used to remove ice from the unloaded fish prior to weighing. The 'plug' ice in the body cavity is assumed to be removed and not part of the 2% deduction for all fish.

Length-net weight curves

We estimated the length-net weight curve for each IPHC Regulatory Area and for each year from 2016-20, allowing us to assess variation in estimated curves over time and space, as well as make comparisons between estimated curves and the historical length-net weight relationship. Variation in space over the five-year period (Figures 2.1 to 2.5) was generally much greater than variation in time within each IPHC Regulatory Area (Figures 2.6 to 2.13). IPHC Regulatory Areas 2A and 4CDE showed much greater temporal variation in estimated curves (Figures 2.6 and 2.13) than other areas: timing and distribution of sampling is less consistent in these Regulatory Areas than elsewhere, which makes inference on changes in the relationship more difficult over short periods. Estimated curves for Regulatory Areas 2B (Figure 2.7) and 3B (Figure 2.10) are close to the historical curve in all years, while those for Regulatory Areas 2C, 3A, 4A and 4B and consistently below the historical curve, with the degree of difference varying among areas.

FISS sampling

Wide-scale weighing of Pacific halibut on the IPHC FISS commenced in 2019 and continued through 2020. In 2019, the intention was to record dressed weight of all legal-sized (O32) fish using motion-compensated scales, with the exception of some larger fish, that were weighed dockside. Due to technical issues, fish on some trips were unable to be weighed. Sample sizes by year and area are given in Table 2.3.

Table 2.3. Sample sizes of weighed FISS Pacific halibut by year and IPHC Regulatory Area.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE
2019	786	3889	10898	15460	4530	3758	495	1545
2020	0	8103	6392	24815	2642	0	0	0

A random subsample of sublegal (U32) fish had dressed weight recorded (those selected for otolith collection), along with round weight, in order to estimate the relationship between round and dressed weight for use in predicting weight of fish not selected for otolith sampling (and therefore with no dressed weight). Predictions of net weight from round weight (coastwide data) and from length (by IPHC Regulatory Area) were compared to determine which variable was the most accurate predictor of net weight. The approach we took was to model the relationship between the ratio of dressed to round weight and round weight, after applying the normalizing arcsin-square root transformation. Thus for the *i*th fish, the model was

$$\sin^{-1}\left(\sqrt{\frac{w_{dressed,i}}{w_{round,i}}}\right) = b_0 + b_1 w_{round,i} + \eta_i$$

where $\eta_i \sim N\left(0,\tau^2\right)$. The parameter estimates (for weights in kg) were $\hat{b}_0$= 1.215 (SE=0.003) and $\hat{b}_1$= -0.007619 (SE=0.000610). Thus, we estimate that as round weight increases, the corresponding dressed weight is a decreasing fraction of round weight, ranging from 88% for fish at 0.5 kg to 84% for 8 kg fish (the approximate weight range of fish in the data).

The estimated relationship with round weight was found to produce more accurate predictions (Figure 2.14), with much less variability from true net weight (scaled from dressed weight as per Table 2.1) and no constraint forced on maximum predicted weight by a strict relationship with length. This led to the recommendation that round weights of U32 Pacific halibut continue to be measured during the FISS, but that measurement of dressed weight for a subsample of such fish can be discontinued. From 2020 onwards, dressed weight (and hence net weight) is being predicted for each U32 fish from the relationship estimated from the 2019 data.

There was general consistency across years for each of the four IPHC Regulatory Area sampled in both 2019 and 2020 (Figures 2.15-2.18) in estimated length-net weight relationships, although differences for Regulatory Areas 2C and 3B (the latter having greatly reduced sampling in 2020) were somewhat larger than Regulatory Areas 2B and 3A. As with length-net weight relationships estimated from commercial sampling data, spatial variation in the estimated relationships among areas was much greater than temporal variation within areas (Figures 2.19-2.20).

Estimating shrinkage

As noted above, there is the assumption of 2% shrinkage when converting weights made on board a vessel to net weight. A subsample of Pacific halibut from FISS sampling was weighed both on the vessels and later at the dock during the 2016 and 2017 FISS seasons, providing data with which to estimate the shrinkage rate of fish. The data file recording at sea and dockside weights for the same individuals includes measurements on 562 fish, although 12 only have a single weight recorded. At sea weights were recorded as round weights, while dockside weights were of head-on and washed fish (i.e., dockside dressed, Table 2.1). To estimate shrinkage, round weights must first be converted into at-sea dressed weights, requiring multiplication of round weights by 0.85 (0.75/0.88 from Table 2.1). Without data to validate this assumed multiplier directly, we are in the problematic position of trying to estimate shrinkage based on values that may themselves be in error due to inaccuracy of the multiplier. While we were able to estimate a relationship between round weight and dressed weight for U32 fish above, the fish weighed twice are O32 fish, and therefore the estimated relationship may not apply. Given the assumed 0.85 multiplier, the average % shrinkage across all 550 fish with both weights is 1.9% (SE=0.2%), and is therefore consistent with a shrinkage multiplier of 2% as assumed in Table 2.1. Future FISS sampling should include a selection of O32 Pacific halibut weighed twice, before and after gutting, to validate the conversion from round weight to dressed at sea.

Commercial and FISS length-weight comparisons

The estimated length-net weight curves above can be used to predict net weight for Pacific halibut with missing direct measurements from both commercial and FISS sampling. With two independent sources of IPHC length-weight data since 2019, thought must be given to how (or whether) to combine the two sources for estimating length-weight curves for use outside of the IPHC when direct weight measurement is not available, i.e., for other survey data (e.g., NMFS and DFO surveys), commercial observer data, and data from recreational catch sampling. While the FISS data are typically collected in a spatially comprehensive manner within each IPHC Regulatory Area, they are temporally restricted to the May-September summer period. Conversely, commercial samples are collected throughout the fishing season, but may more geographically limited due to the concentration of fishing effort in the most productive habitat within each area. In this section we assess the likely importance of any differences in estimated length-net weight curves that may be a result of such sampling differences when it comes to calculating statistics such as mean weight of sampled fish.

For 2019 and 2020 data, we fitted two length-net weight models to the combined commercial and FISS data for each IPHC Regulatory Area:

Model 1: Assume length-net weight relationships are the same for both data sources

Model 2: Allows parameters for length-net weight relationships to differ between the data sources

Table 2.4. Estimated model parameters (with standard errors) for Models 1 and 2 fitted to combined FISS and commercial data (with weight in kg), by IPHC Regulatory Area and year. Note that the historical length-net weight relationship has intercept of -12.57 and slope of 3.24.

Reg Area	Year	Model 1		Model 2			
		Intercept (SE)	Slope (SE)	FISS		Commercial	
				Intercept (SE)	Slope (SE)	Intercept (SE)	Slope (SE)
2A	2019	-13.51 (0.08)	3.42 (0.02)	-13.16 (0.11)	3.35 (0.02)	-13.43 (0.10)	3.40 (0.02)
2B	2019	-12.40 (0.03)	3.18 (0.01)	-12.40 (0.04)	3.18 (0.01)	-12.79 (0.09)	3.26 (0.02)
	2020	-12.69 (0.03)	3.24 (0.01)	-12.72 (0.03)	3.24 (0.01)	-12.57 (0.08)	3.21 (0.02)
2C	2019	-12.44 (0.02)	3.18 (0.00)	-12.46 (0.02)	3.19 (0.00)	-12.20 (0.07)	3.13 (0.01)
	2020	-12.56 (0.03)	3.21 (0.01)	-12.63 (0.03)	3.23 (0.01)	-12.33 (0.07)	3.16 (0.02)
3A	2019	-12.25 (0.02)	3.14 (0.00)	-12.26 (0.02)	3.14 (0.00)	-12.34 (0.07)	3.15 (0.02)
	2020	-12.15 (0.02)	3.11 (0.00)	-12.14 (0.02)	3.11 (0.00)	-12.38 (0.07)	3.16 (0.02)
3B	2019	-12.78 (0.03)	3.26 (0.01)	-12.75 (0.03)	3.26 (0.01)	-13.05 (0.07)	3.32 (0.02)
	2020	-12.59 (0.03)	3.21 (0.01)	-12.51 (0.04)	3.20 (0.01)	-13.16 (0.07)	3.34 (0.02)
4A	2019	-12.00 (0.03)	3.09 (0.01)	-12.07 (0.03)	3.11 (0.01)	-12.56 (0.08)	3.21 (0.02)
4B	2019	-12.13 (0.08)	3.10 (0.02)	-11.80 (0.10)	3.04 (0.02)	-12.72 (0.10)	3.23 (0.02)
4CDE	2019	-12.07 (0.04)	3.11 (0.01)	-12.04 (0.05)	3.10 (0.01)	-12.51 (0.08)	3.20 (0.02)

Model parameter estimates are given in Table 2.4. We compared the actual observed mean net weight of fish mean to net weights predicted from each model for each source (FISS and commercial), and to that predicted by the historical relationship. Only fish included in the modelling were used in the comparison, i.e., only data from fish with directly measured weights were included (some extreme outlying data were excluded). Results of the comparisons of mean net weights are presented in Table 2.5. Figures comparing the FISS and commercial data and estimated length-net weight curves for Model 2 are shown in Figures 2.21-2.32.

As might be expected, Model 2 produced estimated mean net weights closest to the observed values, with differences all within 1% (Table 2.5). In cases where estimated length-net weight curves differed between FISS and commercial data to some degree, this model accounts for such differences. Model 1, while less accurate in estimating observed mean net weights than Model 2, still performed well in almost all cases, with differences of less than 2% except for the FISS mean in IPHC Regulatory Area 2A, the commercial mean in IPHC Regulatory 3A, and the FISS mean in IPHC Regulatory Area 4B, all in 2019. We note that those three cases are ones in which there were differences between the FISS and commercial length-net weight curves when estimated separately (Figures 2.21, 2.24 and 2.27), but where one data source had much larger sample sizes and so had greater influence on the estimates of a single length-net weight curve in Model 1: for IPHC Regulatory Area 2A, 69% of the data came from commercial samples; for 3A in 2019, 90% of the data came from FISS samples; and for 4B, 66% of the data came from commercial samples.

Discussion

Analysis of the IPHC length-weight data has made it clear that currently there is a positive bias in weights predicted from the historical length-net weight relationship in most IPHC Regulatory

Areas, especially (in absolute terms) for the largest Pacific halibut. that the IPHC recommends that this bias can best be eliminated by weighing individual fish directly. In the absence of sampling capability, the bias can be reduced through the use of relationships estimated from more contemporary IPHC FISS and commercial data. For IPHC data where there is no reliable direct weight measurement, the weight of a fish can be predicted from the length-net weight relationship estimated for its IPHC Regulatory Area and year of capture, and for its data source (commercial or FISS sampling). This change has already been made to the prediction of net weight for fish captured on the FISS with missing weight measurements.

For predicting weights for Pacific halibut sampled from non-IPHC data sources, Model 1 is of more practical use than Model 2, as it would not require a choice of which IPHC source was most likely to resemble the data source of interest (recreational, observer, etc). By combining data from the more temporally comprehensive commercial samples with data from the spatially extensive FISS, the resulting length-net weight represents an average that can be applied to a wide range of data sources.

Spatial differences in estimated length-net weight curves imply that area-specific curves should be used. On the other hand, the relative temporal stability of these curves suggests that curves could be estimated from multiple years' data, and only revised periodically. Following the 2021 FISS, three consecutive years of data from both IPHC sources will be available for core areas (2B, 2C, 3A and 3B), and two years (2019 and 2021) for other areas, providing a combined data set for estimation of curves for application to non-IPHC length data in 2021.

In fitting Model 1, we simply combined the data without weighting the two data sources, so each fish, no matter its source, was given equal weight. This resulted in instances where the estimated length-net weight equation was more influenced by data from one source than the other, typically the FISS in the core areas, and sometimes the commercial samples elsewhere. Generally, this did not matter much, as the two sources produced consistent estimated relationships most of the time (Figures 2.21 to 2.32). It may be desirable, however, to weight the data sources equally (i.e., down-weight data from the source with the larger sample size relative to the other source) to produce a relationship that better represents an average of the FISS and commercial data relationships, and thus one that is as widely applicable as possible for each IPHC Regulatory Area.

Therefore, the IPHC intends to produce a revised length-net weight relationship based on Model 1 (combined fitting) and including all data from 2019-2021. This relationship should be used in place of the historical relationships for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected for 2021 and until further notice. The Secretariat anticipates re-evaluating the relationship as additional years of data are collected and updating it accordingly.

Finally, we note that there remain two components to the estimation of weight from length that are not directly estimable from recent FISS and commercial sample data: the conversion from round to net weight (or round to dress weight), and the adjustment factors for ice and slime (conversion from unwashed to wash). The former only has data available for U32 fish, while there are no data available to estimate the latter. We recommend that future FISS sampling include a random sample of O32 fish weighed twice, before and after dressing, and that renewed efforts should be made to weigh a sample of fish twice dockside, before and after washing.

RECOMMENDATIONS

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.2 that presents methods for revised the length-net weight relationships from FISS and commercial sampling data
2) **RECOMMEND** that the IPHC provide a revised length-net weight relationship for each IPHC Regulatory Area based on modelling of combined FISS and commercial sample data to be used for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected, for 2021 and until further notice.

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Table 2.5. Comparison of mean observed Pacific halibut net weight with mean nets weights predicted from Models 1 and 2 (see text) and the historical length-net weight relationship. Intensity of shading indicates magnitude of departures from observed mean, either negative (blue) or positive (orange/brown).

Reg Area	**Calculation method**	**2019**				**2020**			
		FISS		Commercial		FISS		Commercial	
		Mean (kg)	diff from Observed	Mean (kg)	diff from Observed	Mean (kg)	diff from Observed	Mean (kg)	diff from Observed
2A	Observed	9.9		7.6					
	Model 1	9.6	−3.1%	7.7	+1.1%				
	Model 2	9.9	−0.3%	7.6	−0.4%				
	Historical	9.9	−0.8%	8.0	+4.9%				
2B	Observed	9.4		11.0		10.7		11.0	
	Model 1	9.3	−1.4%	11.1	+1.3%	10.6	−0.7%	11.1	+1.0%
	Model 2	9.4	−0.7%	10.9	−0.3%	10.7	−0.3%	10.9	−0.5%
	Historical	9.5	+0.8%	11.4	+3.6%	11.0	+2.3%	11.4	+4.0%
2C	Observed	10.8		13.5		11.4		14.3	
	Model 1	10.8	−0.5%	13.5	−0.3%	11.3	−0.9%	14.4	+0.8%
	Model 2	10.8	−0.5%	13.5	−0.5%	11.3	−0.5%	14.3	−0.4%
	Historical	11.3	+4.3%	14.2	+4.9%	11.5	+0.5%	14.7	+2.4%
3A	Observed	8.5		8.7		8.6		9.1	
	Model 1	8.5	−0.7%	8.9	+2.1%	8.6	−0.6%	9.2	+1.0%
	Model 2	8.5	−0.4%	8.7	−0.5%	8.6	−0.5%	9.0	−0.5%
	Historical	8.9	+3.8%	9.3	+6.8%	9.1	+5.5%	9.7	+7.4%
3B	Observed	8.4		9.1		6.4		9.0	
	Model 1	8.3	−1.1%	9.2	+0.9%	6.3	−0.9%	9.0	−0.1%
	Model 2	8.3	−0.5%	9.1	−0.3%	6.3	−0.5%	8.9	−0.3%
	Historical	8.3	−1.0%	9.3	+1.0%	6.5	+2.1%	9.2	+3.3%
4A	Observed	6.0		9.9					
	Model 1	5.9	−1.4%	10.0	+1.0%				
	Model 2	5.9	−0.4%	9.3	−0.5%				
	Historical	5.9	−0.6%	10.3	+4.2%				
4B	Observed	8.7		9.0					
	Model 1	8.3	−3.7%	9.0	+0.7%				
	Model 2	8.6	−1.0%	9.0	−0.3%				
	Historical	9.2	+3.9%	9.9	+10.7%				
4CDE	Observed	6.9		11.0					
	Model 1	6.8	−1.2%	11.0	−0.0%				
	Model 2	6.9	−0.6%	11.0	−0.4%				
	Historical	6.8	−1.7%	11.2	+1.1%				

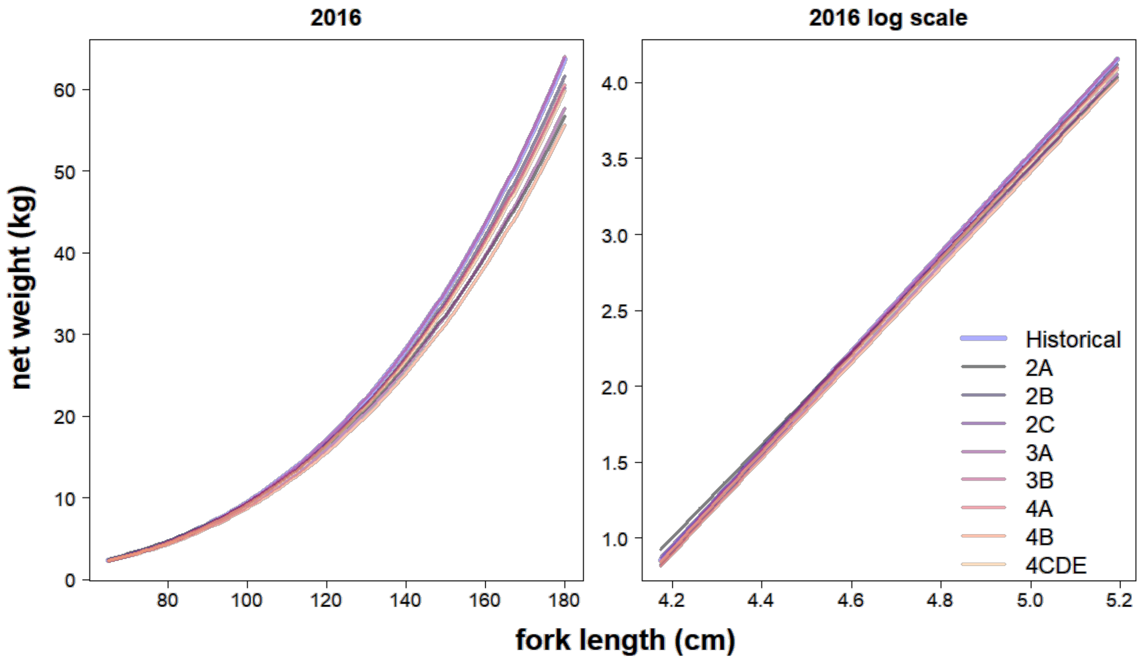

Figure 2.1 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2016.

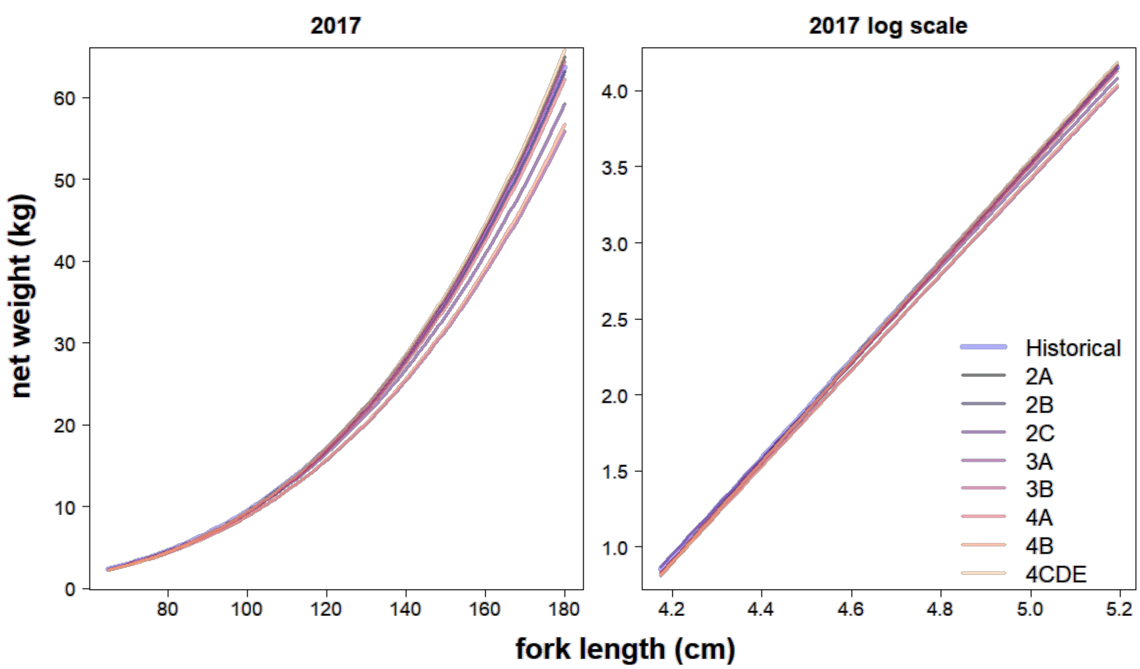

Figure 2.2 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2017.

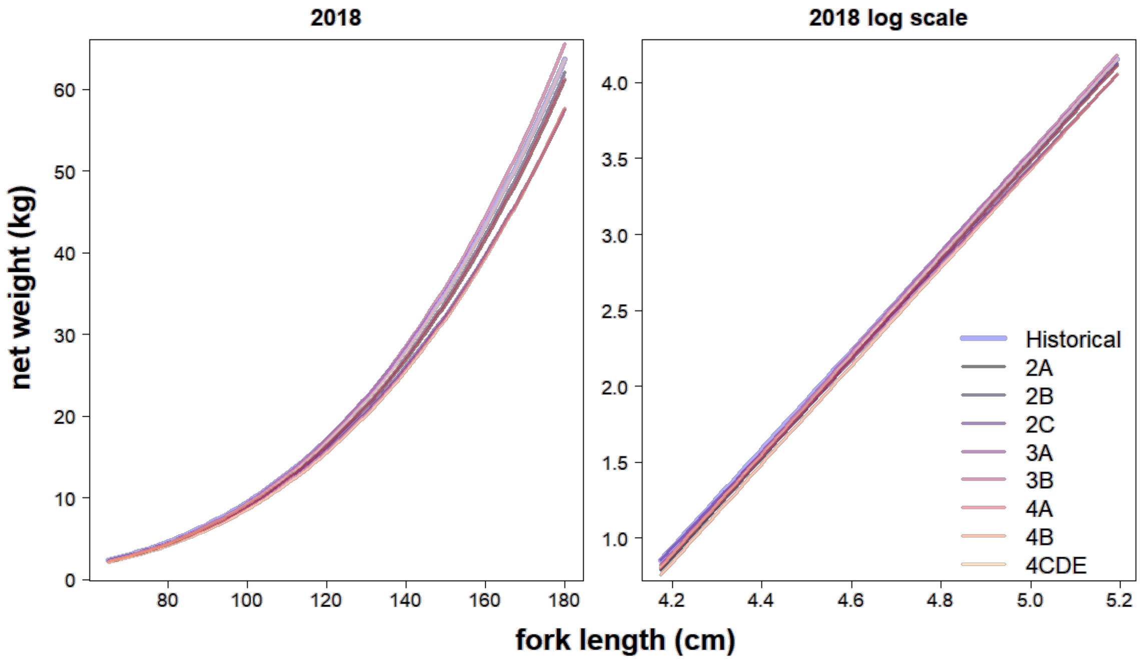

Figure 2.3 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2018.

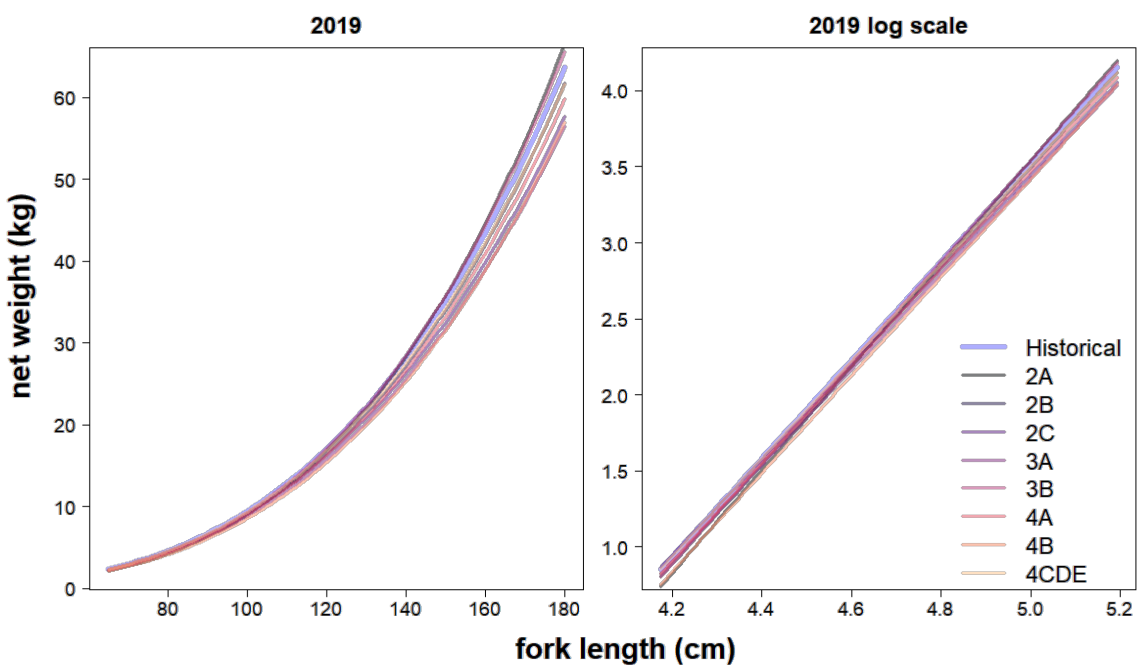

Figure 2.4 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2019.

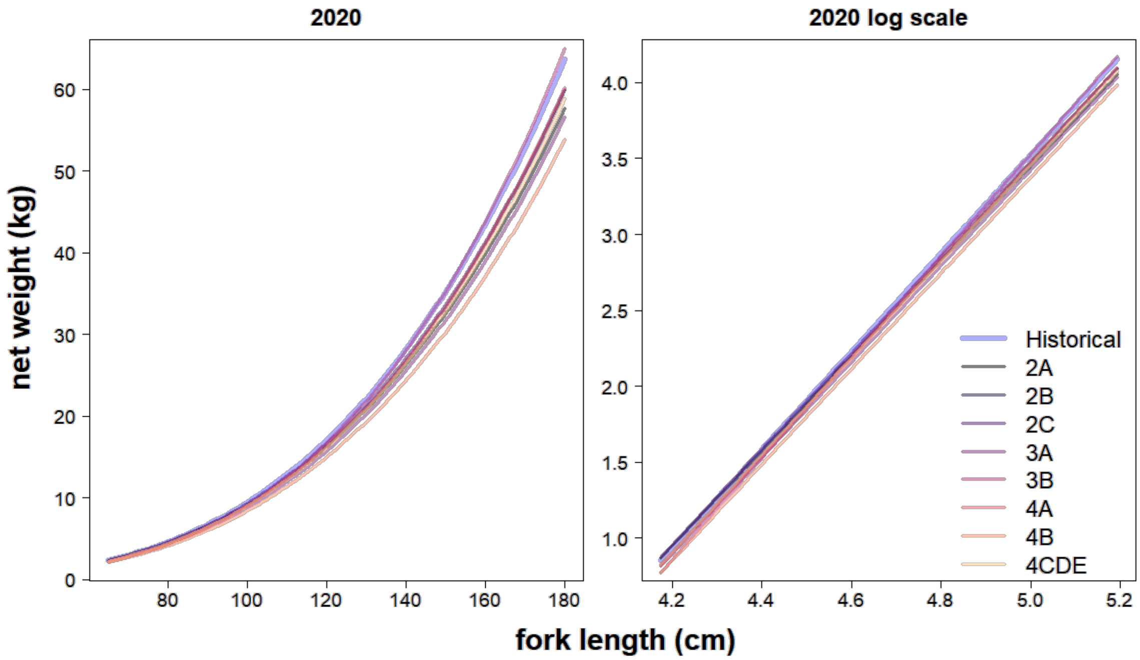

Figure 2.5 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2020.

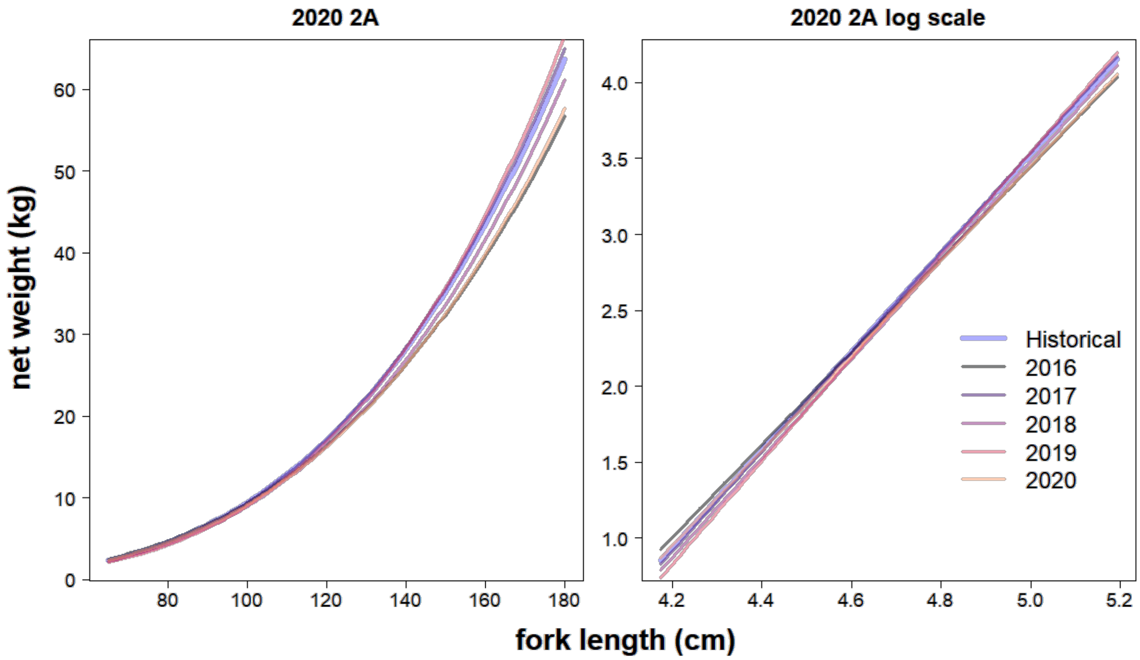

Figure 2.6 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 2A.

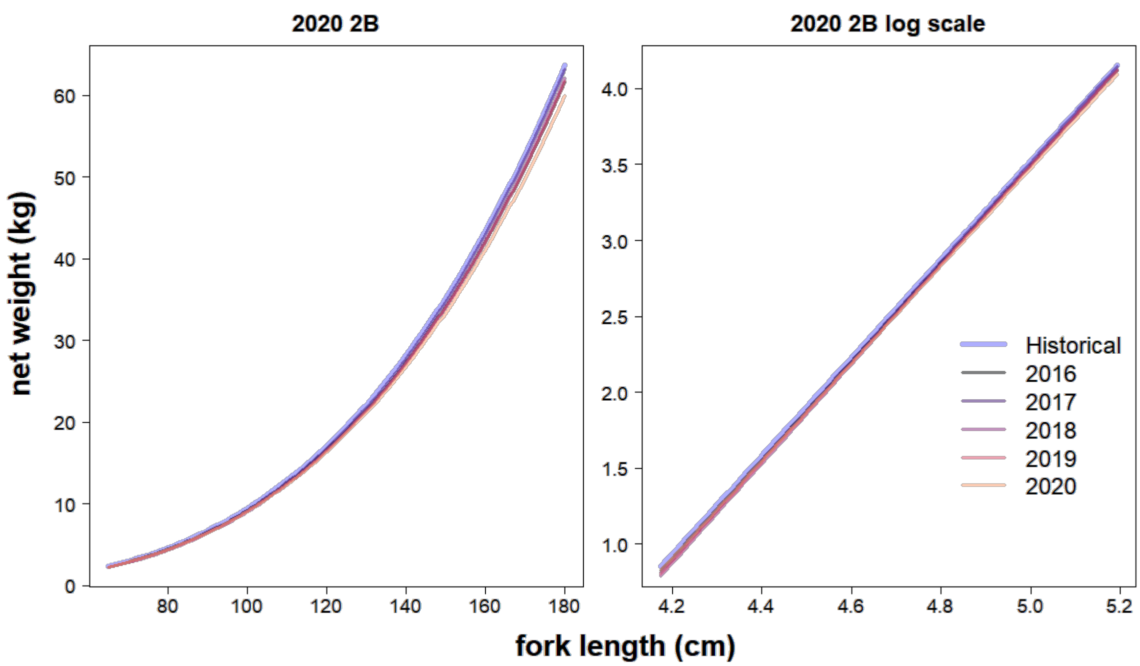

Figure 2.7 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 2B.

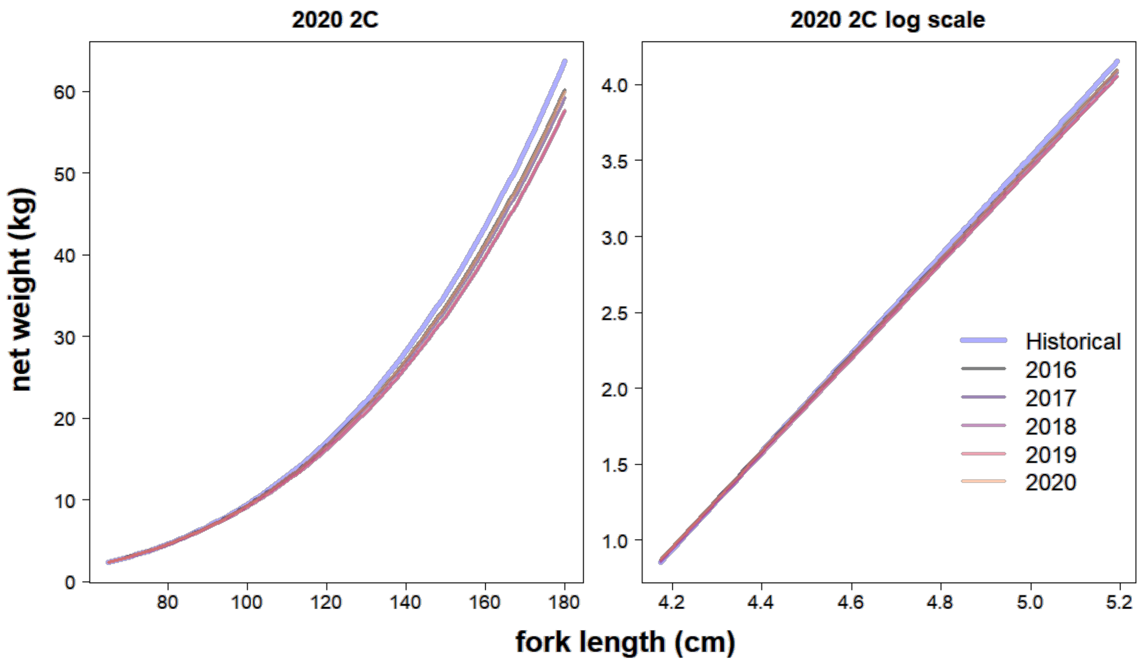

Figure 2.8 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 2C.

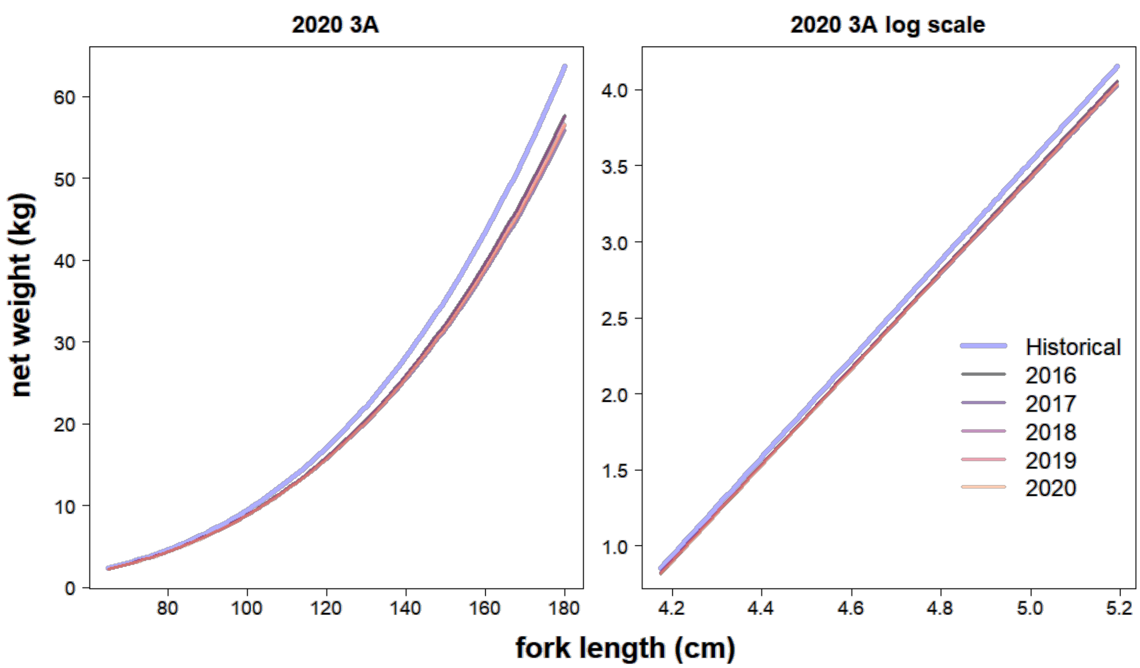

Figure 2.9 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 3A.

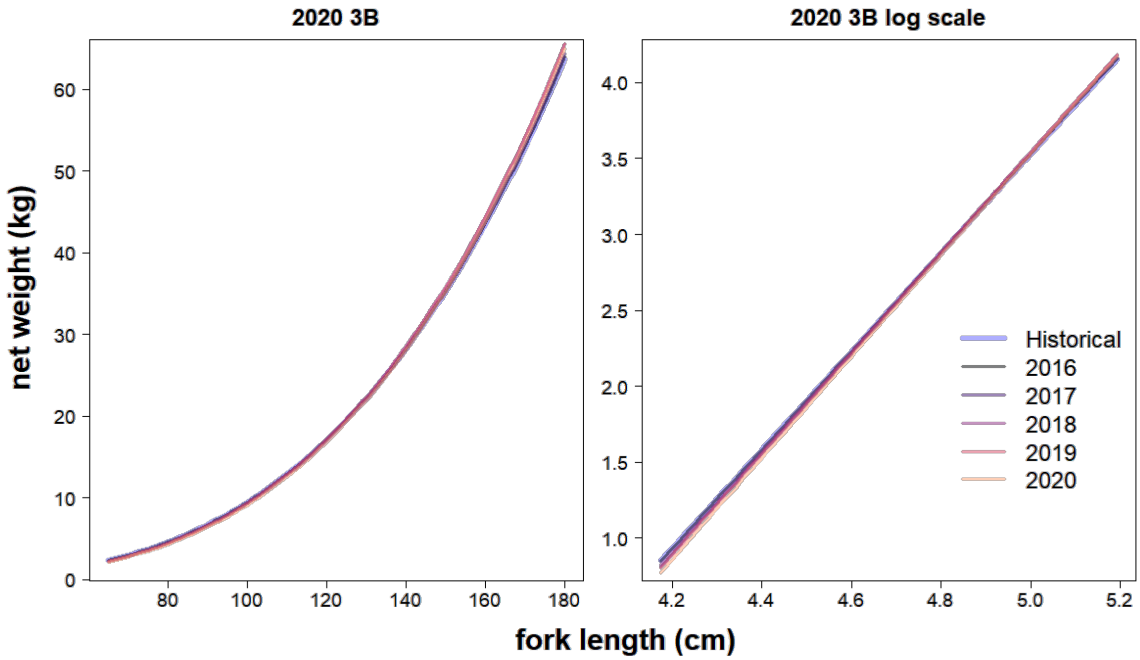

Figure 2.10 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 3B.

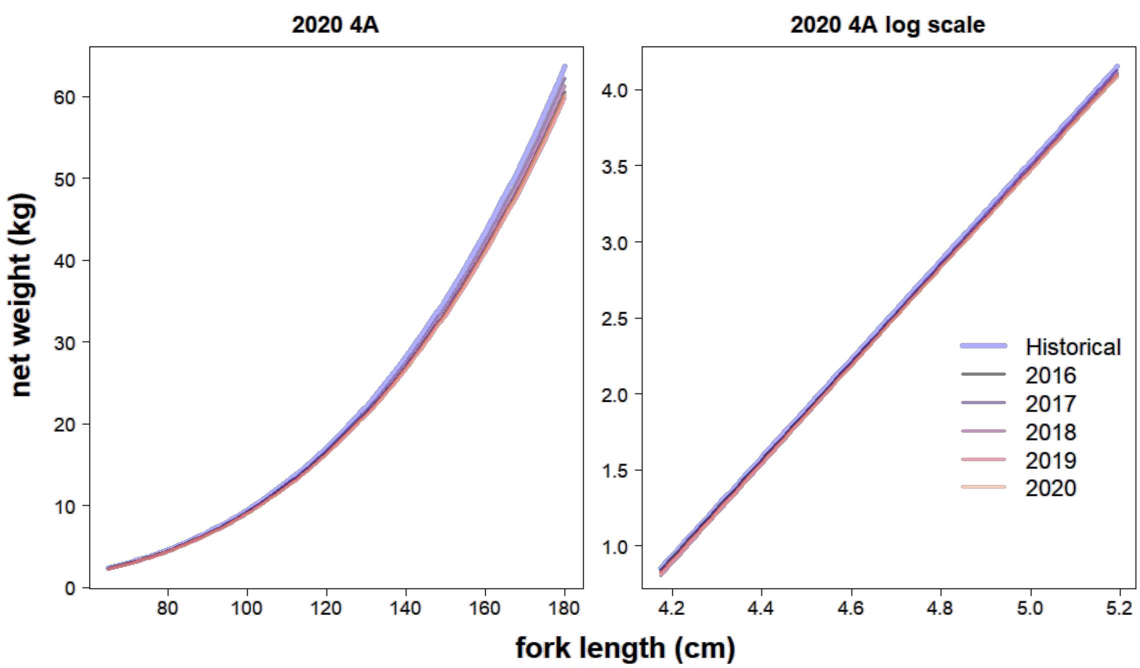

Figure 2.11 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 4A.

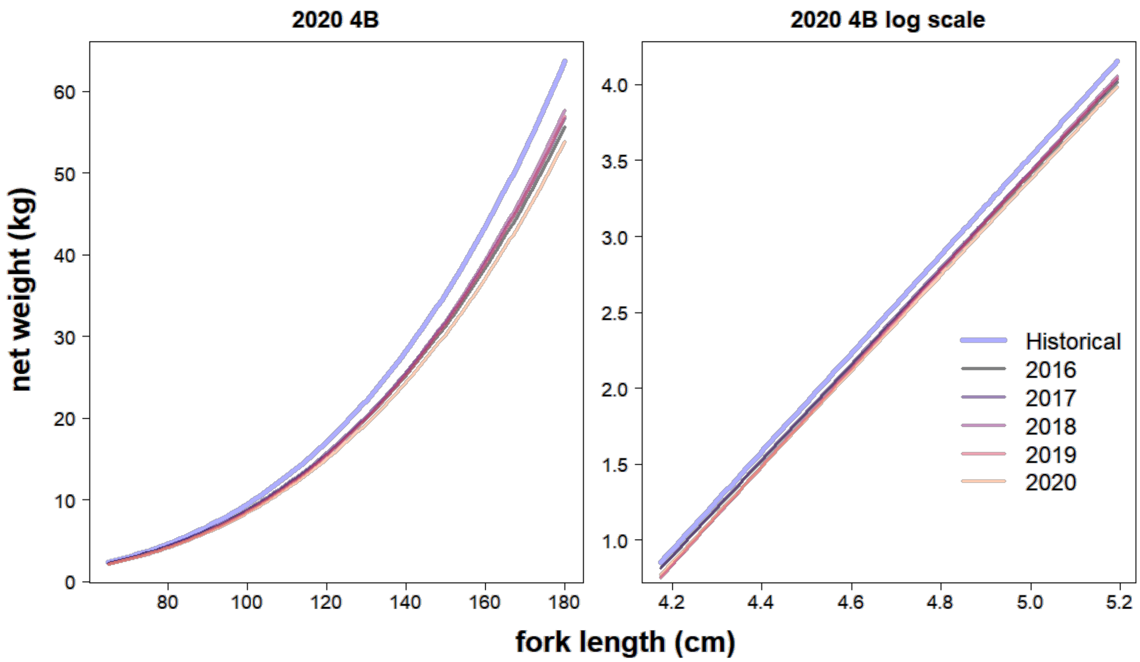

Figure 2.12 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 4B.

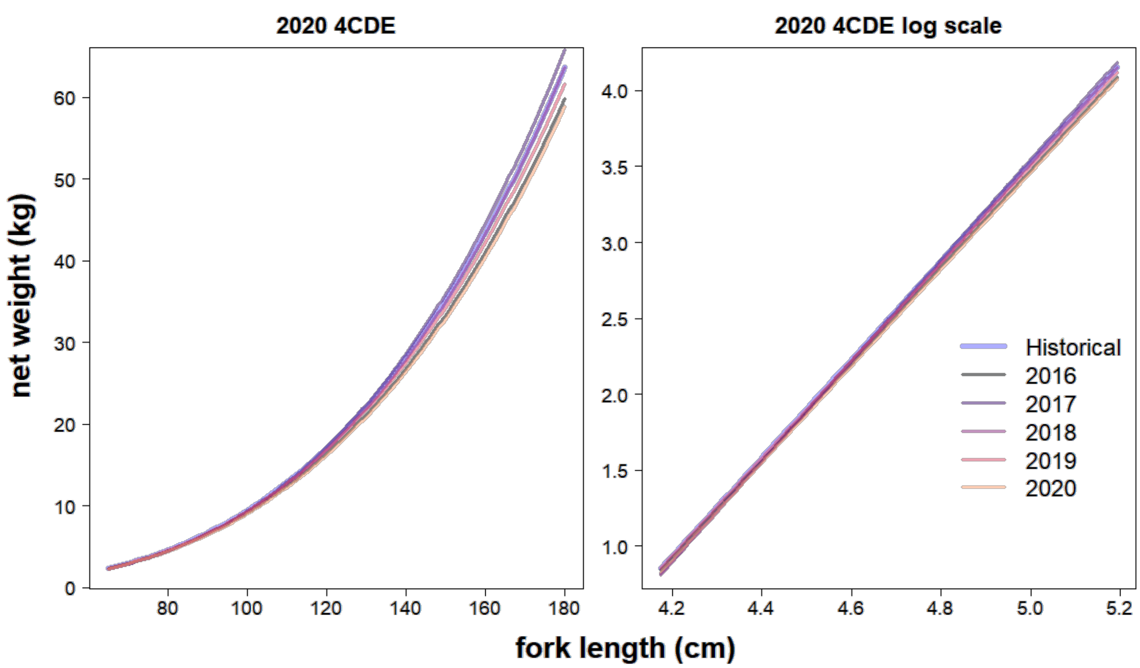

Figure 2.13 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 4CDE.

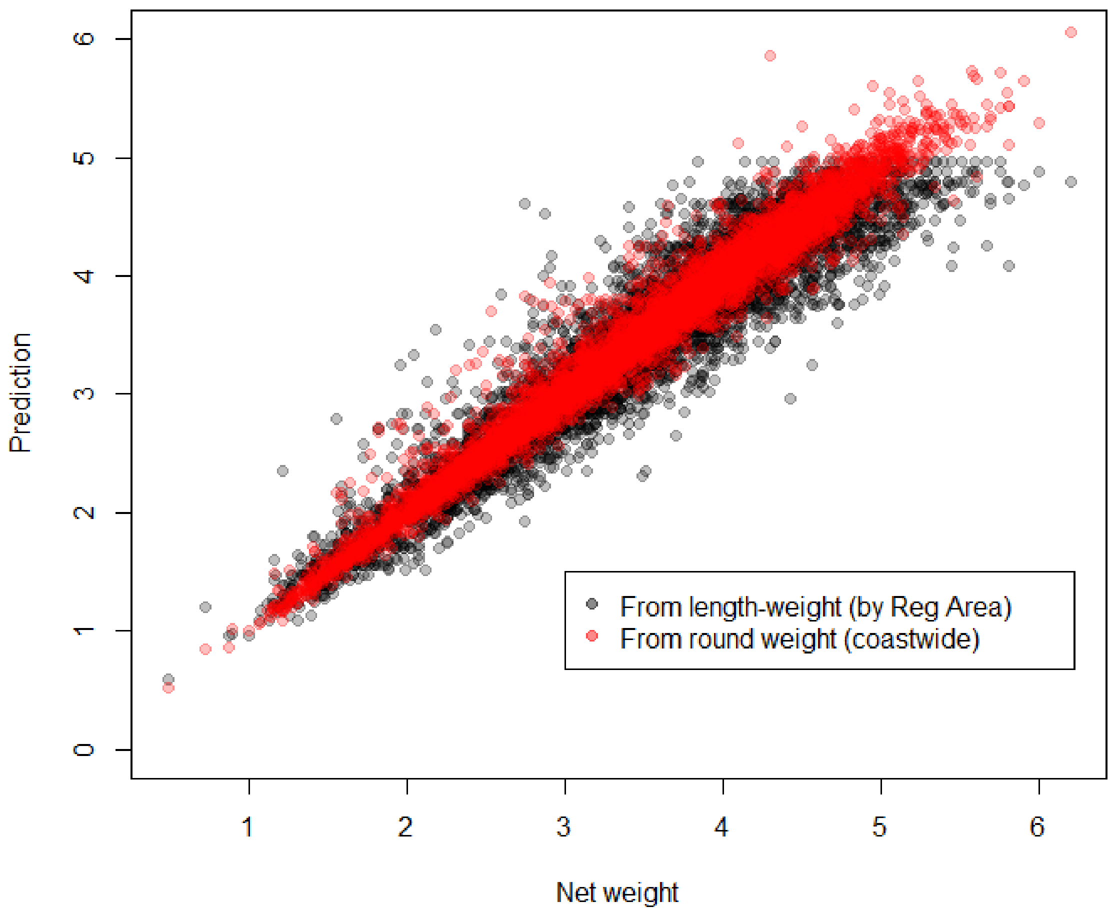

Figure 2.14 Model prediction of net weight from estimated length-net weight relationship (by IPHC Regulatory Area) and estimated coastwide relationship between net weight and round weight.

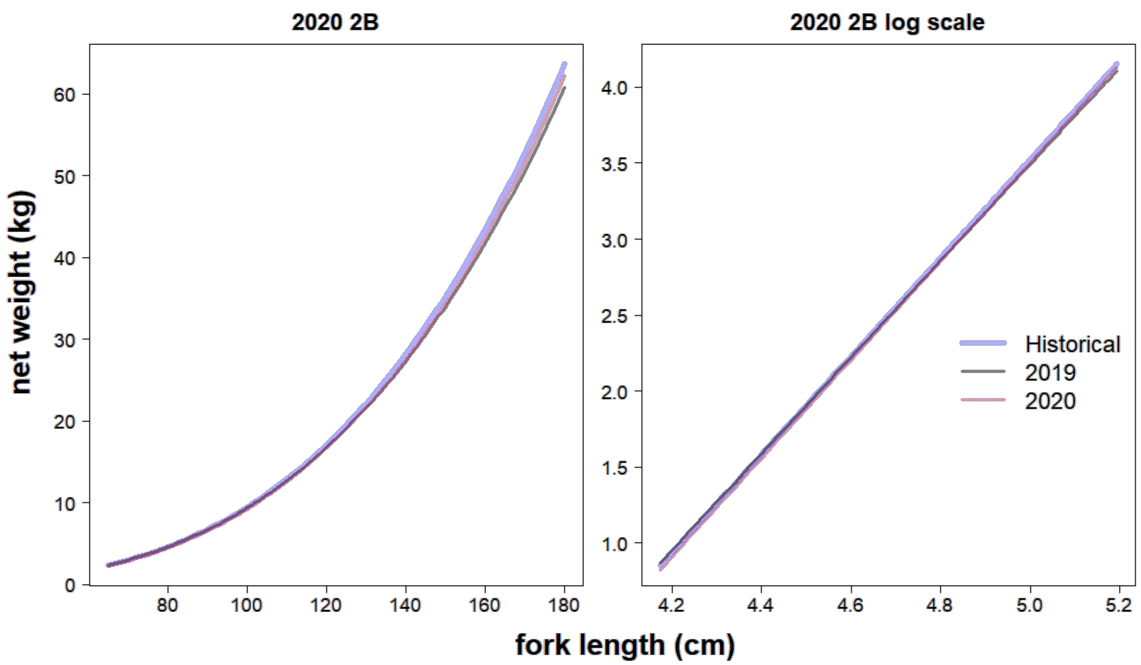

Figure 2.15 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 2B.

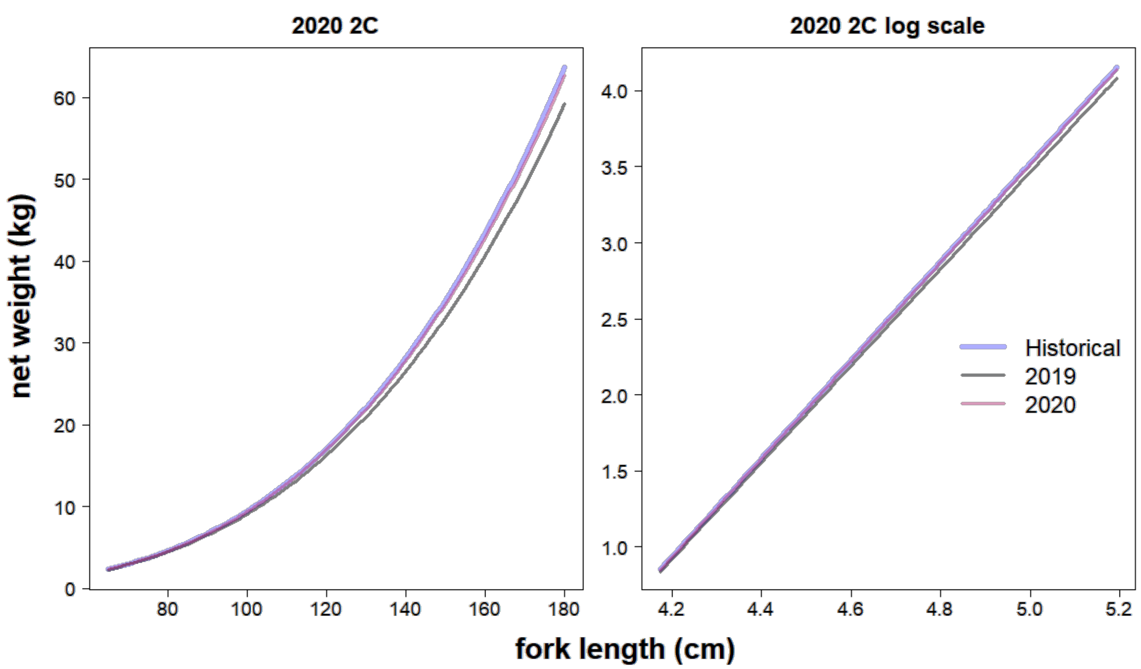

Figure 2.16 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 2C.

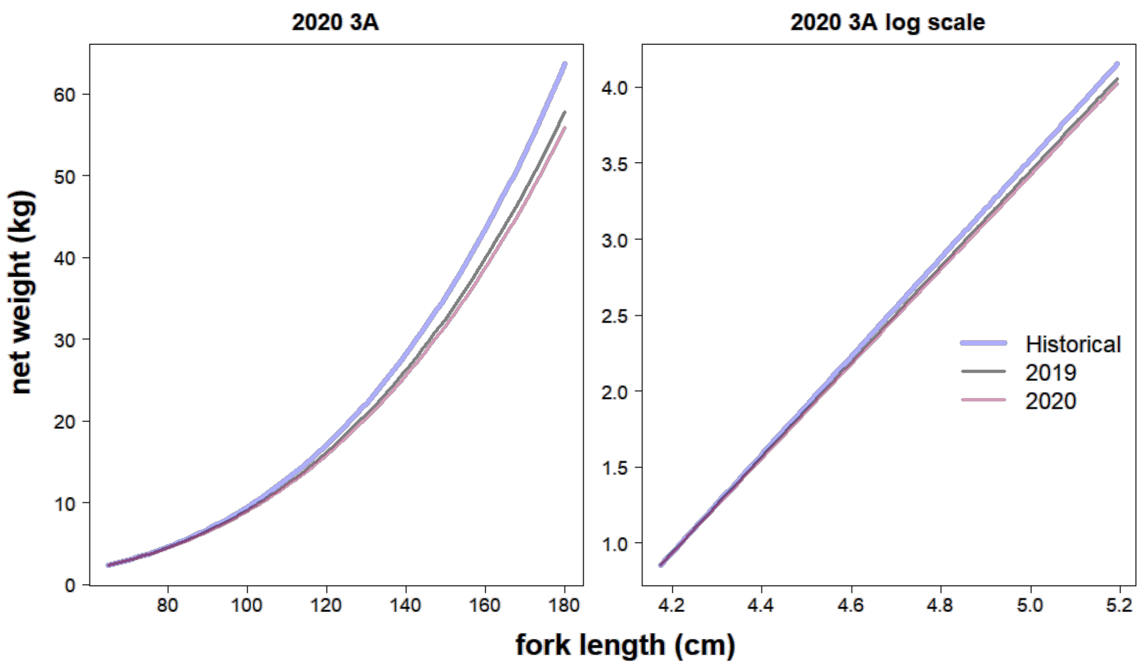

Figure 2.17 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 3A.

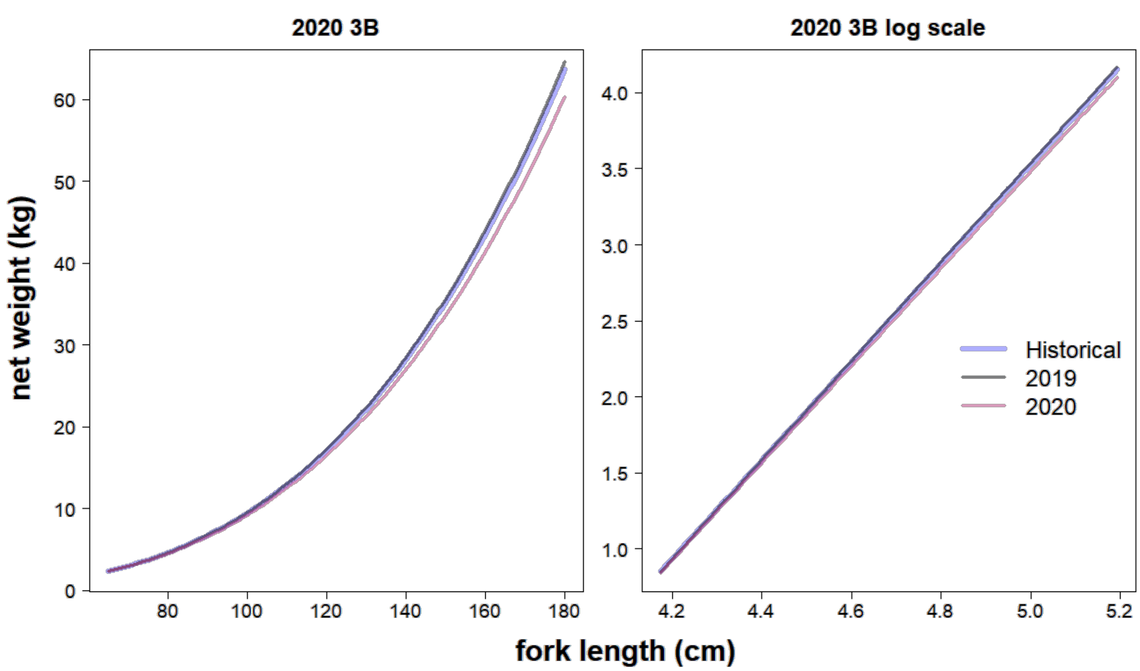

Figure 2.18 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 3B.

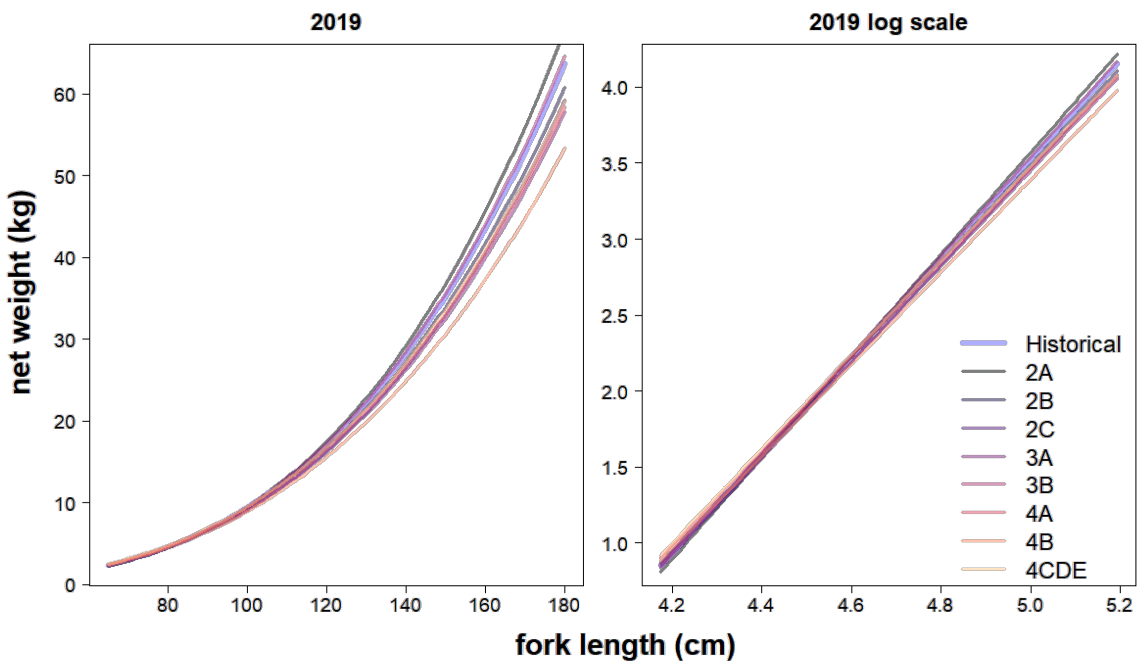

Figure 2.19 Comparison of estimated length-net weight curves from FISS data by IPHC Regulatory for 2019.

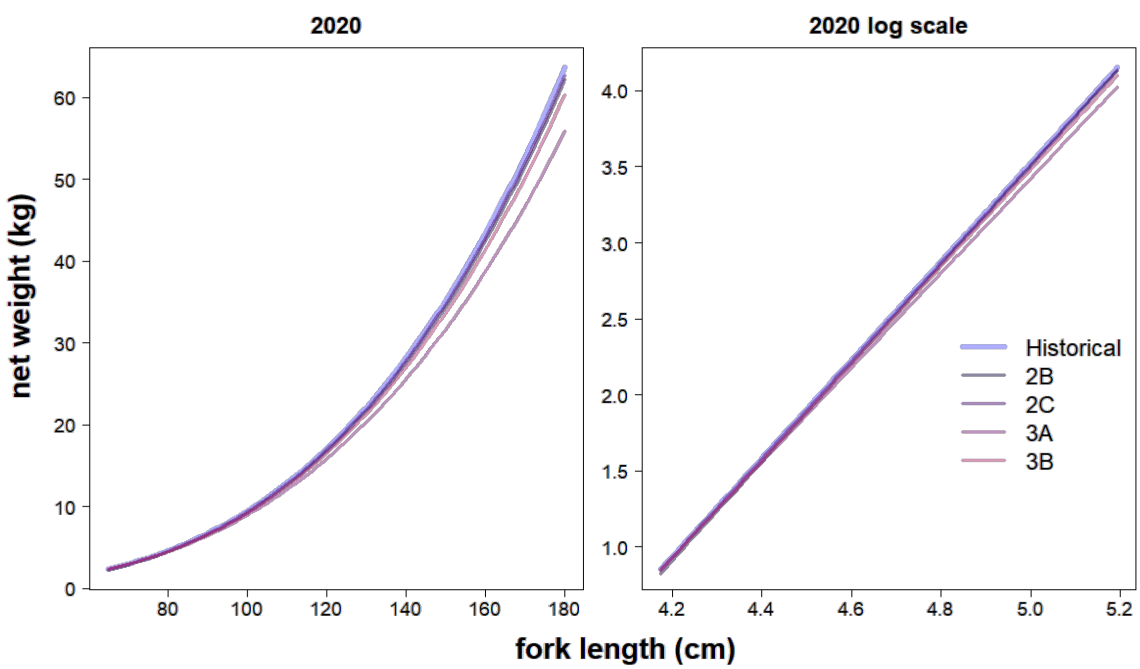

Figure 2.20 Comparison of estimated length-net weight curves from FISS data by IPHC Regulatory for 2020.

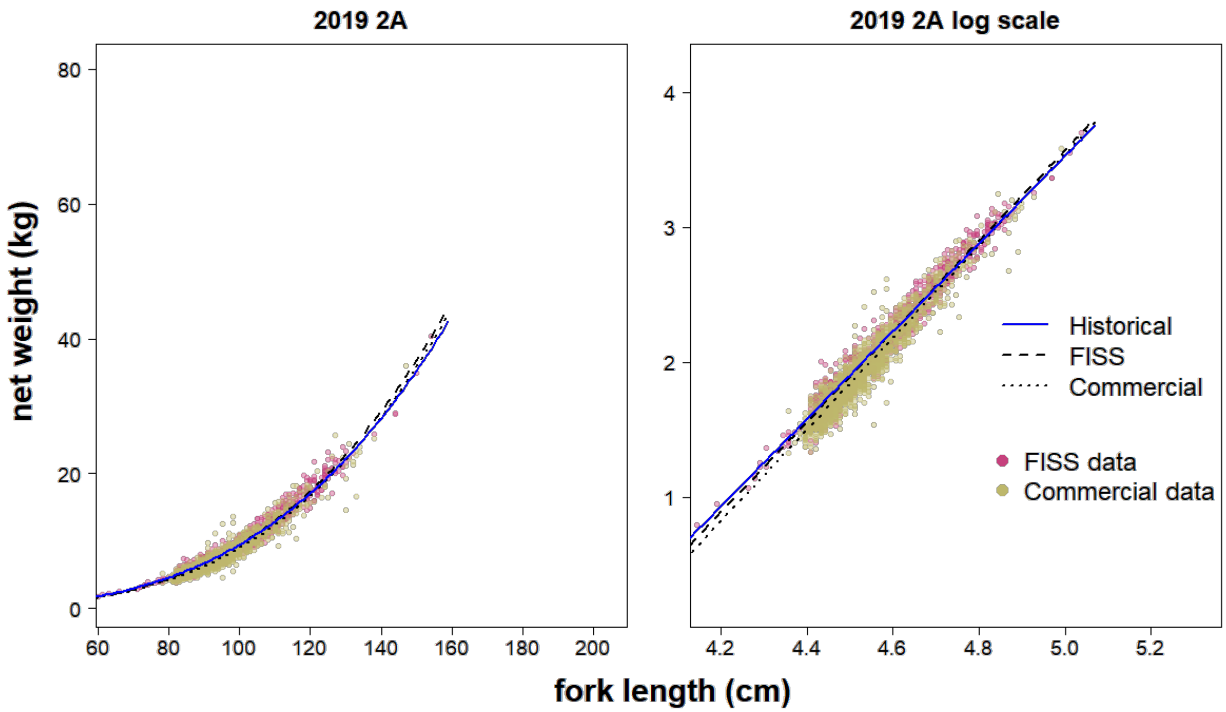

Figure 2.21 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2A in 2019.

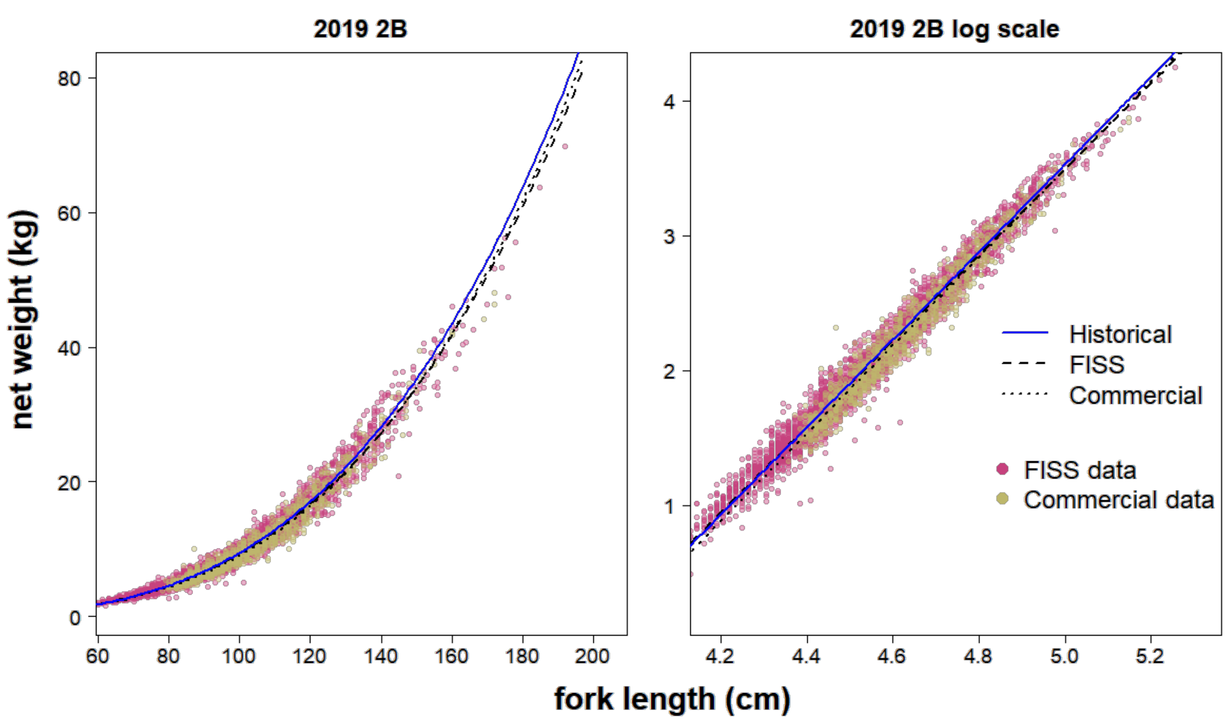

Figure 2.22 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2B in 2019.

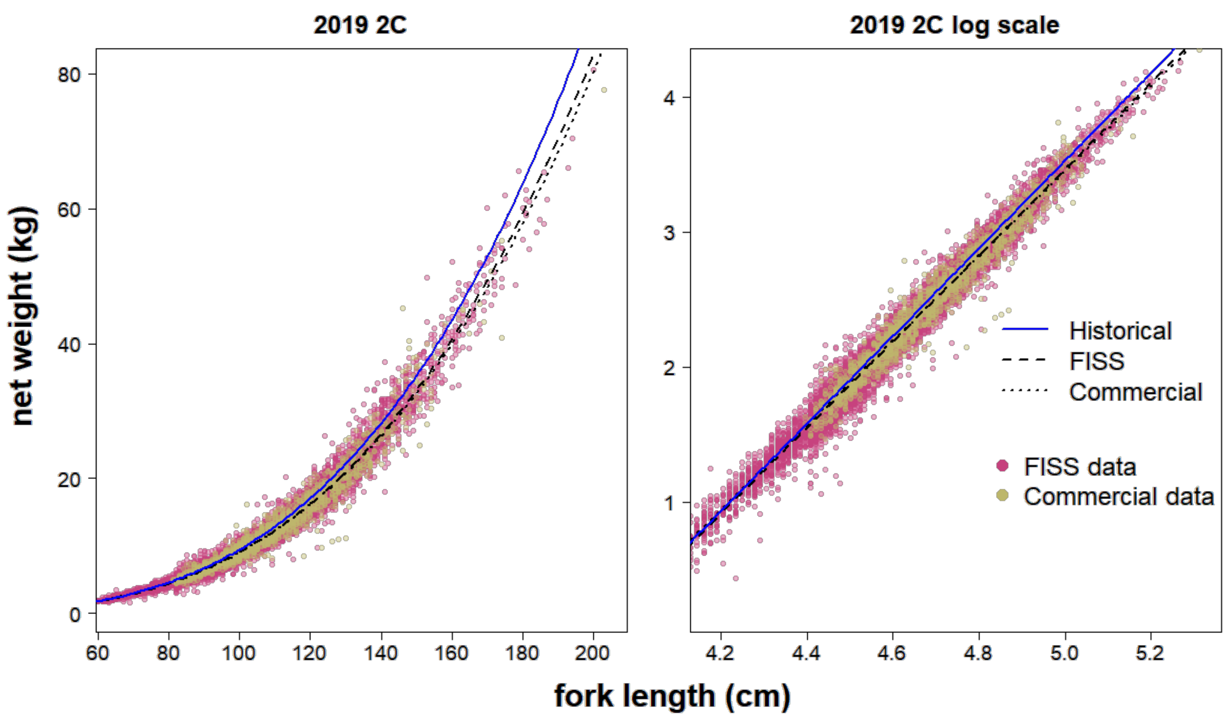

Figure 2.23 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2C in 2019.

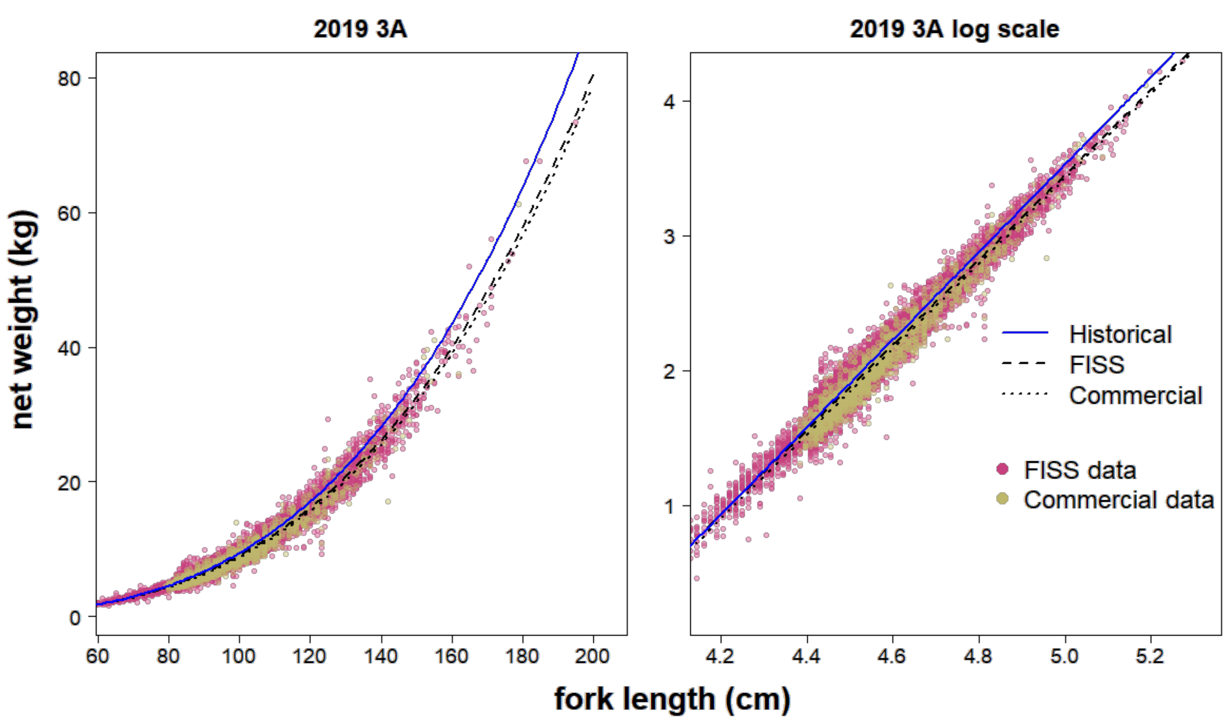

Figure 2.24 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3A in 2019.

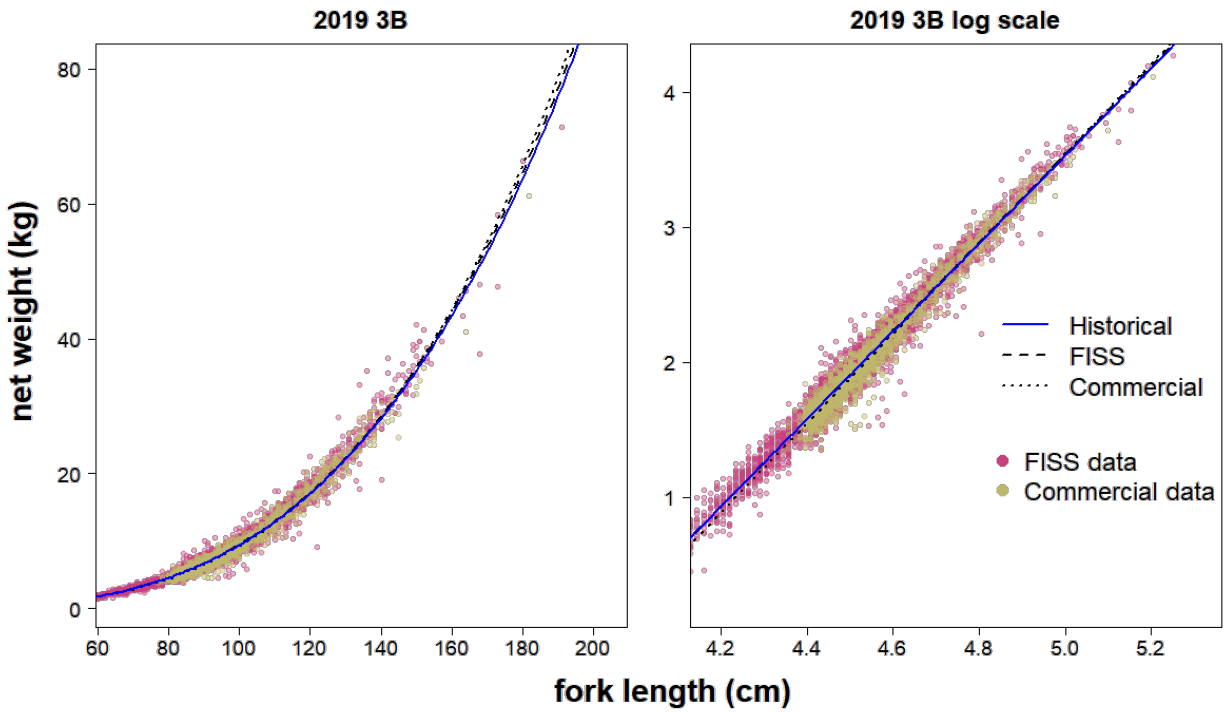

Figure 2.25 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3B in 2019.

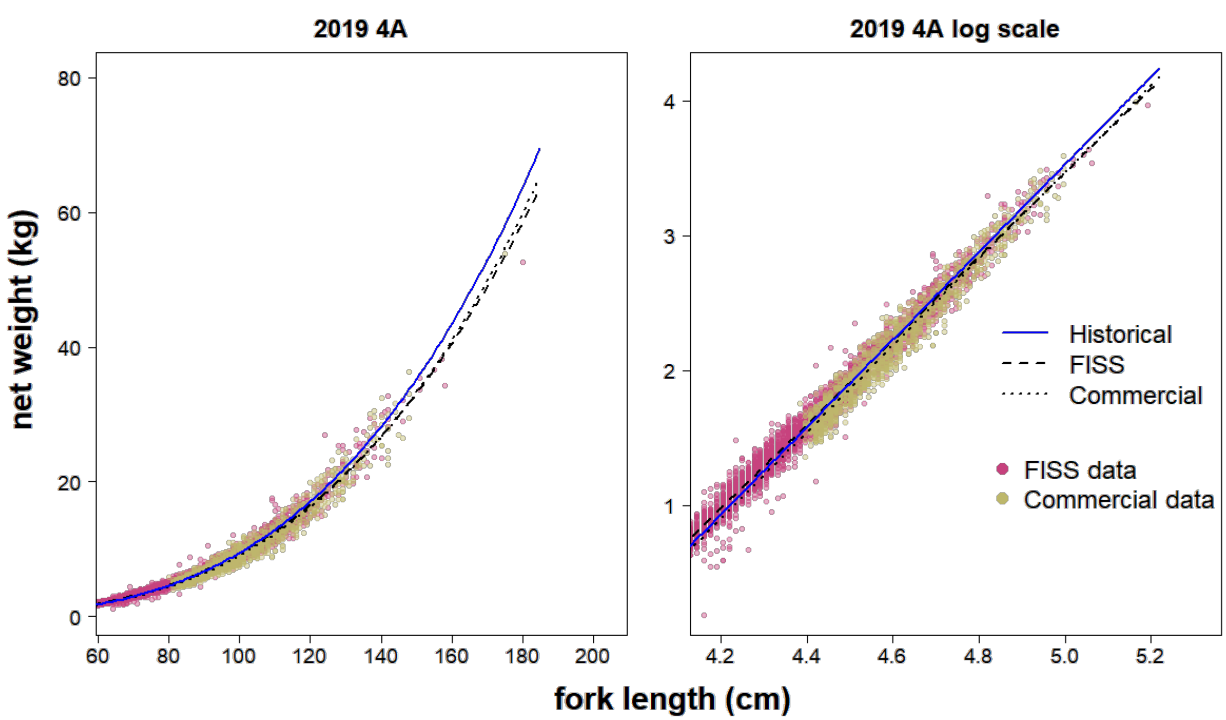

Figure 2.26 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 4A in 2019.

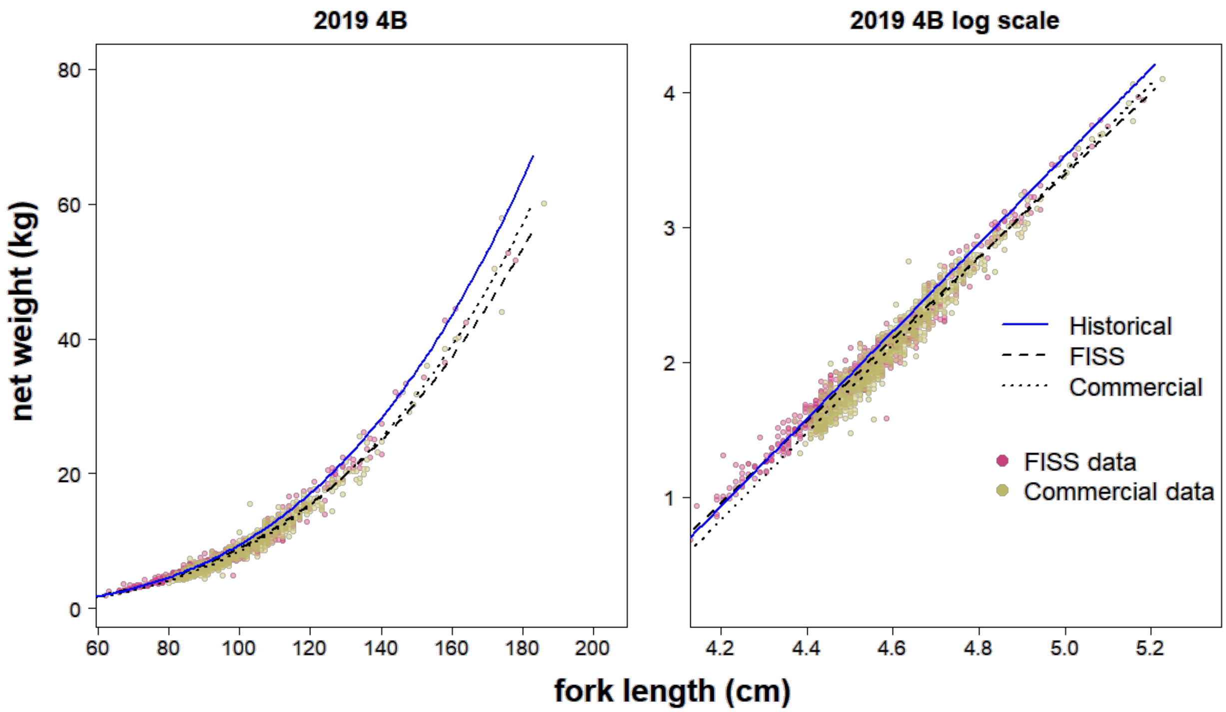

Figure 2.27 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 4B in 2019.

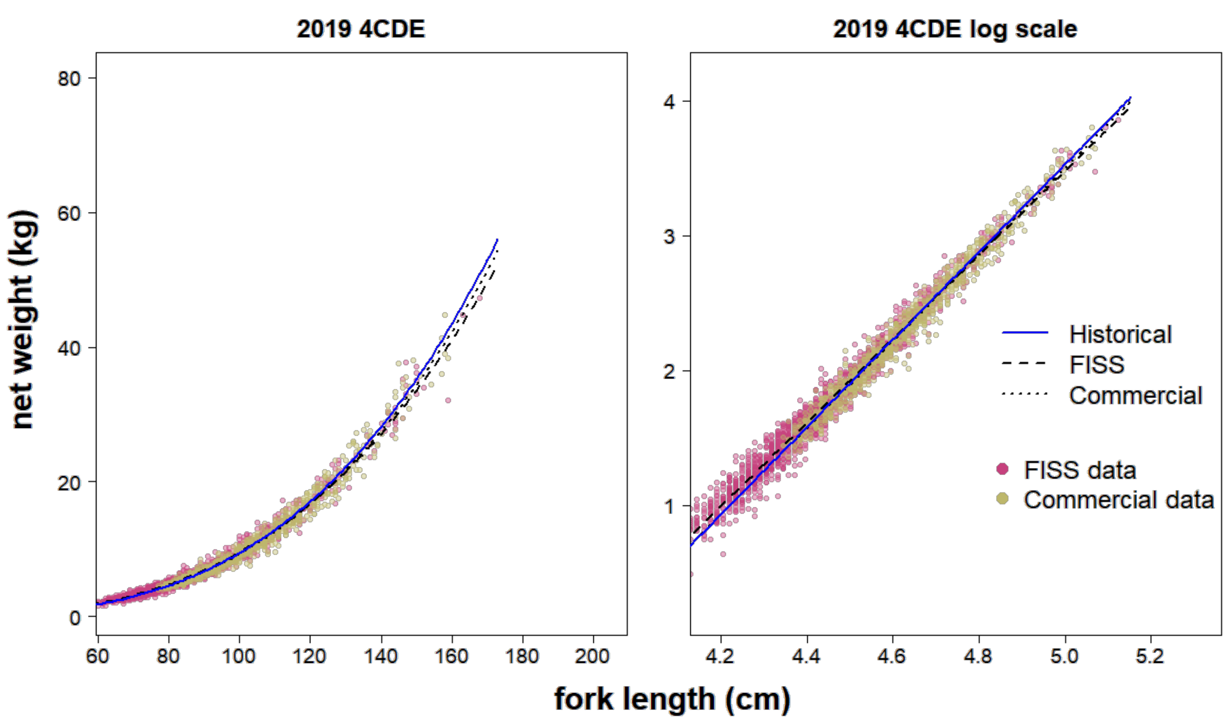

Figure 2.28 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 4CDE in 2019.

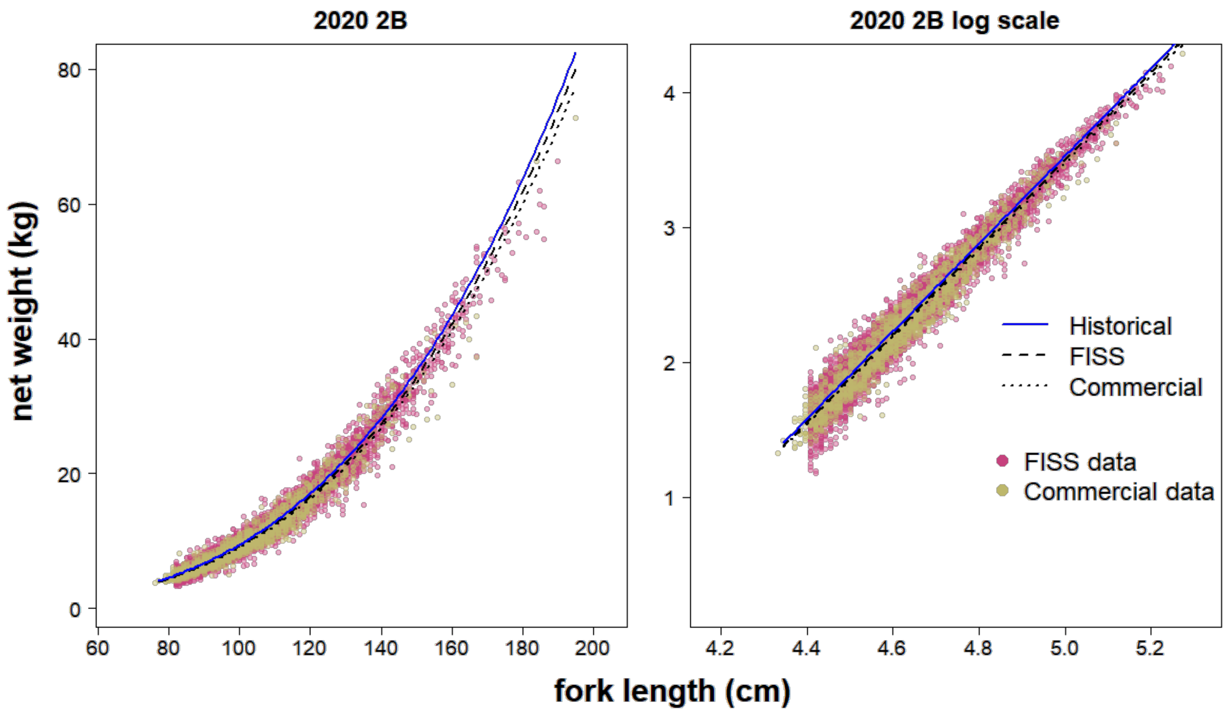

Figure 2.29 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2B in 2020.

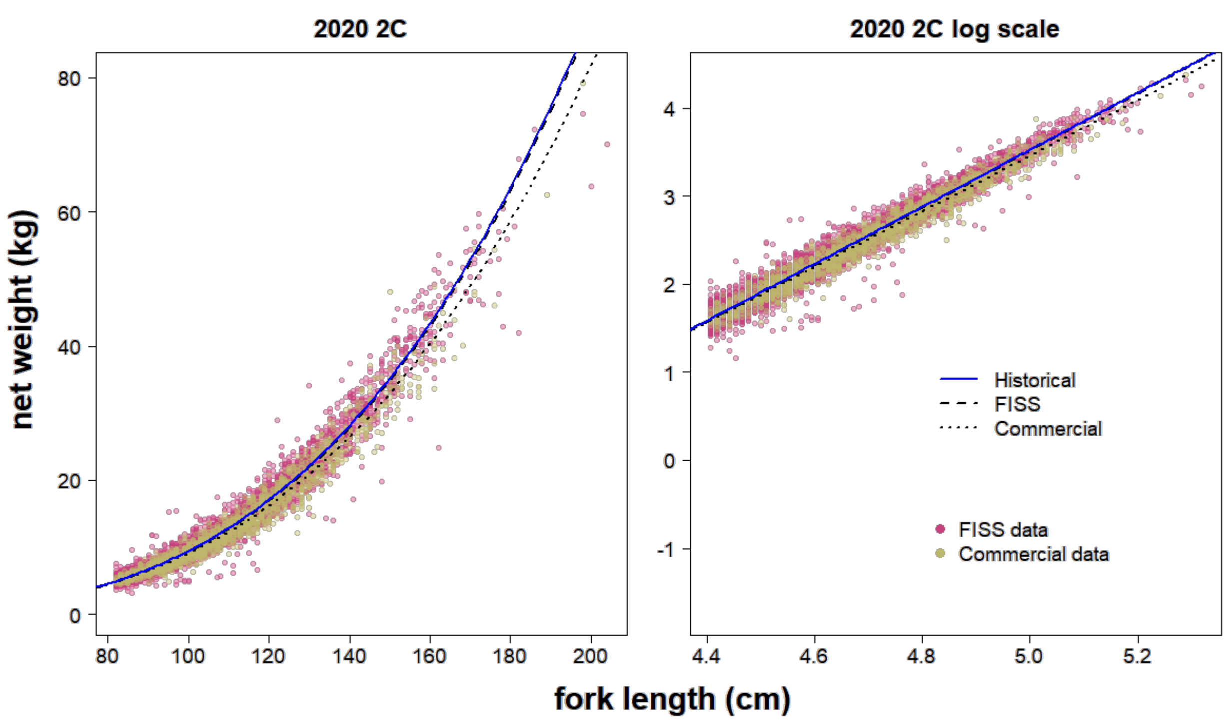

Figure 2.30 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2C in 2020.

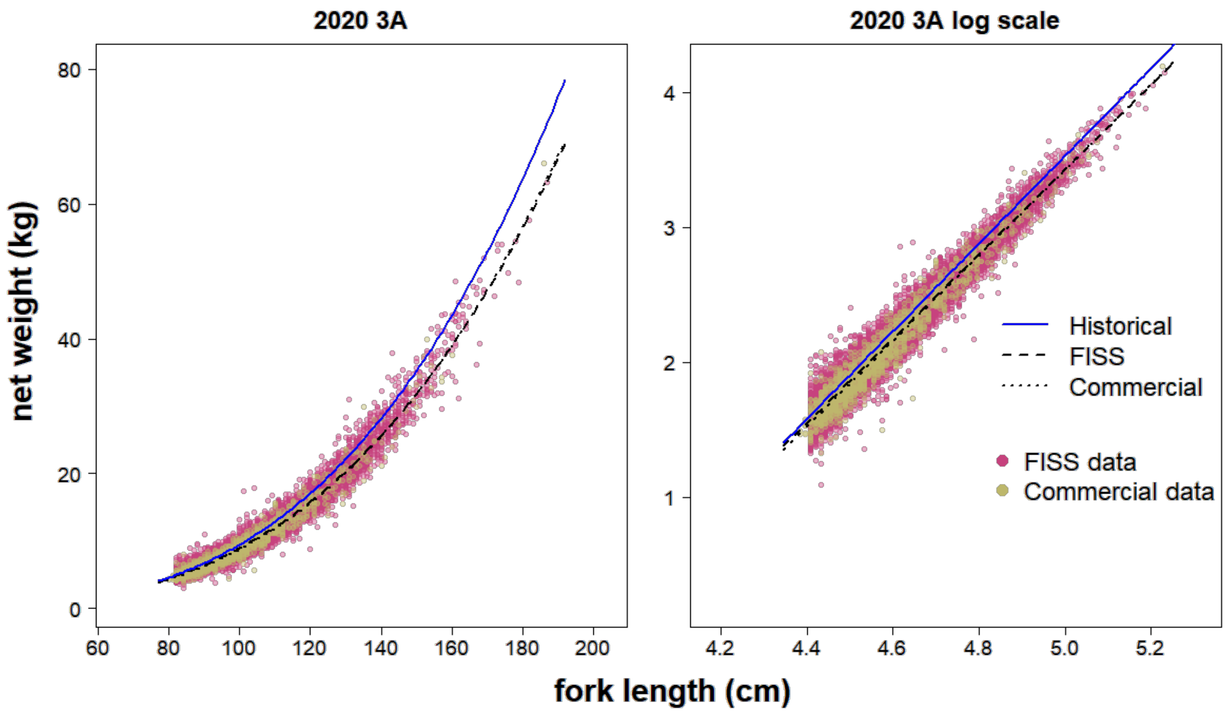

Figure 2.31 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3A in 2020.

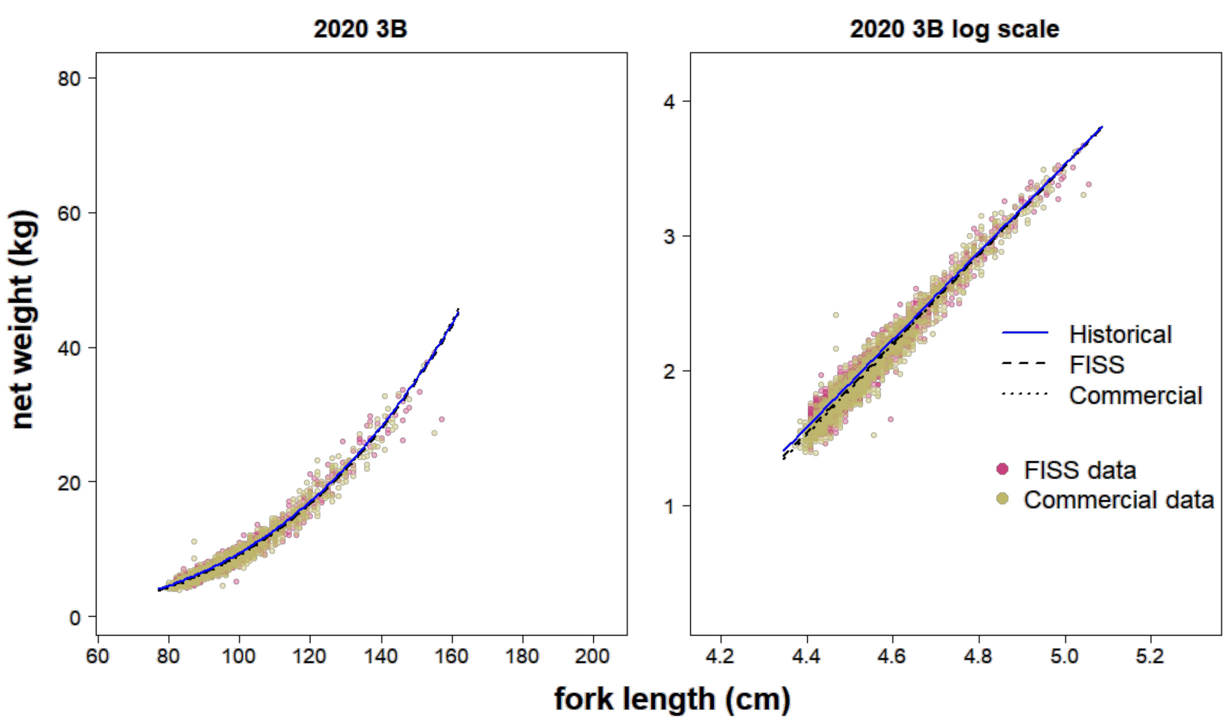

Figure 2.32 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3B in 2020.

Part 3: Review of IPHC hook competition standardization

PURPOSE

To provide a review of the IPHC approach to standardizing WPUE and NPUE for competition for baits on the Fishery-Independent Setline Survey (FISS). A short discussion of IPHC experiments with hook timers is also provided.

BACKGROUND/INTRODUCTION

In 2007, the IPHC transitioned from IPHC Regulatory Area-specific stock assessments to a coastwide stock assessment. At the same time, the IPHC began using the O32 WPUE index (including all fish over 32 inches, 81 cm, in length; this corresponds to the current directed commercial fishery minimum size limit for landings) from the FISS to estimate the distribution of the stock among IPHC Regulatory Areas. In order to address concerns that such an index can be affected by catchability differences among areas, Secretariat staff devised adjustments intended to standardise the index for at least some contributors to catchability differences. The most important of these, and one of only two standardisations still applied (along with an adjustment for FISS timing), is the hook competition standardisation. Originally devised as an average adjustment applied at the IPHC Regulatory Area level, with the introduction of the space-time model for estimating WPUE and NPUE indices, this was updated to a station-specific adjustment in 2016, as supported by the SRB (IPHC-2016-SRB09-R).

STANDARDIZATION FOR HOOK COMPETITION

Gear saturation is the process by which catch rates decrease disproportionately to abundance as the sampling gear becomes fully occupied. Although it may be present for many types of sampling gear, for longline gear, as deployed by the IPHC, gear saturation may be considered via competition for the finite number of hooks deployed. The IPHC method for standardisation for hook competition was developed by Clark (2008), and was based on the number of baits removed on FISS sets, B_i, by predator species *i*. The Baranov catch equation was used to model the B_i, the number of baits removed by predator *i* after a time period, *T*:

$$B_i = B_0 \frac{F_i}{Z}\left(1 - e^{-ZT}\right)$$

Here F_i is the instantaneous rate of bait removal by predator *i*, B_0 is the initial number of baited hooks, and *Z* is the sum of the instantaneous rates applied by all bait takers. It follows that the expected catch (*C*) of halibut (*h*), which is one of the bait predators, is given by

$$C_h = B_0 \frac{F_h}{Z}\left(1 - e^{-ZT}\right) \quad (1)$$

For the FISS sets, soak time is assumed to be of sufficient length that catches of all species are unaffected by the exact value of *T*. For simplicity, we therefore set *T*=1 in the above equations. It is further assumed that empty hooks are due to bait taking by species other than halibut, and, therefore, halibut do not escape once captured. In these equations, $\left(1 - e^{-Z}\right)$ (with *T*=1) is the expected fraction of baits removed by all takers during the active period. An estimate of *Z* is therefore given by $\log(B_0/B_1)$, where B_1 is the number of baits remaining when the gear is hauled.

The IPHC approach to standardising for hook competition is to treat F_h as the standardised index for Pacific halibut at a given station, which is estimated by rearranging (1) and substituting in the estimate of Z:

$$F_h = \frac{C_h}{B_0}\log\left(\frac{B_0}{B_1}\right)\frac{B_0}{B_0 - B_1} \quad (2)$$

With C_h/B_0 representing catch per unit effort, the remaining part of the right-hand side of (2) is the hook competition adjustment factor. We note that the IPHC approach has the same mathematical derivation as the method developed contemporaneously by Etienne et al. (2013).

In practice, we substitute WPUE or NPUE for C_h/B_0 in (2), for which effort is measured by the number of effective skates, rather than the count of baits set. As the adjustment factor has a lower bound of 1, the result of the standardisation would be to increase average WPUE or NPUE, with larger positive adjustments made when fewer baits are returned. To maintain the indices on a scale familiar to stakeholders, all adjustment factors are divided by the same scalar, based on the coastwide mean adjustment factor for 1998. Importantly, this approach implicitly accounts for changes in predator density, not only among stations within a sampling year, but also across years, such that a long-term change in the level of competition would be accounted for.

Pacific halibut represents the most common species captured, and therefore the largest contribution to the hook competition correction. However, non-target species (commonly dogfish, Pacific cod and others depending on the geographical area) are frequently encountered in abundance at some FISS stations every year. Missing baits are attributed to hook competition, except where they are lost during setting, in which case they are recorded as such, and the baits deployed adjusted accordingly. Aggregating by area and year, generally 5-40% of baited hooks are returned with baits, with lowest rates of return in IPHC Regulatory Area 2A (typically less than 10%) and highest in IPHC Regulatory Area 4B (20-40% each year).

To avoid the adjustment going to infinity as the number of baits returned goes to zero, a small amount (B_0/100, for our 100-hook skates) is added to both the B_0 and B_1 when computing Z. Note also that when zero Pacific halibut are captured, the multiplicative adjustment leaves the value of WPUE or NPUE unchanged at zero.

As an example, Figures 3.1-3.3 demonstrate the effect of the standardisation on O32 WPUE from IPHC Regulatory Area 2B in 2018. This was a year in which dogfish captures were higher than normal in parts of the area, leading to lower bait returns and negatively impacting the observed survey catch of Pacific halibut. Figure 3.1 shows the hook competition adjustment factors for each station, while Figures 3.2 and 3.3 respectively plot O32 WPUE by station before and after application of the hook competition standardisation (i.e., before and after multiplication by the factors in Figure 3.1).

IPHC HOOK TIMER STUDIES

Historical work on hook timers (Kaimmer 2011, Parma et al. 1995) was intended to produce data on the rate of bait capture by Pacific halibut and competing species. However, the timers in use in those studies were not tripped most of the time, and it appears they were not sensitive to the capture of smaller fish or to smaller fish taking the bait without being captured (Parma et al. 1995).

The IPHC is currently collaborating on a study of standard and modified circle hooks that will use hook timers to record the capture time of different species. Modern hook timers are expected to be more sensitive than those used in historical studies, and it is therefore hoped that this study will yield data that will help inform the calculation of the hook competition standardisation.

RECOMMENDATION

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.3 that presents an overview of the IPHC standardization for hook competition on FISS sets.

References

Clark, W.G. 2008. Effect of hook competition on survey CPUE. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 2007: 211-215.

Etienne M. P., Obradovich S. Yamanaka L. and McAllister M. 2013. Extracting abundance indices from longline surveys: method to account for hook competition and unbaited hooks. Preprint arXiv:1005.0892v3

IPHC 2016. Report of the 9th Session of the IPHC Scientific Review Board (SRB) IPHC-2016-SRB09-R. 5 p.

Kaimmer, S. M. 2011. Special setline experiments 1985-1994 objectives, data formats, and collections. IPHC Technical Report 53.

Parma, A. M., Kaimmer, S. M. and Sullivan, P. J. 1995. A progress report on the use of hook timers and underwater observations to assess the effect of bait competition on CPUE. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 1994: 211-221.

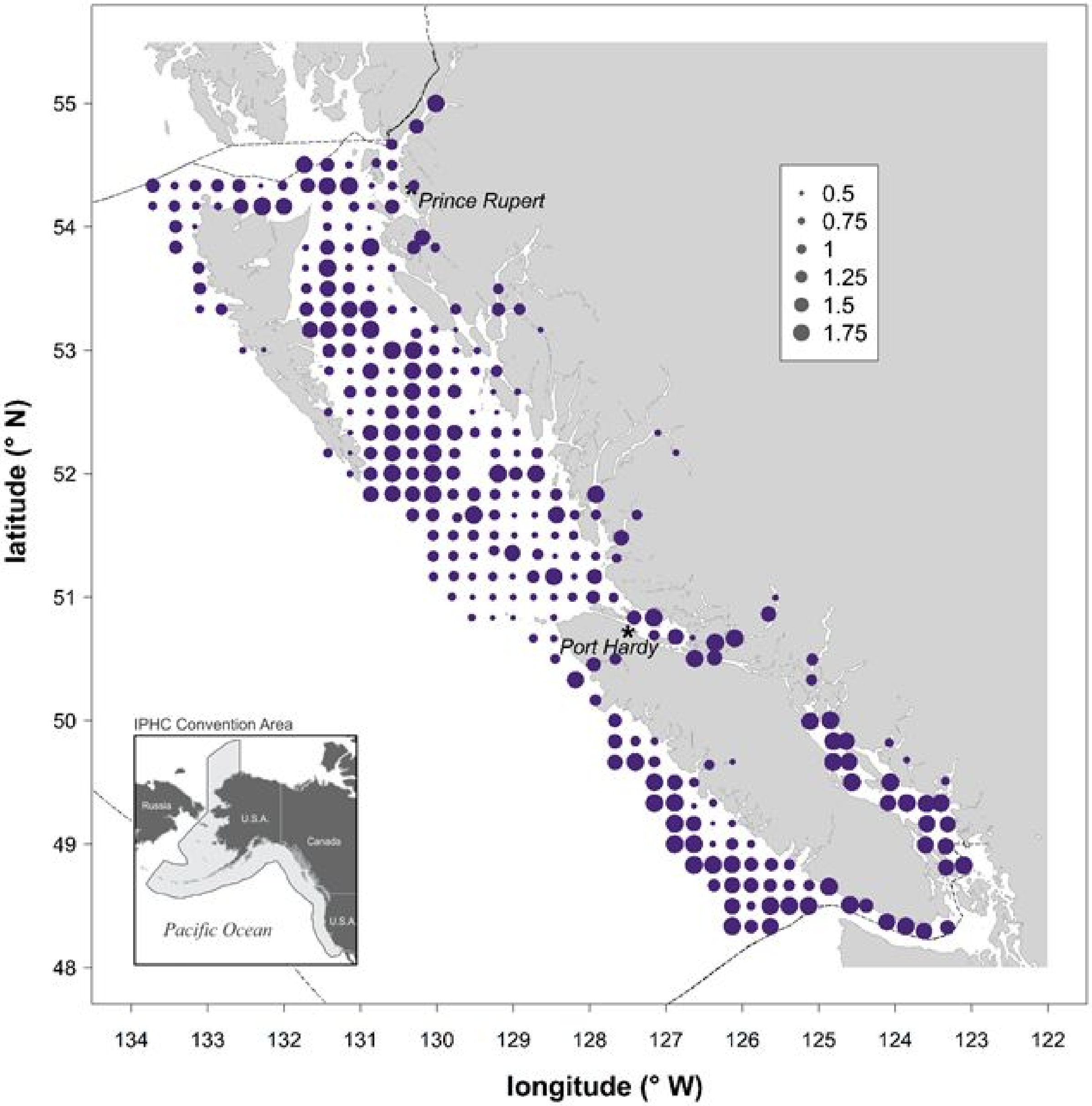

Figure 3.1. Hook competition adjustment factors for each station in IPHC Regulatory Area 2B in 2018. Larger circles are due to greater competition for baits (fewer baits returned), while smaller circles are a result of lower levels of competition.

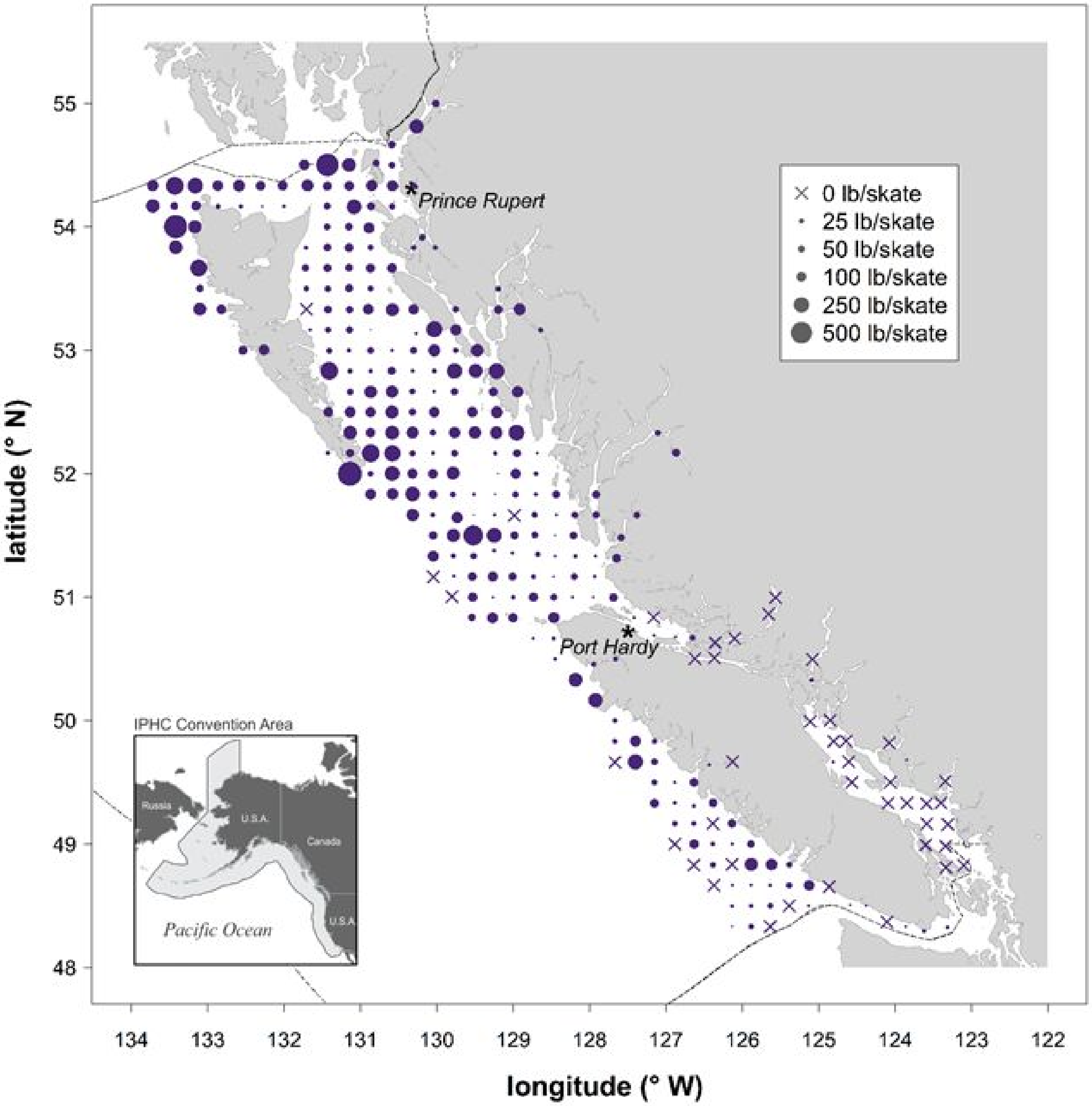

Figure 3.2. Raw O32 WPUE (lb/skate) for each station in IPHC Regulatory Area 2B in 2018.

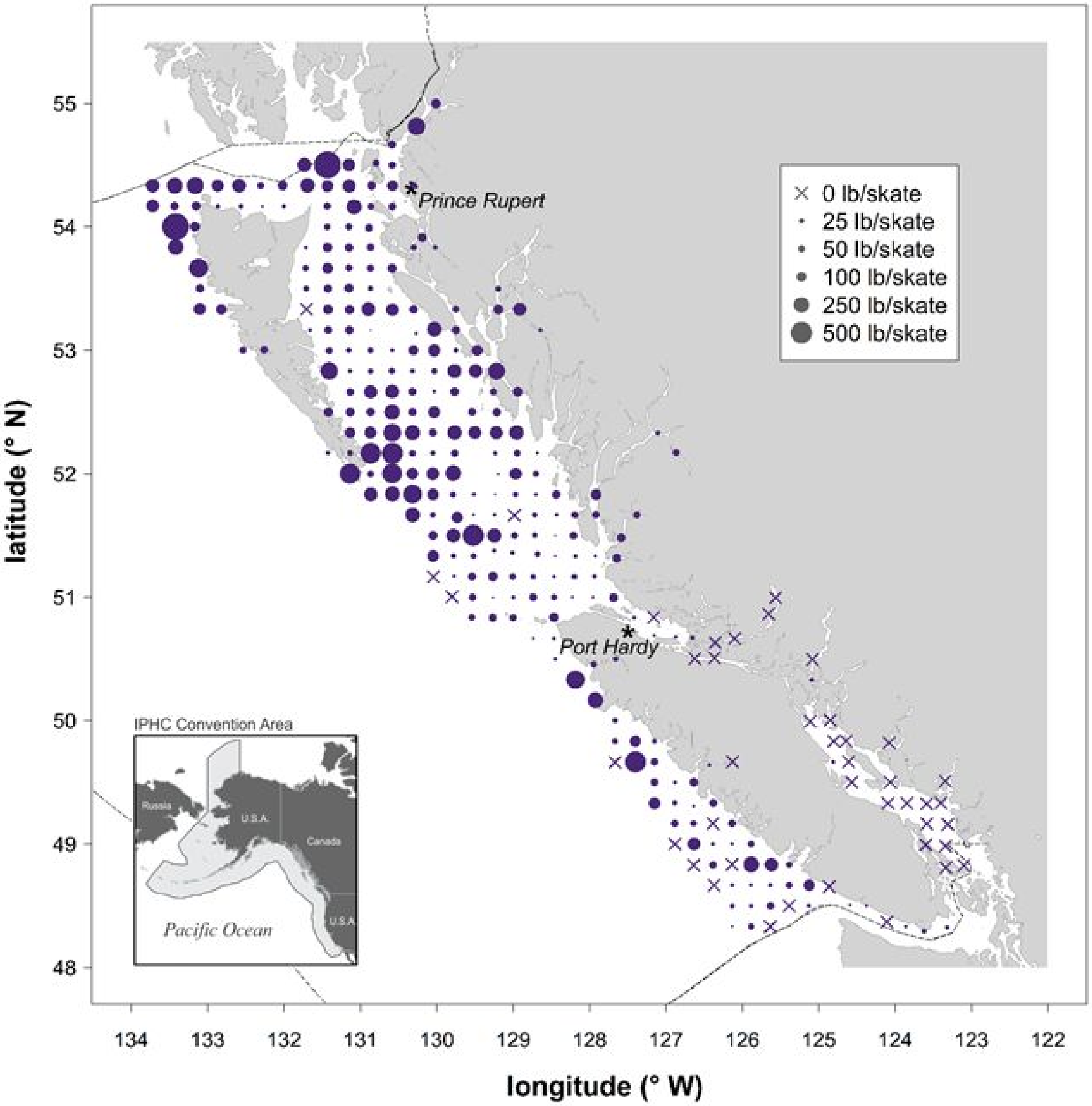

Figure 3.3. O32 WPUE (lb/skate) for each station standardized for hook competition in IPHC Regulatory Area 2B in 2018.

Part 4: Accounting for the effects of whale depredation on the FISS

PURPOSE

To describe a simple approach for accounting for the effects of whale depredation on FISS catch rates within the space-time model.

BACKGROUND/INTRODUCTION

The presence of sperm whales and orcas during the fishing and hauling of FISS sets can lead to such sets being designated as ineffective for the use in analyses due to the potential impact on recorded catch rates Pacific halibut of depredation by these marine mammals (IPHC-2021-VSM01, page 18). The criteria for ineffectiveness, which were tightened in 2019, are as follows:

- Sperm whales: a sperm whale is spotted within 3 nmi of the boat while hauling gear
- Orcas: a set has more than 1 lips-only Pacific halibut or a set has other observations of orca feeding on Pacific halibut

These criteria were designed to minimize the potential for including biased data in the annual indices. Sperm whales have been found to depredate cryptically on the gear at large distances from the vessel, while orcas generally leave clear evidence of depredation or are observed in the act. Coastwide, relatively few sets are designated as ineffective due to sperm whale and orca depredation each year: from 2010-2020, 1.4-3.0% of all sets fished included sperm whales or orcas as a reason for ineffectiveness. However, the impacts can be greater for a given area and year. For example, IPHC Regulatory Area 3A has had up to 6% of sets affected by whales (mainly sperm whales), while IPHC Regulatory Area 4A is the area most affected by orca encounters, with over 10% of sets affected in some years. In the latter case, the FISS expansion year of 2014 has 12% of sets designated as ineffective with sperm whales or orcas given as a reason. Given that several of those sets have only been fished once prior to 2021, the effect of the loss of data on estimates of density indices may be disproportionate.

We propose a simple solution to allow data from sets affected by whale depredation to be included in the estimation of WPUE and NPUE (weight and numbers per unit effort) indices of density: include binary (0=no whale; 1=whale) covariates in the space-time model for sets with whale depredation ineffectiveness codes. By estimating a parameter for the difference between affected and unaffected sets, we can make use of valuable data that would otherwise be excluded from analysis, while basing index estimation only on prediction at a zero value of the covariate (i.e., no whale effects for the standardized indices).

IPHC REGULATORY AREA 4A

As noted above, IPHC Regulatory Area 4A is the area with the greatest proportion of sets affected by whale interactions, almost all of which are interactions with orcas (139 orca sets from 1993-2020 and three sperm whale sets). We refitted the space-time model (see IPHC-2021-SRB018-05 Rev_1, Appendix B for details) to the O32 WPUE 1993-2020 data series, including sets with ineffectiveness codes for either orca or sperm whale interactions but omitting whale-affected sets that also included another ineffectiveness reason (e.g., both orcas and gear issues). As few sets with zero catch were ineffective due to whale interactions, we included the whale covariate in the non-zero model component (noting also that additional modelling showed no evidence of an effect on the probability of zero WPUE, supporting this choice).

The value of the coefficient transforms to 0.51 (95% CI: 0.43 – 0.60) on the original scale, i.e., O32 WPUE on whale-affected sets is estimated to be 51% of that on unaffected sets on average. Figure 4.1 compares the estimated O32 WPUE time series calculated from predictions at all FISS stations in IPHC Regulatory Area 4A for a model that excludes all whale-affected sets ("Excluded") and the model fitted here, that includes those sets but adjusts for the effect of whales by predicting with the whale covariate set to 0 ("Included (adjusted)"). The means of both time series are very close across all years, but we see an improvement in precision (narrower 95% CIs) when the whale-affected sets are included.

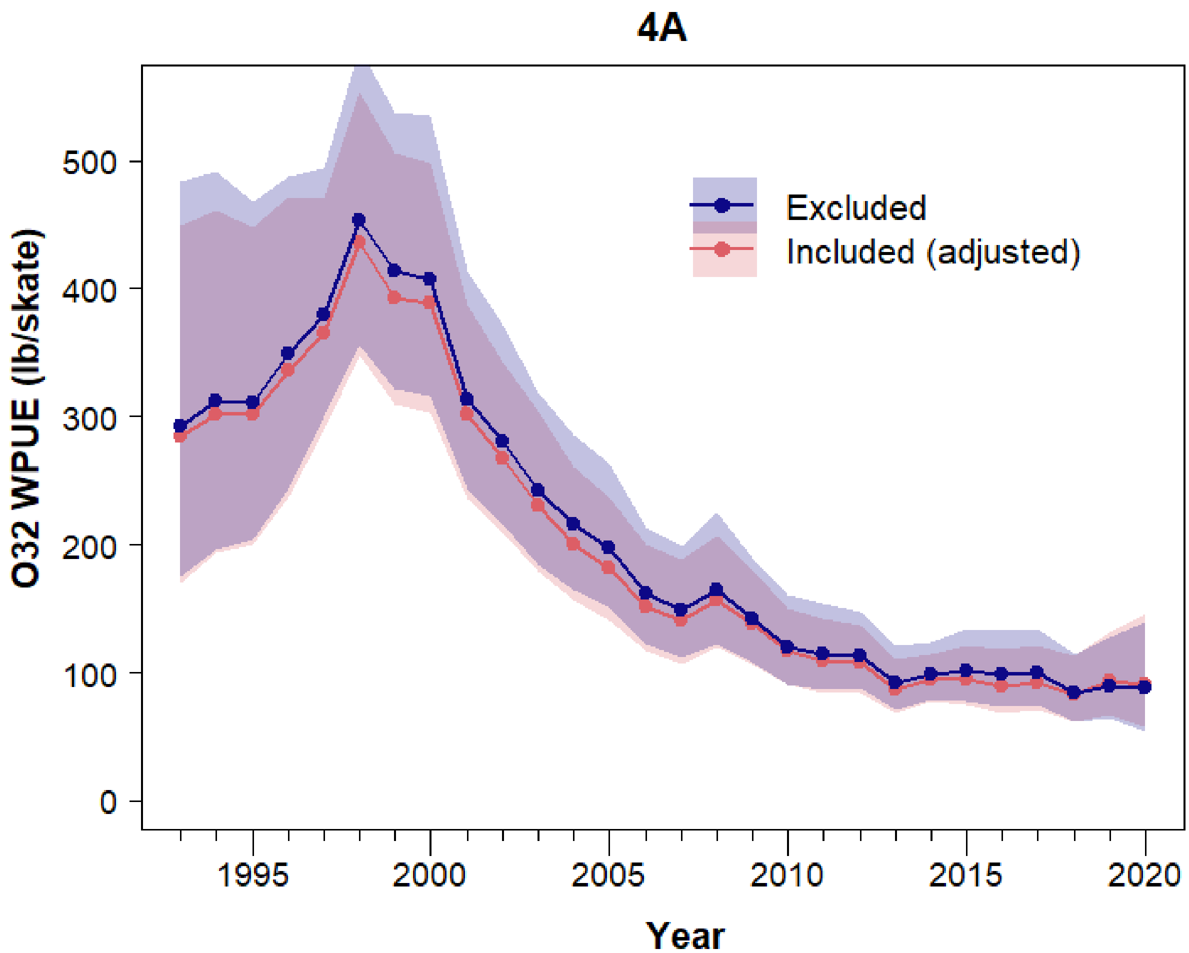

Figure 4.1. Comparison of the estimated O32 WPUE time series from the space time model calculated from predictions at all FISS station locations in IPHC Regulatory Area 4A for a model that excludes all whale-affected sets ("Excluded", blue line) and a model that includes those sets but adjusts for the effect of whales by predicting with the whale covariate set to 0 ("Included (adjusted)", red line). Shaded regions represent 95% posterior credible intervals.

Figure 4.2 compares the time series from the new model ("Included (adjusted)" – note the colour change from Figure 4.1) with the time series estimated the last time most of the whale-affected sets were included as "effective" sets ("Included (effective)"), prior to the tightening of the FISS ineffectiveness criteria for whales in 2019. The time series is consistently lower when these sets are included, a result of the lower average WPUE for these sets. This supports the tightening of the ineffectiveness criteria in 2019, as their inclusion without any adjustment leads to a likely negative bias in the time series.

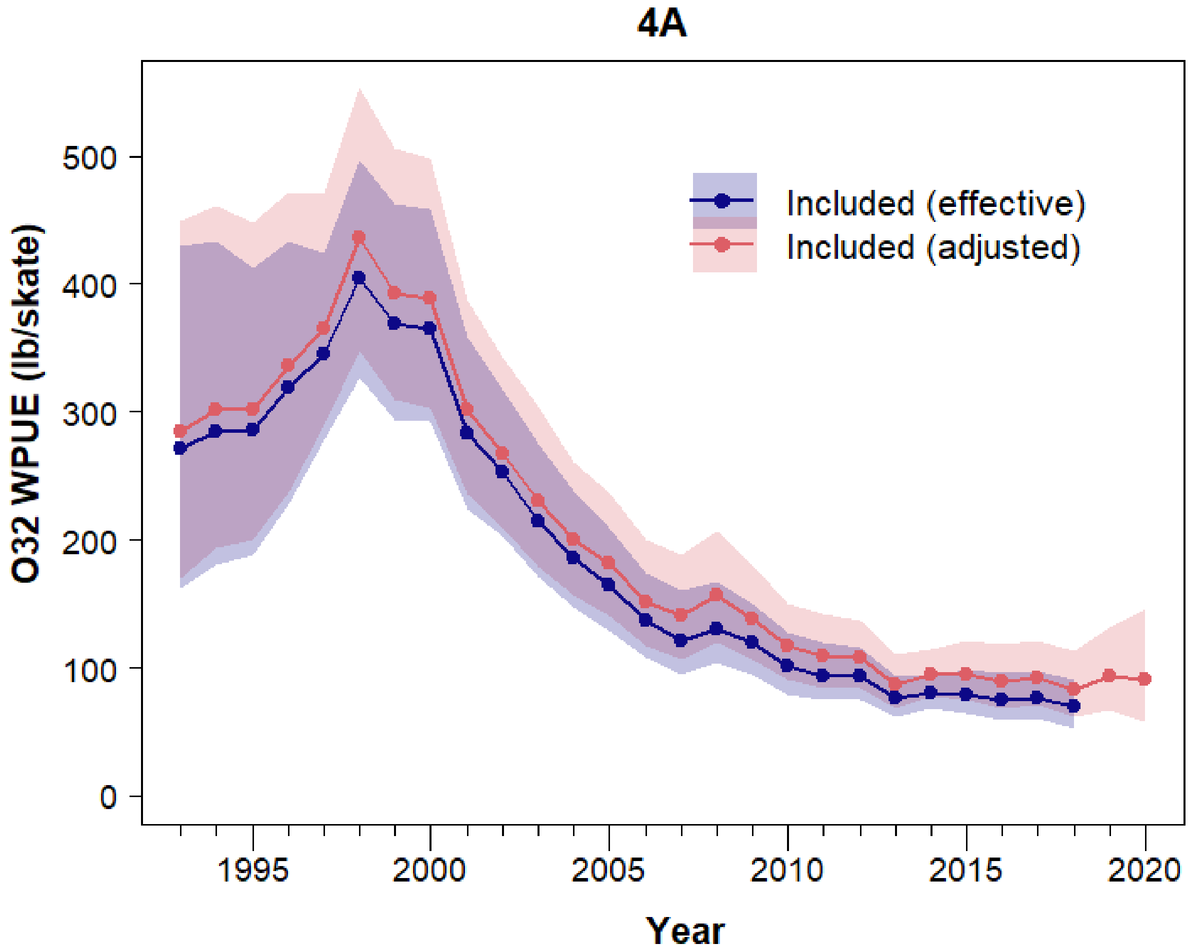

Figure 4.2. Comparison of the estimated O32 WPUE time series from the space time model calculated from predictions at all FISS station locations in IPHC Regulatory Area 4A for a model that included most whale-affected sets ("Included (effective)", blue line) without adjustment, and a model that also includes those sets but adjusts for the effect of whales by predicting with the whale covariate set to 0 ("Included (adjusted)", red line). Shaded regions represent 95% posterior credible intervals.

IPHC REGULATORY AREA 3A

Both sperm whales and orcas interact with FISS sets in IPHC Regulatory Area 3A, but with 116 sets affected by sperm whales over the 1993-2020 period vs 29 orca sets (and 18 with both), the former species provides a large majority of recorded whale interactions. For this area, we fitted a model with binary covariates for each species in the non-zero component of the model. We also fitted a model that included a species interaction effect, but found no evidence for such an interaction. The model estimates a much smaller effect of whale interactions than in IPHC Regulatory Area 4A, with orca-affected estimated to have 84% (68-104%) of the O32 WPUE of unaffected sets, and sperm whale-affected sets having 86% (75-99%) of the O32 WPUE of unaffected sets. With a smaller proportion of affected sets in this area, and with a lower estimated effect of whale interactions, the effect on WPUE of including these sets in the modelling is negligible (Figure 4.3).

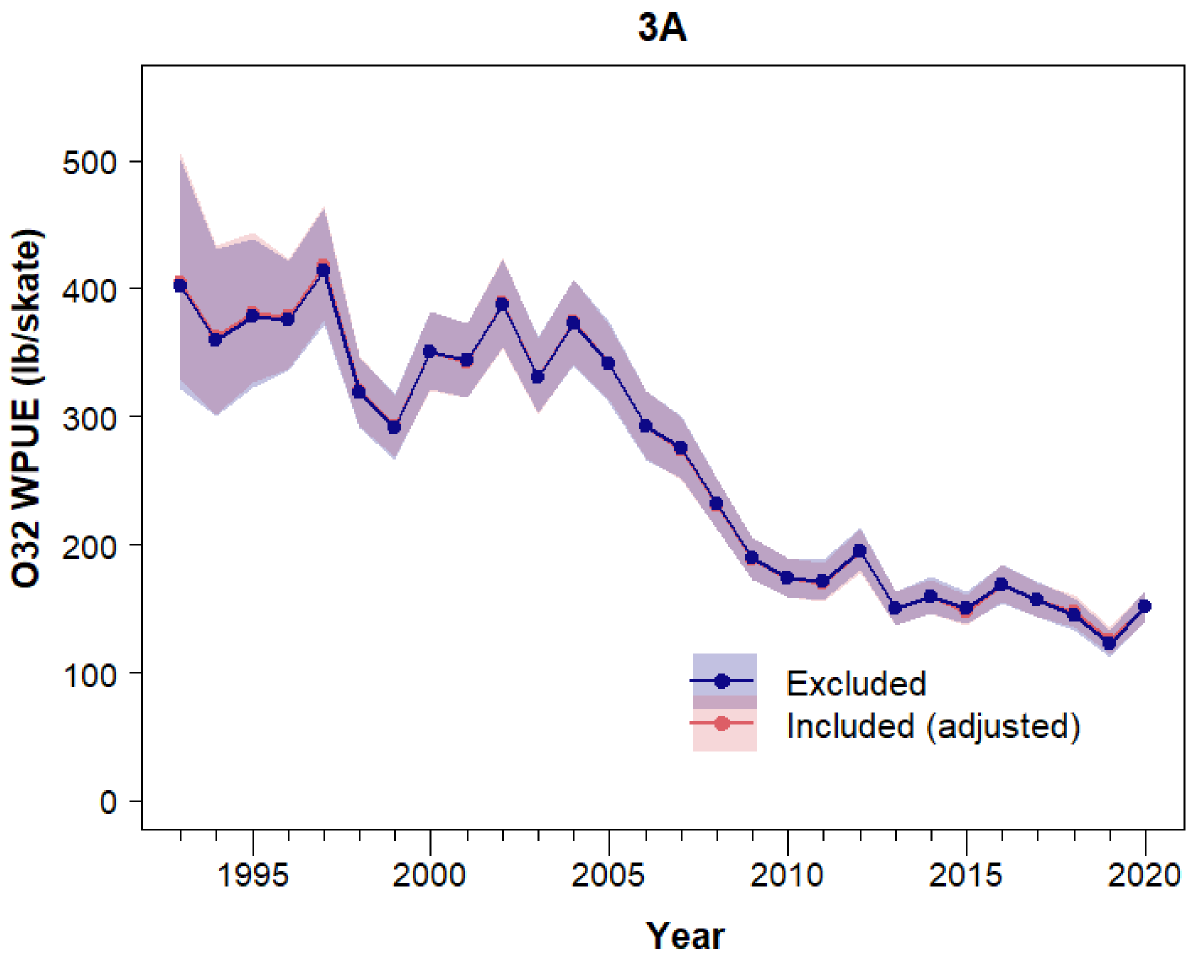

Figure 4.3. Comparison of the estimated O32 WPUE time series from the space time model calculated from predictions at all FISS station locations in IPHC Regulatory Area 3A for a model that excludes all whale-affected sets ("Excluded", blue line) and a model that includes those sets but adjusts for the effect of whales by predicting with the whale covariate set to 0 ("Included (adjusted)", red line). Shaded regions represent 95% posterior credible intervals.

Discussion

Our examples show that including sets deemed ineffective due to whale interactions in the space-time model while accounting for whale effects on catch rates can lead to improved precision in estimates of the WPUE time series when whale effects are strong and those sets are a relatively high proportion of all sets (IPHC Regulatory 4A), but have little to no effect on estimates when whale impacts are weaker and affected sets are a smaller proportion of all sets (IPHC Regulatory Area 3A). Our results also support the strengthening of ineffectiveness criteria related to whale depredation in 2019. The similarity of the two times series in Figure 4.1, in particular, implies that the space-time model has been producing accurate predictions at stations where data were previously missing because of sets that were considered ineffective due to potential whale depredation.

We propose that in order to maximise the information used to produce estimates of density indices from the space-time model, beginning in 2021, data from “ineffective” sperm whale and orca-affected sets be included in the modelling with appropriate covariates to account for difference in catch rates between affected and unaffected sets. In IPHC Regulatory Areas where such interactions are rare, precise estimation of whale covariate parameters will not be possible, and we can simply continue to omit such sets from the analyses with little loss of information.

RECOMMENDATIONS

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.4 that presents an approach to accounting for the effects of whale interactions on FISS catch rates through the space-time modelling.
2) **RECOMMEND** that the Secretariat should apply such an approach going forwards.

References

IPHC 2021. International Pacific Halibut Commission Fishery-Independent Setline Survey Sampling Manual (2021). IPHC-2021-VSM01.

Webster, R. A. 2021. 2022-24 FISS design evaluation. IPHC-2021-SRB018-05 Rev_1.

Update on the development of the 2021 stock assessment

PREPARED BY: IPHC SECRETARIAT (I. STEWART & A. HICKS; 19 AUGUST 2021)

PURPOSE

To provide the IPHC's Scientific Review Board (SRB) a response to requests from SRB018 (IPHC-2021-SRB018-R) and to provide the Commission with an update on the development of the 2021 assessment.

INTRODUCTION

This document provides an update on stock assessment development progress since SRB018. As noted at that meeting (IPHC-2021-SRB018-06), the 2021 stock assessment represents an update of the 2020 assessment, with no major changes to the data or modelling structure planned. This document includes a response to requests from SRB018, as well as a brief summary of software updates, supplementary analyses, and new data for 2021.

SRB REQUESTS AND RESULTS

SRB018, the SRB made the following assessment requests:

SRB018 Req.4 (para. 24):

"The SRB REQUESTED an analysis of annual surplus production and the fraction of that production harvested."

Walters et al. (2008) suggested that surplus production plots be examined routinely as part of the stock assessment process. They note that the basic equation for surplus production (*S*) is simply a function of the estimated 'exploitable' biomass (*B*) from the stock assessment in year (*y*), and the total fishing mortality (*C*):

$$S_{y-1} = B_y - B_{y-1} + C_{y-1}$$

'Exploitable' biomass must be defined such that it relates to the catch. However, the stock assessment for Pacific halibut contains multiple multiple fisheries with differing and time-varying selectivity.

Therefore, the Secretariat considered five methods for evaluating the observed trends and scale of surplus production for Pacific halibut:

1) Previous work (from SRB05) fitting surplus production models directly to time-series data.
2) A 'standard' surplus production calculation based on the stock assessment results for all-ages biomass and observed total fishing mortality in each year.
3) The same calculation as (2) but based on the estimates of spawning biomass and observed total fishing mortality in each year.
4) Decision table results provided for the Commission from 2019-2021 (and interpolated in this analysis for earlier years) showing 3-year projections of surplus production in spawning biomass.

5) A model-free 'empirical harvest rate' calculation that has been provided to the Commission for evaluation each year beginning with the 2017 assessment.

Each of these methods and associated results are discussed below.

1. Fitting surplus production models

During 2014, the Secretariat explored a variety of alternative stock assessment models including Virtual Population Analysis (VPA), and classical surplus production models including Pella-Tomlinson, Schaefer, and Fox parameterizations. Results highlighted several important aspects of the Pacific halibut population dynamics and data that were not conducive to the use of these models. Particularly important is the relationship between biomass and surplus production: for Pacific halibut the largest estimated increase in yield (from approximately 1980-2000) was driven primarily by incoming recruitment. Further, the Fishery Independent Setline Survey (FISS) time-series only extends back to 1993, providing little information on the underlying relationship of biomass and productivity over most of the historical period. The lack of a strong stock-recruitment relationship, as well as the potential extrinsic effect of the Pacific Decadal Oscillation (PDO) being positively correlated with recruitment also make any relationship between biomass and surplus production difficult to detect. However, these models did suggest that Maximum Sustainable Yield (MSY) was around 40-45 million pounds (18-20 thousand mt), on a similar scale with the 100-year average yield of 63 million pounds (28.6 thousand mt).

2. Surplus production based on age-8+ biomass

For this first calculation of surplus production, the all-ages biomass was used to approximate the biomass that would be available to the fisheries. Some fish (predominantly males) are not available to some fisheries until older ages (> 10 for the directed commercial fishery), so this calculation is including a portion of the overall 'production' only available to smaller fisheries harvesting the youngest fish (age-2+ fish are present in the total yield as part of the non-directed discards and in recreational fisheries). The actual yield exceeds the estimated surplus in most of the recent time-series, consistent with the stock trend estimates of declining all-ages biomass over most of this period following historic highs in the late 1990s (Figure 1). As strong recruitments move into the population the surplus production based on all ages may peak earlier than when the majority of these fish are actually entering into the fishery.

The calculation and interpretation of surplus production may be somewhat confusing in the context of the IPHC's interim management procedure which is not designed to stabilize the total biomass at a specific level, but to apply a sustainable harvest rate ($SPR_{43\%}$), in tandem with a sloping control rule (30:20 in relative spawning biomass) such that long-term biological conservation objectives are met and fishery yield is optimized (IPHC-2021-AM097-11).

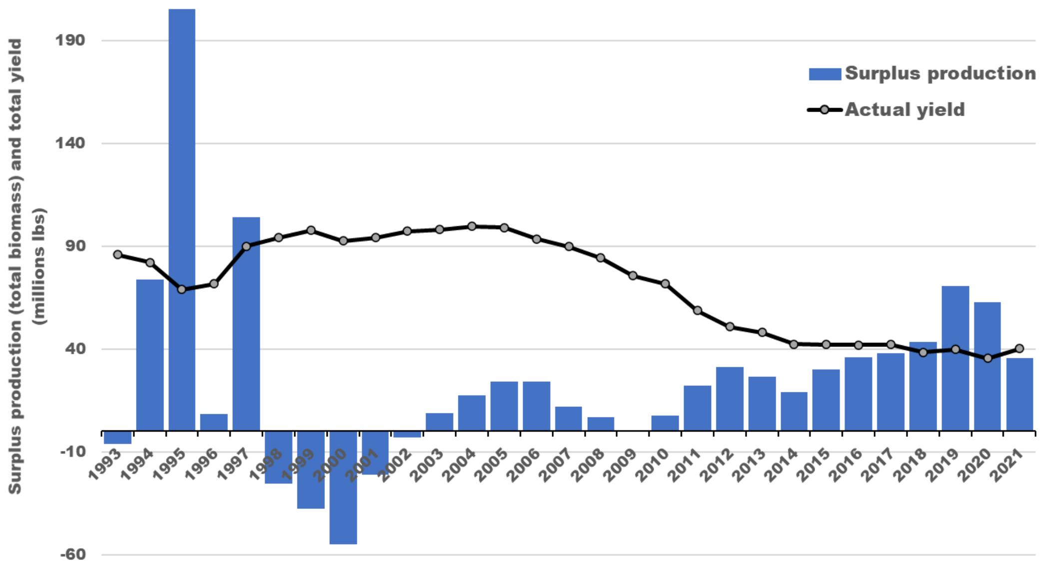

Figure 1. Actual yield (line) and estimated surplus production based on the all-ages biomass (bars). Where the surplus production exceeds the yield the stock is estimated to have increased in that year.

3. Surplus production based on spawning biomass

Following the same calculation used for total biomass, but instead using the spawning biomass to measure surplus production provides a smoother trend (Figure 2). Periods of positive surplus production seen when using spawning biomass tend to lag those seen in total biomass (Figure 1). Surplus production based on spawning biomass provides an interpretation that is perhaps more relevant to the Commission's management reference points. It is clear from these results that the fishery exceeded the surplus production in the spawning biomass from 1998-2010, a period of continuous stock decline. From 2011-2017 yield and surplus production were similar, and then surplus production has again been exceeded over 2018-2021. These results are consistent with the high probability of stock decline estimated in each year's stock assessment over this later period, and the Commission's decisions to follow a 'fishing-down' policy over this period, while maintaining the target harvest rate ($SPR_{46\%}$, and then $SPR_{43\%}$ beginning in 2021).

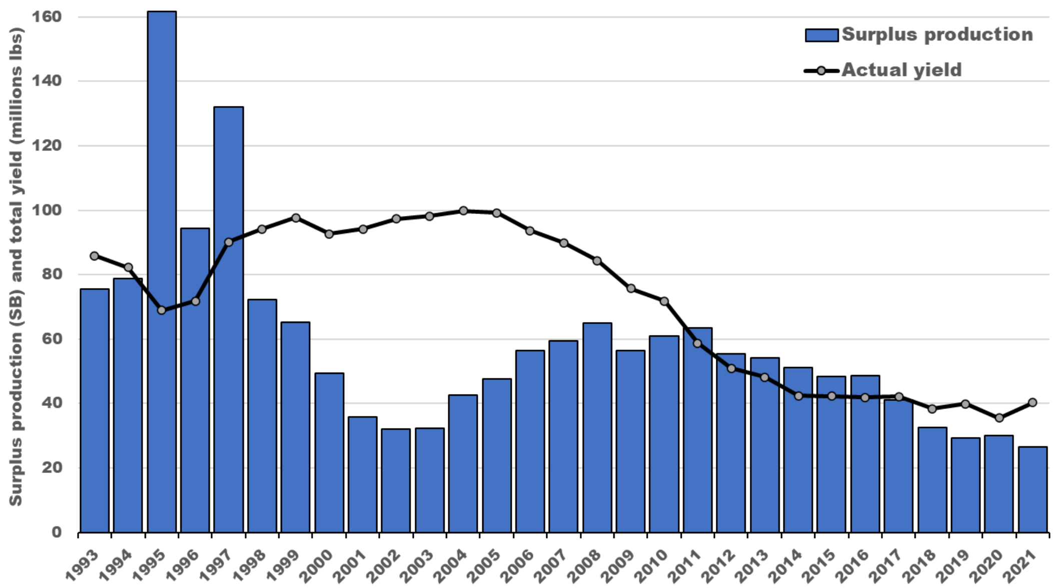

Figure 2. Actual yield (line) and estimated surplus production based on the spawning biomass (bars). Where the surplus production exceeds the yield the stock is estimated to have increased in that year.

4. Decision table-based surplus production

Beginning with the 2019 stock assessment the harvest decision table summarizing the results of the annual stock assessment has included a 3-year 'surplus production' calculation for comparison with other management alternatives (Table 1). This calculation differs importantly from the annual surplus production described above in that it reports the yield (in TCEY and total mortality) that can be taken for the next 3 years that would result in an estimated 50% chance of decrease in spawning biomass. Thus, even though the Commission currently uses an annual mortality limit setting process, this column provides a projection of the yield available in the near-term that would not adversely affect the spawning stock. Anecdotal response to this information indicates that it has been helpful as a comparison to the management procedure, and to put in context the yield that is set for the upcoming year.

Using the calculated probabilities in earlier harvest decision tables, an interpolation was made to approximate the 3-year surplus back to the 2012 stock assessment (Figure 4). As the Commission did not use the TCEY prior to the 2017 stock assessment (providing the 2018 3-year calculation), the total mortality is used for comparison with more recent stock assessments. Similar to the one-year surplus calculations reported above, the yield approached parity with surplus production in 2015-2016 (noting that the three-year calculation is somewhat lower based on subsequent stock declines) and then has exceeded the 3-year surplus for 2017+.

Table 1. Harvest decision table for 2021 mortality limits (provided at AM097; IPHC-2021-AM097-08). Columns correspond to yield alternatives and rows to risk metrics. Values in the table represent the probability, in "times out of 100" (or percent chance) of a particular risk.

		2021 Alternative		3-Year Surplus		Status quo		Reference $F_{43\%}$					
		Total mortality (M lb)	0.0	25.7	36.8	37.9	39.1	40.3	41.5	42.9	44.1	61.3	
		TCEY (M lb)	0.0	24.4	35.5	36.6	37.8	39.0	40.3	41.6	42.8	60.0	
		2021 fishing intensity	$F_{100\%}$	$F_{58\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{30\%}$	
		Fishing intensity interval	--	39-76%	29-65%	29-64%	28-63%	27-62%	26-61%	26-60%	25-59%	18-49%	
Stock Trend (spawning biomass)	in 2022	is less than 2021	<1	42	61	62	64	65	66	67	69	82	a
		is 5% less than 2021	<1	7	32	34	36	39	41	44	46	66	b
	in 2023	is less than 2021	<1	51	62	63	64	65	66	67	69	81	c
		is 5% less than 2021	<1	32	53	54	55	56	57	59	59	74	d
	in 2024	is less than 2021	<1	50	60	61	62	63	64	66	67	80	e
		is 5% less than 2021	<1	40	55	56	57	57	58	59	60	74	f
Stock Status (Spawning biomass)	in 2022	is less than 30%	29	35	39	40	40	41	41	42	42	47	g
		is less than 20%	<1	<1	<1	<1	1	1	1	1	1	4	h
	in 2023	is less than 30%	23	32	39	40	40	41	42	43	43	49	i
		is less than 20%	<1	<1	2	2	3	3	4	5	5	19	j
	in 2024	is less than 30%	12	29	38	39	40	41	42	43	44	50	k
		is less than 20%	<1	<1	4	5	6	8	9	10	12	25	l
Fishery Trend (TCEY)	in 2022	is less than 2021	0	17	48	49	50	50	50	51	51	77	m
		is 10% less than 2021	0	6	41	44	46	48	49	50	50	63	n
	in 2023	is less than 2021	0	21	49	50	50	50	50	51	51	75	o
		is 10% less than 2021	0	11	45	47	48	49	50	50	50	64	p
	in 2024	is less than 2021	0	23	49	50	50	50	50	51	51	74	q
		is 10% less than 2021	0	13	47	48	49	49	50	50	50	64	r
Fishery Status (Fishing intensity)	in 2021	is above $F_{43\%}$	0	15	48	49	50	50	50	51	51	78	s

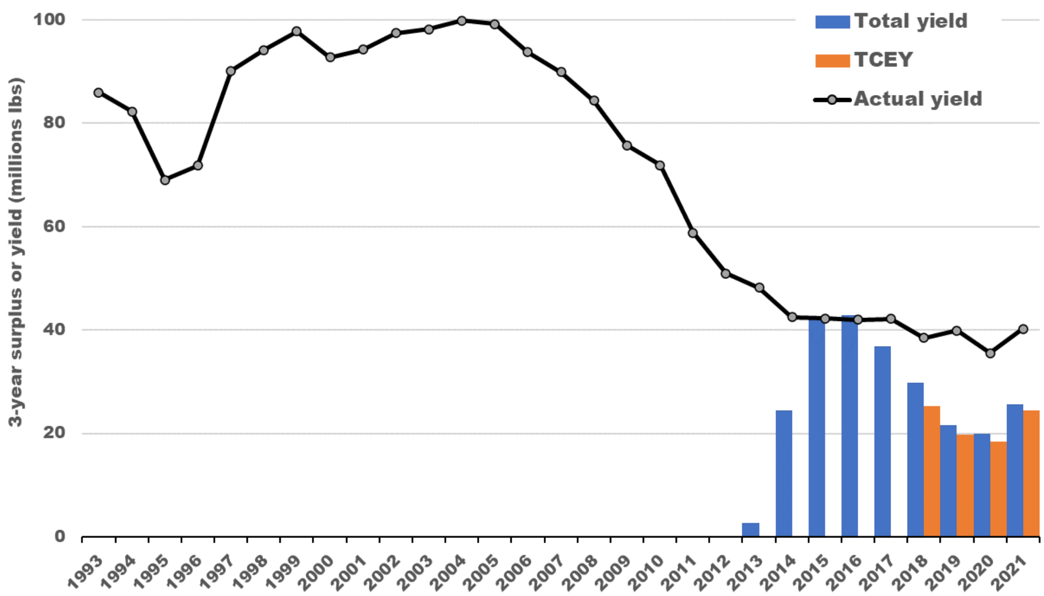

Figure 3. Actual yield (line) and 3-year projected surplus production based on the TCEY (orange bars) and total mortality (blue bars).

5. Empirical harvest rates

Beginning in 2017, the Secretariat developed a model-free method to evaluate the relationship between FISS indices and fishing mortality. This simple method provides an empirical approach for evaluating relative harvest rates based solely on data (rather than stock assessment output). A measure of exploitation (*U*) in each year (*y*) and Biological Region (*r*) can be based on the O26 mortality (Pacific halibut >= 26 inches, 66 cm, in length; 'catch': *C*) and some measure of the biomass (*B*):

$$U_{y,r} \sim \frac{C_{y,r}}{B_{y,r}}$$

The biomass is a function of the modelled survey index (*I*) and an unknown catchability parameter (*q*):

$$B_{y,r} = q_{y,r} \cdot I_{y,r}$$

Finally, the survey index is a function of the modelled survey WPUE of all sizes of Pacific halibut (primarily O26), and the geographic extent (*A*) of each Biological Region:

$$I_{y,r} = WPUE_{y,r} \cdot A_r$$

O26 mortality is used in this calculation as it corresponds most closely to the TCEY, or the mortality limit set by the Commission. In this calculation, it is assumed that the catchability parameter is constant (or at least that variation is random) across years and among Biological Regions (note that the FISS timing and station-specific hook competition are already accounted for in the space-time modelling of WPUE; IPHC-2021-AM097-07). Since the absolute scale of the exploitation is unknown, an arbitrary scalar (*k*) is used to make the results easily interpretable, leaving the estimated relative exploitation ($\widehat{U}$) as:

$$\widehat{U}_{y,r} = \frac{C_{y,r}}{I_{y,r}} k$$

An arbitrary value of *k* was used that resulted in the coastwide aggregate in the terminal year taking a value of 1.0. Much higher *U* values are estimated for Biological Region 2 than in other Regions; however, all Regions experienced peak harvest rates between 2003 and 2009 (Figure 4). The harvest rates in all Biological Regions were generally lower than most historical values over the period 2012 -2014, and then increased in Regions 2-3 during 2017-20. These coastwide results are generally consistent with those from the surplus production analyses described above, and also provide a corroboration of Region-specific harvest rate trends that does not rely on assessment model output.

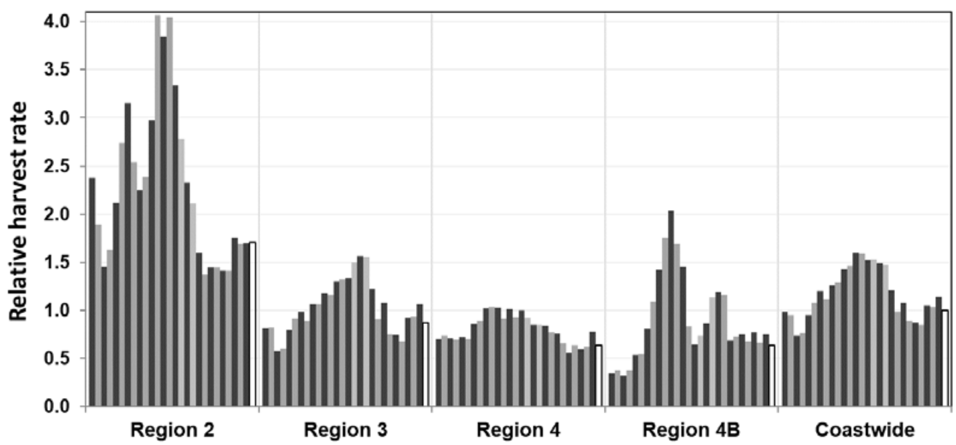

Figure 4. Empirical harvest rates from 1993-2020. All rates are relative to the coastwide aggregate in the terminal year (open bars), which is arbitrarily set equal to 1.0.

SOFTWARE UPDATES

As described for SRB018, the stock synthesis software was updated in the spring of 2021 to version 3.30.16.02 (Methot Jr et al. 2020), which resulted in no change to results, but an increase in model run times. A newer version (3.30.17.00) is now available (Methot Jr et al. 2021). Updating to this version again produced no change in model results, but improved run times to be consistent with older versions and will be used for the 2021 stock assessment. Keeping the Pacific halibut assessment models current will make future transitions easier and facilitate development during the next full assessment.

ADDITIONAL STOCK ASSESSMENT DEVELOPMENT IN 2021

During 2021 the Secretariat has begun exploration of marine mammal depredation reported in commercial fishery logbooks. New fields were included in the 2017 and 2018 fishery logbooks (depending on the IPHC Regulatory Area and whether a new log was requested/required) allowing for the documentation of marine mammal encounters (primarily orca and sperm whales) during directed commercial Pacific halibut fishing. The specific information requested includes: the type and number of marine mammals observed (if any), and the type and extent of gear and/or catch damage observed (if any). Based on analysis of FISS data, gear or catch damage is often indicative of depredation. From these records it will be possible to estimate the frequency with which the directed commercial fishery is encountering marine mammals and therefore potentially experiencing depredation. They may also allow for the development of indicators of the degree of depredation that is occurring, including the change in Catch-Per-Unit-Effort (CPUE) relative to nearby fishing that occurred in the absence of whale activity. As these data have not been previously analyzed, an extensive effort is being made to evaluate the consistency and accuracy of the data collection, as well as the formatting of the information in IPHC databases. Preliminary results may be available for presentation at SRB019.

PRELIMINARY DATA UPDATES

No preliminary data were available from 2021 in time for inclusion in this document. Standard data sources that will be included in the final 2021 stock assessment include:

1) New modelled trend information from the 2021 FISS for all IPHC Regulatory Areas.
2) Age, length, individual weight, and average weight-at-age estimates from the 2021 FISS.
3) 2021 (and a small amount of 2020) Directed commercial fishery logbook trend information from all IPHC Regulatory Areas.
4) 2021 Directed commercial fishery biological sampling (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas.
5) Directed commercial fishery sex-ratio-at-age data from the 2020 fishery (extending the series to four years: 2017-2020) are anticipated to be available prior to SRB2019. Preliminary summary and models fitted to these data may be presented if time-permits.
6) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2020.
7) Updated mortality estimates from all sources for 2020 (where preliminary values were used) and estimates for all sources in 2021.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-06 which provides a response to requests from SRB018, and an update on model development for 2021.
b) **RECOMMEND** any changes to be included in the final 2021 stock assessment to be completed for presentation at IM097, 30 November – 1 December 2021.
c) **REQUEST** any further analyses to be provided at SRB020, June 2021.

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IPHC Secretariat MSE Program of Work (2021–2023) and an update on progress

PREPARED BY: IPHC SECRETARIAT (A. HICKS & I. STEWART; 19 AUGUST 2021)

PURPOSE

To provide the SRB with a description of the Management Strategy Evaluation program of work for 2021–2023 and update the SRB on recent MSE progress.

1 INTRODUCTION

The current interim management procedure (MP) at the International Pacific Halibut Commission (IPHC) is shown in Figure 1.

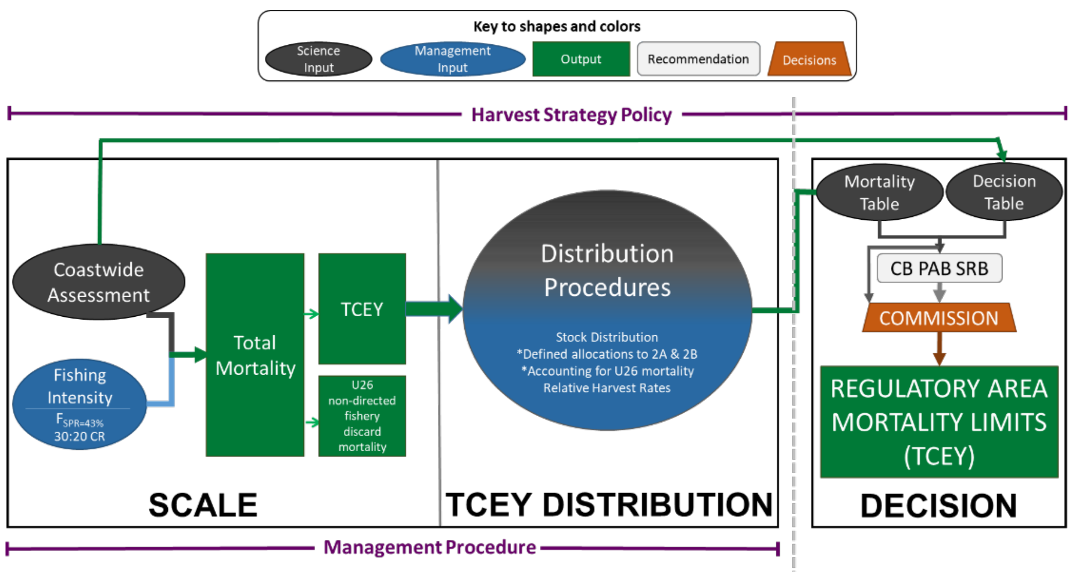

Figure 1. Illustration of the Commission interim IPHC harvest strategy policy (reflecting paragraph ID002 in IPHC CIRCULAR 2020-007) showing the coastwide scale and TCEY distribution components that comprise the management procedure. Items with an asterisk are interim agreements to 2022. The decision component is the Commission decision-making procedure, which considers inputs from many sources.

The Management Strategy Evaluation (MSE) at the IPHC completed an evaluation in 2021 of management procedures (MPs) relative to the coastwide scale and distribution of the Total Constant Exploitation Yield (TCEY) to IPHC Regulatory Areas for the Pacific halibut fishery using a recently developed framework. The development of this MSE framework aimed to support the scientific, forecast-driven evaluation of the trade-offs between fisheries management scenarios. The MSE framework with a multi-area operating model (OM) and three options for examining estimation error is described in Hicks et al. (2020) with technical details available in IPHC-2021-MSE-01. Descriptions of the MPs evaluated and simulation results are presented in Hicks et al. (2021). Additional tasks were identified at the 11th Special Session of the IPHC (IPHC-2021-SS011-R) to supplement and extend this analysis for future evaluation (Table 1).

Table 1. Tasks recommended by the Commission at SS011 (IPHC-2021-SS011-R para 7) for inclusion in the IPHC Secretariat MSE Program of Work for 2021–2023.

ID	Category	Task	Deliverable
F.1	Framework	Develop migration scenarios	Develop OMs with alternative migration scenarios
F.2	Framework	Implementation variability	Incorporate additional sources of implementation variability in the framework
F.3	Framework	Develop more realistic simulations of estimation error	Improve the estimation model to more adequately mimic the ensemble stock assessment
F.5	Framework	Develop alternative OMs	Code alternative OMs in addition to the one already under evaluation.
M.1	MPs	Size limits	Identification, evaluation of size limits
M.3	MPs	Multi-year assessments	Evaluation of multi-year assessments
E.3	Evaluation	Presentation of results	Develop methods and outputs that are useful for presenting outcomes to stakeholders and Commissioners

2 VARIABILITY IN THE MSE FRAMEWORK

The IPHC MSE closed-loop simulation framework consists of an operating model written in C++ that incorporates management procedures that are written in R. Figure 2 shows the elements of the closed-loop simulation and the annual process of an MP feeding back into the simulated population (OM).

At SRB018, the SRB requested an improved explanation of variation included in the MSE.

> IPHC-2021-SRB018-R, para. 30: *The SRB* ***REQUESTED*** *that the IPHC Secretariat present a revised system diagram of the MSE, showing components of variability and their implementation within MSE.*

Leach et al. (2014) identified eight categories of uncertainty from the initial MSE of North Atlantic swordfish (*Xiphias gladius*) (see Sharma et al. 2020). These eight categories each contained multiple sources of uncertainty which provide a convenient framework for considering the components in the Pacific halibut MSE framework. We subsumed the "Recruitment" category into the "Population" category and list important sources of variability for the remaining seven categories in Table 2.

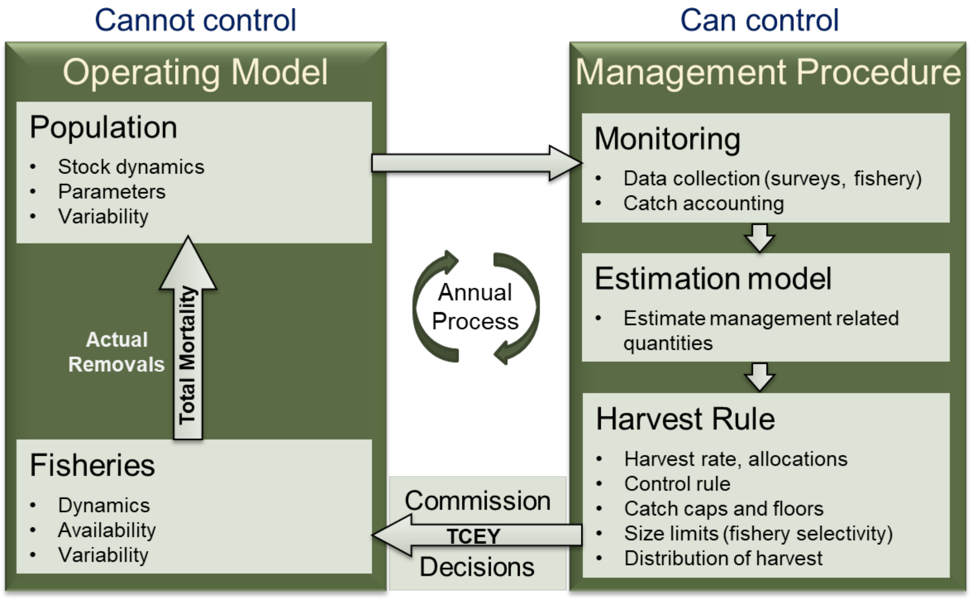

Figure 2. Illustration of the closed-loop simulation framework with the operating model (OM) and the management procedure (MP). This is the annual process on a yearly timescale.

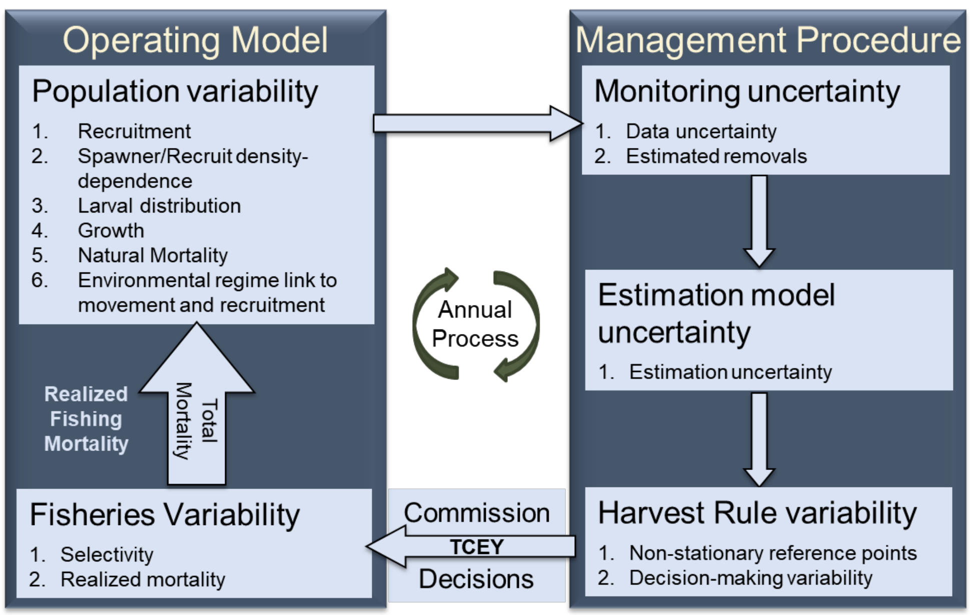

Figure 3. Sources of variability incorporated into the IPHC MSE closed-loop simulation framework. Additional sources of variability not currently included in this framework are listed in Table 2.

Figure 3 shows the sources of variability that are currently included in the IPHC MSE closed-loop simulation framework and under which elements they occur within the framework. Many sources of variability occur within the operating model because it contains many unknowns, and the goal of MSE is to identify management strategies that are robust to the unknowns. The management procedure inherently contains uncertainty because of the sampling process and the use of an estimation model. The harvest rule uses dynamic reference points and the Commission may depart from the specific harvest rule outcome, which is called decision-making variability. Future additions of variability sources are indicated with italic script in Table 2.

Table 2. Sources of variability for seven categories (based on Leach et al. (2014)) for the Pacific halibut MSE. Items not currently included in the IPHC MSE framework are shown with bullets and in italics. Shaded cells indicate combinations of categories and elements that do not have sources of variability identified.

	MSE Framework Element (Figure 2)				
Leach et al. (2014) Categories	**Population**	**Fisheries**	**Monitoring**	**Estimation Model**	**Harvest Rule**
Reference points					1. Non-stationary
Population structure	1. Recruitment 2. Spawner/Recruit density-dependence 3. Larval distribution • *Stock structure* • *Annual movement*				
Model	• *Number of bio-regions* • *Density-dependent processes (other than recruitment)*	1. Selectivity • *Number of fisheries/sectors* • *Catchability*	• *Data generation processes*	• *Estimation model structure*	
Management		• *Response of fisheries*	1. Uncertain data	1. Estimation uncertainty	2. Decision-making variability
Life History Traits	4. Growth 5. Natural mortality • *Maturation, fecundity, spawning*				
Environmental	6. Regimes 6.1. Movement 6.2. Recruitment • *Growth* • *Mortality* • *Climate change*	• *Effects on fisheries*	• *Effects on data collection*		• *Response of harvest rule*
Fishing mortality (catch)		2. Realized removals	2. Estimated removals		

3 MSE RESULTS FOR BIENNIAL STOCK ASSESSMENTS

One of the tasks recommended by the Commission at SS011 (Table 1, IPHC-2021-SS011-R para 7) for inclusion in the IPHC Secretariat MSE Program of Work for 2021–2023 was to investigate multi-year assessments. This would be an MP that incorporates a process where the stock assessment occurs at intervals longer than annually. The mortality limits in a year with the stock assessment can be determined as in previously defined MPs, but in years without a stock assessment, the mortality limits would need an alternative approach. This may be as simple as maintaining the same mortality limits for each IPHC Regulatory Area in years with no stock assessment, or as complicated as invoking an alternative MP that does not require a stock assessment (such as an empirical-based MP relying only on data/observations).

Simulations using a MP where the stock assessment occurs biennially and the mortality limits remain unchanged from the previous year were performed using the MSE framework. The specifications of the simulation model are the same as reported in Hicks et al. (2020), Hicks et al. (2021), and IPHC-2021-MSE-01. The MP specified as A was used with the addition of a biennially assessment (Table 3). Coastwide performance metrics for MP-A with and without the biennial mortality limit specification are shown in Table 4 along with MP-D and MP-J which were the best performing MPs from the previous MSE simulations.

Table 3. Specifications of MPs with an annual stock assessment and management advice (MP-A, MP-D, and MP-J), and with a biennial stock assessment and mortality limit specification (MP-A2).

Element	MP-A	MP-A2	MP-D	MP-J
Maximum coastwide TCEY change of 15%				
Maximum Fishing Intensity buffer (SPR=36%)				
O32 stock distribution				
O32 stock distribution (5-year moving average)				
All sizes stock distribution				
Fixed shares updated in 5th year from O32 stock distribution				
Relative harvest rates of 1.0 for 2-3A, and 0.75 for 3B-4				
Relative harvest rates of 1.0 for 2-3, 4A, 4CDE, and 0.75 for 4B				
Relative harvest rates by Region: 1.0 for R2-R3, 0.75 for R4-R4B				
1.65 Mlbs fixed TCEY in 2A				
Formula percentage for 2B				
National Shares (2B=20%)				
Frequency of stock assessment & mortality limits				

Table 4. Coastwide long-term performance metrics for the biological sustainability objective and P(all RSB<36%) and short-term performance metrics for the remaining fishery sustainability objectives for MPs A, D, and J with an annual mortality limit setting process, and MP-A with a biennial mortality limit setting process (A2). All results use an SPR value of 43% with simulated estimation error.

Input SPR/TM	**43**	**43**	**43**	**43**
Management Procedure	**A**	**A2**	**D**	**J**
Number of Simulations	500	480	500	500
Biological Sustainability				
P(any RSB_y<20%)	<0.01	<0.01	0.01	<0.01
Fishery Sustainability				
P(all RSB<36%)	0.25	0.28	0.44	0.28
Median average TCEY (Mlbs)	39.92	38.31	40.22	37.90
P(any3 change TCEY > 15%)	0.44	0.36	0.10	0.00
Median AAV TCEY	12.1%	9.0%	5.9%	9.5%

The biennial mortality limit specification improved the coastwide performance metrics related to variability in the TCEY compared to MP-A with an annual mortality limit specification. The median average TCEY was less than MP-A and MP-D, but slightly higher than MP-J. The median relative spawning biomass was above the 36% target, but slightly closer than MP-A.

MP-A2 shows a different pattern of variability that is not completely captured with the performance metrics presented in Table 4. The variability performance metrics with the biennial mortality limit specification show improvements because half of the years in a ten-year period have no change in the TCEY compared to an MP with an annual mortality limit specification while the other half may show a slightly larger change. Trajectories of the projected TCEY for a 60-year period show the biennial specification process in MP-A2 (Figure 4). Comparing the trajectories for MP-A and MP-A2 shows that the biennial process generally follows the annual process but with steps. However, there are cases where the biennial process takes longer to catch up (e.g. the start of the trajectory) and where the biennial process does not unnecessarily change the TCEY (e.g. near the year 2065 for some simulations).

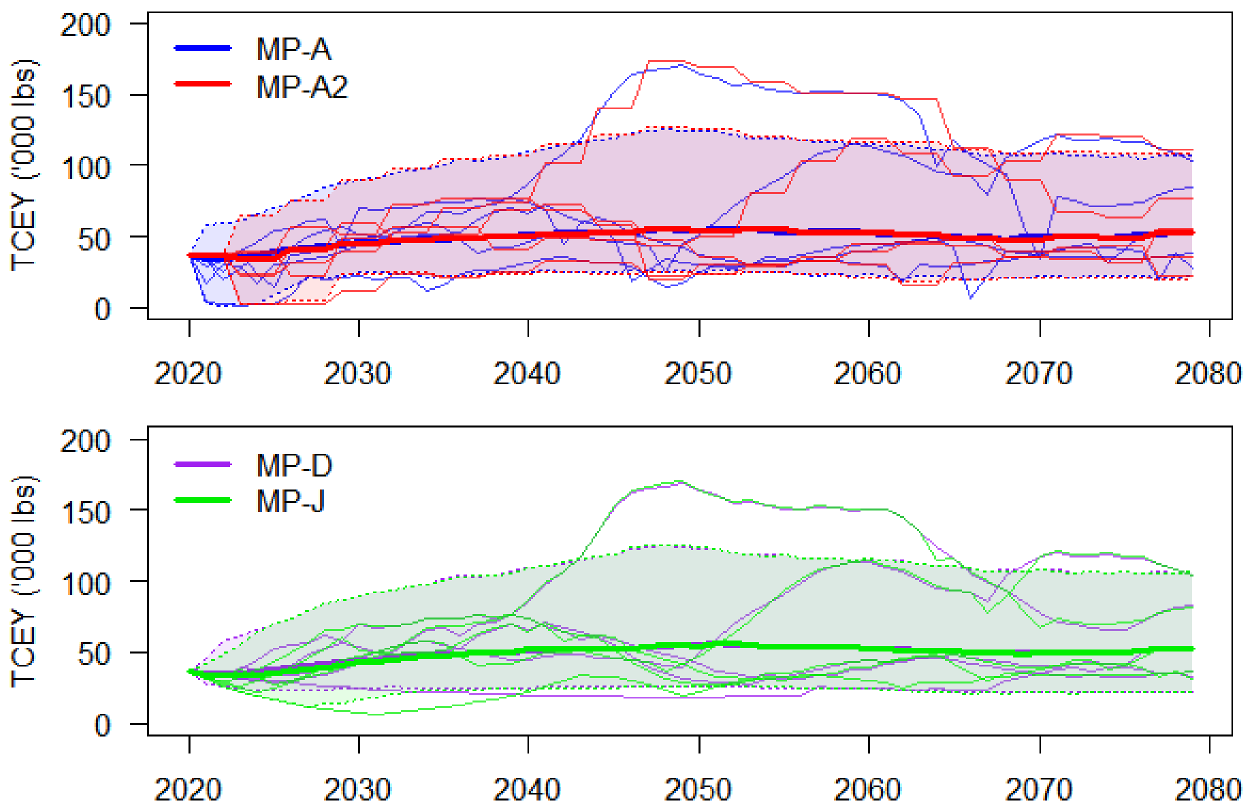

Figure 4. Trajectories of TCEY for MPs A, D, and J with an annual mortality limit setting process, and MP-A with a biennial mortality limit specification process (A2). All results use an SPR value of 43% with simulated estimation error. The 5th and 95th quantiles are shown as a shaded polygon. Five individual trajectories are shown as thin lines and the median of all simulations is shown as a thick line.

Therefore, three new performance metrics are reported to provide a better indication of how the TCEY may change in a given year. Over a ten-year period these are, the probability that the TCEY exceeds a change greater than 15% in any one year [P(any1 change TCEY > 15%)], the probability that the TCEY exceeds a change greater than 15% in any two years [P(any2 change TCEY > 15%)], and the median maximum absolute percentage change (up or down) in the TCEY over a 10-year period (Median max abs % change TCEY). Table 5 shows that all of these performance metrics are highest for MP-A2, indicating that the change in the TCEY is typically higher in years when it changes compared to an annual mortality limit specification process. Although the maximum absolute percent change in the TCEY is on average higher for MP-A2 compared to MP-A, the inter-quartile range (middle 50% of the distribution) is diminished for MP-A2 compared to MP-A (Figure 5).

Overall, there is a clear trade-off between slightly higher biennial change and consistency within each two-year period. The benefits to a biennial mortality limit specification include stability for a two-year period and resources needed for conducting a stock assessment can be directed towards other research such as improving the stock assessment or MSE. However, it is likely that the change in the mortality limit every other year may be larger than desired for an annual process. These trade-offs must be considered when analysing any MP with a biennial mortality limit specification.

Table 5. Additional coastwide short-term and long-term performance metrics for the fishery sustainability objectives related to TCEY variability for MPs A, D, and J with an annual mortality limit setting process, and MP-A with a biennial mortality limit specification process (A2). All results use an SPR value of 43% with simulated estimation error.

	Short-term				**Long-term**			
Input SPR/TM	**43**	**43**	**43**	**43**	**43**	**43**	**43**	**43**
Management Procedure	**A**	**A2**	**D**	**J**	**A**	**A2**	**D**	**J**
Fishery Sustainability								
P(any1 change TCEY > 15%)	0.75	0.93	0.56	0.00	0.46	0.67	0.17	0.00
P(any2 change TCEY > 15%)	0.63	0.74	0.26	0.00	0.31	0.32	0.02	0.00
Median max absolute % change TCEY	18%	23%	11%	15%	13%	21%	9%	14%

The mortality limit does not need to be held constant in years when there is no stock assessment, but may instead use other methods to determine a mortality limit. The projection from the stock assessment may be used, or an empirical, data-driven approach can inform changes to the mortality limit. This may reduce the potential for large changes in years when a stock assessment is used for setting the mortality limit and could be extended to periods of longer than 2 years between stock assessments.

An alternative approach that would not require a stock assessment would be to adopt an empirical-based MP as the method for setting annual mortality limits. The stock assessment would not be used specifically to set mortality limits but would be used at a defined interval to verify that management is effective and to potentially tune the MSE and existing MP (Cox and Kronlund 2008). Any of the MPs mentioned in this section, empirical- or model-based or a hybrid of the two, can be evaluated using the current MSE framework.

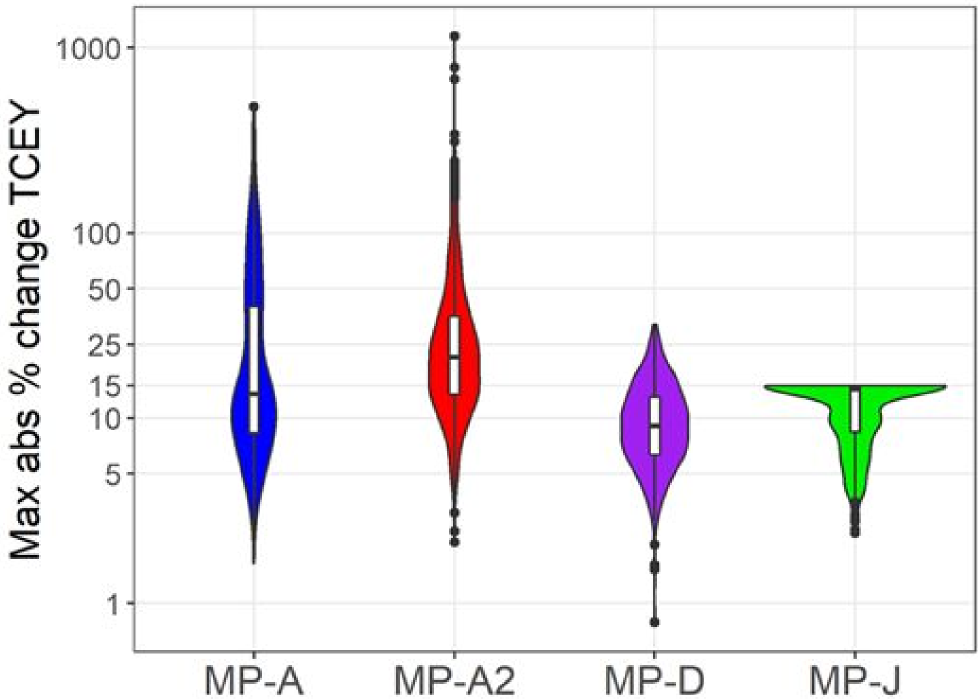

Figure 5. Boxplots (white) within violin plots (colors) of short-term maximum percent absolute change in the TCEY for MPs A, D, and J with an annual mortality limit setting process, and MP-A with a biennial mortality limit specification process (MP-A2). All results use an SPR value of 43% with simulated estimation error. A value of 15% is shown as a horizontal grey line. White boxes represent the interquartile (50%) range with the median (dark solid line).

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-07 describing the MSE Program or Work for 2021–2023, sources of variability in the MSE framework, and results from simulations with a biennial mortality limit specification.

b) **RECOMMEND** MP specifications to investigate multi-year stock assessments as part of the MSE program of work for 2021-2023.

c) **REQUEST** any further analyses to be provided at SRB020, June 2021.

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APPENDICES

Nil

Report on Current and Future Biological and Ecosystem Science Research Activities

PREPARED BY: IPHC SECRETARIAT (J. PLANAS, 20 AUGUST 2021)

PURPOSE

To provide the Scientific Review Board with a description of progress on IPHC's five-year Biological and Ecosystem Science Research Plan (2017-21).

BACKGROUND

The primary biological and ecological research activities at IPHC that follow Commission objectives are identified and described in the IPHC Five-Year Biological and Ecosystem Science Research Plan (2017-21). These activities are integrated with stock assessment and the management strategy evaluation processes (Appendix I) and are summarized in five main areas, as follows:

1) Migration and Distribution. Studies are aimed at further understanding reproductive migration and identification of spawning times and locations as well as larval and juvenile dispersal.
2) Reproduction. Studies are aimed at providing information on the sex ratio of the commercial catch and to improve current estimates of maturity.
3) Growth and Physiological Condition. Studies are aimed at describing the role of some of the factors responsible for the observed changes in size-at-age and to provide tools for measuring growth and physiological condition in Pacific halibut.
4) Discard Mortality Rates (DMRs) and Survival. Studies are aimed at providing updated estimates of DMRs in both the longline and the trawl fisheries.
5) Genetics and Genomics. Studies are aimed at describing the genetic structure of the Pacific halibut population and at providing the means to investigate rapid adaptive changes in response to fishery-dependent and fishery-independent influences.

A ranked list of biological uncertainties and parameters for stock assessment (Appendix II) and the management strategy evaluation process (Appendix III) and their links to research activities and outcomes derived from the five-year research plan are provided.

SRB RECOMMENDATIONS AND REQUESTS

The SRB issued the following recommendations and requests in their report of SRB018 (IPHC-2021-SRB018-R):

*Request 1 (*SRB018–Req.08 (para. 39))

> ***"****The SRB* ***REQUESTED*** *that the IPHC Secretariat focus future reproductive biology studies on the development of updated regulatory area-specific maturity ogives (schedules of percent maturity by age).."*

The IPHC Secretariat is focusing studies on the development of updated maturity ogives (please see Section 2.2.2., page 04)

*Request 2 (*SRB018–Req.09 (para. 40))

> ***"****The SRB* ***REQUESTED*** *that the IPHC Secretariat provide information on the age distribution of all females collected to characterize reproductive development throughout the annual cycle in order to refine efforts to identify potential skip-spawning females."*
>
> The IPHC Secretariat has provided the age distribution of Pacific halibut females collected throughout an annual cycle to characterize reproductive development in this document (please see Section 2.2.4, page 05).

*Request 3 (*SRB018–Req.10 (para. 41))

> ***"****The SRB* ***REQUESTED*** *that planned studies on fecundity assessment are prioritized and that the sampling design be developed in coordination with the SA to ensure that the results are as informative as possible for assessment purposes. Effective sample stratification along age, weight and length gradients that maximise the contrast in the effect of these variables will be key to precise estimates of fecundity. Oocyte diameter in contrast may be a important covariate to provide but cannot be used in stratification. The primary goal of the fecundity research should be to estimate the exponent of the fecundity vs. weight relationship for incorporation in the SA"*
>
> The Secretariat has prioritized studies on fecundity assessment. Sampling design considerations are currently being evaluated and will be discussed at SRB019.

*Request 4 (*SRB018–Req.11 (para. 42))

> ***"****The SRB* ***REQUESTED*** *that the Secretariat explicitly describe how the gene regions identified as 'over' or 'under' expressed would be used. For example, research has yet to determine mechanisms for transcriptional differences other than there is over- or under-representation of mRNA transcripts associated with different treatment groups (e.g. warm vs. cool water) from a heterogeneous set of individuals collected from a single location. The Secretariat has not yet established that results can be generalized to other regions in the species range. Neither has the transcriptional patterns been generalized to individuals of different size/age. These questions should be investigated."*

The IPHC Secretariat is currently working towards fulfilling this request.

*Request 5 (*SRB018–Req.12 (para. 43))

> ***"****The SRB* ***REQUESTED*** *that the Secretariat use these gene regions and align sequences to the whole genome sequence data. Specifically, the Secretariat should investigate whether there is sequence variability within gene coding regions or in regions around gene coding regions that may be transcriptional modifiers (e.g. promoters). If genetic variation exists in or near these genes, these variable base pair position(s) (i.e. single nucleotide polymorphisms*

or SNPs) should be incorporated in other aspects of the Secretariat research; for example for research activities under the Migration and Population Dynamics Research area."

The IPHC Secretariat is currently working towards fulfilling this request and initial efforts are described in this document (please see Section 3.2) and results will be presented at SRB019.

*Request 6 (*SRB018–Req.13 (para. 44))

*"The SRB **REQUESTED** that the analysis of seasonal patterns in gonad development be explicitly tied to the development/improvement of the maturity ogive (the vector of proportion mature at age that SA requires)."*

The IPHC Secretariat has explicitly tied the analysis of seasonal patterns in gonad development to the development/improvement of the maturity ogive (Appendix IV).

UPDATE ON PROGRESS ON THE MAIN RESEARCH ACTIVITIES

1. Migration and Distribution.

   Research activities in this Research Area aim at improving existing knowledge on Pacific halibut larval and juvenile distribution. The relevance of research outcomes from these activities for stock assessment (SA) is in the improvement of estimates of productivity. These research outcomes will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region and represent one of the top three biological inputs into SA (Appendix II). The relevance of these research outcomes for the management and strategy evaluation (MSE) process is in the improvement of the parametrization of the Operating Model and represent the top ranked biological input into the MSE (Appendix III).

   1.1. Larval distribution and connectivity between the Gulf of Alaska and Bering Sea.
   Principal Investigator: Lauri Sadorus (M.Sc.)

   No updates to report.

   1.2. Wire tagging of U32 Pacific halibut.
   Principal Investigator: Joan Forsberg (B.Sc.)

   No updates to report.

2. Reproduction.

   Research activities in this Research Area aim at providing information on key biological processes related to reproduction in Pacific halibut (maturity and fecundity) and to provide sex ratio information of Pacific halibut commercial landings. The relevance of research outcomes from these activities for stock assessment (SA) is in the scaling of Pacific halibut biomass and in the estimation of reference points and fishing intensity. These research outputs will result in a revision of current maturity schedules and will be included as inputs into the SA (Appendix II), and represent the most important biological inputs for stock assessment (please see document IPHC-2021-SRB018-06). The relevance of these research outcomes for the management and strategy evaluation (MSE) process is in the improvement of the simulation of spawning biomass in the Operating Model (Appendix III).

2.1. Sex ratio of the commercial landings.
Principal Investigator: Anna Simeon (M.Sc.)

The IPHC Secretariat has finalized the processing of genetic samples from the 2020 age commercial landings, completing four consecutive years of sex ratio information (2017-2020).

2.2. Maturity assessment.
Principal Investigator: Josep Planas (Ph.D.)

Recent sensitivity analyses have shown the importance of changes in spawning output due to skip spawning and/or changes in maturity schedules for stock assessment (Stewart and Hicks, 2018). Information of these key reproductive parameters provides direct input to stock assessment. For example, information on fecundity-at-age and –at-size could be used to replace spawning biomass with egg output as the metric of reproductive capability in the stock assessment and management reference points. This information highlights the need for a better understanding of factors influencing reproductive biology and success of Pacific halibut. In order to fill existing knowledge gaps related to the reproductive biology of female Pacific halibut, research efforts are devoted to characterize female maturity in this species. Specific objectives of current studies include: 1) histological assessment of the temporal progression of female developmental stages and reproductive phases throughout an entire reproductive cycle; 2) update of maturity schedules based on histological-based data; 3) fecundity determinations, and 4) investigations on skip-spawning.

2.2.1. Histological assessment of the temporal progression of female developmental stages and reproductive phases throughout an entire reproductive cycle. Details on sample collection, histological protocols and analyses, and results on reproductive developmental characteristics by month, by ovarian developmental stage and by reproductive phase in Pacific halibut females were provided in document IPHC-2021-SRB018-08. A manuscript describing the temporal progression of reproductive development in female Pacific halibut and the relationship of reproductive development with physiological condition indicators (e.g. hepatosomatic index, Fulton's condition factor, fat content) is currently being finalized for submission to a peer-reviewed journal (Fish et al., in preparation).

2.2.2. Update of maturity schedules based on histological-based data. An important outcome of the work conducted on the seasonal characterization of female reproductive development (Section 2.2.1; Appendix IV) has been to determine that the months of July and August represent an appropriate time during the FISS for the collection of ovaries for updating maturity schedules and fecundity estimations. The IPHC Secretariat is currently investigating various sampling designs for ovarian sample collection during the 2022 FISS effort.

2.2.3. Fecundity estimations. Methods for fecundity determinations are currently being researched and will be selected based on accuracy and feasibility for Pacific halibut field collections. Ovaries from three females that are classified as maturing (stage 2) have been collected during the 2021 FISS for testing selected fecundity assessment methods in the Fall of 2021.

2.2.4. Investigation on skip spawning. As reported in document IPHC-2021-SRB018-08, only eight out of 180 Pacific halibut females (4.4%) collected during the spawning capable phase (August to February) showed histological signs of reproductive delay and were only identified in the months of November (1) and December (7). Ages of these females were 10 yrs (1), 11 yrs (2), 12 yrs (2), 14 yrs (1) and 15 yrs (2). The age distribution of the entire collection of aged Pacific halibut females collected between September 2017 and August 2018 and used for characterizing seasonal reproductive development (n=342; Section 2.2.1) is shown in Figure 1. Therefore, the proportion of sampled females that showed reproductive delay was 11.1% at 10 yrs (n=9), 12.5% at 11 yrs (n=16), 4.7% at 12 yrs (n=42), 1.7% at 14 yrs (n=57), and 3.6% at 15 yrs (n=56). Given that 11.6 years is the estimated average age at which 50% of female Pacific halibut are sexually mature (Stewart and Webster, 2021), with nearly all fish estimated to mature by approximately age 17, it cannot be fully determined if the observed reproductive delays in eight females of ages 10 to 15 represent a delay of immature females entering puberty (initiation of the first reproductive cycle) or a delay in the initiation of a given reproductive cycle after having successfully spawned previously (i.e. mature females skipping a reproductive cycle). A larger sample size during the spawning capable phase (ideally during the late FISS season) would be needed to further characterize the observed reproductive delays, likely in combination with the work proposed in Section 2.2.2.

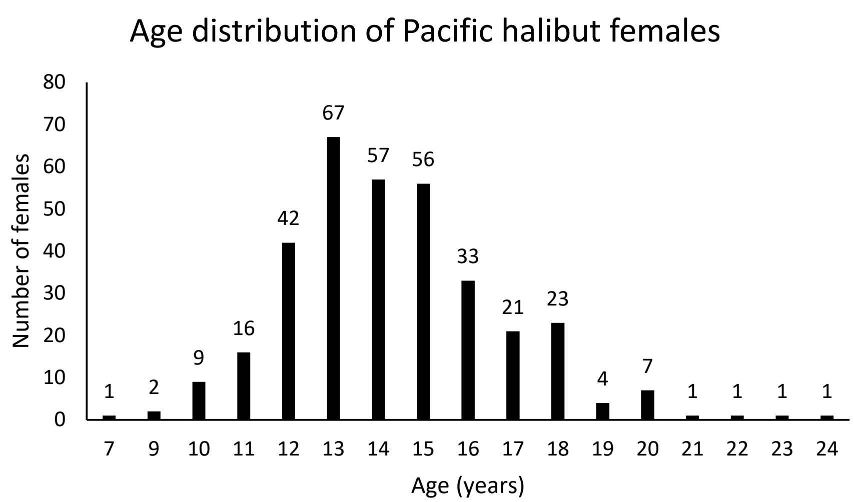

Figure 1. Distribution of ages of Pacific halibut females collected from September 2017 until August 2018 for analyses of reproductive progression over an annual reproductive cycle.

3. Growth.
   Principal Investigator: Josep Planas (Ph.D.)

   Research activities conducted in this Research Area aim at providing information on somatic growth processes driving size-at-age in Pacific halibut. The relevance of research outcomes from these activities for stock assessment (SA) resides, first, in their ability to inform yield-per-recruit and other spatial evaluations for productivity that support mortality limit-setting, and, second, in that they may provide covariates for projecting short-term size-at-age and may help delineate between fishery and environmental effects, thereby informing appropriate management responses (Appendix II). The relevance of these research outcomes for the management and strategy evaluation (MSE) process is in the improvement of the simulation of variability and to allow for scenarios investigating climate change (Appendix III).

   The IPHC Secretariat has conducted studies aimed at elucidating the drivers of somatic growth leading to the decline in SAA by investigating the physiological mechanisms that contribute to growth changes in the Pacific halibut. The two main objectives of these studies have been: 1) the identification and validation of physiological markers for somatic growth; and 2) the application of molecular growth markers for evaluating growth patterns in the Pacific halibut population.

   3.1. Identification and validation of physiological markers for somatic growth. A manuscript describing the procedures and results of this study is in preparation (Planas et al., in preparation; provided previously).

   3.2. Application of molecular growth markers for evaluating growth patterns in the Pacific halibut population. The IPHC Secretariat is conducting a test of a set of real time qPCR-validated gene markers (alpha actin, asparagine synthetase, fast muscle myosin heavy chain, myosin regulatory light chain 2, ornithine carbamoyltransferase, fructose-2,6-bisphosphatase) on skeletal muscle samples from juvenile Pacific halibut. These muscle samples correspond to a total of 30 age-matched individuals (4 years-old) of different sizes and are being used to test the hypothesis that size differences in age-match individuals are reflected by differences in the mRNA expression levels of growth marker genes, as assessed by real time qPCR. The muscle samples that are currently being processed correspond to three size categories of juvenile Pacific halibut: 30-36 cm (N=10), 44 cm (N=10) and 53-61 cm (N=10) in fork length.

   In response to SRB018–Req.12 (para. 43), The IPHC Secretariat has selected ten putative growth marker genes that showed significant down-regulation during temperature-induced growth suppression and significant up-regulation during temperature-induced compensatory growth stimulation at the mRNA level in skeletal muscle from juvenile Pacific halibut, as described in the supplementary data provided for SRB018-08 (Table 6). These transcripts were mapped to the Pacific halibut genome to identify the presence of sequence variability (SNPs) within coding and non-coding regions of these genes. In brief, Minimap2 (v2.17) (Li 2018) was used to align the assembled transcripts associated with the putative growth marker genes to the Pacific halibut genome (GCF_013339905.1). Transcripts were aligned using the "--splice" preset option enabled. For transcripts that aligned to the genome, the NCBI RefSeq annotation of the Pacific halibut genome was searched for any genes that overlapped the alignment and were oriented in the same direction as the alignment. The coding regions of the largest transcript for each of these genes were initially compared to the positions of 10,474,925 SNPs identified by low-coverage whole-genome resequencing of 285 individual Pacific halibut (please see Section 5.1.1 for details on sequencing and SNP identification). An additional region defined as 5kb upstream from the start of these genes was also interrogated to identify SNPs that may be involved in the transcriptional regulation of these genes. The preliminary results indicate that the transcripts associated with growth in Pacific halibut overlapped with genes in the Pacific halibut NCBI RefSeq annotation. A total of 1,299 SNPs were located in the regions examined and may potentially have some influence on growth (Table 1). Current efforts are now devoted to characterizing SNPs in the coding sequence and upstream regulatory regions of these putative growth marker genes. As a result of this effort, a bioinformatic pipeline is now in place to interrogate SNPs in and around gene regions that can be incorporated into future Secretariat research.

Transcript ID	Gene	Annotation	Non-coding	Coding	Five prime flanking
TRINITY_DN102963_c0_g1_i1	LOC118098571	glycine--tRNA ligase-like	86	11	94
TRINITY_DN98755_c4_g1_i1	LOC118105518	myosin heavy chain, fast skeletal muscle-like	60	39	30
TRINITY_DN88997_c0_g1_i1	LOC118110038	troponin I, slow skeletal muscle-like	52	6	94
TRINITY_DN105325_c2_g1_i1	LOC118118854	zinc finger protein 638-like	529	52	101
TRINITY_DN104023_c1_g2_i2	LOC118124806	asparagine synthetase [glutamine-hydrolyzing]-like	242	23	77
TRINITY_DN105033_c2_g1_i1	acta1a	actin alpha 1, skeletal muscle a	18	7	104
TRINITY_DN97221_c0_g3_i1	mylpfb	myosin light chain, phosphorylatable, fast skeletal muscle b	29	2	71
TRINITY_DN97789_c1_g1_i1	rhcga	Ammonium transporter, Rh family, C glycoprotein a	30	7	28
TRINITY_DN87895_c0_g1_i2	ttn.1	titin, tandem duplicate 1	420	205	124
TRINITY_DN106670_c2_g1_i1	ubp1	upstream binding protein 1	121	7	84

Table 1. Summary of SNPs present in genes associated with growth in Pacific halibut.

4. Discard Mortality Rates (DMRs) and Survival Assessment.

Information on all Pacific halibut removals is integrated by the IPHC Secretariat, providing annual estimates of total mortality from all sources for its stock assessment. Bycatch and wastage of Pacific halibut, as defined by the incidental catch of fish in non-target fisheries and by the mortality that occurs in the directed fishery (i.e. fish discarded for sublegal size or for regulatory reasons), respectively, represent important sources of mortality that can result in significant reductions in exploitable yield in the directed fishery. Given that the incidental mortality from the commercial Pacific halibut fisheries and bycatch fisheries is included as part of the total removals that are accounted for in stock assessment, changes in the estimates of incidental mortality will influence the output of the stock assessment and, consequently, the catch levels of the directed fishery. Research activities conducted in this Research Area aim at providing information on discard mortality rates and producing guidelines for reducing discard mortality in Pacific halibut in the longline and recreational fisheries. The relevance of research outcomes from these activities for stock assessment (SA) resides in their ability to improve trends in unobserved mortality in order to improve estimates of stock productivity and represent the most important inputs in fishery yield for stock assessment (Appendix II). The relevance of these research outcomes for the management and strategy evaluation (MSE) process is in fishery parametization (Appendix III).

For this reason, the IPHC Secretariat is conducting two research projects to investigate the effects of capture and release on survival and to improve estimates of DMRs in the directed longline and guided recreational Pacific halibut fisheries:

4.1. Evaluation of the effects of hook release techniques on injury levels and association with the physiological condition of captured Pacific halibut and estimation of discard mortality using remote-sensing techniques in the directed longline fishery.
Principal Investigator: Claude Dykstra (M.Sc. candidate)

The objective of this study was to evaluate the effects of capture conditions and different hook release techniques on injury levels and associated physiological condition and survival of longline-discarded Pacific halibut.

A detailed description of fish capture conditions and related environmental parameters, hook release techniques, hook injury assessment, physiological condition and blood stress indicators was provided in document IPHC-2021-SRB018-08.

Initial data exploration focused on investigating the relationships of the hook release treatments to the biological (size, sex, somatic fat levels, Fulton's condition factor, physiological blood stress indicators) and environmental (soak time, depth, sea state, time on deck, and temperature influences) conditions and the resultant injuries and release viability classifications of the test fish. The data showed less severe injuries and nearly identical injury profiles for the two regulatorily approved removal methods (careful shake and gangion cut), and more severe injuries from the mechanical hook stripper (Section 4.1 Figure 1; provided separately). Similarly, the approved release methods resulted in significantly greater outcomes of fish in the Excellent viability category, while the hook stripper resulted in significantly higher number of fish in the Moderate and Poor viability categories.

The interplay of these variables was further investigated by conducting correlation analyses among the numeric variables collected (Section 4.1 Figure 2; provided separately). Of the three physiological blood stress indicators only lactate proved to have significantly different blood levels across release viabilities, with fish classified as “dead” having significantly higher blood lactate levels than fish in other viability categories (one-way ANOVA, $F(3,502)=16.82$, $p<0.001$) (Section 4.1 Figure 3; provided separately). This is likely related to the fact that 89% of dead sub-legal fish had sand flea presence and these fish had presumably been struggling to get away from them while hooked. Pacific halibut exhibited a wide range in the blood levels of stress indicators (glucose, lactate and cortisol) that were largely not correlated to other biological or environmental variables. Similarly, no significant differences were found between the blood parameters and individual injury or the severity of injuries incurred.

Categorical variables (release condition, injury type) where then analyzed by logistic regression through the use of generalized linear models (GLM) of the binomial family (Section 4.1 Figure 4, provided separately). Release method was examined in the model as both an additive and an interactive variable. Interactive effects were not found to improve the models. Again, the wide range of values for each numeric variable led to minimal significance in the results. When using the full set of data (including legal fish) the weight of the fish was found to have some significance for injury outcome in fish subjected to the hook stripper release method; however, when restricting to sublegal fish, this relationship disappeared. Additional analyses were attempted by making different groupings based on the injury incurred such as injury location (jaw, cheek, etc.), type (tear, puncture, other) and injury severity (minimal, fair, severe), but this did little to affect the outcome of the models.

Treating the categorical injuries as ordinal (different degrees of severity) allowed for exploration of the relationship of fish weight to injury. This was achieved through Paired Ordinal Linear Regression (POLR) analysis (Section 4.1 Figure 5; provided separately). POLR predictions for Hook Stripper are dynamically affected by the weight of the fish. In this particular hook release method, the hook is mechanically forced out through a “path of least resistance”. As a result, Pacific halibut of low weight (<10kg) predominantly suffer “Torn Face” injuries, slightly larger fish (10kg ~ 20 kg) suffer from “Cheek and Jaw” injuries, larger fish (20kg - 30kg) suffer from “Torn Jaw” injuries, even larger fish (30kg - 45kg) suffer the more typical “Torn Cheek” injuries, and finally the largest fish tend to show no severe injuries, likely due to the hook never penetrating fully through the cheek, either due to its thickness or due to stronger bones in the very large fish. Mechanistically this is an interesting observation in the dynamics of injuries in Pacific halibut and the influence of fish weight in those injuries. Results from the POLR analysis do not produce confidence bounds, so an effort is ongoing to generate an equivalent through the additive GLM models and bootstrapping of the data. The ordinality of the injuries are not fully straight forward (i.e. injuries are not uniformly distributed from one another, and many are confounded, i.e. a torn cheek hooking injury inevitably tears through the cheek, or the jaw, the more force or the less resistance provided) and this is likely constraining this form of analysis.

Principal component analysis (PCA) and Random Forest (RF) methods were also explored as part of the analysis. The underlying variability of the data made these methods largely uninformative, other than pointing to some influence of size (length correlated with weight) and the influence of sand flea presence and fish categorized as dead (Section 4.1 Figure 6, provided separately).

Survival of discarded fish was directly assessed by biotelemetric monitoring of released fish with the use of satellite-transmitting electronic archival tags equipped with accelerometers (sPAT tags), as described in document IPHC-2021-SRB018-08. Post-release behavioral data were evaluated for 75 sPAT-tagged Pacific halibut that were at liberty for 2-96 days. Three fish were confidently inferred to have died after periods at liberty of 41-80 days and another three fish may have died 96 days after release; resulting in minimum and maximum estimated 96-day post-release discard mortality rates (DMRs) of 4.2% (range = 0.0-8.7%) and 8.4% (range = 1.7-14.6%), respectively. These ranges are consistent with the currently-applied DMR value of 3.5%.

A manuscript describing discard mortality rate estimations in the directed longline fishery is currently in review in the Journal of North American Fishery Management (Loher et al., in review; provided separately).

4.2. Estimation of discard mortality rates in the charter recreational sector.
Principal Investigator: Claude Dykstra (M.Sc. candidate)

The IPHC Secretariat is conducting a research project to better characterize the nature of charter recreational fisheries with the ultimate goal of better understanding discard practices relative to that which is employed in the directed longline fishery. This project has received funding from the National Fish and Wildlife Foundation and the North Pacific Research Board (Appendix V) and the project narratives of both projects have been provided in previous meeting documentations. The experimental field components of this research project took place in Sitka, Alaska (IPHC Regulatory Area 2C) from 21-27 May 2021, and in Seward, Alaska (IPHC Regulatory Area 3A) from 11-16 June 2021, with methods and analyses detailed in the project narratives provided.

The fishing vessels were required to fish 6 rods at a time, three (3) rigged with 12/0 circle hooks and three (3) rigged with 16/0 circle hooks (Figure 1C) in order to establish a comparison of the two most common gear types used in the Pacific halibut recreational fishery, as informed by the survey conducted in 2019 and subsequent discussions. The overall goal was to capture at least 240 Pacific halibut in 2C and in 3A (480 total) over five days of fishing per Regulatory Area. In IPHC Regulatory Area

2C, we aimed to sample 60 fish in each of the following size classes: ≤ 68 cm, 69 cm – 77 cm, 78 cm – 93 cm, ≥ 94 cm (or ≤ 26.67”, 27” – 30.5”, 31” – 36.5”, ≥ 37”). In IPHC Regulatory Area 3A, we aimed to sample 60 fish from each of the following size classes: ≤ 61 cm, 62 cm – 69 cm, 70 cm – 83 cm, ≥84 cm (or ≤ 24”, 24.25” – 27”, 27.25” – 32.75”, ≥ 33”).

In IPHC Regulatory Area 2C (Sitka, AK), we captured, sampled and released 243 Pacific halibut that were on average 80.1 ± 19.0 cm in fork length (range from 52 to 149 cm) and 7.4 ± 7.5 Kg in weight (range from 1.5 to 49.75 Kg). In IPHC Regulatory Area 3A (Seward, AK), we captured, sampled and released 118 Pacific halibut that were on average 72.5 ± 14.1 cm in fork length (range from 42 to 110 cm) and 5.0 ± 3.3 Kg in weight (range from 0.55 to 17 Kg). Therefore, a total of 361 Pacific halibut were captured, sampled and released in the two research charters conducted. The distribution of lengths of all encountered fish is shown in Figure 2A, showing a similar length distribution between fish captured in the two sites. In addition, the distribution of fish lengths by hook size (12/0 and 16/0) was similar (Figure 2B).

For all Pacific halibut captured, we recorded the time from hooking to release, length and weight, the injury code and release viability category using the standard IPHC criteria, and air and fish temperature. In addition, from each fish we collected a blood sample by caudal puncture, we measured somatic fat content with the use of a Distell Fat Meter, we took a picture of the hooking injury, collected a fin clip for genetic sexing and tagged the fish with an opercular wire tag prior to release (Figure 3A). Pacific halibut captured in IPHC Regulatory Area 3A were subjected to the same sampling protocol with the exception of the 80 fish that were tagged with acceleration-logging survivorship pop-up archival transmitting (sPAT) tags. sPAT-tagged fish were selected only among those fish that were classified in the “excellent” viability category and did not have a blood sample taken to minimize handling-related stress (Figure 3B). The distribution of fish lengths by tag type (wire tag or sPAT) in fish captured and released in IPHC Regulatory Area 3A is shown in Figure 2C.

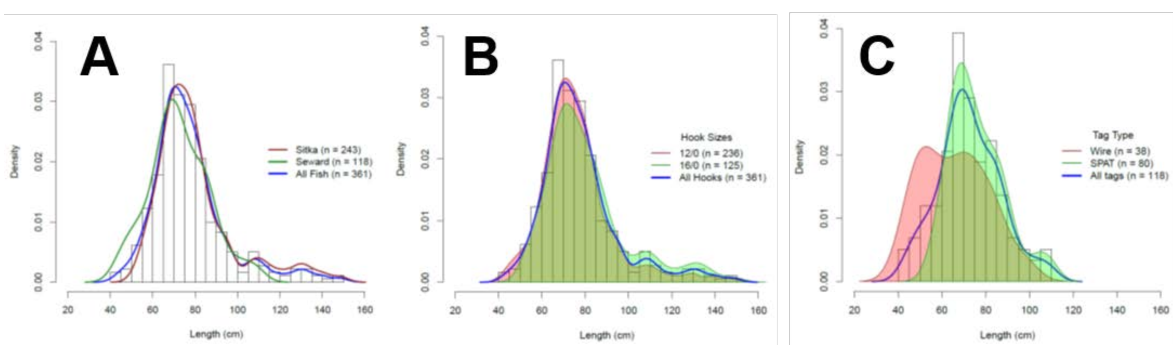

Figure 2. Length distributions of Pacific halibut captured, sampled and released by IPHC Regulatory Area (A: Sitka, AK for 2C and Seward, AK for 3A), by hook size (B: 12/0 and 16/0) and by type of tag (C: wire tag and sPAT).

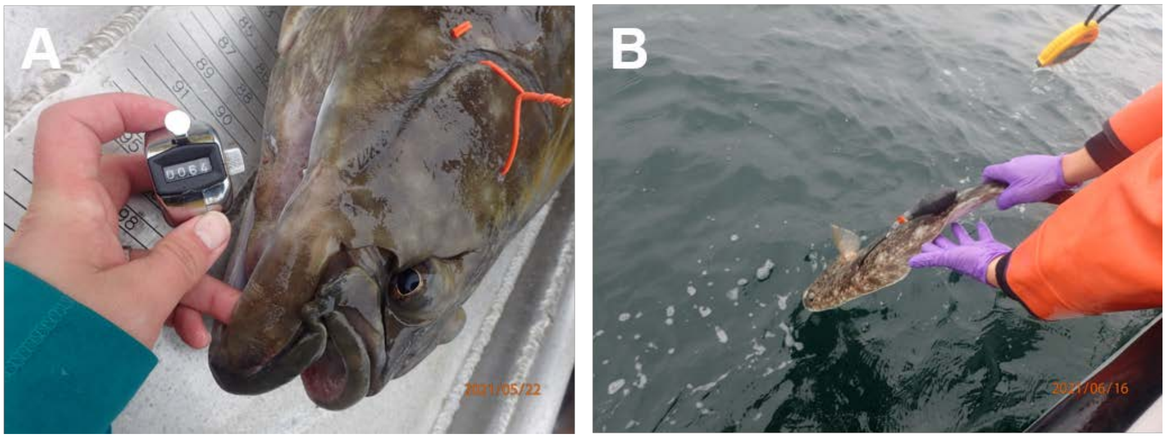

Figure 3. Tags used in this study: A) orange wire tag through the operculum; B) sPAT attached to the dorsal musculature, as fish is being carefully released.

The deployed sPAT tags were programmed to be released after 96 days and we expect to recover the accelerometer data by 25 September 2021 or earlier (i.e. due to mortality or capture).

Processing of blood samples for the determination of stress indicators (cortisol, glucose and lactate) is in progress and analysis of injuries and viability by hook size and fish size is currently being conducted.

5. Genetics and genomics. The IPHC Secretariat is conducting studies that incorporate genomics approaches in order to produce useful information on population structure and distribution and connectivity of Pacific halibut. The relevance of research outcomes from these activities for stock assessment (SA) resides (1) in the introduction of possible changes in the structure of future stock assessments, as separate assessments may be constructed if functionally isolated components of the population are found (e.g. IPHC Regulatory Area 4B), and (2) in the improvement of productivity estimates, as this information may be used to define management targets for minimum spawning biomass by Biological Region. These research outcomes provide the second and third top ranked biological inputs into SA (Appendix II). Furthermore, the relevance of these research outcomes for the management and strategy evaluation (MSE) process is in biological parametization and validation of movement estimates, on one hand, and of recruitment distribution, on the other hand (Appendix III).

5.1. Population genomics.
Principal Investigator: Andy Jasonowicz (M.Sc.)

The primary objective of the studies that the IPHC Secretariat is currently conducting is to investigate the genetic structure of the Pacific halibut population and to conduct genetic analyses to inform on Pacific halibut movement and distribution within the Convention Area.

5.1.1. Studies to resolve the genetic structure of the Pacific halibut population in the Convention Area. Details on sample collection, bioinformatic processing and proposed analyses utilizing low-coverage whole genome sequencing (lcWGR) to investigate Pacific halibut population structure were provided in document IPHC-2021-SRB018-08. The bioinformatic processing pipeline has been successfully migrated to Microsoft Azure cloud computing services and the raw sequence data from a second sequencing run of 250 samples has been processed. This includes alignment to the Pacific halibut reference genome and quality filters to ensure integrity of the data prior to analysis. Quality metrics are comparable to those obtained from a preliminary sequencing run of 36 samples (Table 2). A single sample failed to produce any sequence reads and was omitted from any summaries, single nucleotide polymorphism (SNP) identification and downstream analyses.

These sequence alignments were combined with the alignments from a previous sequencing run (n=36) and used to identify SNPs and estimate genotype likelihoods using the samtools model implemented in ANGSD (v0.934) (Korneliussen et al. 2014). SNPs were retained if they had a global minor allele frequency (MAF) ≥ 0.01 or greater, p-value of 1e-6 or less for a site being variable, and present in at least 214 out of 285 (~75%) of the individuals. A total of 10,474,925 SNPs were identified using these parameters.

Library	iphc_001	iphc_002
Number of samples	36	250
Sequencing Platform	Illumina HiSeq 4000	Illumina NovaSeq S4
Raw Reads Per Sample (Millions)*	26.5 (21.8 - 42.9)	24.7 (10.7 – 47.2)
Reads Retained (%)*	60 (54 - 69)	63 (22 - 70)
Coverage Per Sample (x)*	3.2 (2.6 – 5)	3.5 (1.0 - 5.6)

Table 2. Summary of raw sequence data and genome alignments for two Pacific halibut lcWGR sequencing runs. *expressed as mean (min – max)

With this dataset, principal component analysis was used to gain a preliminary look at population structure and signals of natural selection in the genome. Prior to these analyses, the dataset was filtered to remove SNPs in any unplaced scaffolds, the mitochondrial genome, and chromosome 9 (RefSeq: NC_048935.1), which contains a large sex-associated region. PCAngsd (v1.02) (Meisner and Albrechtsen 2018; Meisner et al. 2021) was run using default parameters (MAF ≥ 0.5 by default) to estimate a covariance matrix among individuals using genotype likelihoods for 285 Pacific halibut. Numpy (v1.21.2) (Harris et al. 2020) was then used to compute the eigenvalues and eigenvectors for the covariance matrix obtained using PCAngsd. A genome-wide selection scan was also carried out using the "-selection" flag in PCAngsd.

A total of 4,850,093 sites were retained by PCAngsd. These preliminary results suggest that there may be some degree of spatial and temporal separation among these sampling collections (Fig. 4), and regions of the genome that are potentially under natural selection (Fig. 5). However, additional samples are to be processed to reach our target sample size of 50 per collection with collections from British Columbia (2007) and Central Gulf of Alaska (1999 & 2018) to be included in the next sequencing run. The inclusion these additional samples of will help resolve these patterns further.

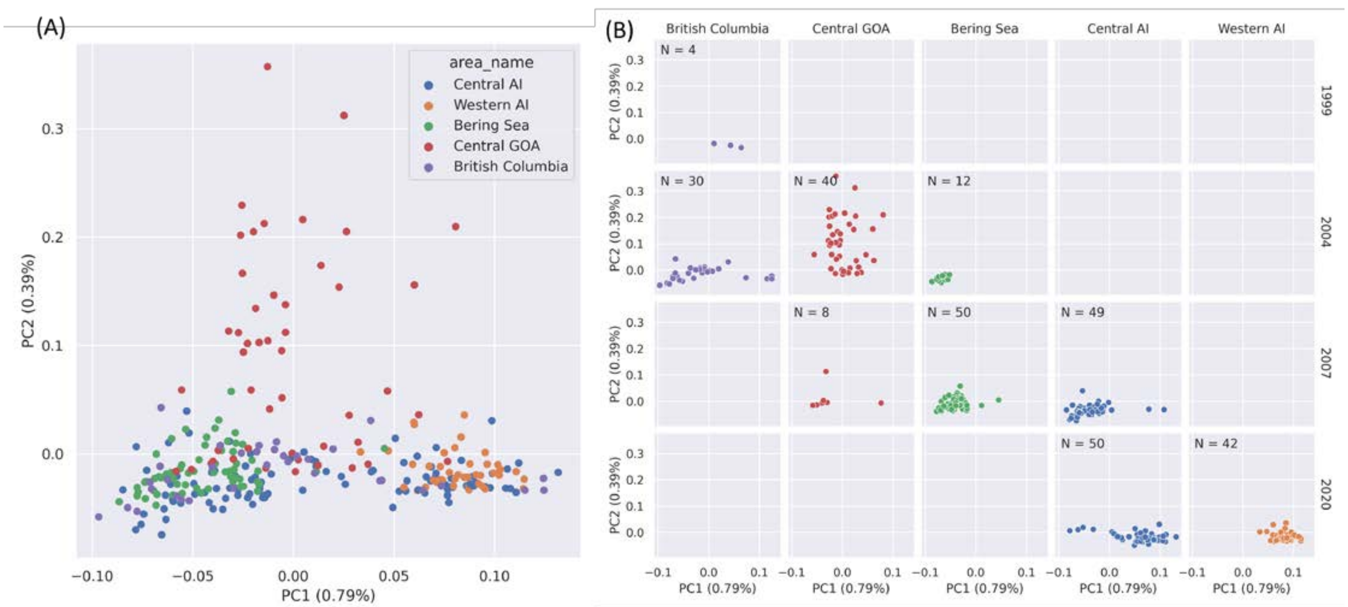

Figure 4. Principal component analysis scores of genotype likelihoods from 4,850,093 SNPs in 285 Pacific halibut sequenced to date. A) Plot of PC1 vs PC2 for all populations together. B) PC1 vs PC2 plotted separately for each geographic area and collection year. Number of samples analyzed for each collection are listed in each facet.

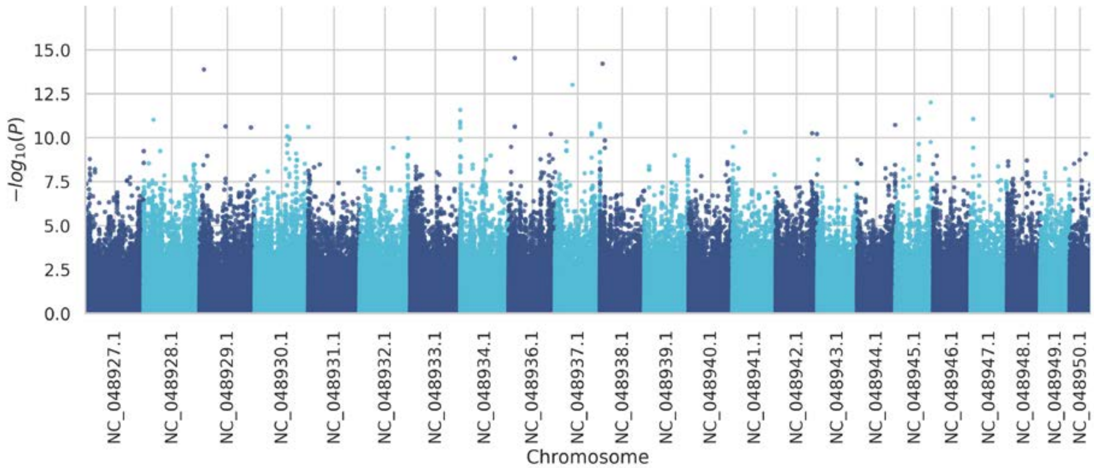

Figure 5. Manhattan plot based on the genome-wide selection scan implemented in PCAngsd.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-08 which provides a response to requests from SRB018, and a report on current research activities contemplated within the IPHC Five-Year Biological and Ecosystem Science Research Plan (2017-2021).

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APPENDIX I

Integration of biological research, stock assessment and harvest strategy policy (2017-21)

Biological research		Stock assessment	Stock assessment MSE
Research areas	**Research outcomes**	**Relevance for stock assessment**	**Inputs to stock assessment and MSE development**
Reproduction	Sex ratio Spawning output Age at maturity	Spawning biomass scale and trend Stock productivity Recruitment variability	Sex ratio Maturity schedule Fecundity
Growth	Identification of growth patterns Environmental effects on growth Growth influence in size-at-age variation	Temporal and spatial variation in growth Yield calculations Effects of ecosystem conditions Effects of fishing	Predicted weight-at-age Mechanisms for changes in weight-at-age
Discard Survival	Bycatch survival estimates Discard mortality rate estimates	Scale and trend in mortality Scale and trend in productivity	Bycatch and discard mortality estimates Variability in bycatch and uncertainty in discard mortality estimates
Migration	Larval distribution Juvenile and adult migratory behavior and distribution	Geographical selectivity Stock distribution	Information for structural choices Recruitment indices Migration pathways and rates Timing of migration
Genetics and Genomics	Genetic structure of the population Sequencing of the Pacific halibut genome	Spatial dynamics Management units	Information for structural choices

APPENDIX II

List of ranked biological uncertainties and parameters for stock assessment (SA) and their links to potential research areas and research activities (2017-21)

SA Rank	Research outcomes	Relevance for stock assessment	Specific analysis input	Research Area	Research activities
1. Biological input	Updated maturity schedule	Scale biomass and reference point estimates	Will be included in the stock assessment, replacing the current schedule last updated in 2006	Reproduction	Histological maturity assessment
	Incidence of skip spawning		Will be used to adjust the asymptote of the maturity schedule, if/when a time-series is available this will be used as a direct input to the stock assessment		Examination of potential skip spawning
	Fecundity-at-age and -size information		Will be used to move from spawning biomass to egg-output as the metric of reproductive capability in the stock assessment and management reference points		Fecundity assessment
	Revised field maturity classification		Revised time-series of historical (and future) maturity for input to the stock assessment		Examination of accuracy of current field macroscopic maturity classification
2. Biological input	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area	Altered structure of future stock assessments	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	Genetics and Genomics	Population structure
3. Biological input	Assignment of individuals to source populations and assessment of distribution changes	Improve estimates of productivity	Will be used to define management targets for minimum spawning biomass by Biological Region		Distribution
	Improved understanding of larval and juvenile distribution		Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	Migration	Larval and juvenile connectivity studies
1. Assessment data collection and processing	Sex ratio-at-age	Scale biomass and fishing intensity	Annual sex-ratio at age for the commercial fishery fit by the stock assessment	Reproduction	Sex ratio of current commercial landings
	Historical sex ratio-at-age		Annual sex-ratio at age for the commercial fishery fit by the stock assessment		Historical sex ratios based on archived otolith DNA analyses
2. Assessment data collection and processing	New tools for fishery avoidance/deterence; improved estimation of depredation mortality	Improve mortality accounting	May reduce depredation mortality, thereby increasing available yield for directed fisheries. May also be included as another explicit source of mortality in the stock assessment and mortality limit setting process depending on the estimated magnitude	Mortality and survival assessment	Whale depredation accounting and tools for avoidance
1. Fishery yield	Physiological and behavioral responses to fishing gear	Reduce incidental mortality	May increase yield available to directed fisheries	Mortality and survival assessment	Biological interactions with fishing gear
2. Fishery yield	Guidelines for reducing discard mortality	Improve estimates of unobserved mortality	May reduce discard mortality, thereby increasing available yield for directed fisheries	Mortality and survival assessment	Best handling practices: recreational fishery

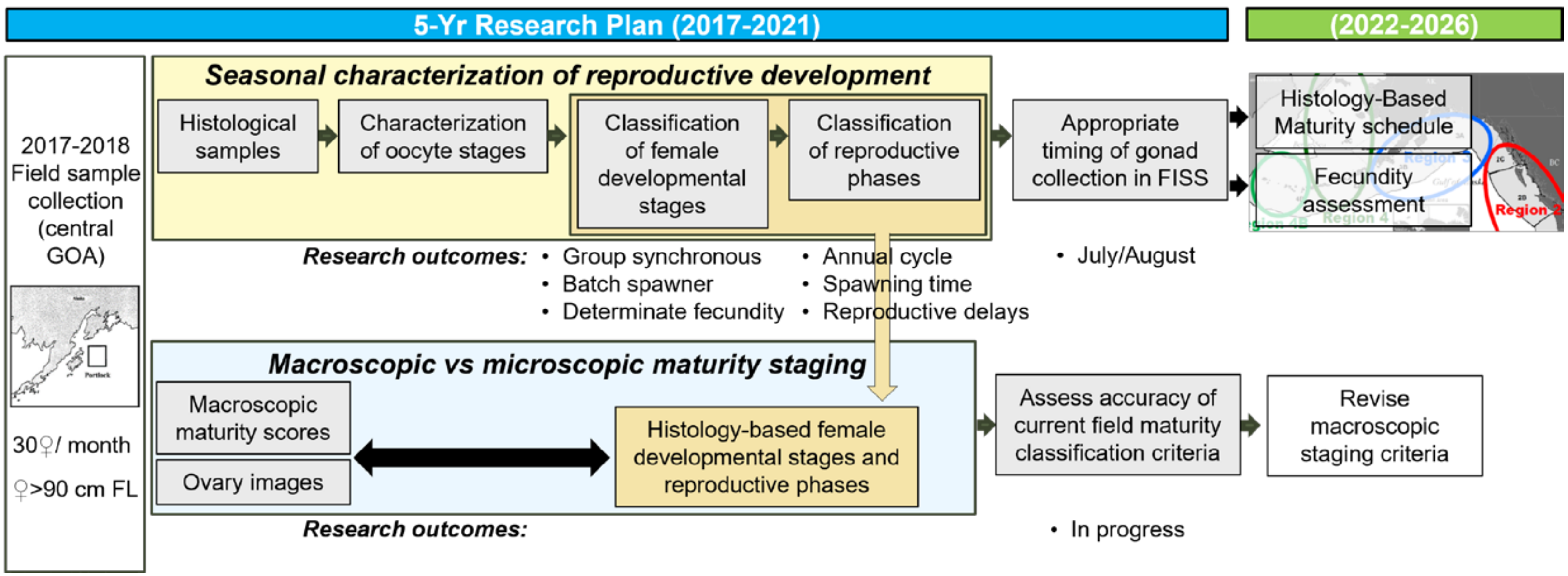
APPENDIX III

List of ranked biological uncertainties and parameters for management strategy evaluation (MSE) and their potential links to research areas and research activities (2017-21)

MSE Rank	Research outcomes	Relevance for MSE	Research Area	Research activities
1. Biological parameterization and validation of movement estimates	Improved understanding of larval and juvenile distribution	Improve parametization of the Operating Model	Migration	Larval and juvenile connectivity studies
	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area		Genetics and Genomics	Population structure
2. Biological parameterization and validation of recruitment variability and distribution	Assignment of individuals to source populations and assessment of distribution changes	Improve simulation of recruitment variability and parametization of recruitment distribution in the Operating Model		Distribution
	Establishment of temporal and spatial maturity and spawning patterns	Improve simulation of recruitment variability and parametization of recruitment distribution in the Operating Model	Reproduction	Recruitment strength and variability
3. Biological parameterization and validation for growth projections	Identification and application of markers for growth pattern evaluation	Improve simulation of variability and allow for scenarios investigating climate change	Growth	Evaluation of somatic growth variation as a driver for changes in size-at-age
	Environmental influences on growth patterns			
	Dietary influences on growth patterns and physiological condition			
1. Fishery parameterization	Experimentally-derived DMRs	Improve estimates of stock productivity	Mortality and survival assessment	Discard mortality rate estimate: recreational fishery

APPENDIX IV

Flow of research activities and outcomes on Reproduction during the 5-Year Research Plan (2017-2021) and their link with planned research activities for the 5-Year Research Plan (2022-2026)



APPENDIX V

Summary of current awarded research grants

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	**National Fish & Wildlife Foundation**	Improving the characterization of discard mortality of Pacific halibut in the recreational fisheries (NFWF No. 61484)	IPHC Dr J. Planas and Mr Claude Dykstra	Alaska Pacific University, U of A Fairbanks, charter industry	$98,902	Bycatch estimates	1 April 2019 – 1 November 2021
2	**North Pacific Research Board**	Pacific halibut discard mortality rates (NPRB No. 2009)	IPHC Dr. J. Planas	Alaska Pacific University,	$210,502	Bycatch estimates	1 January 2021 – 31 March 2022
Total awarded ($)					**$309,404**		

Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA): update for SRB019

PREPARED BY: IPHC SECRETARIAT (B. HUTNICZAK; 19 AUGUST 2021)

PURPOSE

To provide the IPHC's Scientific Review Board (SRB) with an update on the development of the Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) and respond to comments made during the SRB18 (IPHC-2021-SRB018-R).

BACKGROUND

The goal of the IPHC economic study is to provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource that includes the full scope of Pacific halibut's contribution to regional economies of Canada and the United States of America. To that end, the Secretariat continues improving the Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) with an intention to inform stakeholders on the importance of the Pacific halibut resource and fisheries to their respective communities, but also broader regions and nations, and contribute to a wholesome approach to Pacific halibut management that is optimal from both biological and socioeconomic perspective, as mandated by the Convention.

The PHMEIA is a multiregional social accounting matrix-based model describing economic interdependencies between sectors and regions developed to assess three economic impact (EI) components pertaining to Pacific halibut. The **direct EIs** reflect the changes realized by the direct Pacific halibut resource stock users (fishers, charter business owners), as well as the forward-linked Pacific halibut processing sector (i.e., downstream economic activities). The **indirect EIs** are the result of business-to-business transactions indirectly caused by the direct EIs. The indirect EIs provide an estimate of the changes related to expenditures on goods and services used in the production process of the directly impacted industries. In the context of the PHMEIA, this includes an impact on upstream economic activities associated with supplying intermediate inputs to the direct users of the Pacific halibut resource stock. Finally, the **induced EIs** result from increased personal income caused by the direct and indirect effects. In the context of the PHMEIA, this includes economic activity generated by households spending earnings that rely on the Pacific halibut resource, both directly and indirectly. The model also accounts for interregional spillovers. These represent economic stimulus in regions other than the one in which the exogenous change is considered. This allows accommodation of increasing economic interdependence of regions and nations.

The current PHMEIA incorporates a series of improvements to the economic impact assessment[1] model introduced this year. These are as follows:

(1) The model uses an updated set of data, and estimates are now available for 2019. Previously, the estimates were available up to 2018.

[1] While this type of assessment is typically termed "economic impact assessment," calculated alongside impact in terms of output also impacts on employment and incomes, and households' prosperity, introduce a broader socioeconomic context.

(2) The estimates incorporate flows of earnings related to all Pacific halibut sectors in the model (commercial fishing, processing, and charter sector/Alaska only). See appendix for compilation of data on the flows of benefits in the Pacific halibut sectors in Alaska, from harvest location to buyer's headquarters (**Figure 2**), from the landing area to vessel owner residence and quota holder residence (**Figure 3**), and from sport fishing location to Charter Halibut Permit owner residence (**Figure 4**).

(3) The latest update of the PHMEIA provides preliminary estimates of community effects. The model informs on the county-level economic impacts in Alaska and highlights communities particularly dependent on Pacific halibut fishing-related economic activities. The results are available in the model app, tab "Community impacts in AK."

(4) The extended model (labeled PHMEIA-r) provides preliminary estimates for the Alaskan saltwater charter sector that is disaggregated from the services-providing industry. The results are available in the model app, tab "EI of charter fishing in AK." The inclusion of the British Columbia and US West Coast charter sector is underway, pending sufficient primary data submissions and/or compilation of necessary components from secondary data sources. Additional update on this component is anticipated ahead of the IM97.

PHMEIA MODEL RESULTS

The PHMEIA model results suggest that Pacific halibut commercial fishing's total estimated impact in 2019 amounts to USD 194.2 mil. (CAD 257.7 mil.) in households' earnings,[2] including an estimated USD 42.5 mil / CAD 56.4 mil in direct earnings in the Pacific halibut fishing sectors, and USD 178.4 mil (CAD 236.7 mil.) in households income. Moreover, the results suggest that incorporating Pacific halibut-specific outflows has a considerable impact on results. While 1 USD of Pacific halibut output by the commercial sector in Alaska could generate USD 0.71 USD for Alaskan households, out-of-state employment, flows related to beneficial ownership of Pacific halibut fishing rights in Alaska (i.e., quota holdings), and corporate interests of processing sector entities cause this estimate to drop to USD 0.58. This also translates to the unevenness of earnings and economic impact between Alaskan counties (**Figure 1**). The highest economic impacts are estimated for Kenai Peninsula, Kodiak Island, and Petersburg counties.

The total contribution of the Pacific halibut charter sector in Alaska to households is assessed at USD 27.1.7 mil for 2019. This translates into 15% less per 1 USD of output in comparison with the commercial sector. This is not surprising since the commercial sector's production supports not only suppliers to the harvesting sector, but also the forward-linked processing sector. However, the economic impact of 1 lb of Pacific halibut removal counted against TAC in the stock assessment is 66% higher for the charter sector when compared with the commercial sector. It should also be noted that this assessment accounts for only a fraction of the Pacific halibut contribution to the economy through recreational fishing. At this time, the analysis does not account for the impact of anglers spending money on durable goods they use on the charter trips (e.g., fishing equipment) and expenditures by private anglers. The analysis should also not be used as an argument in sectoral allocations

[2] Earnings include both employee compensation and proprietors' income.

discussions because, as a snapshot analysis, it does not reflect the implications of shifting supply-demand balance.

It is important to note that the model continues to rely heavily on secondary data sources, and as such, the results are conditional on the adopted assumptions for the components for which up-to-date data are not available (summarized for Alaska in Appendix 1 of the IPHC-2021-SRB018-09; details for other regions available in IPHC-2021-ECON-02-R01). That said, the Secretariat strives to make the best use of data collection programs of national and regional agencies, academic publications on the topic, and grey literature reporting on fisheries in Canada and the United States.

A detailed description of the model is available in the economic study section of the IPHC website. Additional details on the methodology are available in IPHC-2021-ECON-03. The PHMEIA is accompanied by the economic impact visualization tool, which use can be guided by the PHMEIA app manual (IPHC-2021-ECON-04).

Looking forward, the Secretariat also identified a number of tasks that would enhance PHMEIA usability to the Commission. These are described in more detail in the *IPHC 5-year Program of Integrated Science and Research* (IPHC, 2021).

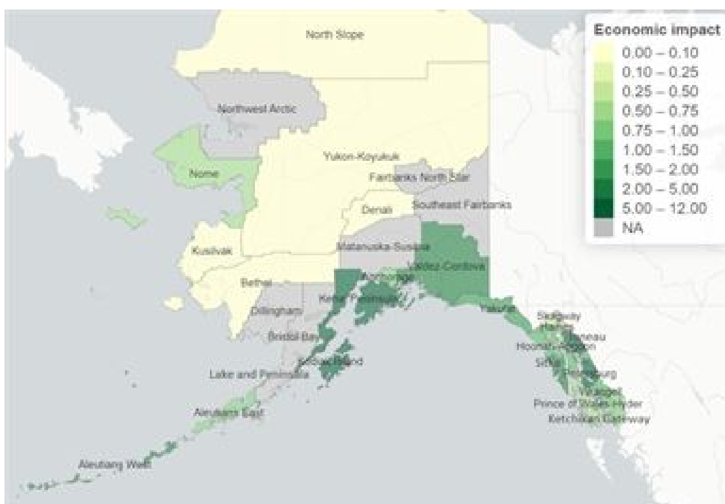


Figure 1 County-level economic impact estimates for Alaska in [mil. USD, 2019].

FINAL REMARKS

The PHMEIA model fosters stakeholders' better understanding of a broad scope of regional impacts of the Pacific halibut resource. Leveraging multiple sources of socioeconomic data, it provides essential input for designing policies with desired effects depending on regulators' priorities. By tracing the socioeconomic impacts cross-regionally, the model accommodates the transboundary nature of the Pacific halibut and supports joint management of a shared resource, such as the case of collective management by the IPHC. Moreover, the study informs on the community impacts of the Pacific halibut resource throughout its range, highlighting communities particularly dependent on economic activities that rely on Pacific halibut. A good understanding of the localized effects is pivotal to policymakers who are often concerned about community impacts, particularly in terms of impact on employment opportunities and households' welfare.

Integrating economic approaches with stock assessment and MSE can assist fisheries in bridging the gap between the current and the optimal economic performance without compromising the stock biological sustainability. Economic performance metrics presented alongside already developed biological/ecological performance metrics would bring the human dimension to the MSE framework, adding to the IPHC's portfolio of tools for assessing policy-oriented issues (as requested by the Commission, IPHC-2021-AM097-R, AM097-Req.02). Moreover, the study can also inform on socioeconomic drivers (human behavior, human organization) that affect the dynamics of fisheries, and thus contribute to improved accuracy of the stock assessment and the MSE (Lynch, Methot and Link, 2018). As such, it can provide a complementary resource for the development of harvest control rules, thus directly contributing to Pacific halibut management.

Lastly, while the quantitative analysis is conducted with respect to components that involve monetary transactions, Pacific halibut's value is also in its contribution to the diet through subsistence fisheries and importance to the traditional users of the resource. To native people, traditional fisheries constitute a vital aspect of local identity and a major factor in cohesion. One can also consider the Pacific halibut's existence value as an iconic fish of the Pacific Northwest. While these elements are not quantified at this time, recognizing such an all-encompassing definition of the Pacific halibut resource contribution, the project echoes a broader call to include the human dimension into the research on the impact of management decisions, as well as changes in environmental or stock conditions.

COMMENTS FROM SRB18

The SRB "*AGREED that an economic impacts study provides considerable value and leverage to stakeholders in establishing the importance of the Pacific halibut resource and fisheries to their respective communities, both locally, regionally, and internationally*" (SRB18, para. 49). Recognizing that it is commonplace to consider socioeconomic factors when designing harvest policies without formal assessment, the SRB also made several comments focused on improving stakeholders' confidence in the model results.

The SRB "*NOTED improving the accuracy of the economic impact assessment of the Pacific halibut resource depends on broader stakeholders' active participation in developing the necessary data for analysis and ENCOURAGED additional outreach activities*" (SRB18, para. 50). The Secretariat is working on an improved strategy for primary data collection following the 2021 fishing season. Further simplification of the survey is anticipated ahead of the IM97. The Secretariat is also cautiously optimistic regarding engagement with stakeholders on economic data collection in post-covid times.

Further, the SRB "*NOTED that an external peer review of the economic study would be useful given the lack of economics expertise on the SRB and the importance of having a robust, well-vetted economic impact analysis*" (SRB18, para. 51). To that end, the Secretariat notes that it has initiated the development of terms of reference for external review of the PHMEIA model.

The Secretariat also informed the Commission that the SRB "*REQUESTED specific guidance and clarification from the Commission on the objectives and intended use of this study*"[3] (SRB18, para. 52) and "*AGREED that there is potential value in introducing socioeconomic performance metrics to the MSE framework*" (SRB18, para. 53).[4]

OBJECTIVES

Table 1 summarizes the progress to date against the IPHC economic study objectives.

Table 1. The study objectives – summary of progress

Objective	Status*
Item 1: Survey of previous studies and existing information	**---**
Item 1.a: Literature review	**COMPLETED**
Item 1.b: Description of ongoing regular data collection programs	**COMPLETED**
Item 1.c: Collection of primary data – commercial sector survey	**IN PROGRESS**
Item 1.d: Collection of primary data – charter sector survey	**IN PROGRESS**
Item 2: Comprehensive qualitative structural description of the current economics of the Pacific halibut resource	**---**
Item 2.a: Description of the economics of the Pacific halibut commercial sector	**COMPLETED**
Item 2.b: Description of the economics of the Pacific halibut recreational sector	**COMPLETED**
Item 2.c: Description of the economics of other Pacific halibut sectors (bycatch, subsistence, ceremonial, research, non-directed)	**IN PROGRESS**
Item 3: Quantitative analysis of the economic impact of the directed Pacific halibut fishery	**---**
Item 3.a: Methodology – a model of the economy	**COMPLETED**
Item 3.b: Methodology – inclusion of the commercial sector in the SAM	**COMPLETED(1)**
Item 3.c: Methodology – inclusion of the recreational sector in the SAM	**COMPLETED(1)**
Item 3.d: Methodology – economic value of the subsistence use	**IN PROGRESS(2)**
Item 4: Account of the geography of the economic impact of the Pacific halibut sectors	**---**
Item 4.a: Visualization of region-specific economic impacts	**COMPLETED(1)**
Item 5: Analysis of the community impacts of the Pacific halibut fishery throughout its range, including all user groups	**---**
Item 5.a: Community impacts assessment of the Pacific halibut fishery	**COMPLETED(1)**
Item 6: Summary of the methodology and results of the IPHC study in comparison to other economic data and reports for the Pacific halibut resource, other regional fisheries, and comparable seafood industry sectors	**---**
Item 6.a: Putting results into perspective	**IN PROGRESS**

* All items marked as COMPLETED are subject to updates based on the direction of the project and evolution of the situation in the Pacific halibut fisheries. (1)Subject to changes based on the data collected through the IPHC Economic survey. (2)Subject of collaborative research proposal with NOAA Alaska Fisheries Science Center.

[3] The SRB "*NOTED that, without a clearer understanding of the Commissions purpose for future use of this work, it is difficult to provide guidance on prioritising model development (e.g. improve spatial resolution, incorporate dynamic / predictive processes, adding more detail on subsistence and recreational fisheries, including uncertainty in the assessment)*" (SRB18, para. 52).

[4] The SRB also noted a caveat that "*there may be alternative methods to accomplish this specific task*" (SRB18, para. 53), but no potential alternatives approaches were mentioned.

RECOMMENDATION/S

That the SRB:

1) **NOTE** paper IPHC-2021-SRB019-09 which provides an update on the development of the Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) and responds to comments made during the SRB18.

LITERATURE

ADFG (2021) *Commercial Permit and License Holders Listing*. Available at: https://www.adfg.alaska.gov/index.cfm?adfg=fishlicense.holders.

CFEC (2021a) *CFEC Public Search Application - Permits*. Available at: https://www.cfec.state.ak.us/plook/#permits.

CFEC (2021b) *CFEC Public Search Application - Vessels*. Available at: https://www.cfec.state.ak.us/plook/#vessels.

IPHC (2021) *International Pacific Halibut Commission 5-Year program of integrated science and research (2021-26)*, *IPHC–2021–5YPISR*. Seattle, WA.

Lynch, P. D., Methot, R. D. and Link, J. S. (2018) 'Implementing a Next Generation Stock Assessment Enterprise: Policymakkers' Summary', *NOAA Technical Memorandum NMFS-F/SPO-183*.

NOAA (2021) *Charter (Sport) Halibut - Charter Halibut Permits List*. Available at: https://www.fisheries.noaa.gov/alaska/commercial-fishing/permits-and-licenses-issued-alaska#charter-(sport)-halibut.

APPENDIX

Income flows in the Pacific halibut commercial fishing sectors in Alaska

Figure 2 depicts the flow of revenue from the harvest location to the processing profit beneficiary. Here, nods represent spatial aggregation:

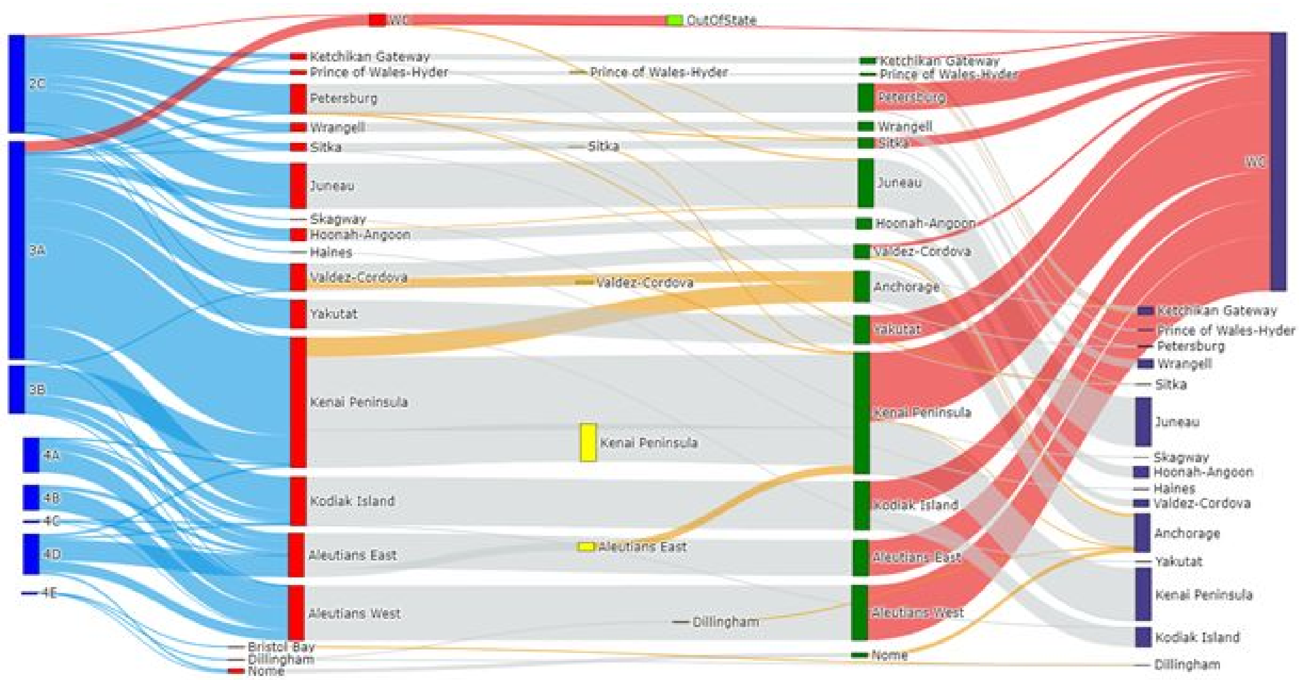
- Blue – harvest by IPHC Regulatory Areas;
- Red – county of the landing site;
- Yellow – if ordered, county of the custom processing;
- Green – county of the reported buyer, as reported in the ADFG's Commercial Permit and License Holders Listing (ADFG, 2021);
- Purple – location of the Fisheries Business License holder, based on the contact address reported in ADFG (2021b).

Ribbons represent flows in terms of the estimated value of landings (mil. USD) (i.e., landing value, not adjusted for value added through processing):

- Blue ribbons represent the flows from harvest grounds to landing sites in Alaska;
- Grey ribbons represent the flows between nodes that are located in the same Alaskan county;
- Orange ribbons represent the flows between nodes that are located in different counties;
- Red ribbons represent the flows out of Alaska.

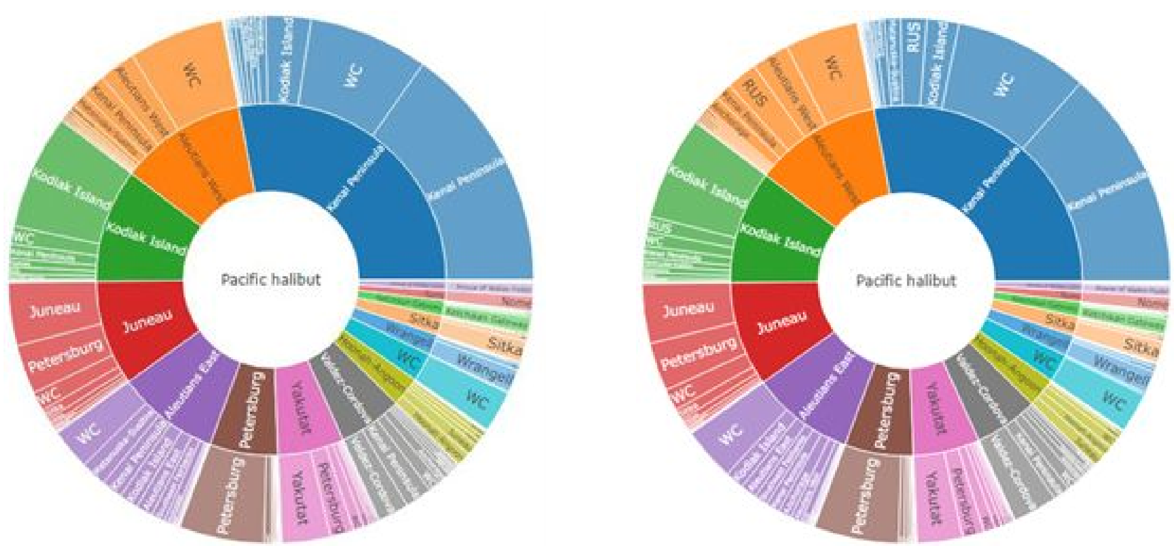
The direction of the flow of benefits from the landing area to vessel owner residence and quota holder residence is depicted in **Figure 3**. Here, the inner circle represents the county where the fish was landed, and the outer circle represents the county where (1) the vessel owner resides, as reported in CFEC (2021), and (2) where the quota owner resides, as reported in CFEC (2021a). The width of the ring section represents the estimated value of landings.

The cross-regional flows related to proprietors' income in the charter sector were assessed using permit holder addresses reported by NOAA (2021b) and approximated by the number of endorsed anglers associated with each permit. These flows are depicted in **Figure 4**.



WC represents US West Coast (WA, OR and CA)

Figure 2 Flow of Pacific halibut harvest from harvest location to buyer's headquarters (2020).



(1) Landing area vs. vessel owner residence

(2) Landing area vs. permit owner residence

Figure 3 Direction of the flow of benefits from the landing area to (1) vessel owner residence, (2) quota holder residence (2020).

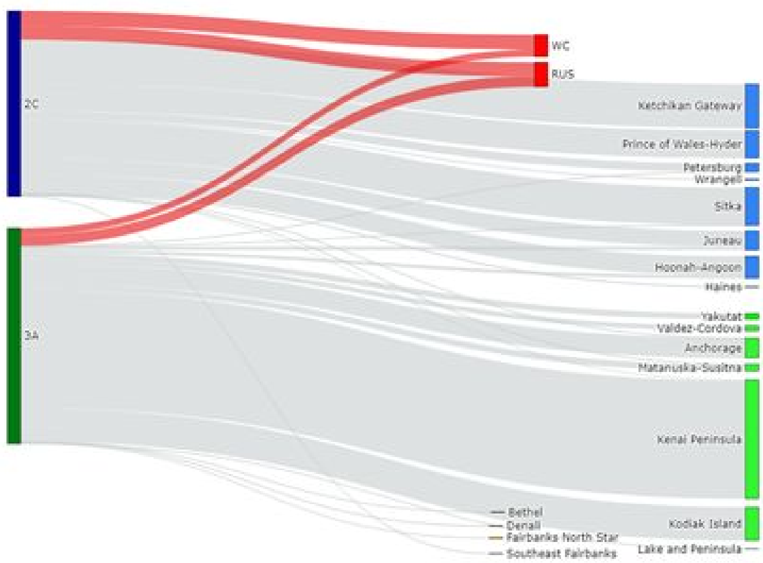


Figure 4 Benefit flows for Alaska charter sector (2020).

INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED SCIENCE AND RESEARCH (2021-26)

PREPARED BY: IPHC SECRETARIAT (D. WILSON, J. PLANAS, I. STEWART, A. HICKS, B. HUTNICZAK, R. WEBSTER; 19 AUGUST 2021)

PURPOSE

To provide the SRB with the current draft of the new IPHC 5-year program of integrated science and research (2021-26)

BACKGROUND

The IPHC has a long-standing history (since 1923) of collecting data, undertaking research, and stock assessment, devoted to describing and understanding the Pacific halibut (*Hippoglossus stenolepis*) stock and the fisheries that interact with it.

The IPHC Secretariat conducts activities to address key issues identified by the Commission, its subsidiary bodies, the broader stakeholder community, and of course, the IPHC Secretariat itself. The process of identifying, developing, and implementing our science-based activities involves several steps that are circular in nature, but result in clear project activities and associated deliverables. The process includes developing and proposing projects based on direct input from the Commission, the experience of the IPHC Secretariat given our broad understanding of the resource and its associated fisheries, and concurrent consideration by relevant IPHC subsidiary bodies, and where deemed necessary, additional external peer review.

An overarching goal of the IPHC 5-Year Program of Science and Research (2021-26) is therefore to promote integration and synergies among the various science and research activities of the IPHC Secretariat in order to improve our knowledge of key inputs into the Pacific halibut stock assessment, and Management Strategy Evaluation (MSE) processes.

DISCUSSION

The SRB is invited to again review and provide additional guidance to assist the IPCH Secretariat finalise the draft plan provided at Appendix A.

RECOMMENDATION

That the SRB:

1) **NOTE** paper IPHC-2021-SRB019-10 which provides the current draft of the new IPHC 5-year program of integrated science and research (2021-26).

APPENDICES

Appendix A: DRAFT: IPHC 5-Year program of integrated science and research (2021-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, B. Hutniczak, & R. Webster)

APPENDIXA

INTERNATIONAL PACIFIC HALIBUT COMMISSION

5-YEAR PROGRAM OF INTEGRATED SCIENCE AND RESEARCH

(January 2022 - June 2026)

INTERNATIONAL PACIFIC

HALIBUT COMMISSION

BIBLIOGRAPHIC ENTRY

IPHC 2021. International Pacific Halibut Commission 5-Year program of integrated science and research (2021-26). Seattle, WA, U.S.A. *IPHC–2021–5YPISR, 33 pp.*

INTERNATIONAL PACIFIC HALIBUT COMMISSION

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ACRONYMS

<<<To be completed>>>

DEFINITIONS

A set of working definitions are provided in the IPHC Glossary of Terms and abbreviations: https://iphc.int/the-commission/glossary-of-terms-and-abbreviations

TABLE OF CONTENTS

1. Introduction

The International Pacific Halibut Commission (IPHC) is an intergovernmental organization established by a Convention between Canada and the United States of America. The IPHC Convention was concluded in 1923 and entered into force that same year. The Convention has been revised several times since, to extend the Commission's authority and meet new conditions in the fishery. The most recent change occurred in 1979 and involved an amendment to the 1953 Halibut Convention. The amendment, termed a "protocol", was precipitated in 1976 by Canada and the United States of America extending their jurisdiction over fisheries resources to 200 miles. The 1979 Protocol along with the U.S. legislation that gave effect to the Protocol (Northern Pacific Halibut Act of 1982) has affected the way the fishery is conducted, and redefined the role of IPHC in the management of the fishery during the 1980s. Canada does not require specific enabling legislation to implement the protocol.

The basic texts of the Commission are available on the IPHC website: https://www.iphc.int/the-commission, and prescribe the mission of the organization as:

*"….. **to develop the stocks of [Pacific] halibut in the Convention waters to those levels which will permit the optimum yield from the fishery and to maintain the stocks at those levels**. ….." IPHC Convention*, Article I, sub-article I, para. 2). The IPHC Convention Area is detailed in Fig. 1.

The IPHC Secretariat, formed in support the Commission's activities, is based in Seattle, WA, USA. As its shared vision, ***the IPHC Secretariat aims to deliver positive economic, environmental, and social outcomes for the Pacific halibut resource for Canada and the U.S.A. through the application of rigorous science, innovation, and the implementation of international best practice.***

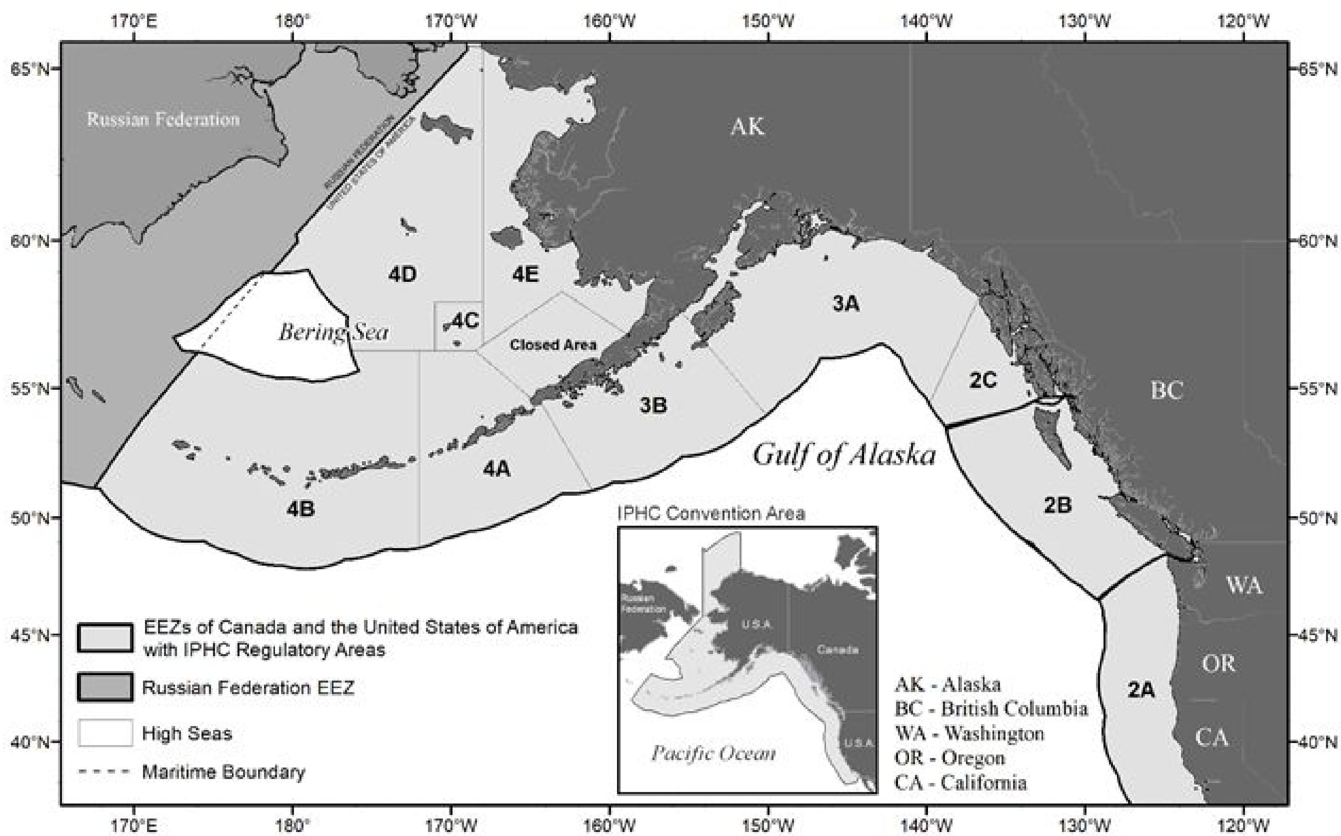

Figure 1. Map of the IPHC Convention Area (map insert) and IPHC Regulatory Areas.

2. *Science and Research objectives*

The IPHC has a long-standing history (since 1923) of collecting data, undertaking research, and stock assessment, devoted to describing and understanding the Pacific halibut (*Hippoglossus stenolepis*) stock and the fisheries that interact with it.

The IPHC Secretariat conducts activities to address key issues identified by the Commission, its subsidiary bodies, the broader stakeholder community, and of course, the IPHC Secretariat itself. The process of identifying, developing, and implementing our science-based activities involves several steps that are circular in nature, but result in clear project activities and associated deliverables. The process includes developing and proposing projects based on direct input from the Commission, the experience of the IPHC Secretariat given our broad understanding of the resource and its associated fisheries, and concurrent consideration by relevant IPHC subsidiary bodies, and where deemed necessary, additional external peer review.

An **overarching goal** of the *IPHC 5-Year Program of Science and Research (2021-26)* is therefore to promote integration and synergies among the various science and research activities of the IPHC Secretariat in order to improve our knowledge of key inputs into the Pacific halibut stock assessment, economic impact assessment of the resource, and Management Strategy Evaluation (MSE) processes.

The science and research activities conducted by the IPHC Secretariat are directed towards fulfilling the following five (5) **objectives** within areas of data collection, biological and ecological research, stock assessment, MSE, and fisheries economics, with the overall aim of proving an integrated program of science and research (Fig 2):

1) **Fisheries data**: collect representative fishery dependent and fishery-independent data on the distribution and abundance of Pacific halibut through ongoing monitoring activities;
2) **Biology and Ecology**: identify and assess critical knowledge gaps in the biology and ecology of Pacific halibut within its known range, including the influence of environmental conditions on population and fishery dynamics;
3) **Stock assessment**: apply the resulting knowledge to reduce uncertainty in current stock assessment models and the stock management advice provided to the Commission;
4) **Management Strategy Evaluation (MSE)**: to provide inputs that inform the MSE process, which will evaluate the consequences of alternative management options, known as harvest strategies;
5) **Fishery socioeconomics**: to provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource in Canada and the United States of America.

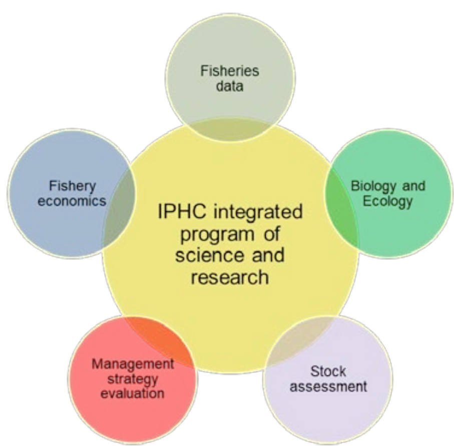

Figure 2. Core areas of the IPHC's integrated program of science and research.

3. *Strategy*

The IPHC Strategic Plan (2019-23) (the Plan) contains five (5) enduring strategic goals in executing our mission, including our overarching goal and associated science and research objectives. Although priorities and tasking will change over time in response to events and developments, the Plan provides a framework to standardise our approach when revising or setting new priorities and tasking. The Strategic goals as they apply to the science and research activities of the IPHC Secretariat, are operationalised through a multi-year tactical activity matrix (Appendix I) at the organisational and management unit (Branch) level (Fig. 3). The tactical activity matrix is described in the sections below, and has been developed based on the core needs of the Commission, in developing and implementing robust, scientifically-based management decisions on an annual, and multi-year level. Relevant IPHC subsidiary bodies may be involved in project development and ongoing review.

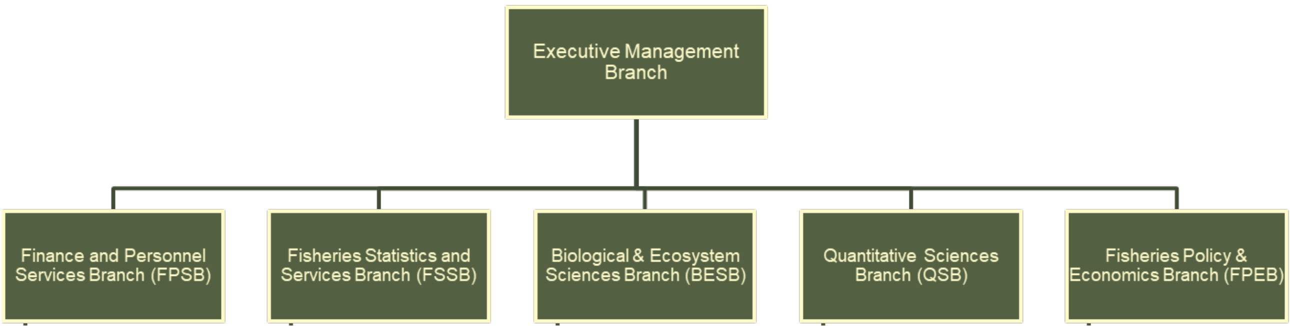

Figure 3. IPHC Secretariat organisation chart (May 2021).

4. *Measures of Success*

The Secretariat's success in the implementing the *IPHC 5-Year Program of Integrated Science and Research (2021-26)* will be measured according to the following criteria:

4.1 Delivery of specified products

Each project line item will contain specific deliverables that constitute useful inputs into the stock assessment and the management strategy evaluation process, as well as support their implementation in the decision making process at the level of the Commission.

4.2 External research funding

The Secretariat has set a funding goal of at least 20% of the funds for this program to be sourced from external funding bodies on an annual basis.

4.3 Peer-reviewed journal publication

Publication of research outcomes in peer-reviewed journals will be clearly documented and monitored as a measure of success. This may include single publications at the completion of a particular project, or a series of publications throughout the project as well as at its completion. Each sub-project shall be published in a timely manner, and shall be submitted no later than 12 months after the end of the research.

4.4 Future Strategic Science and Research Activities

Along with the implementation of the medium- and long-term activities contemplated in this *IPHC 5-Year Program of Integrated Science and Research (2021-26)*, the IPHC Secretariat shall strive to:

1) Establish world-leading programs in fisheries research, particularly on genomics and genetics.

2) Establish new collaborative agreements and interactions with research agencies and academic institutions.
3) Promote the international involvement of the IPHC by continued and new participation in international scientific organizations and by leading international science and research collaborations.
4) Incorporation of talented students and early researchers in research activities contemplated.

5. *Core focal areas - Background*

The goals of the main activities of the *5-Year program of integrated science and research (2021-26)* are integrated across the organisation, involving 1) monitoring (fisheries-dependent and –independent data collection), and 2) research (biological, ecological), modelling (FISS and stock assessment), Management Strategy Evaluation (MSE), and fishery socioeconomic analysis, as outlined in the following sub-sections. These components are closely linked to one another, and all feed into management decision making (Fig. 4). The current program builds on the outcomes and experiences of the Commission arising from the implementation of the 2017-21 5-Year Biological and Ecosystem Science Research Plan (IPHC–2019–BESRP-5YP), and which is summarized in Appendix II.

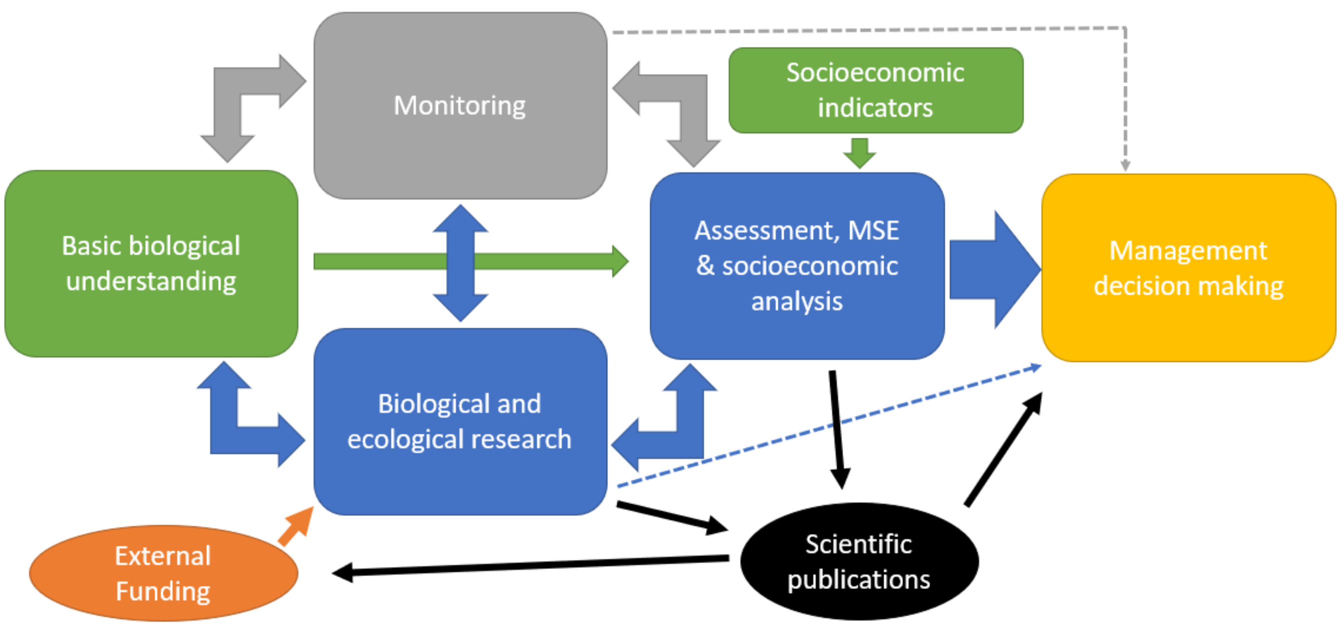

Figure 4. Relationships among organizational components and decision-making.

5.1 Stock Assessment

Focal Area Objective	To reduce uncertainty in the current stock assessment and the resultant stock management advice provided to the Commission.
IPHC Website portal	https://www.iphc.int/management/science-and-research/stock-assessment

The IPHC conducts an annual stock assessment, using data from the fishery-independent setline survey (FISS), the commercial Pacific halibut and other fisheries, as well biological information from its research program. The assessment includes the Pacific halibut resource in the IPHC Convention Area, covering the Exclusive Economic

Zones of Canada and the United States of America. Data sources are updated each year to reflect the most recent scientific information available for use in management decision making.

The 2020 stock assessment relied on an ensemble of four population dynamics models to estimate the probability distributions describing the current stock size, trend, and demographics. The ensemble is designed to capture both uncertainty related to the data and stock dynamics (due to estimation) as well as uncertainty related to our understanding of the way in which the Pacific halibut stock functions and is best approximated by a statistical model (structural uncertainty).

Stock assessment results are used as inputs for harvest strategy calculations, including mortality projection tables for the upcoming year that reflect the IPHCs harvest strategy policy and other considerations, as well as the harvest decision table which provides a direct tool for the management process. The harvest decision table uses the probability distributions from short-term (three year) assessment projections to evaluate the trade-offs between alternative levels of potential yield (catch) and the associated risks to the stock and fishery.

The stock assessment research priorities have been subdivided into three categories:

1) Assessment data collection and processing;
2) biological inputs; and
3) fishery yield.

It is important to note that ongoing monitoring, including the annual FISS and directed commercial landings sampling programs is not considered research and is therefore not included in this research priority list despite the critical importance of these collections. These are prescribed in the sections below.

5.2 Management Strategy Evaluation (MSE)

Focal Area Objective	To provide inputs that inform the MSE process, which will evaluate the consequences of alternative management options, known as harvest strategies.
IPHC Website portal	https://www.iphc.int/management/science-and-research/management-strategy-evaluation

Management Strategy Evaluation (MSE) is a process to evaluate the consequences of alternative management options, known as harvest strategies. MSE uses a simulation tool to determine how alternative harvest strategies perform given a set of pre-defined fishery and conservation objectives, taking into account the uncertainties in the system and how likely candidate harvest strategies are to achieve the chosen management objectives.

MSE is a simulation technique based on modelling each part of a management cycle. The MSE uses an operating model to simulate the entire population and all fisheries, factoring in management decisions, the monitoring program, the estimation model, and potential ecosystem effects using a closed-loop simulation.

Undertaking an MSE has the advantage of being able to reveal the trade-offs among a range of possible management decisions. Specifically, to provide the information on which to base a rational decision, given harvest strategies, preferences, and attitudes to risk. The MSE is an essential part of the process of developing, evaluating and agreeing to a harvest strategy.

The MSE process involves:

- Defining fishery and conservation objectives with the involvement of stakeholders and managers;
- Identifying harvest strategies (a.k.a. management procedures) to evaluate;
- Simulating a Pacific halibut population using those harvest strategies;

- Evaluating and presenting the results in a way that examines trade-offs between objectives;
- Applying a chosen harvest strategy for the management of Pacific halibut;
- Repeating this process in the future in case of changes in objectives, assumptions, or expectations.

There are many tasks that would improve the MSE framework and the presentation of future results to the Commission. The tasks can be divided into five general categories, which are common to MSE in general:

1. **Objectives**: The goals and objectives that are used in the evaluation.
2. **Management Procedures (MPs)**: Specific, well-defined management procedures that can be coded in the MSE framework to produce simulated TCEYs for each IPHC Regulatory Area.
3. **Framework**: The specifications and computer code for the closed-loop simulations including the operating model and how it interacts with the MP.
4. **Evaluation**: The performance metrics and presentation of results. This includes how the performance metrics are evaluated (e.g. tables, figures, and rankings), presented to the Commission and its subsidiary bodies, and disseminated for outreach.
5. **Application**: Specifications of how an MP may be applied in practice and re-evaluated in the future, including responses to exceptional circumstances.

All of these categories provide inputs and outputs of the MSE process, but the Framework category benefits most from the integration of biological and ecosystem research because the operating model, the simulation of the monitoring program, the estimation model, and potential ecosystem effects are determined from this knowledge.

Outcomes of the MSE process will not only inform the Commission on trade-offs between harvest strategies and assist in choosing an optimal strategy for management of the Pacific halibut resource, but will inform the prioritization of research activities related to fisheries monitoring, biological and ecological research, stock assessment, and fishery socio-economics.

5.3 Fishery socioeconomics

Focal Area Objective	To provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource in Canada and the United States of America.
IPHC Website portal	https://www.iphc.int/management/economic-research

Under the Convention, the IPHC's mandate is optimum management of the Pacific halibut resource, which necessarily includes a socioeconomic dimension. Fisheries economics is an active field of research around the world in support of fisheries policy and management. Adding the economic expertise to the Secretariat, the IPHC has become the first regional fishery management organization (RFMO) in the world to do so.

The goal of the IPHC economic study is to provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource that includes the full scope of Pacific halibut's contribution to regional economies of Canada and the United States of America. The economic effects of changes to harvest policies can be far-reaching. Altered catch limits have an impact on the direct users of the stock (commercial harvesters, recreational anglers, subsistence fishers), but at the same time, there is a ripple effect through the economy. Fisheries operations create demand for inputs from other sectors while at the same time support industries further along the value chain that rely on the supply of fish, such as seafood processors. The viability of the Pacific halibut sectors is vital to the prosperity of fisheries-dependent households, having a considerable impact on coastal communities. The economic impacts are transmitted cross-regionally through business-to-business transactions (trade in commodities), labor commuting patterns, and the dissemination of profits along the value chain. There is also an inflow if economic benefits to the local economies from outside when non-residents partake in local leisure activities that would not attract the same number of visitors if not for the opportunity to catch this iconic fish of the Pacific Northwest. Pacific halibut's value is also in its contribution to the diet through subsistence fisheries and importance to the traditional users of the resource. To native people, traditional fisheries constitute a vital aspect of local identity and a major factor in cohesion.

Understanding such a broad scope of regional impacts is essential for designing policies with desired effects depending on regulators' priorities. The ability to trace the socioeconomic impacts cross-regionally is particularly important in the context of shared resources and joint management, such as the case of collective management of Pacific halibut by the IPHC. Moreover, the study informs on the community impacts of the Pacific halibut resource throughout its range, highlighting communities particularly dependent on economic activities that rely on Pacific halibut. A good understanding of the localized effects is pivotal to policymakers who are often concerned about community impacts, particularly in terms of impact on employment opportunities and households' welfare. Integrating economic approaches with stock assessment and MSE can assist fisheries in bridging the gap between the current and the optimal economic performance without compromising the stock biological sustainability. Moreover, the study can also inform on socioeconomic drivers (human behavior, human organization) that affect the dynamics of fisheries, and thus contribute to improved accuracy of the stock assessment and the MSE. As such, it can provide a complementary resource for the development of harvest control rules, thus directly contributing to Pacific halibut management.

5.4 Monitoring

Focal Area Objective	To collect fishery-dependent and fishery-independent data on the distribution and abundance of Pacific halibut, as well as other key biological data, through ongoing monitoring activities.
IPHC Website portal	***Fishery-dependent data:*** • https://www.iphc.int/datatest/commercial-fisheries • https://www.iphc.int/data/datatest/non-directed-commercial-discard-mortality-fisheries • https://www.iphc.int/data/datatest/pacific-halibut-recreational-fisheries-data • https://www.iphc.int/datatest/subsistence-fisheries • https://www.iphc.int/data/time-series-datasets ***Fishery-independent data:*** • https://www.iphc.int/management/science-and-research/fishery-independent-setline-survey-fiss • https://www.iphc.int/data/datatest/fishery-independent-setline-survey-fiss

5.4.1 ***Fishery-dependent data***. The IPHC estimates all Pacific halibut removals taken in the IPHC Convention Area and uses this information in its yearly stock assessment and other analyses. The data are compiled by the IPHC Secretariat and include data from Federal and State agencies of each Contracting Party. Specific activities in this area include:

- **Directed commercial fisheries data**: The IPHC Secretariat collects logbooks, otoliths, tissue samples, and associated sex-length-weight data from directed commercial landings coastwide (Fig. 5). A sampling rate is determined for each port by IPHC Regulatory Area. The applicable rate is calculated from the current year's mortality limits and estimated percentages of weight of fish landed, and estimated percentages of weight sampled in that port to allow for collection of the target number of biological samples by IPHC Regulatory Area. An example of the data collected and the methods used are provided in the annually updated directed commercial sampling manual (e.g. IPHC Directed Commercial Landings Sampling Manual 2021). Directed commercial fishery landings are recorded by the Federal and State agencies of each Contracting Party and summarized each year by the IPHC. Discard mortality for the directed commercial fishery is currently estimated using a combination of research survey (USA) and observer data (Canada).

- Quality control and sampling rate estimations: [detail current QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Non-directed commercial discard mortality data**: The IPHC accounts for non-directed commercial discard mortality by IPHC Regulatory Area and sector. Non-directed commercial discard mortality estimates are provided by State and Federal agencies of each Contracting Party, and compiled annually for use in the stock assessment and other analysis. https://www.iphc.int/data/datatest/non-directed-commercial-discard-mortality-fisheries.

- Non-directed commercial discard mortality of Pacific halibut is estimated because not all fisheries have 100% monitoring and not all Pacific halibut that are discarded are assumed to die. The IPHC relies upon information supplied by observer programs run by Contracting Party agencies for non-directed commercial discard mortality estimates in most fisheries. Non-IPHC research survey information or other sources are used to generate estimates of non-directed commercial discard mortality in the few cases where fishery observations are unavailable. Trawl fisheries off Canada British Columbia are monitored and non-directed commercial discard mortality information is provided to IPHC by DFO. NOAA Fisheries operates observer programs off the USA West Coast and Alaska, which monitor the major groundfish fisheries. Data collected by those programs are used to estimate non-directed commercial discard mortality.
  - Quality control and sampling rate estimations: [detail current QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Subsistence fisheries data**: Subsistence fisheries are non-commercial, customary, and traditional use of Pacific halibut for direct personal, family, or community consumption or sharing as food, or customary trade. The primary subsistence fisheries are the treaty Indian Ceremonial and Subsistence fishery in IPHC Regulatory Area 2A off northwest Washington State (USA), the First Nations Food, Social, and Ceremonial (FSC) fishery in British Columbia (Canada), and the subsistence fishery by rural residents and federally-recognized native tribes in Alaska (USA) documented via Subsistence Halibut Registration Certificates (SHARC). Subsistence fishery removals of Pacific halibut, including estimated subsistence discard mortality, are provided by State and Federal agencies of each Contracting Party, estimated, and compiled annually for use in the stock assessment and other analysis. https://www.iphc.int/datatest/subsistence-fisheries.
  - Quality control and sampling rate estimations: [detail current QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Recreational fisheries data**: Recreational removals of Pacific halibut, including estimated recreational discard mortality, are provided by State agencies of each Contracting Party, estimated, and compiled annually for use in the stock assessment and other analysis. https://www.iphc.int/data/datatest/pacific-halibut-recreational-fisheries-data.

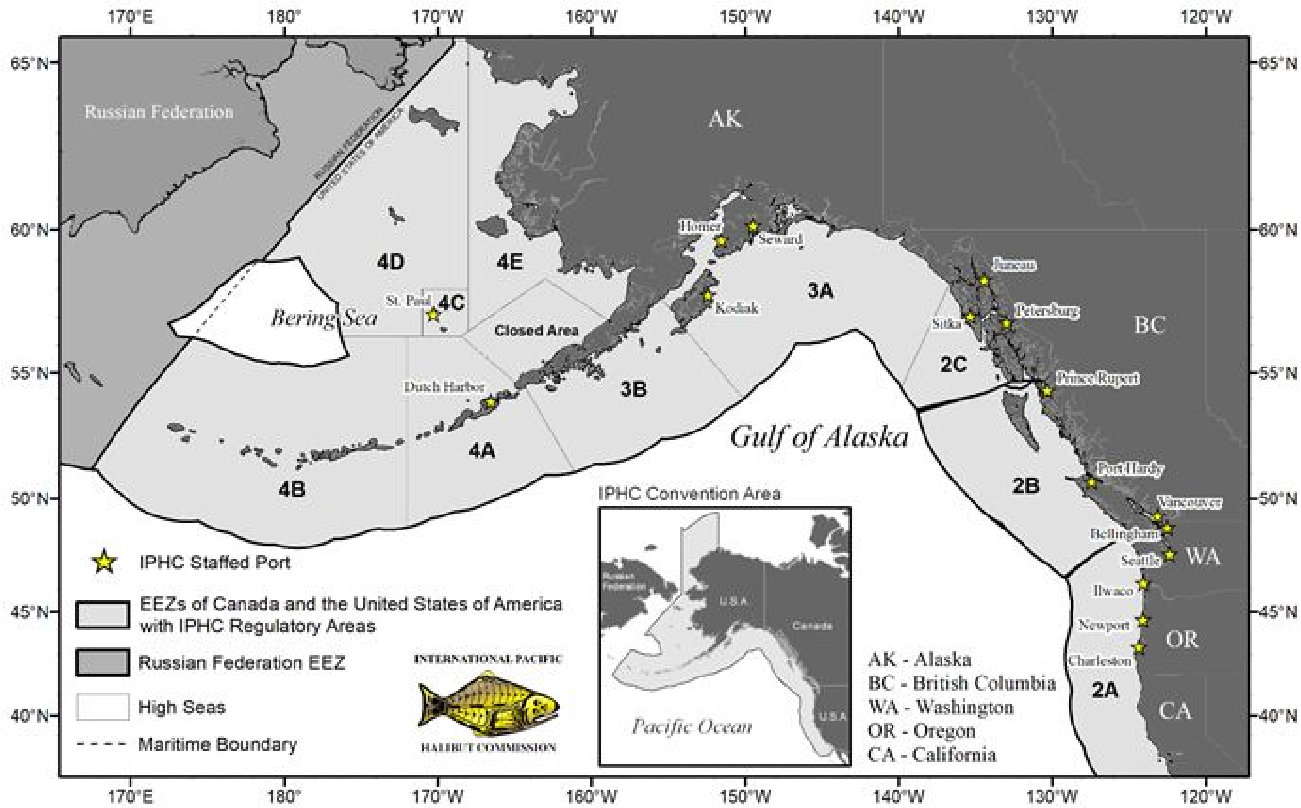

Figure 5. Ports where the IPHC has sampled directed commercial landings throughout the fishing period in recent years (note: ports sampled in a given year may change for operational reasons).

- Quality control and sampling rate estimations: [detail current QC practices, protocol references, and most recent sampling rate/design evaluation]

5.4.2 ***Fishery-independent data***. Data collection and monitoring activities aimed at providing a standardised time-series of biological and ecological data that is independent of the fishing fleet.

- **Fishery-independent setline survey (FISS)**: The IPHC Fishery-Independent Setline Survey (FISS) provides catch-rate information and biological data on Pacific halibut that are independent of the fishery. These data, collected using standardized methods, bait, and gear during the summer of each year, are used to estimate the primary index of population abundance used in the stock assessment. The FISS is restricted to the summer months, but encompasses nearly all of the commercial fishing grounds in the Pacific halibut fishery, and almost all known Pacific halibut habitat in Convention waters outside the Bering Sea. The standard FISS grid totals 1,890 stations (Fig. 6). Biological data collected on the FISS (e.g. the length, weight, age, and sex composition of Pacific halibut) are used to monitor changes in biomass, growth, and mortality of the Pacific halibut population. In addition, records of non-target species caught during FISS operations provide insight into bait competition, and serve as an index of abundance over time, making them valuable to the potential management and avoidance of non-target species. An example of the data collected and the methods used are provided in the annually updated FISS sampling manual (e.g. IPHC FISS Sampling Manual 2021).

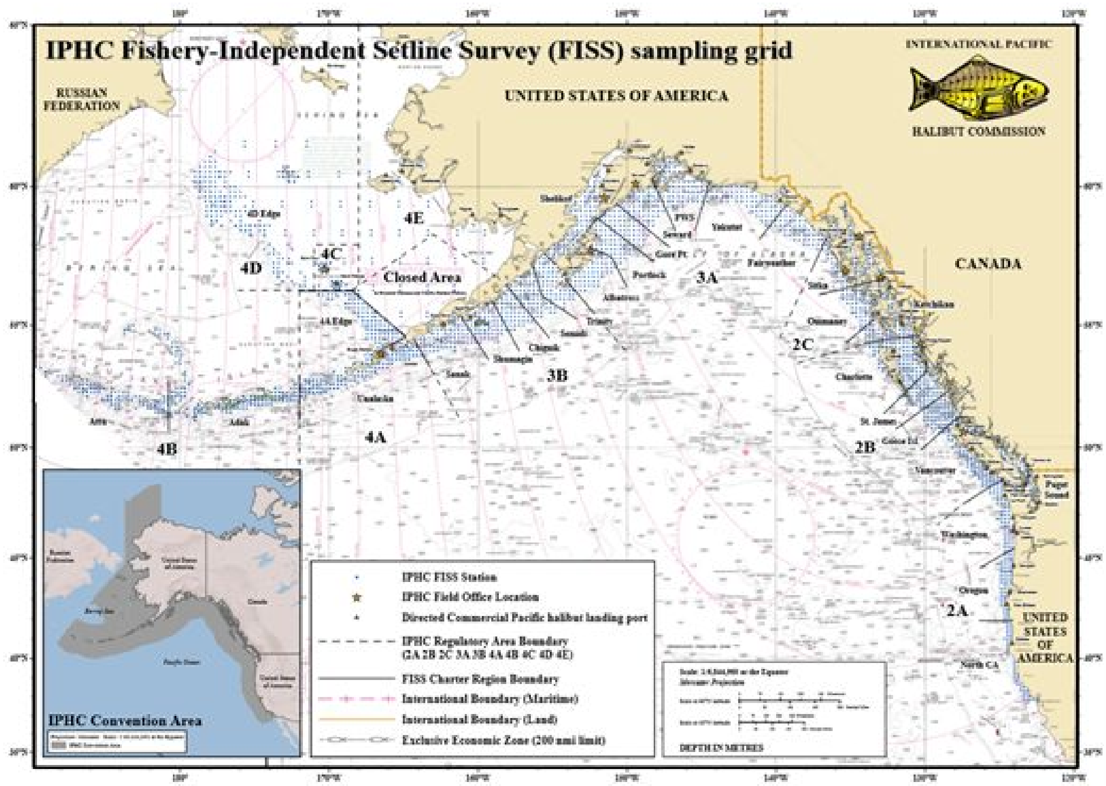

Figure 6. IPHC Fishery-Independent Setline Survey (FISS) with full sampling grid shown.

- Quality control and sampling rate estimations: Following a program of planned FISS expansions from 2014-19, a process of rationialisation of the FISS was undertaken. The goal was to ensure that, given constraints on resources available for implementing the FISS, station selection was such that precise density indices would be estimated with high precision and low bias. An annual design review process has been developed during which potential FISS designs for the subsequent three years are evaluated according to precision and bias criteria. The resulting proposed designs and their evaluation are presented for review at the June Scientific Review Board meeting (IPHC-2021-SRB018-R), and potentially modified following SRB input before presentation to the Commissioners at the Work Meeting and Interim Meeting. Annual biological sampling rates for each IPHC Regulatory Area are calculated based on the previous year's catch rates and an annual target of 2000 sampled fish (with 100 additional archive samples) (IPHC FISS Sampling Manual 2021).
    - .[detail current QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Fishery-independent Trawl Survey (FITS)**: Since 1996, the IPHC has participated annually in the NOAA Fisheries trawl surveys operating in the Bering Sea (Fig. 7) and Aleutian Islands (Fig. 8) and Gulf of Alaska (Fig. 9). The information collected from Pacific halibut caught on these surveys, together with data from the IPHC Fishery-Independent Setline Survey (FISS) and commercial Pacific halibut data, are used directly in estimating indices of abundance and in the stock assessment and to monitor population trends, growth/size, and to supplement understanding of recruitment, and age composition of young Pacific halibut.

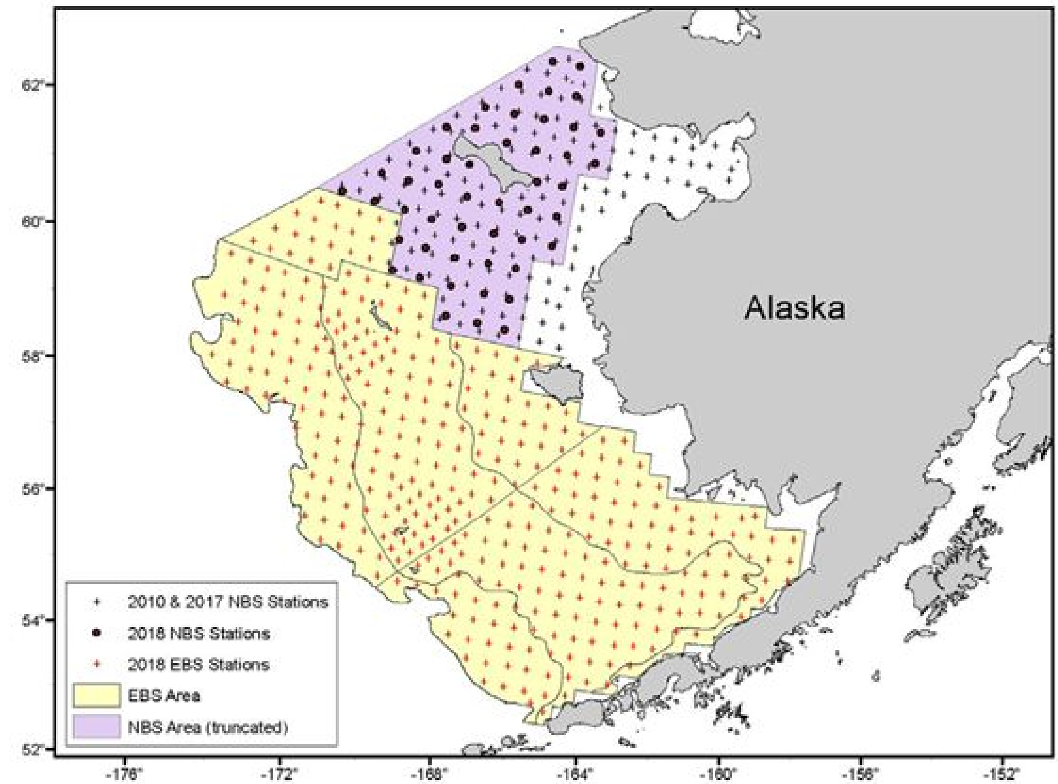

Figure 7. Sampling station design for the 2018 NOAA Bering Sea bottom trawl survey. Black dots are stations sampled in the 2018 "rapid-response" NBS trawl survey and black plus signs are stations sampled in the 2010 and 2017 standard NBS trawl surveys.

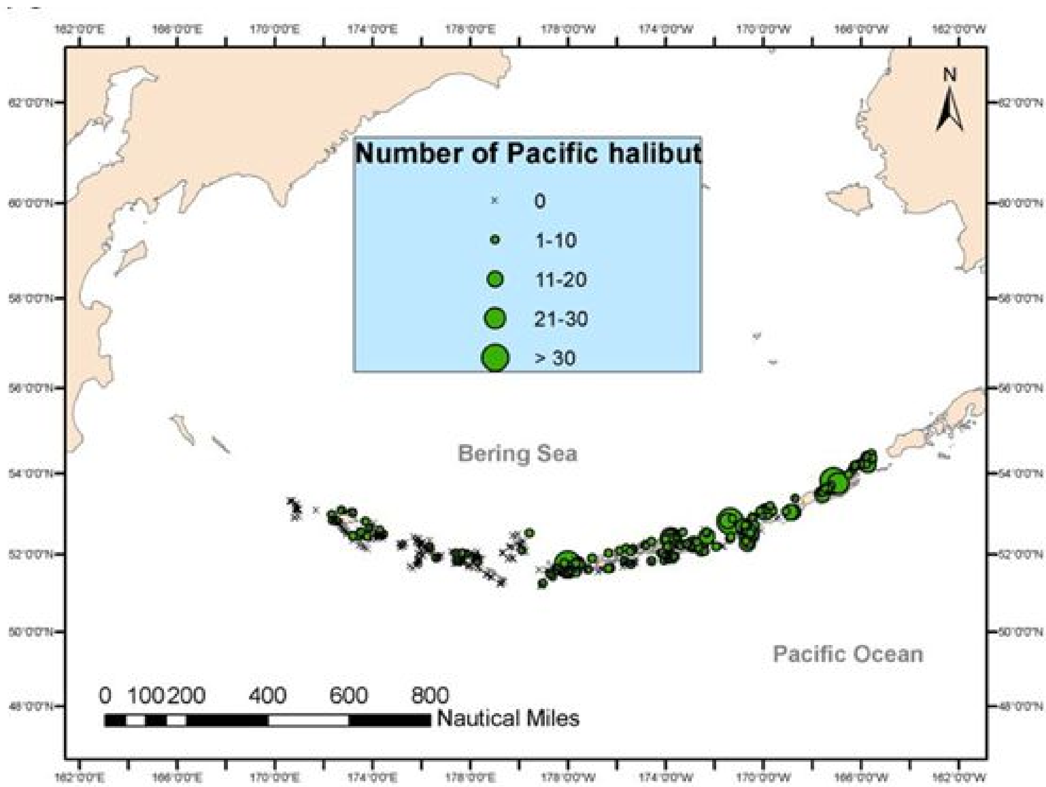

Figure 8. Sampling stations and catch for the 2018 NOAA-Fisheries Aleutian Islands bottom trawl survey.

[2021 Map to be added]

Figure 9. Sampling stations and catch for the yyyy NOAA-Fisheries Gulf of Alaska bottom trawl survey.

- Quality control and sampling rate estimations: [detail current QC practices, protocol references, and most recent sampling rate/design evaluation]

5.5 Biology and Ecology

Focal Area Objective	To identify and assess critical knowledge gaps in the biology and ecology of Pacific halibut within its known range, including the influence of environmental conditions on population and fishery dynamics.
IPHC Website portal	https://www.iphc.int/management/science-and-research/biological-and-ecosystem-science-research-program-bandesrp

Since its inception, the IPHC has had a long history of research activities devoted to describe and understand the biology of the Pacific halibut (*Hippoglossus stenolepis*). At present, the main objectives of the Biological and Ecosystem Science Research Program at IPHC are to: 1) identify and assess critical knowledge gaps in the biology of the Pacific halibut; 2) understand the influence of environmental conditions in the biology of the Pacific halibut and its fishery; and 3) apply the resulting knowledge to reduce uncertainty in current stock assessment models.

The primary biological research activities at the IPHC that follow Commission objectives and selected for their important management implications are identified and described in the proposed 5-Year Research Plan for the period 2022-2026. An overarching goal of the 5-Year Research Plan is to promote integration and synergies among the various research activities led by the IPHC in order to improve our knowledge of key biological inputs that feed into the stock assessment and MSE process. The goals of the main research activities of the 5-Year Research Plan are therefore aligned and integrated with the IPHC stock assessment and MSE processes. The IPHC Secretariat conducts research activities to address key biological issues based on the IPHC Secretariat's own input as well as input from the IPHC Commissioners, stakeholders and particularly from specific subsidiary bodies to the IPHC such, including the Scientific Review Board (SRB) and the Research Advisory Board (RAB).

The biological research activities contemplated in the 5-Year Research Plan and their specific aims are detailed in Section 6. Overall, the biological research activities at IPHC aim at providing information on factors that influence the biomass of the Pacific halibut population (e.g. distribution and movement of fish among IPHC Regulatory Areas, growth patterns and environmental influences on growth in larval, juvenile and adult fish, drivers of changes in size-at-age) and, specifically, of the spawning (female) population (e.g. reproductive maturity, skipped spawning, reproductive migrations) and resulting changes in population dynamics. Furthermore, the research activities of IPHC also aim, on one hand, at providing information on the survival of regulatory-discarded Pacific halibut in the directed fisheries with the objective to refine current estimates of discard mortality rates and develop best handling practices, and, on the other hand, at reducing whale depredation and Pacific halibut bycatch through gear modifications and through a better understanding of behavioral and physiological responses of Pacific halibut to fishing gear.

6. *Core focal areas – Planned and opportunistic activities (2022-2026)*

6.1 Stock Assessment

Within the three assessment research categories, the following topics have been identified as priorities in order to focus attention on their importance for the stock assessment and management of Pacific halibut. A brief narrative is provided here to highlight the specific use of products from these studies in the stock assessment.

6.1.1 <u>Assessment data collection and processing</u>:

6.1.1.1 Commercial fishery sex-ratio-at-age via genetics and development of methods to estimate historical sex-ratios-at-age

Commercial fishery sex-ratio information has been found to be closely correlated with the absolute scale of the population estimates in the stock assessment, and has been identified as the greatest source of uncertainty since 2013. With only three years (2017-19) of commercial sex-ratio-at-age information available for the 2020 stock assessment, the annual genetic assay of fin clips sampled from the landings remains critically important. When the time series grows longer, it may be advantageous to determine the ideal frequency at which these assays need to be conducted. Development of approaches to use archived otoliths, scales or other samples to derive historical estimates (if possible) could provide valuable information on earlier time-periods (with differing fishery and biological properties), and therefore potentially reconcile some of the considerable historical uncertainty in the present stock assessment.

6.1.1.2 Whale depredation accounting and tools for avoidance

Whale depredation currently represents a source of unobserved and unaccounted-for mortality in the assessment and management of Pacific halibut. A logbook program has been phased in over the last several years, in order to record whale interactions observed by commercial fishermen. Estimation of depredation mortality, from logbook records and supplemented with more detailed data and analysis from the FISS represents a first step in accounting for this source of mortality; however, such estimates will likely come with considerable uncertainty. Reduction of depredation mortality through improved fishery avoidance and/or catch protection would be a preferable extension and/or solution to basic estimation. As such, research to provide the fishery with tools to reduce depredation is considered a closely-related high priority.

6.1.2 Biological inputs:

6.1.2.1 Maturity, skip-spawning and fecundity

Management of Pacific halibut is currently based on reference points that rely on relative female spawning biomass. Therefore, any changes to our understanding of reproductive output – either across age/size (maturity), over time (skip spawning) or as a function of body mass (fecundity) are crucially important. Each of these components directly affects the annual reproductive output estimated in the assessment. Ideally, the IPHC would have a program in place to monitor each of these three reproductive traits over time and use that information in the estimation of the stock-recruitment relationship, and the annual reproductive output relative to reference points. This would reduce the potential for biased time-series estimates created by non-stationarity in these traits (illustrated via sensitivity analyses in several of the recent assessments). However, at present we have only historical time-aggregated estimates of maturity and fecundity schedules. Therefore, the current research priority is to first update our estimates for each of these traits to reflect current environmental and biological conditions. After current stock-wide estimates have been achieved, a program for extending this information to a time-series via transition from research to monitoring can be developed.

6.1.2.2 Stock structure of IPHC Regulatory Area 4B relative to the rest of the convention area

The current stock assessment and management of Pacific halibut assume that IPHC Regulatory Area 4B is functionally connected with the rest of the stock, i.e., that recruitment from other areas can support harvest in Area 4B and that biomass in Area 4B can produce recruits that may contribute to other Areas. Tagging (Webster et al. 2013) and genetic (Drinan et al. 2016) analyses have indicated the potential for Area 4B to be demographically isolated. An alternative to current assessment and management structure would be to treat Area 4B separately from the rest of the coast. This would not likely have a large effect on the coastwide stock assessment as Area 4B represents only approximately 5% of the surveyed stock (Stewart et al. 2021b). However, it would imply that the specific mortality limits for Area 4B could be very important to local dynamics and should be separated from stock-wide trends. Therefore, information on the stock structure for Area 4B has been identified as a top priority.

6.1.2.3 Meta-population dynamics (connectivity) of larvae, juveniles and adults

The stock assessment and current management procedure treat spawning output, juvenile Pacific halibut abundance, and fish contributing to the fishery yield as equivalent across all parts of the Convention Area. Information on the connectivity of these life-history stages could be used for a variety of improvements to the assessment and current management procedure, including: investigating recruitment covariates, structuring spatial assessment models, identifying minimum or target spawning biomass levels in each Biological Region, refining the stock-recruitment relationship to better reflect source-sink dynamics and many others. Spatial dynamics have been highlighted as a major source of uncertainty in the Pacific halibut assessment for decades, and will continue to be of high priority until they are better understood.

6.1.3 Fishery yield:

6.1.3.1 Biological interactions with fishing gear

In 2020, 16% of the total fishing mortality of Pacific halibut was discarded (Stewart et al. 2021b). Discard mortality rates can vary from less than 5% to 100% depending on the fishery, treatment of the catch and other factors (Leaman and Stewart 2017). A better understanding of the biological underpinnings for discard mortality could lead to increased precision in these estimates, avoiding potential bias in the stock assessment. Further, improved biological understanding of discard mortality mechanisms could allow for reductions in this source of fishing mortality, and thereby increased yield available to the fisheries.

6.1.3.2 Guidelines for reducing discard mortality

Much is already known about methods to reduce discard mortality, in non-directed fisheries as well as the directed commercial and recreational sectors. Promotion and adoption of best handling practices could reduce discard mortality and lead to greater retained yield.

Looking forward, the IPHC has recently considered adding close-kin genetics (e.g. Bravington et al. 2016) to its ongoing research program. Close-kin mark-recapture can potentially provide estimates of the absolute scale of the spawning output from the Pacific halibut population. This type of information can be fit directly in the stock assessment, and if estimated with a reasonable amount of precision, even a single data point could substantially reduce the uncertainty in the scale of total population estimates. Further, close-kin genetics may provide independent estimates of total mortality (and therefore natural mortality conditioned on catch-at-age), relative fecundity-at-age, and the spatial dynamics of spawning and recruitment. All of these quantities could substantially improve the structure of the current assessment and reduce uncertainty. Data collection of genetic samples from 100% of the sampled commercial landings has been in place since 2017 (as part of the sex-ratio monitoring) and routine comprehensive genetic sampling of FISS catch will begin in 2021. The genetic analysis required to produce data allowing the estimation of reproductive output and other population parameters from close-kin mark-recapture modelling is both complex and expensive, and it could take several years for this project to get fully underway.

6.2 Management Strategy Evaluations

MSE priorities for have been subdivided into two categories: 1) biological parameterisation and 2) fishery parameterization. The following topics have been identified as top priorities. Research provides specifications for the MSE simulations, such as inputs to the OM, but another important outcome of the research is to define the range of plausibility to include in the MSE simulations as a measure of uncertainty.

6.2.1 Biological and population parameterization

6.2.1.1 Distribution of life stages and stock connectivity

Research topics in this category will mainly inform parameterization of movement in the OM, but will also provide further understanding of Pacific halibut movement, connectivity, and the temporal variability. This knowledge may also be used to refine specific objectives to reflect reality and possible outcomes.

This research includes examining larval and juvenile distribution which is a main source of uncertainty in the OM that is currently not fully incorporated. Outcomes will assist with conditioning the OM, verify patterns simulated from the OM, and provide information to develop reasonable sensitivity scenarios to test the robustness of MPs.

Also included in this number one priority is stock structure research, especially with regard to IPHC Regulatory Area 4B. The dynamics of this IPHC Regulatory Area are not fully understood and it is useful to continue research on the connectivity of IPHC Regulatory Area 4B with other IPHC Regulatory Areas.

Finally, genomic analysis of population size is also included in this ranked category because that would help inform development of the OM as well as the biological sustainability objective related to maintaining a minimum spawning biomass in each IPHC Regulatory Area. An understanding of the spatial distribution of population size will help to inform this objective as well as the OM conditioning process.

6.2.1.2 Spatial spawning patterns and connectivity between spawning populations

An important parameter that can influence simulation outcomes is the distribution of recruitment across Biological Regions. Continued research in this area will improve the OM and provide justification for parameterising temporal variability. Research includes assigning individuals to spawning areas and establishing temporal and spatial spawning patterns. Outcomes may also provide information on recruitment strength and the relationship with environmental factors. For example, recent work by Sadorus et al (2020) used a biophysical and spatio-temporal models to examine connectivity across the Bering Sea and Gulf of Alaska. Furthermore, close-kin mark-recapture (Bravington et al. 2016) may provide insights into spatial relationships between juveniles and adults as well as abundance in specific regions.

6.2.1.3 Understanding growth variation

Changes in the average weight-at-age of Pacific halibut is one of the major drivers of changes in biomass over time. The OM currently simulates temporal changes in weight-at-age via a random autocorrelated process which is unrelated to population size or environmental factors. Ongoing research in drivers related to growth in Pacific halibut will help to improve the simulation of weight-at-age.

6.2.2 Fishery parameterization

The specifications of fisheries and their parameterizations involved consultation with Pacific halibut stakeholders but some aspects of those parameterizations benefit from targeted research. One specific example is knowledge of discarding and discard mortality rates in directed and non-directed fisheries. Discard mortality can be a significant source of fishing mortality in some IPHC Regulatory Areas and appropriately modelling that mortality will provide a more robust evaluation of MPs.

6.2.1 MSE Program of Work for 2021–2023

Following the 1tth Special Session of the IPHC, an MSE program of work for 2021–2023 was developed. Seven tasks were identified that pertained to further developments of the MSE framework, evaluation of alternative MPs, and improvements in evaluation and presentation of results. Table 1 lists these tasks and provides a brief description. Additional details can be found in the program of work available on the MSE webpage.

Table 1. Tasks recommended by the Commission at SS011 (IPHC-2021-SS011-R para 7) for inclusion in the IPHC Secretariat MSE Program of Work for 2021–2023.

ID	Category	Task	Deliverable
F.1	Framework	Develop migration scenarios	Develop OMs with alternative migration scenarios
F.2	Framework	Implementation variability	Incorporate additional sources of implementation variability in the framework
F.3	Framework	Develop more realistic simulations of estimation error	Improve the estimation model to more adequately mimic the ensemble stock assessment

ID	Category	Task	Deliverable
F.5	Framework	Develop alternative OMs	Code alternative OMs in addition to the one already under evaluation.
M.1	MPs	Size limits	Identification, evaluation of size limits
M.3	MPs	Multi-year assessments	Evaluation of multi-year assessments
E.3	Evaluation	Presentation of results	Develop methods and outputs that are useful for presenting outcomes to stakeholders and Commissioners

6.3 Fishery socioeconomics

The priorities of the IPHC fisheries socioeconomics program can be subdivided into four categories. These are described below.

6.3.1 Primary economic data collection

In order to accurately capture the economic impact of the Pacific halibut, the IPHC designed a series of surveys to gather information from the sectors relying on the Pacific halibut resource. The survey target groups are commercial fishers, processing plant operators, and charter business owners. The goal of the survey is to improve the understanding of each sector's production structure (i.e. data on the distribution of revenue between profit and expenditure items), profitability (including the viability of the sector depending on the stock condition), and distribution of earnings. The compiled survey data, together with secondary data from various governmental and non-governmental sources, serve as an input to the economic impact assessment model.

6.3.2 Development of the Pacific halibut multiregional economic impact assessment (PHMEIA) model

PHMEIA model is a multiregional model based on a social accounting matrix (SAM) framework that describes the economic interdependencies between sectors and regions developed to assess the economic contribution of Pacific halibut resource to the economy of the United States and Canada. The model describes the within-region production structure of the Pacific halibut sectors (fishing, processing, charter). In addition, it accounts for interregional spillovers, which represent economic stimulus in the regions other than the one in which the harvest occurs. This is done by tracing Pacific halibut-dependent earnings from the landing stage to beneficial owners of the resource.

It is important to note that accurate characterization of the Pacific halibut sectors in the PHMIA model requires active participation of IPHC stakeholders, including commercial fishers, processing plant operators, and charter business owners in developing the necessary data for analysis.

The following components have been identified as priorities for improving the PHMEIA model for it to better serve management decisions.

6.3.2.1 Expanding the static SAM model to a computable general equilibrium model

Relaxing the assumption of fixed technical coefficients by specifying these coefficients econometrically as a function of relative prices of inputs is one of the most compelling extensions to the static SAM model. Such models, generally referred to as computable general equilibrium (CGE) models, require research to develop credible functional relationships between prices and consumption that would guide economic agents' behavior in the model. The CGE approach is a preferred way forward when expanding the model usability and applying it in conjunction with the Pacific halibut management strategy evaluation. In addition, the dynamic model is well suited to analyze the impact of a broad suite of policies or external factors that would affect the stock over time.

6.3.2.2 Improving the spatial granularity of the SAM model

Extending the community analysis beyond a simplified approach described in the IPHC-2021-SRB018-09 (section *Community impacts in Alaska*) to a full community level (or any other spatial scale) SAM-based model requires significant investment in identifying the economic relationships between different sectors or industries (including both seafood and non-seafood industries) within each broader-defined region, this including deriving estimates on intra-regional trade in commodities and flow of earnings. It is an appealing extension of the current model with a great potential for more accurate estimates of the community effects.

6.3.2.3 Study of recreational demand

It is important to note that while it is reasonable to assume that changes in harvest limits have a relatively proportional impact on production by commercial fishers (unless these are dramatic and imply fleet restructure or a significant shift in prices), the effects on the recreational sector are not so straightforward. A separate study estimating changes in saltwater recreational fishing participation as a response to the changing recreational harvest limits is necessary to assess policy impacts in the recreational sector rather than provide a snapshot economic impact. Such studies typically require surveying recreational fishers.

6.3.2.4 Study of demand for Pacific halibut products

Catches can be converted to revenues, but one has to determine what price to multiply harvests by. Since price fluctuates with harvest levels, pragmatic assessment of harvest limits changes needs to be supplemented with a model of demand for Pacific halibut. The demand-adjusted prices provide more economics-sound projections of gross revenues in the sector.

The demand model can also be used to estimate final consumer benefits from changing Pacific halibut harvests and prices (i.e., consumer surplus). In 2019, fresh Alaskan Pacific halibut fillets routinely sold for USD 24-28 a pound, and often more, downtown Seattle. Understanding the formation of the price paid by final consumers is an important step in assessing the contribution of Pacific halibut along the entire value chain, from the hook to the plate.

6.3.2.5 Uncertainty in the PHMEIA model

The PHMEIA model results focus on the magnitude of the Pacific halibut contribution to the economy and its spatial distribution. To increase confidence in the PHMEIA results, the model needs to consider sources of input variations and the cumulative effect of interactions among them. The natural next step is to conduct sensitivity analysis to account for the uncertainties in the system. The current framework would benefit from proposing methods for calculating the range (confidence intervals) of impacts from input variations within a PHMEIA framework, explicitly accounting for multiple sources of input variations.

6.3.2.6 Assessment of the economic impact of other sources of Pacific halibut mortality

All-sectors-encompassing quantitative assessment of the economic impact of the Pacific halibut resource necessitates the development of a methodological approach for the remaining sources of Pacific halibut mortality, including subsistence fishing, bycatch, and research catch. Methods adopted for the commercial and charter sector are not adequate for this portion of the harvest.

6.3.3 Provide stakeholders with a user-friendly tool visualizing the spatial distribution of socioeconomic impacts

The complexity of Pacific halibut supply-side restriction in the form of region-based allocations suggests the need for a tool enabling regulators to assess various combinations of quota allocations easily. To address this, the results of the PHMEIA model are complemented by an interactive web-based application allowing users to estimate and visualize joint economic impacts based on custom changes simultaneously applied to all IPHCmanaged Pacific halibut producing areas. In addition, the app highlights the spatial variation of the economic impacts and the importance of cross-regional flows in assessing the dependence of fishing communities on the Pacific halibut resource.

6.3.4 Provide input to the management strategy evaluation

MSE implementation has been generally oriented towards biological target reference points despite socioeconomic objectives being prevalent in the legislation of the USA and Canada. The PHMIA model may be used alongside the Pacific halibut MSE framework to translate alternative management options (harvest strategies) and resulting harvest allocations by IPHC Regulatory Area directly to socioeconomic performance metrics by region. Socioeconomic performance metrics presented alongside already developed biological/ecological performance metrics will bring the human dimension to the MSE framework, adding to the IPHC's portfolio of tools for assessing policy-oriented issues for the Pacific halibut throughout the Convention Area.

6.4 Monitoring

6.4.1 ***Fishery-dependent data***. …………………

- **Directed commercial fisheries data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………
- **Non-directed commercial discard mortality data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………
- **Subsistence fisheries data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………
- **Recreational fisheries data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………

6.4.2 ***Fishery-independent data***. Data collection and monitoring activities aimed at providing a standardised time-series of biological and ecological data that is independent of the fishing fleet.

- **Fishery-independent setline survey (FISS)**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development……….
- **Fishery-independent Trawl Survey (FITS)**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………

6.5 Biology and Ecology

6.5.1 ***Migration and Population Dynamics***. Genetic and genomic studies aimed at improving current knowledge of Pacific halibut migration and population dynamics throughout all life stages in order to achieve a complete understanding of stock structure and distribution across the entire distribution range of Pacific halibut in the North Pacific Ocean and the biotic and abiotic factors that influence it (specifically excluding satellite tagging). Specific objectives in this area include:

- Improve current knowledge of the genetic structure of the Pacific halibut population through the use of state-of-the-art low-coverage whole genome resequencing approaches. Establishment of genetic signatures of spawning sites.

- Improve our understanding of the mechanisms and magnitude of larval connectivity in the North Pacific Ocean. Identification of environmental and biological predictors of larval abundance and recruitment.
- Improve our understanding of spawning site contributions to nursery/settlement areas in relation to year-class, recruit survival and strength, and environmental conditions in the North Pacific Ocean. Measure of genetic diversity of Pacific halibut juveniles from the eastern Bering Sea and the Gulf of Alaska.
- Improve our understanding of the relationship between nursery/settlement origin and adult distribution and abundance over temporal and spatial scales. Genomic assignment of individuals to source populations and assessment of distribution changes.
- Integrate analyses of Pacific halibut connectivity and distribution changes by incorporating genomic approaches.
- Improve estimates of population size, migration rates among geographical regions, and demographic parameters (e.g. fecundity-at-age, survival rate), through the application of close-kin mark-recapture-based approaches.
- Improve our understanding of the influences of oceanographic and environmental variation on connectivity, population structure and adaptation at a genomic level using seascape genomics approaches.

6.5.2 ***Reproduction***. Studies aimed primarily at addressing two critical issues for stock assessment analysis based on estimates of female spawning biomass: 1) the sex ratio of the commercial catch and 2) maturity estimations. Specific objectives in this area include:

- Continued improvement of genetic methods for accurate sex identification of commercial landings from fin clips and otoliths in order to incorporate recent and historical sex-at-age information into the stock assessment process.
- Improve our understanding of the temporal progression of reproductive development and gamete production during an entire annual reproductive cycle in female and male Pacific halibut.
- Update current maturity-at-age estimates.
- Provide estimates of fecundity-at-age and fecundity-at-size.
- Investigate the possible presence of skip spawning in Pacific halibut females.
- Improve accuracy in current staging criteria of maturity status used in the field.
- Investigate possible environmental effects on the ontogenetic establishment of the phenotypic sex and their influence on sex ratios in the adult Pacific halibut population.
- Improve our understanding of potential temporal and spatial changes in maturity schedules and spawning patterns in female Pacific halibut and possible environmental influences.
- Improve our understanding of the genetic basis of variation in age and/or size-at-maturity, fecundity, and spawning timing, by conducting genome-wide association studies.

6.5.3 ***Growth***. Studies aimed at describing the role of factors responsible for the observed changes in size-at-age and at evaluating growth and physiological condition in Pacific halibut. Specific objectives in this area include:

- Evaluate possible variation in somatic growth patterns in Pacific halibut as informed by physiological growth markers, physiological condition, energy content and dietary influences.
- Investigate the effects of environmental and ecological conditions that may influence somatic growth in Pacific halibut. Evaluate the relationship between somatic growth and temperature and trophic histories in Pacific halibut through the integrated use of physiological growth markers.
- Improve our understanding of the genetic basis of variation in somatic growth and size-at-age by conducting genome-wide association studies.

6.5.4 ***Mortality and Survival Assessment***. Studies aimed at providing updated estimates of discard mortality rates (DMRs) for Pacific halibut in the guided recreational fisheries and at evaluating methods for reducing mortality of Pacific halibut. Specific objectives in this area include:

- Provide information on the types of fishing gear and fish handling practices used in the Pacific halibut recreational (charter) fishery as well as on the number and size composition of discarded Pacific halibut in this fishery.
- Establish best handling practices for reducing discard mortality of Pacific halibut in recreational fisheries.
- Investigate new methods for whale avoidance and/or deterrence for the reduction of Pacific halibut depredation by whales and for improved estimation of depredation mortality.
- Investigate physiological and behavioral responses of Pacific halibut to fishing gear in order to reduce Pacific halibut bycatch.

6.5.5 Climate Change Studies aimed …

<<In development>>>

6.5.6 Fishing Technology Studies aimed …

<<In development>>>

7. Conclusion and future review/amendments

<<In development>>>

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APPENDICES

Appendix I: Multi-year tactical activity matrix

Appendix II: Outcomes of the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21)

Appendix III: Proposed schedule of outputs

Appendix IV: Proposed schedule with funding and staffing indicators

APPENDIX I

Multi-year tactical activity matrix

<<In development>>

APPENDIX II

Outcomes of the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21) (IPHC–2019–BESRP-5YP)

A. Outcomes by Research Area:

1. Migration and Distribution.

1. Larval and juvenile connectivity and early life history studies. Planned research outcomes: improved understanding of larval and juvenile distribution.

Main results:

- Larval connectivity between the Gulf of Alaska and the Bering Sea occurs through large island passes across the Aleutian Island chain.
- The degree of larval connectivity between the Gulf of Alaska and the Bering Sea is influenced by spawning location.
- Spawning locations in the western Gulf of Alaska significantly contribute Pacific halibut larvae to the Bering Sea.
- Pacific halibut juveniles counter-migrate from inshore settlement areas in the eastern Bering Sea into the Gulf of Alaska through Unimak Pass.
- Elemental signatures of otoliths from juvenile Pacific halibut vary geographically at a scale equivalent to IPHC regulatory areas.

Publications:

- Sadorus, L.; Goldstein, E.; Webster, R.; Stockhausen, W.; Planas, J.V.; Duffy-Anderson, J. Multiple life-stage connectivity of Pacific halibut (Hippoglossus stenolepis) across the Bering Sea and Gulf of Alaska. Fisheries Oceanography. 2021. 30:174-193. doi: https://doi.org/10.1111/fog.12512.
- Loher, T., Bath, G. E., Wischniowsky, S. The potential utility of otolith microchemistry as an indicator of nursery origins in Pacific halibut (Hippoglossus stenolepis) in the eastern Pacific: the importance of scale and geographic trending. Fisheries Research. 243: 106072. https://doi.org/10.1016/j.fishres.2021.106072.

Links to 5-Year Research Plan (2022-2026):

- Evaluate the level of genetic diversity among juvenile Pacific halibut in the Gulf of Alaska and the Bering sea due to admixture.
- Assignment of individual juvenile Pacific halibut to source populations.

2. Reproduction.

1. Sex ratio of commercial landings. Planned research outcomes: sex ratio information.

Main results:

- Establishment of TaqMan-based genetic assays for genotyping Pacific halibut in the IPHC Biological Laboratory.

- Sex ratio information for the 2017-2020 commercial landings.
- Transfer of genotyping efforts for sex identification to IPHC monitoring program.

Links to 5-Year Research Plan (2022-2026):

- Monitoring effort.

2. Histological maturity assessment. Planned research outcomes: updated maturity schedule.

Main results:

- Oocyte developmental stages have been characterized and fully described in female Pacific halibut for the first time.
- Oocyte developmental stages have been used for the classification of female developmental stages and to be able to characterize female Pacific halibut as group synchronous with determinate fecundity.
- Female developmental stages have been used for the classification of female reproductive phases and to be able to characterize female Pacific halibut as following an annual reproductive cycle with spawning in January and February.
- Female developmental stages and reproductive phases of females collected in the central Gulf of Alaska have been used to identify the month of August as the time of the transition between the Vtg2 and Vtg3 developmental stages marking the beginning of the spawning capable reproductive phase.
- Future gonad collections for revising maturity schedules and estimating fecundity can be conducted in August during the FISS.

Publications:

- Fish, T., Wolf, N., Harris, B.P., Planas, J.V. A comprehensive description of oocyte developmental stages in Pacific halibut, Hippoglossus stenolepis. Journal of Fish Biology. 2020. 97: 1880-1885. doi: 10.1111/jfb.14551.
- Fish et al. 2021. In Preparation.

Links to 5-Year Research Plan (2022-2026):

- Revision of maturity schedule by gonad collection during the FISS, as informed by previous studies on reproductive development.
- Estimation of fecundity by age and size, as informed by previous studies demonstrating determinate fecundity.

3. **Growth**.

1. Identification of physiological growth markers and their application for growth pattern evaluation. Planned research outcomes: informative physiological growth markers.

Main results:

- Transcriptomic profiling by RNAseq of white skeletal muscle from juvenile Pacific halibut subjected to growth suppression and to growth stimulation resulted in the identification of a number of genes that change their expression levels in response to growth manipulations.

- Proteomic profiling by LC-MS/MS of white skeletal muscle from juvenile Pacific halibut subjected to growth suppression and to growth stimulation resulted in the identification of a number of proteins that change their abundance in response to growth manipulations.
- Genes and proteins that changed their expression levels in accordance to changes in the growth rate in juvenile Pacific halibut were selected as putative growth markers for future studies on growth pattern evaluation.

Publications:

- Planas et al. 2021. In Preparation.

Links to 5-Year Research Plan (2022-2026):

- Application of identified growth markers in studies aiming at investigating environmental influences on growth patterns and at investigating dietary influences on growth patterns and physiological condition.

2. Environmental influences on growth patterns. Planned research outcomes: information on growth responses to temperature variation.

Main results:

- Laboratory experiments under controlled temperature conditions have shown that temperature affects the growth rate of juvenile Pacific halibut through changes in the expression of genes that regulate growth processes.

Publications:

- Planas et al. 2021. In Preparation.

Links to 5-Year Research Plan (2022-2026):

- Identification of temperature-specific responses in skeletal muscle through comparison between transcriptomic responses to temperature-induced growth changes and to density- and stress-induced growth changes.
- Application of growth markers for additional studies investigating the link between environmental variability and growth patterns and the effects of diet (prey quality and abundance) on growth and physiological condition.

4. **Mortality and Survival Assessment**.

1. Discard mortality rate estimation in the longline Pacific halibut fishery. Planned research outcomes: experimentally-derived DMR.

Main results:

- Different hook release methods used in the longline fishery result in specific injury profiles and viability classification.
- Plasma lactate levels are high in Pacific halibut with the lowest viability classification.
- Survival of discarded fish with the highest viability classification is estimated to be between 4.2 and 8.4%.

Publications:

- Kroska, A.C., Wolf, N., Planas, J.V., Baker, M.R., Smeltz, T.S., Harris, B.P. Controlled experiments to explore the use of a multi-tissue approach to characterizing stress in wild-caught Pacific halibut (Hippoglossus stenolepis). 2021. Conservation Physiology 9(1):coab001; doi:10.1093/conphys/coab001.
- Loher, T., Dykstra, C.L., Hicks, A., Stewart, I.J., Wolf, N., Harris, B.P., Planas, J.V. Estimation of post-release longline mortality in Pacific halibut (*Hippoglossus stenolepis*) using acceleration-logging tags. North American Journal of Fisheries Management (In Review).

Links to 5-Year Research Plan (2022-2026):

- Integration of information on capture and handling conditions, injury and viability assessment and physiological condition will lead to establishing a set of best handling practices in the longline fishery.

    2. Discard mortality rate estimation in the guided recreational Pacific halibut fishery. Planned research outcomes: experimentally-derived DMR.

Main results:

- Field experiments testing two different types of gear types (i.e. 12/0 and 16/0 circle hooks) resulted in the capture, sampling and tagging of 243 Pacific halibut in IPHC Regulatory Area 2C (Sitka, AK) and 118 in IPHC Regulatory Area 3A (Seward, AK).
- The distributions of fish lengths by regulatory area and by hook size were similar.

Links to 5-Year Research Plan (2022-2026):

- Estimation of discard mortality rate in the guided recreational fishery.
- Integration of information on capture and handling conditions, injury and viability assessment and physiological condition linked to survival.
- Establishment of a set of best handling practices in the guided recreational fishery.

5. **Genetics and genomics**.

    1. Generation of genomic resources for Pacific halibut. Planned research outcomes: sequenced genome and reference transcriptome.

Main results:

- A first draft of the chromosome-level assembly of the Pacific halibut genome has been generated.
- The Pacific halibut genome has a size of 586 Mb and contains 24 chromosome-size scaffolds covering 98.6% of the complete assembly with a N50 scaffold length of 25 Mb at a coverage of 91x.
- The Pacific halibut genome has been annotated by NCBI and is available as NCBI Hippoglossus stenolepis Annotation Release 100 (https://www.ncbi.nlm.nih.gov/genome/annotation_euk/Hippoglossus_stenolepis/100/).
- Transcriptome (i.e. RNA) sequencing has been conducted in twelve tissues in Pacific halibut and the raw sequence data have been deposited in NCBI's Sequence Read Archive (SRA) under the bioproject number PRJNA634339 (https://www.ncbi.nlm.nih.gov/bioproject/PRJNA634339) and with SRA accession numbers SAMN14989915 - SAMN14989926.

Publications:

- Jasonowicz et al. 2021. In Preparation.

- Jasonowicz et al. 2022. In Preparation.

Links to 5-Year Research Plan (2022-2026):

- Genome-wide analysis of stock structure and composition.

2. Determine the genetic structure of the Pacific halibut population in the Convention Area. Planned research outcomes: genetic population structure.

Main results:

- The collection of winter genetic samples in the Aleutian Islands completed the winter sample collection needed to conduct studies on the genetic population structure of Pacific halibut in the Convention Area.
- Initial results of low coverage whole genome resequencing of winter samples indicate that an average of 26.5 million raw sequencing reads per obtained per sample that provided average individual genomic coverages for quality filtered alignments of 3.2x.

Links to 5-Year Research Plan (2022-2026):

- Fine-scale delineation of population structure, with particular emphasis on IPHC Regulatory 4B structure.

B. External funding received:

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	**Saltonstall-Kennedy NOAA**	Improving discard mortality rate estimates in the Pacific halibut by integrating handling practices, physiological condition and post-release survival (NOAA Award No. NA17NMF4270240)	IPHC	Alaska Pacific University	$286,121	Bycatch estimates	September 2017 – August 2020
2	**North Pacific Research Board**	Somatic growth processes in the Pacific halibut (*Hippoglossus stenolepis*) and their response to temperature, density and stress manipulation effects (NPRB Award No. 1704)	IPHC	AFSC-NOAA-Newport, OR	$131,891	Changes in biomass/size-at-age	September 2017 – February 2020
3	**Bycatch Reduction Engineering Program - NOAA**	Adapting Towed Array Hydrophones to Support Information Sharing Networks to Reduce Interactions Between Sperm Whales and Longline Gear in Alaska	Alaska Longline Fishing Association	IPHC, University of Alaska Southeast, AFSC-NOAA	-	Whale Depredation	September 2018 – August 2019
4	**Bycatch Reduction Engineering Program - NOAA**	Use of LEDs to reduce Pacific halibut catches before trawl entrainment	Pacific States Marine Fisheries Commission	IPHC, NMFS	-	Bycatch reduction	September 2018 – August 2019
5	**National Fish & Wildlife Foundation**	Improving the characterization of discard mortality of Pacific halibut in the recreational fisheries (NFWF Award No. 61484)	IPHC	Alaska Pacific University, U of A Fairbanks, charter	$98,902	Bycatch estimates	April 2019 – November 2021

				industry			
6	**North Pacific Research Board**	Pacific halibut discard mortality rates (NPRB Award No. 2009)	IPHC	Alaska Pacific University,	$210,502	Bycatch estimates	January 2021 – March 2022
Total awarded ($)					**$727,416**		

C. Publications in the peer-reviewed literature:

2020:

- Fish, T., Wolf, N., Harris, B.P., Planas, J.V. A comprehensive description of oocyte developmental stages in Pacific halibut, Hippoglossus stenolepis. Journal of Fish Biology. 2020. 97: 1880-1885. https://doi: 10.1111/jfb.14551.

2021:

- Carpi, P., Loher, T., Sadorus, L., Forsberg, J., Webster, R., Planas, J.V., Jasonowicz, A., Stewart, I. J., Hicks, A. C. Ontogenetic and spawning migration of Pacific halibut: a review. Rev Fish Biol Fisheries. 2021. https://doi.org/10.1007/s11160-021-09672-w.
- Kroska, A.C., Wolf, N., Planas, J.V., Baker, M.R., Smeltz, T.S., Harris, B.P. Controlled experiments to explore the use of a multi-tissue approach to characterizing stress in wild-caught Pacific halibut (Hippoglossus stenolepis). 2021. Conservation Physiology 9(1):coab001. https://doi:10.1093/conphys/coab001.
- Loher, T., Bath, G. E., Wischniowsky, S. The potential utility of otolith microchemistry as an indicator of nursery origins in Pacific halibut (Hippoglossus stenolepis) in the eastern Pacific: the importance of scale and geographic trending. Fisheries Research. 243: 106072. https://doi.org/10.1016/j.fishres.2021.106072.
- Lomeli, M.J.M., Wakefield, W.W., Herrmann, B., Dykstra, C.L., Simeon, A., Rudy, D.M., Planas, J.V. Use of Artificial Illumination to Reduce Pacific Halibut Bycatch in a U.S. West Coast Groundfish Bottom Trawl. Fisheries Research. 2021. 233: 105737. doi: 10.1016/j.fishres.2020.105737.
- Sadorus, L.; Goldstein, E.; Webster, R.; Stockhausen, W.; Planas, J.V.; Duffy-Anderson, J. Multiple life-stage connectivity of Pacific halibut (Hippoglossus stenolepis) across the Bering Sea and Gulf of Alaska. Fisheries Oceanography. 2021. 30:174-193. doi: https://doi.org/10.1111/fog.12512.

APPENDIX III

Proposed schedule of outputs

<<In development>>

APPENDIX IV

Proposed schedule of funding and staffing indicators

<<In development>>

INTERNATIONAL PACIFIC

HALIBUT COMMISSION

IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling

Agenda item 4.1

IPHC-2021-SRB019-05

(R. Webster)

Topics

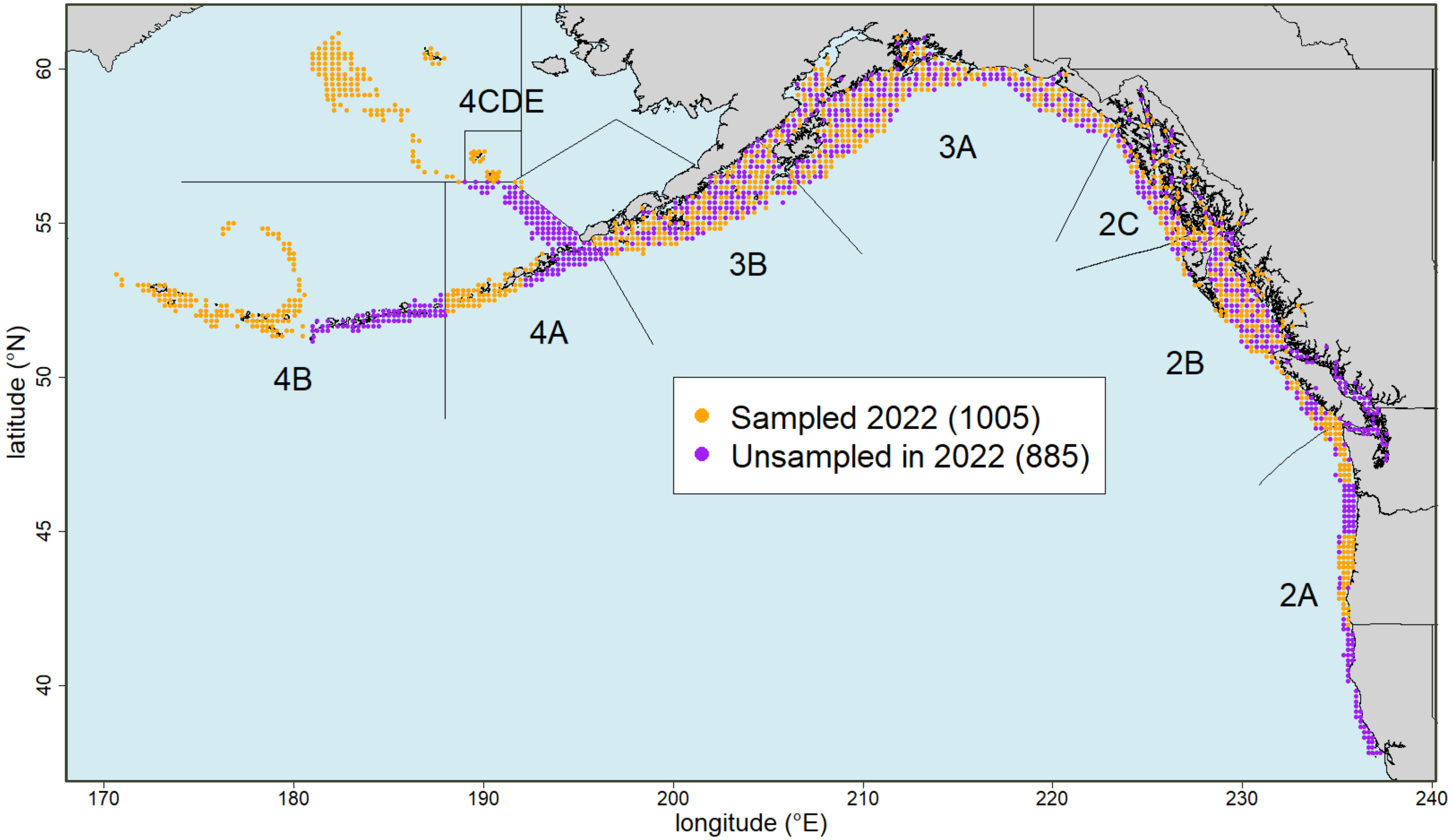
1. 2022-24 FISS design evaluation
2. Modelling of IPHC length-weight data
3. Review of IPHC hook competition standardization
4. Accounting for the effects of whale depredation on the FISS

1. 2022-24 FISS design evaluation

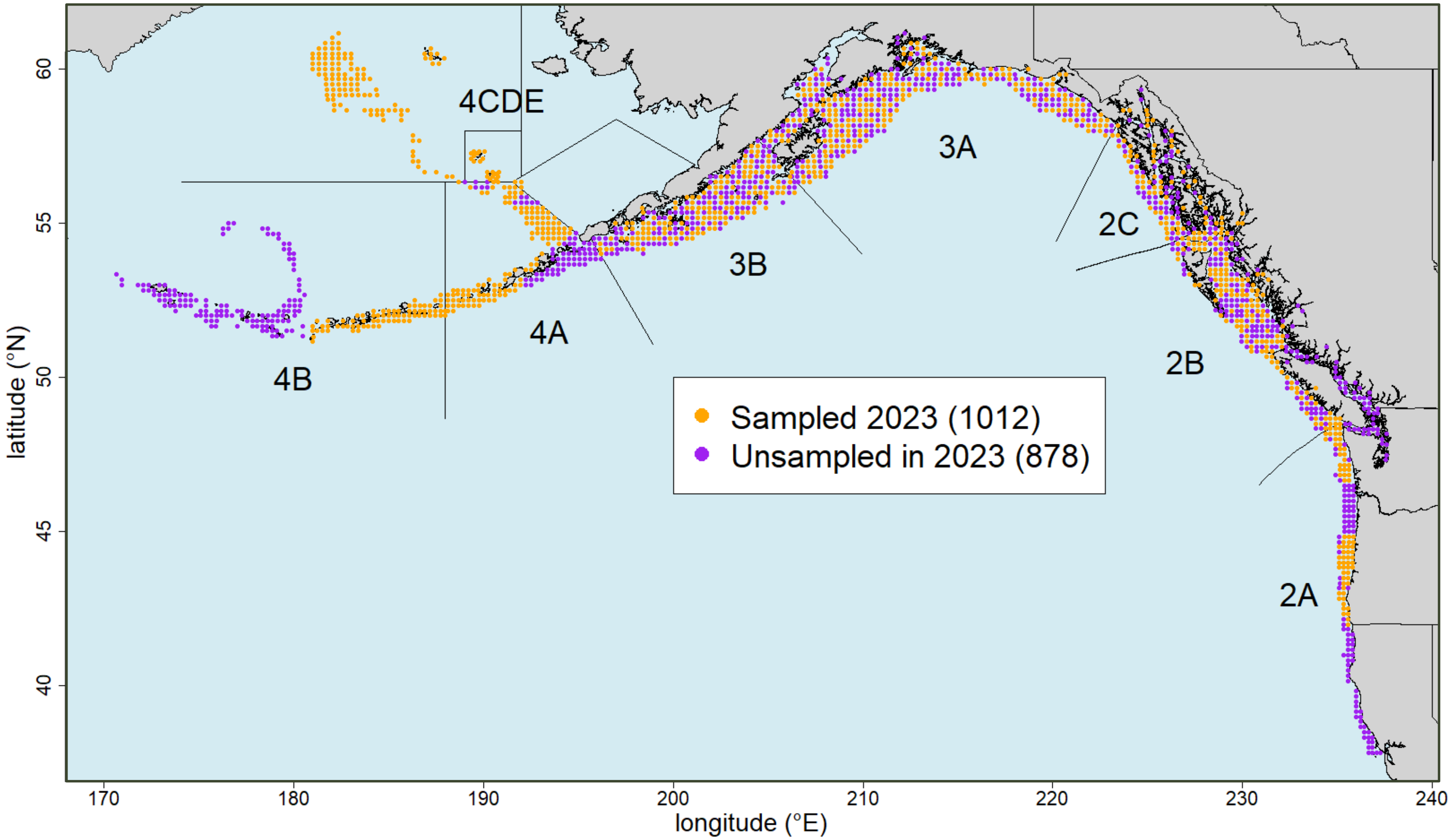
- At SRB018, the Secretariat presented proposed FISS designs for 2022-24 together with an evaluation of those designs.
- Based on the evaluation, it is expected that the proposed designs would lead to estimated indices of density that would meet bias and precision criteria.
- In their report (IPHC-2021-SRB018-R, paragraph 16) the SRB stated:

> *The SRB **ENDORSED** the final 2022 FISS design as presented in Fig. 2, and provisionally **ENDORSED** the 2023-24 designs (Figs. 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.*

Proposed 2022 FISS design

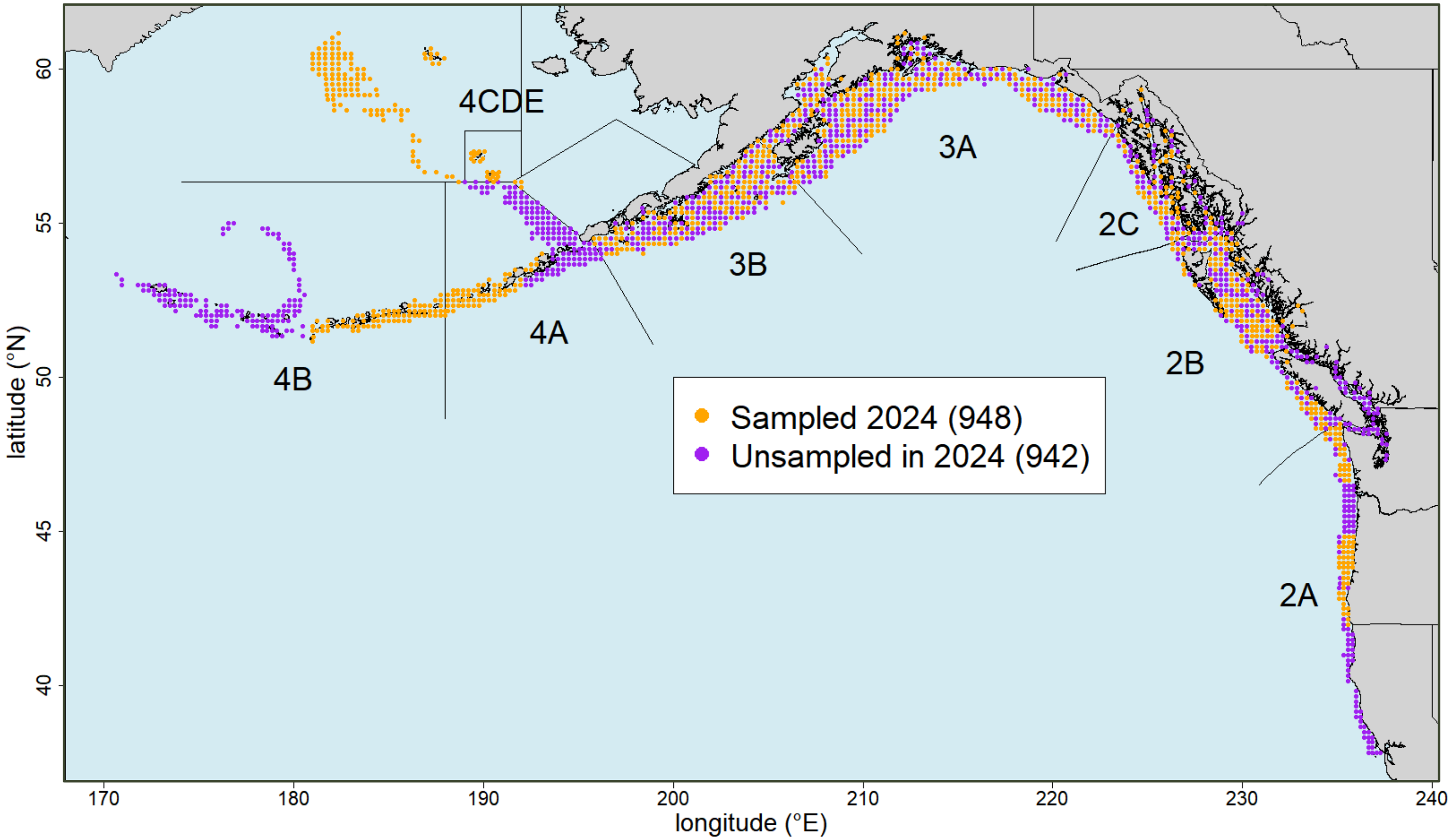


Proposed 2023 FISS design



Slide 5

Proposed 2024 FISS design



Recommendation

That the Scientific Review Board:

1) **RECOMMEND** that the Commission note the SRB endorsement of the proposed 2022 design (Figure 1.1 of IPHC-2021-SRB019-05) and provisional endorsement of the proposed 2023-24 designs (Figures 1.2 and 1.3).

2. Modelling of IPHC length-weight data

- The IPHC and other agencies sampling Pacific halibut use a standard length-weight relationship to estimate Pacific halibut weight from length when direct weight measurements are not recorded.
- This relationship was estimated in 1926 from 454 fish captured in IPHC Regulatory Area 2B
- A review by Clark (1991) showed that the relationship still held up well
- In recent years there has been evidence that this historical relationship is biased, with weight being overestimated on average
  - Pacific halibut appear to have become thinner since the relationship was estimated

IPHC data sources

- Since 2015, the IPHC commercial sampling program has collected dockside weight data on Pacific halibut
- Since 2019, FISS charter vessels have been equipped with motion-compensated scales with the goal of weighing all captured Pacific halibut
- These data allow us to obtain contemporary estimates of the length-weight relationship, and examine variation in the relationship over time and space

Weight measures and conversion multipliers

Weight	Definition	Multiplier to convert to net weight	Notes
Round FISS (U32)	Head-on, not gutted, no ice and slime	0.75	
Gross (vessel weight)	Head-on, gutted, with ice and slime	0.8624	Assumes 10% head weight and 2% shrinkage, or 12% head, and 2% ice and slime
Dressed (vessel weight) FISS (O32)	Head-on, gutted, no ice and slime	0.88	Assumes 10% head weight and 2% shrinkage, or 12% head only
Gross (dock weight) Commercial (O32) FISS (some O32)	Head-on, gutted, with ice and slime	0.882 or 0.88	Assumes 10% head weight and 2% ice and slime; deductions either additive (10+2=12% in 2A and 2B) or multiplicative (1-0.9*0.98=0.118 or 11.8% in Alaska)
Dressed (dock weight) Commercial (O32)	Head-on, no ice and slime (washed)	0.9	Assumes 10% head weight
Net	Head-off, gutted, no ice and slime (washed)	1	

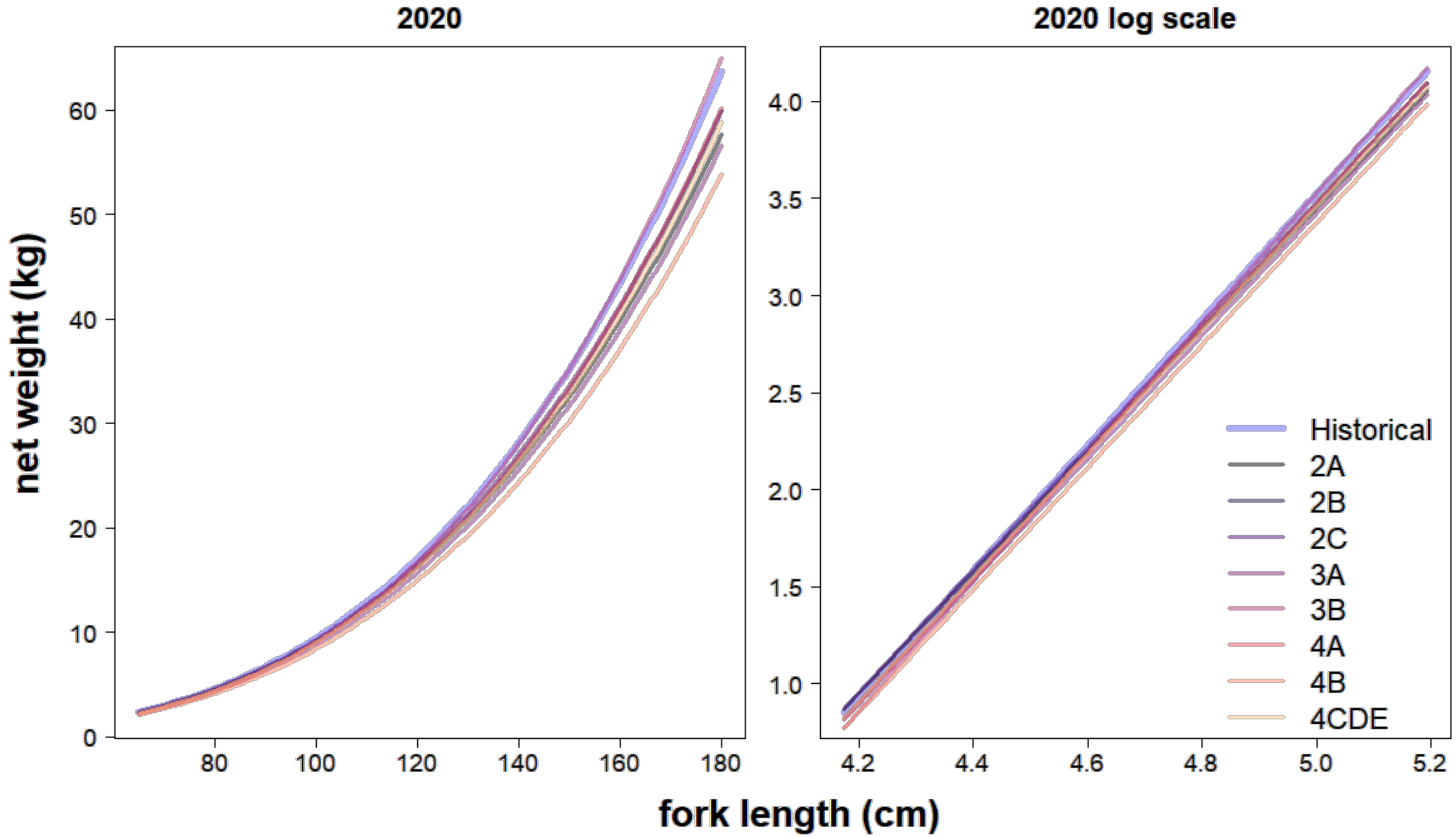
Commercial length-net weight

- We fitted linear models on the log scale to estimate the parameters of the length-net weight relationship from commercial sampling data:

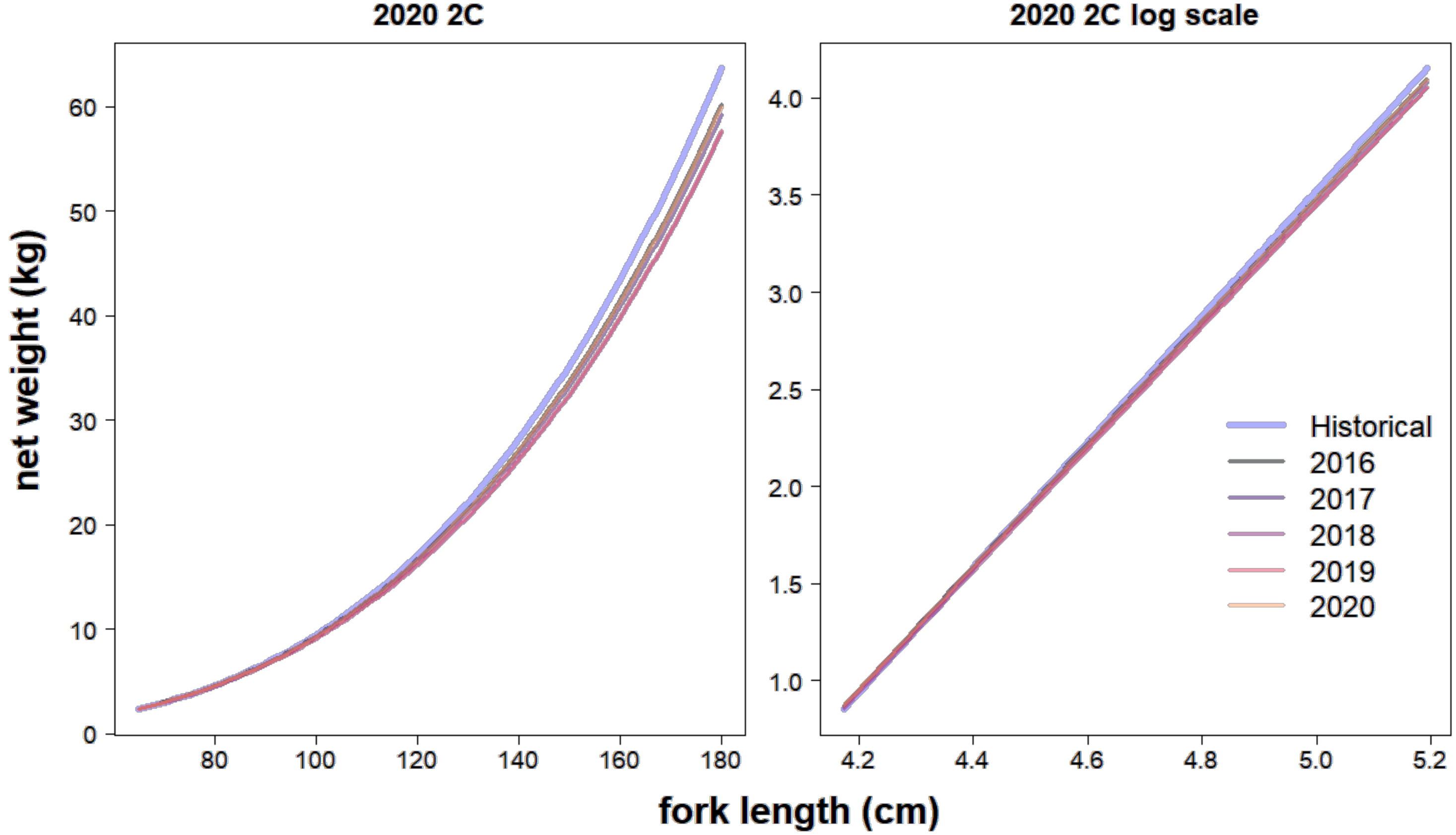
$$\log\left(W_i\right) = a + \beta \log\left(L_i\right) + \varepsilon_i$$

$$\varepsilon_i \sim N\left(0, \sigma^2\right)$$

Estimated length-net weight relationships by IPHC Regulatory Area, 2020 (commercial data)



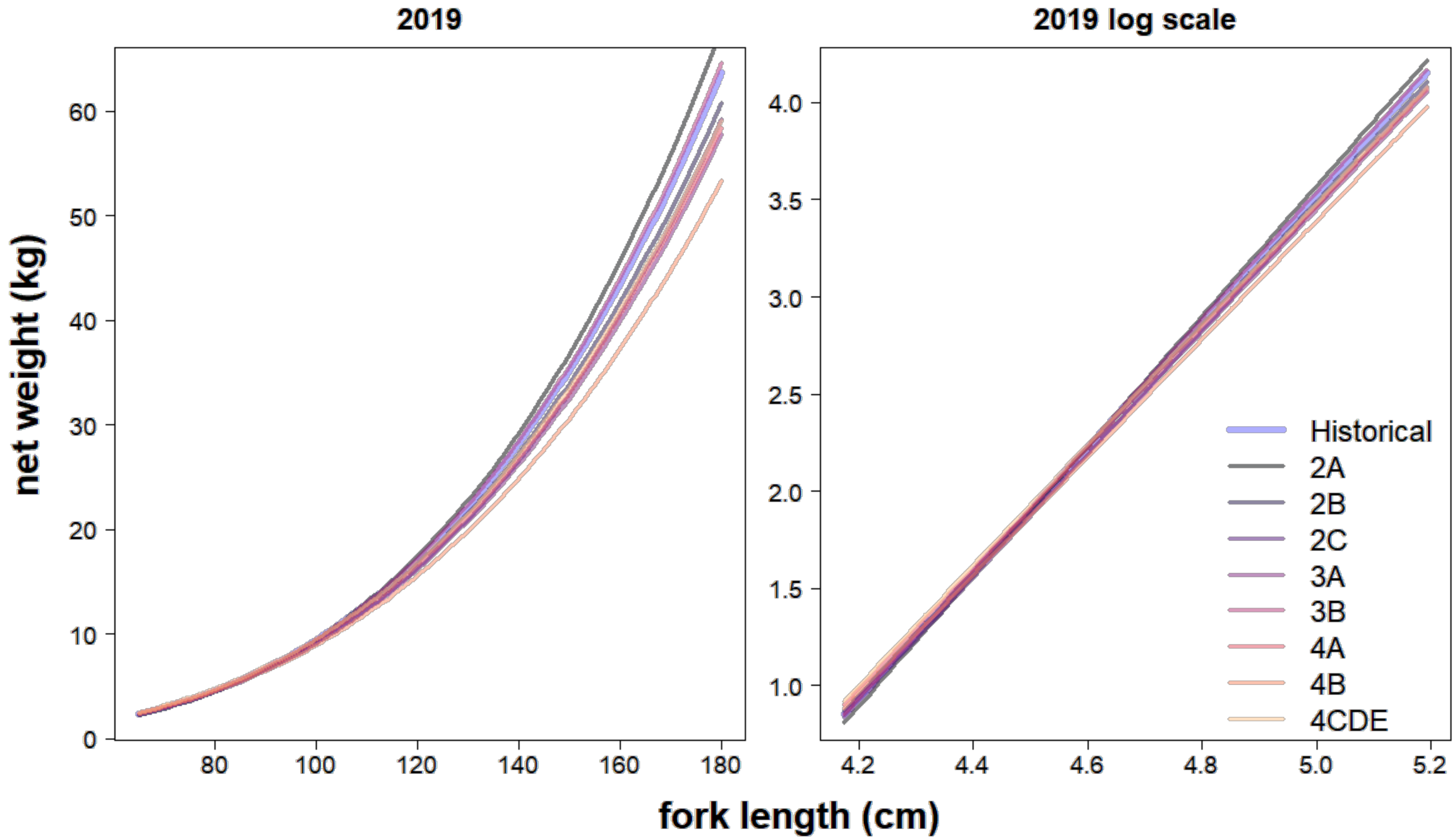
Estimated length-net weight relationships for IPHC Regulatory Area 2C by year (commercial data)



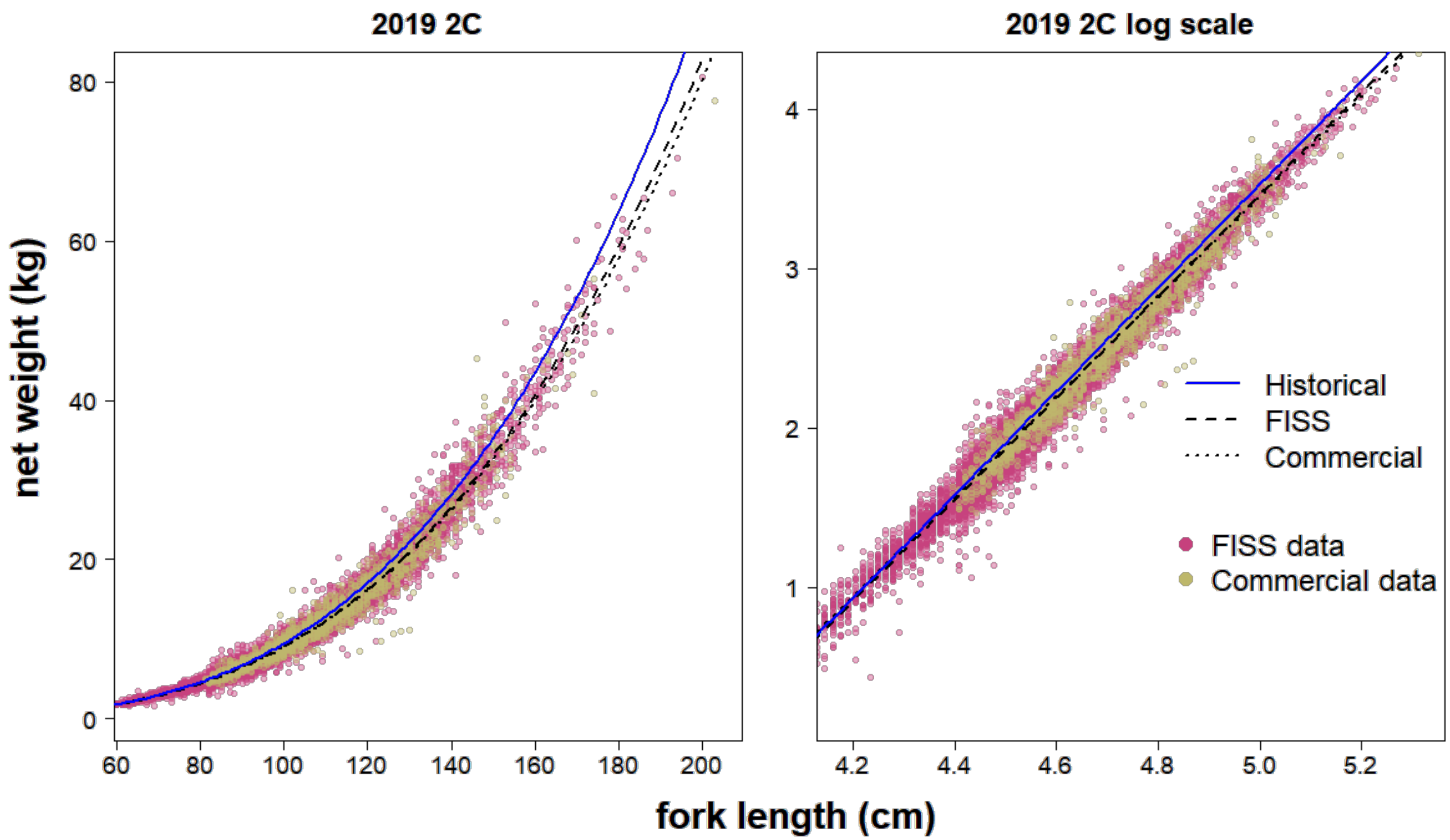
FISS length-net weight

- As with commercial data, linear models were fitted to estimated parameters of the length-net weight relationship
  - Data from two years to date only: little information on year-to-year variation
- U32 fish with both round and dressed weight recorded in 2019 were used to estimate a round-dressed weight relationship for use in subsequent years

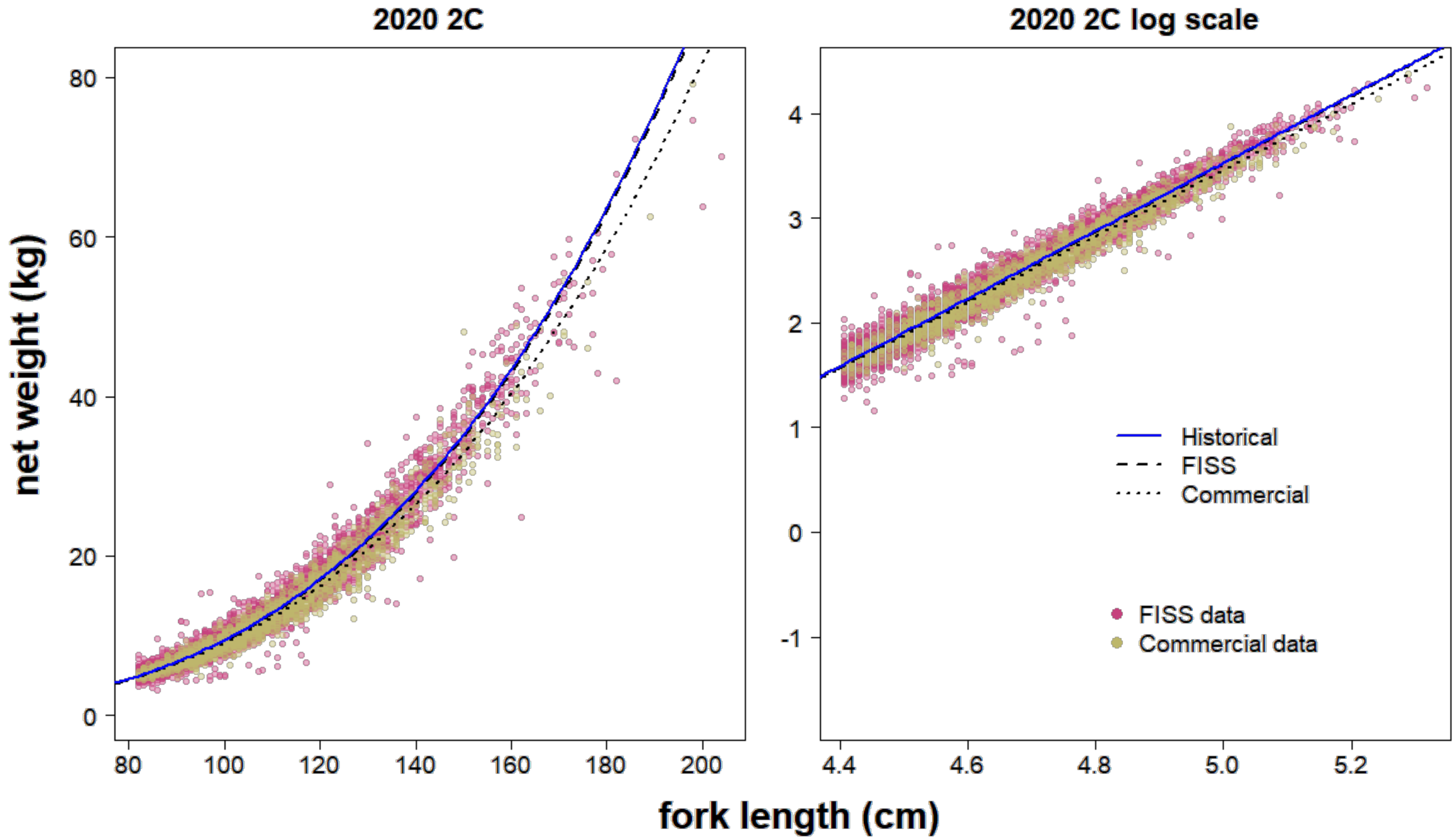
Estimated length-net weight relationships by IPHC Regulatory Area, 2019 (FISS data)



Comparison of commercial and FISS relationships, 2C in 2019



Comparison of commercial and FISS relationships, 2C in 2020



Comparison of commercial and FISS relationships

- Commercial data is collected throughout the fishing season (March-November) but is limited to fishing grounds
- FISS data is limited to the summer survey period, but is more spatially extensive within each sampled region
- We fitted two models to the combined commercial and FISS data:
  - Model 1: Fitting a single relationship to all data
  - Model 2: Allows parameters to differ between the two data sources
- Models fitted for 2019 and 2020 data only
  - 2020 FISS only sampled core areas, 2B, 2C, 3A and eastern 3B
- Compared predicted mean weights with observed mean weights to help understand potential for bias in model estimates

Comparison of commercial and FISS relationships

- Model 2 produced mean net weights within 1% of observed means of both commercial and FISS data for each year and IPHC Regulatory Area
- In almost all cases, Model 1 produced mean net weights within 2% of observed means
- The historical relationship had differences between predicted and observed means ranging from 1.1% to 10.7% for commercial data, and −1.7% to 5.5% for FISS data.

Discussion

- Using linear models fitted to contemporary data is likely to reduce bias in weight estimates relative to estimates from the historical relationship
- Model 1 is simpler and does not require users (e.g., other agency staff) to make a choice of which data source (commercial or FISS) most closely resembles their own
  - Estimated from combined data sources, so represents a blend of spatially extensive (FISS) and temporally extensive (commercial) samples: more generally applicable

Discussion

- All data had equal weight, so a source with larger sample sizes has more influence on model results
  - One option would be to equally weight commercial and FISS samples, i.e., apply lower relative weights to observations from the source with greater sample size
- Given apparent temporal stability (2016-20) and spatial variability, we recommend:
  - Providing curves to non-IPHC users estimated from (at least) three years' worth of combined data from commercial and FISS sources for each IPHC Regulatory Area (so 2019-21 at present)
  - Re-evaluating the relationships annually as additional years of data are collected and updating if necessary

Outstanding data needs

- At present we lack data to validate the assumed round to net weight conversion for O32 fish
  - We can obtain this be making two measurements (round and dressed) on a sample of O32 FISS fish
- We have no data to validate adjustment factors for ice and slime, despite collecting commercial weight samples since 2015

Recommendations

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.2 that presents methods for revised the length-net weight relationships from FISS and commercial sampling data

2) **RECOMMEND** that the IPHC provide a revised length-net weight relationship for each IPHC Regulatory Area based on modelling of combined FISS and commercial sample data to be used for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected, for 2021 and until further notice.

3. Review of IPHC hook competition standardization

- Since 2007, the IPHC has used the O32 WPUE index of density to estimate the distribution of the stock among IPHC Regulatory Areas
- Recognising that such indices are affected by variability catchability, adjustments to the WPUE index were devised to help account for catchability differences
- The most important of these is the hook competition standardization
  - One of only two standardizations still applied to the index (the other being for FISS timing relative to the fishery)

Standardisation for hook competition

- Gear saturation: catch rates decrease disproportionately to abundance as the sampling gear becomes fully occupied.
- Although it may be present for many types of sampling gear, for longline gear, as deployed by the IPHC, gear saturation may be considered via competition for the finite number of hooks deployed.
- The IPHC method for standardisation for hook competition was developed by Clark (2008), and is based on the number of baits removed on FISS sets, B_i, by predator species *i*.
- The Baranov catch equation was used to model the B_i after a time period, *T*:

$$B_i = B_0 \frac{F_i}{Z}\left(1 - e^{-ZT}\right)$$

Instantaneous rate of bait removal for predator *i*

Initial number of baits

Sum of F_i over all predators

Standardisation for hook competition

- It follows that the expected catch of Pacific halibut (C_h), which is one of the bait predators, is given by

$$C_h = B_0 \frac{F_h}{Z}\left(1 - e^{-ZT}\right)$$

- Soak time is assumed to be of sufficient length that catches of all species are unaffected by the value of *T*, and we set *T*=1
- The standardized index is given by the estimator of F_h:

$$\hat{F}_h = \frac{C_h}{B_0} \log\left(\frac{B_0}{B_1}\right)\frac{B_0}{B_0 - B_1}$$

CPUE

Adjustment factor

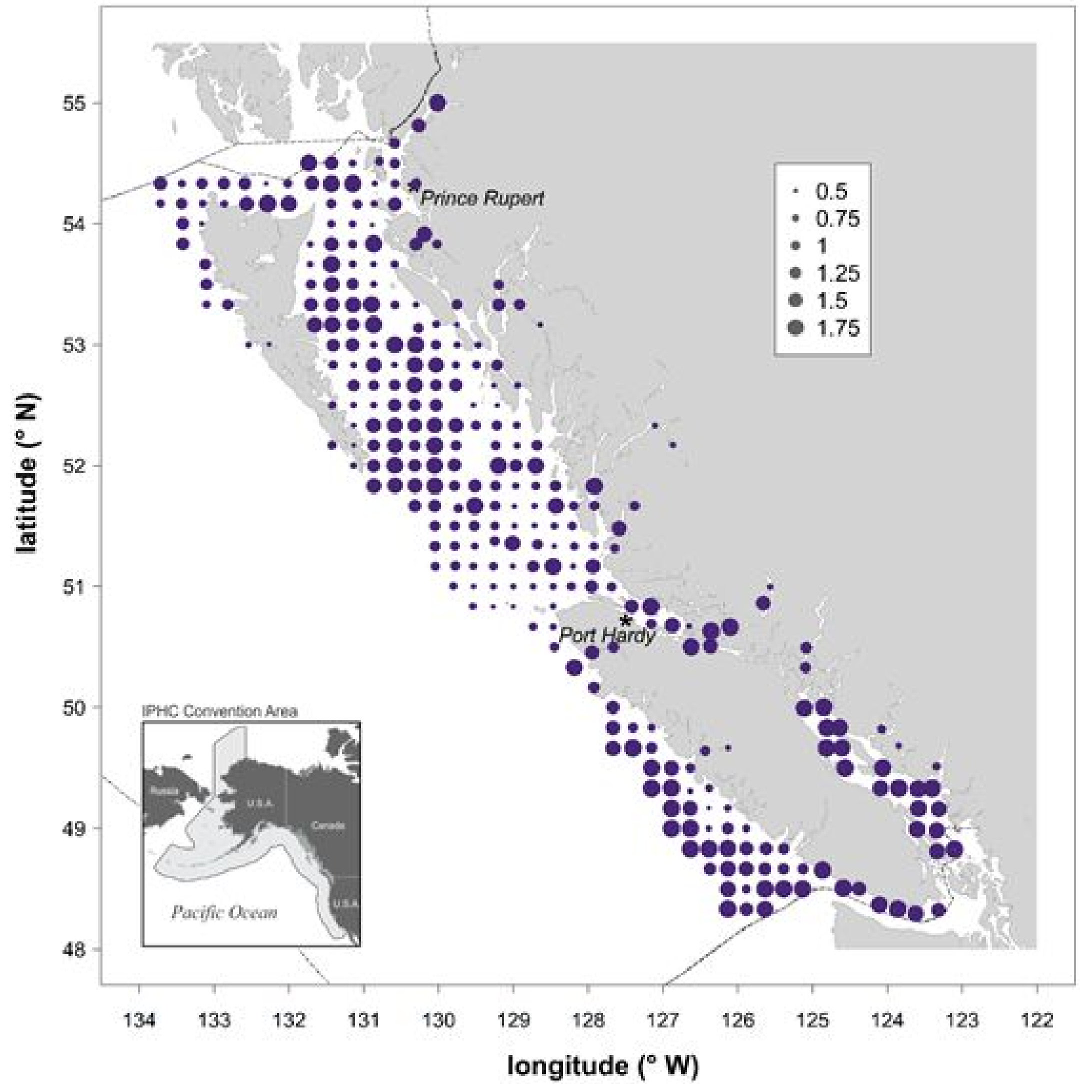
Final number of baits

Standardisation for hook competition

- The adjustment factors have a lower bound of one, so can only increase WPUE or NPUE
- To maintain indices on scale familiar to stakeholders, we divide by a scalar based on mean adjustment factor for 1998
- Other notes:
  - Mean adjustment factors can vary with year, allowing for changes in predator density with time
  - Missing baits on hauling attributed to escaped predators other than Pacific halibut
  - Adjustment is multiplicative, so zero catch rates of Pacific halibut remain as zeros after standardisation
  - Aggregating by area and year, generally 5-40% of baited hooks are returned with baits
- Method is mathematically the same as the multinomial exponential approach developed by Étienne et al. (2013).

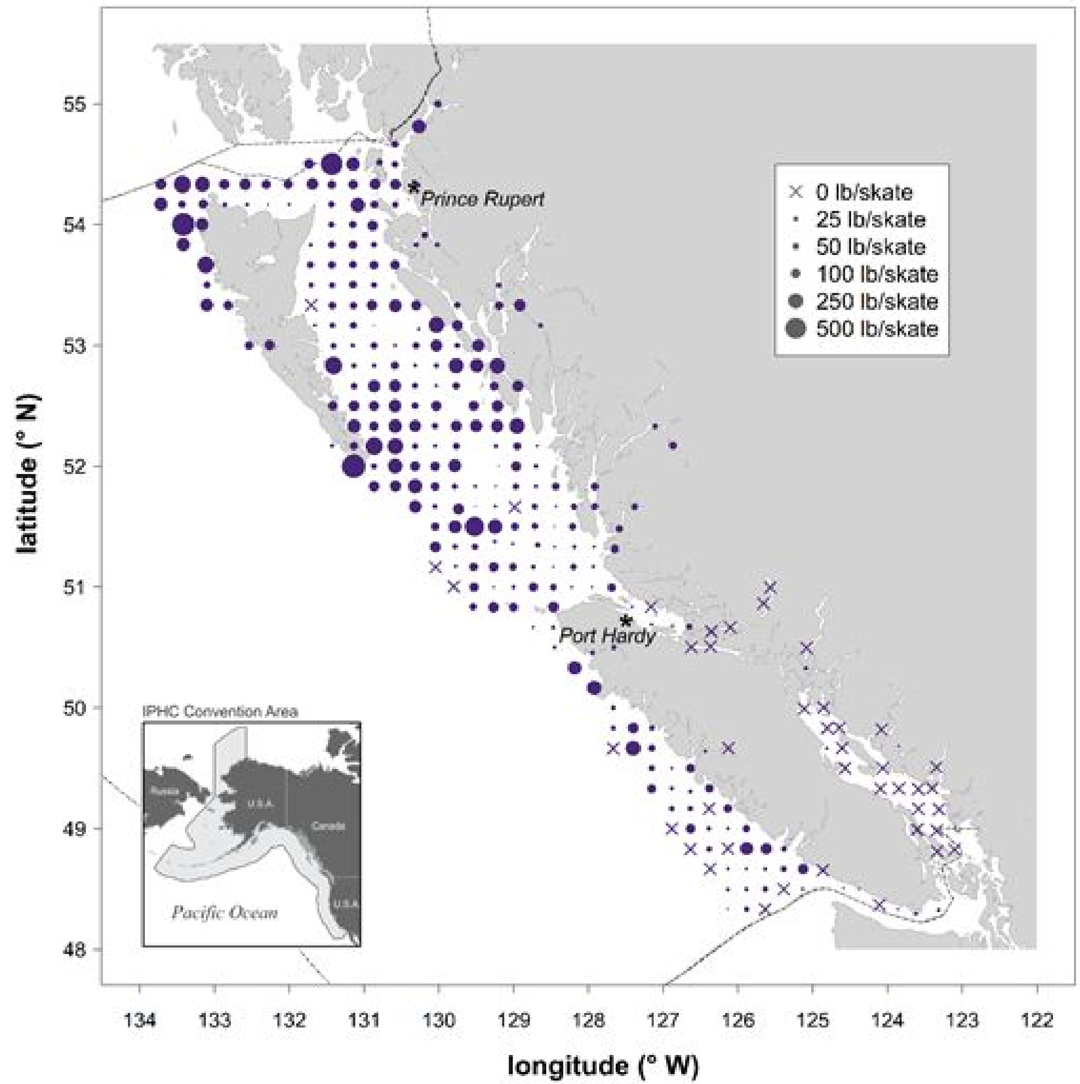
Example: 2B 2018

Adjustment factors by station



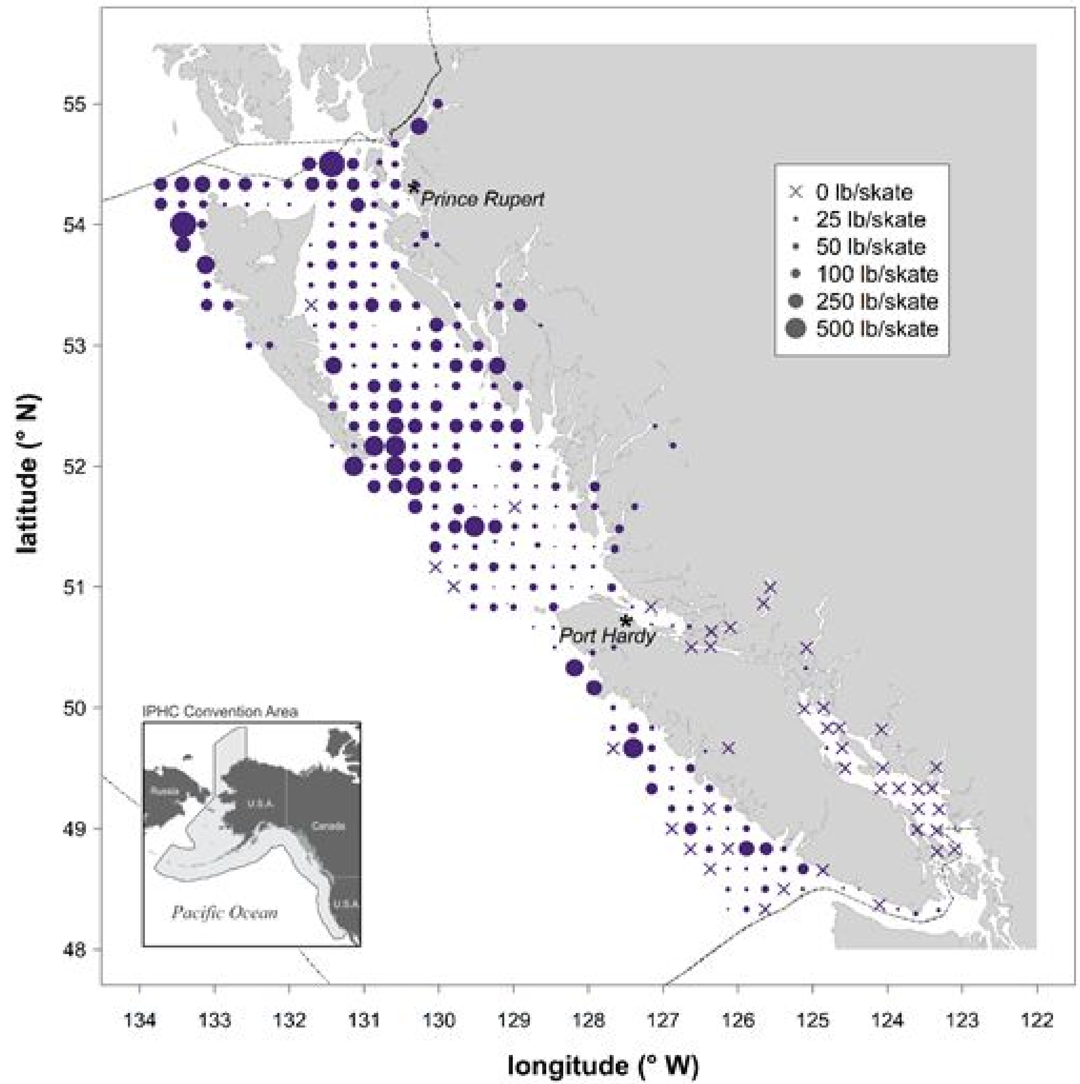
Example: 2B 2018

Unadjusted O32 WPUE



Example: 2B 2018

O32 WPUE standardized
for hook competition



IPHC hook timer studies

- Historical work on hook timers was intended to produce data on the rate of bait capture by Pacific halibut and competing species.
- The timers in use in those studies were not tripped most of the time:
  - It appears the timers were not sensitive to the capture of smaller fish or to smaller fish taking the bait without being captured
- The IPHC is currently collaborating on a study of standard and modified circle hooks that will use hook timers to record the capture time of different species.
  - Modern hook timers are expected to be more sensitive than those used in historical studies
  - It is therefore hoped that this study will yield data that will help inform the calculation of the hook competition standardisation.

Recommendation

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.3 that presents an overview of the IPHC standardization for hook competition on FISS sets.

4. Accounting for the effects of whale depredation on the FISS

- The presence of sperm whales and orcas during the fishing and hauling of FISS sets can lead to such sets being designated as ineffective for the use in analyses due to the potential impact on recorded catch rates Pacific halibut of depredation
- The criteria for ineffectiveness, which were strengthened in 2019, are as follows:
  - Sperm whales: a sperm whale is spotted within 3 nmi of the boat while hauling gear
  - Orcas: a set has more than 1 lips-only Pacific halibut or a set has other observations of orca feeding on Pacific halibut
- These criteria were designed to minimize the potential for including biased data in the annual indices.

Accounting for the effects of whale depredation on the FISS

- Sperm whales have been found to depredate cryptically on the gear at large distances from the vessel, while orcas generally leave clear evidence of depredation or are observed in the act.
- Coastwide, from 2010-2020, 1.4-3.0% of all sets fished included sperm whales or orcas as a reason for ineffectiveness (see https://www.iphc.int/data/fiss-performance).
- However, the impacts can be greater for a given area and year.
  - IPHC Regulatory Area 3A has had up to 6% of sets affected by whales (mainly sperm whales);
  - IPHC Regulatory Area 4A is the area most affected by orca encounters, with over 10% of sets affected in some years, and 12% of sets during the 2014 FISS expansion (the only time some of these stations were fished prior to 2021)

Accounting for the effects of whale depredation on the FISS

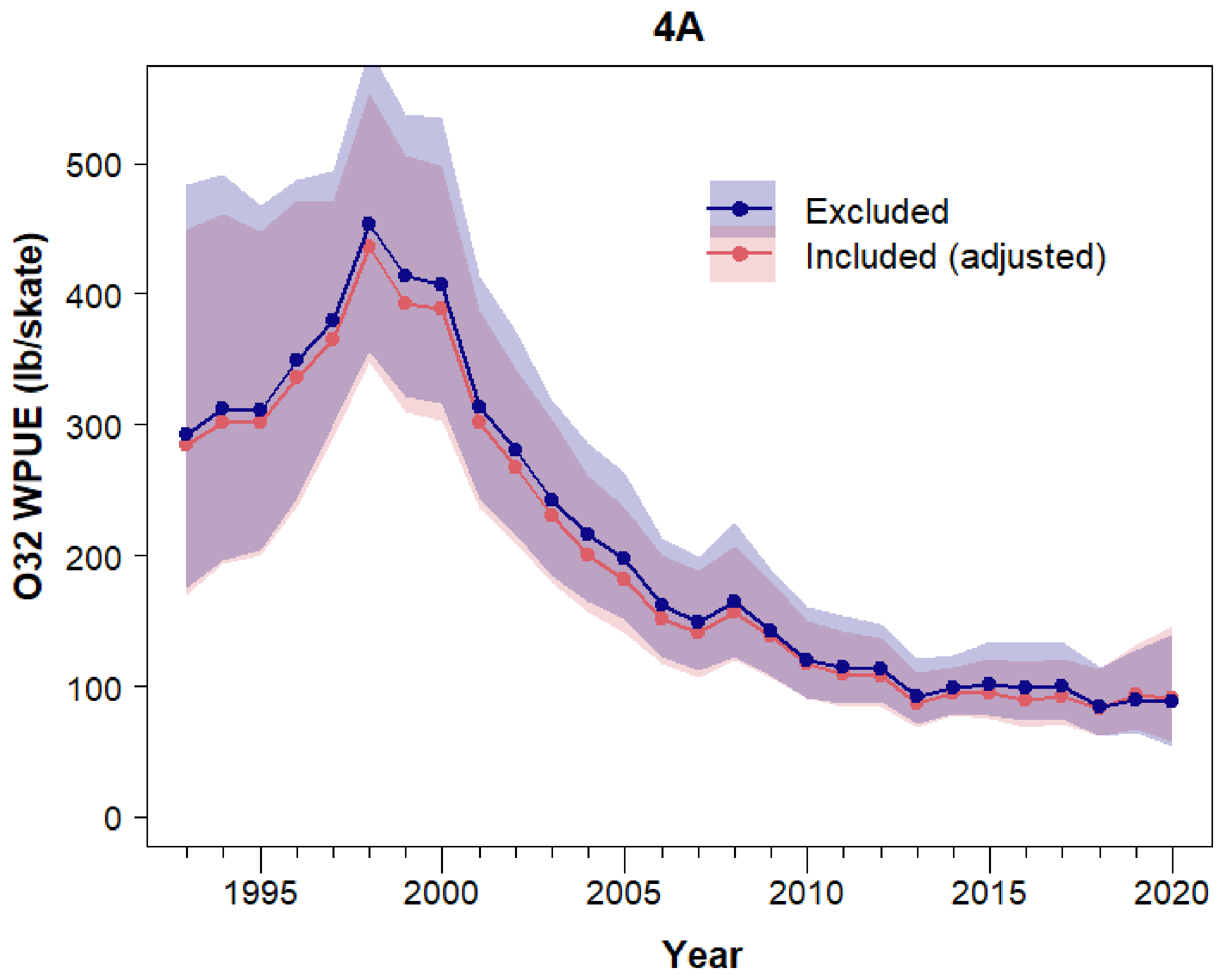
- We added covariates to the non-zero component of the space-time model to account for differences in catch rates between whale-affected sets and unaffected sets.
- Covariates were simple binary variables, taking the values zero or one:
  - 0 if set was effective
  - 1 if sperm whales and/or orcas were the reason for the set being marked as ineffective
- Prediction of WPUE or NPUE for time series estimation is done with this covariate set to zero for all sets.
- This allows us to include additional valuable data while accounting for the impact of these marine mammals on catch rates.

IPHC Regulatory Area 4A

- Area most affected by marine mammal interactions:
  - 139 orca-affected sets since 1993
  - 3 sperm whale-affected sets
  - In some years >10% of sets are affected by orcas
- Space-time model estimates that O32 WPUE on affected sets is 51% (95% CI: 43-60%) of unaffected sets.

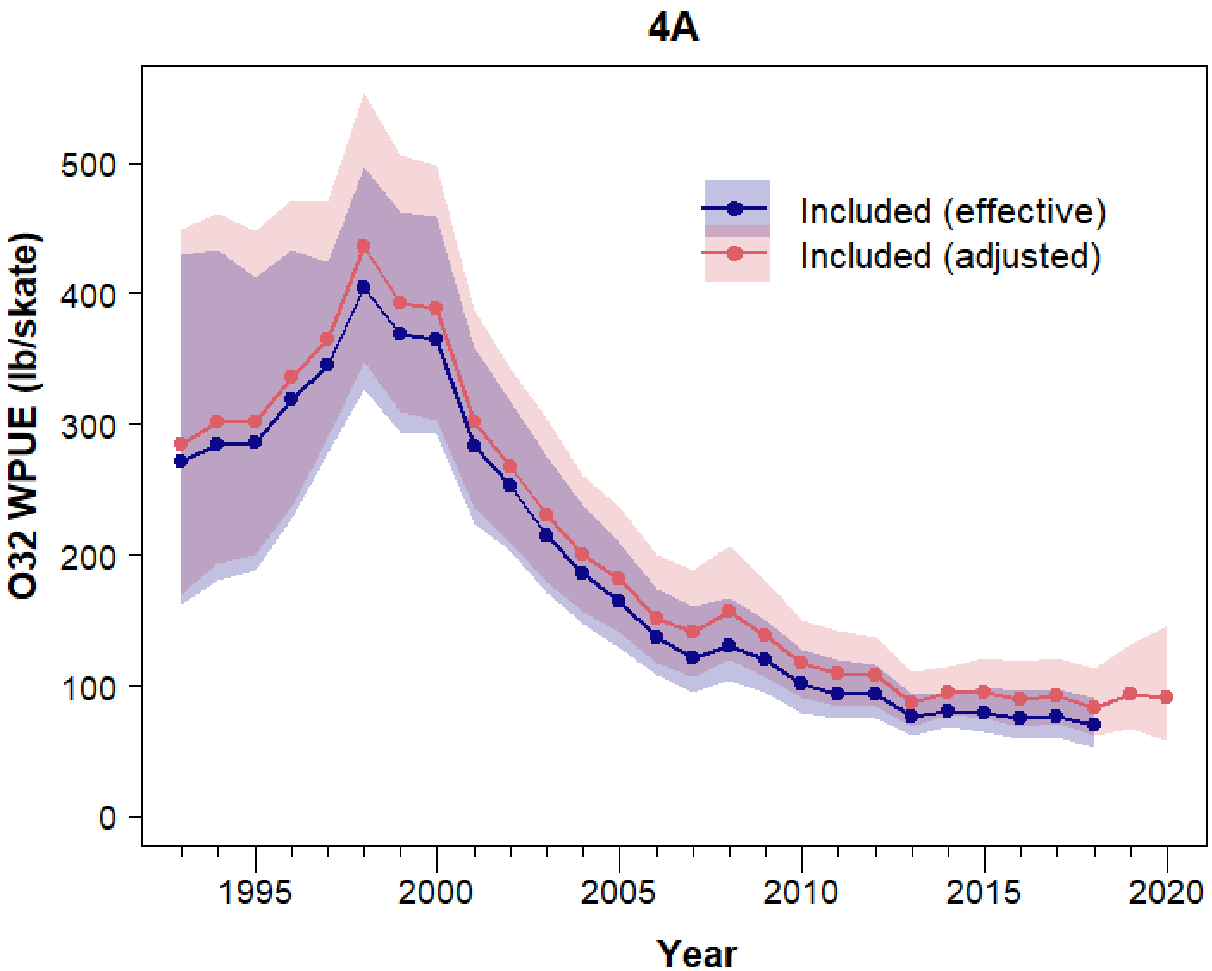
Comparison of estimated time series for O32 WPUE with and without whale-affected sets.

Inclusion of such sets while accounting for their effect on WPUE leads to some improvement in precision (narrow 95% CIs).



Many currently ineffective sets were included in analyses prior to 2019 when effectiveness criteria were tightened.

Model results show their exclusion was justified at the time, as failing to account for impact of orcas resulted in likely negative bias in time series estimates.



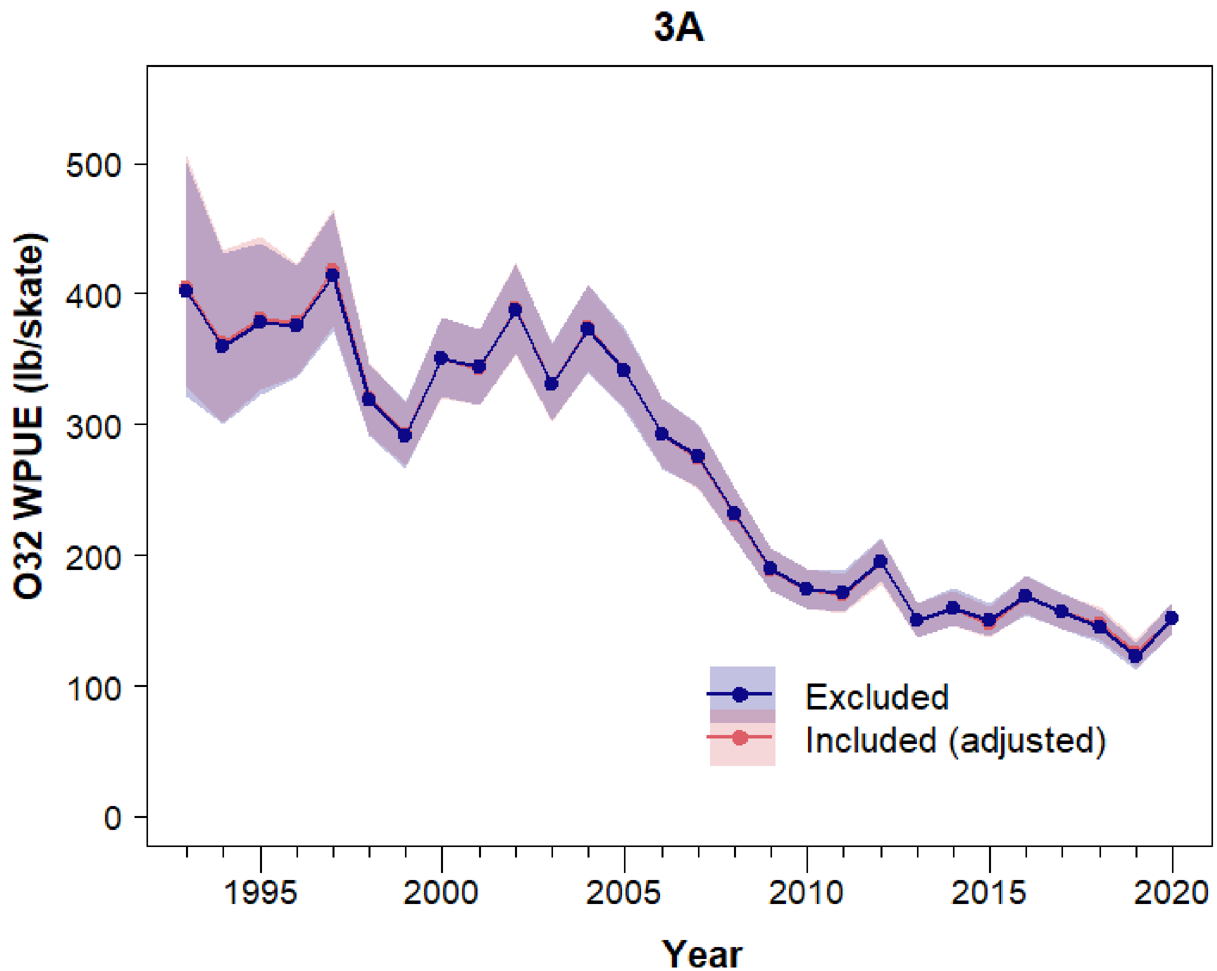
IPHC Regulatory Area 3A

- Area most affected by sperm whale interactions:
  - 116 sperm whale-affected sets since 1993
  - 29 orca-affected sets
  - 18 sets affected by both species
  - In some years >10% of sets are affected by orcas
- Space-time model estimates:
  - O32 WPUE on sperm whale-affected sets is 86% (95% CI: 75-99%) of unaffected sets
  - O32 WPUE on orca-affected sets is 84% (68-104%) of unaffected sets

Comparison of estimated time series for O32 WPUE with and without whale-affected sets.

Inclusion of such sets while accounting for their effect on WPUE leads to no apparent effect on estimates:

- Smaller proportion of affected sets than 4A
- Effect of marine mammals is much less



Discussion

- We propose that beginning in 2021, data from "ineffective" sperm whale and orca-affected sets be included in the modelling with appropriate covariates to account for differences in catch rates between affected and unaffected sets.
- In IPHC Regulatory Areas where such interactions are rare, precise estimation of whale covariate parameters will not be possible, and we can continue to omit such sets from the analyses with little loss of information.

Recommendation

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.4 that presents an approach to accounting for the effects of whale interactions on FISS catch rates through the space-time modelling.

2) **RECOMMEND** that the Secretariat should apply such an approach going forwards.

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Update on the development of the 2021 stock assessment

Agenda item 5.1

IPHC-2021-SRB019-06

Topics

- Assessment process
  - Software updates
- SRB requests
- Preliminary data updates

Recent assessments

- 2019: Full assessment
  - Independent and SRB review
  - Standard data updates (fishery and FISS)
  - New data source: 2017-2018 commercial sex-ratio at age
- 2020: Update
  - Standard data updates (fishery and FISS) + 2019 commercial sex-ratio at age
  - New data source: recreational sex-ratios at age
- 2021: Update
  - Standard data updates (fishery and FISS) + 2020 commercial sex-ratio at age

2021 Model development

- Updating software:
  - Stock synthesis 3.30.16.02 (For SRB018)
  - Stock synthesis 3.30.17.00 (August)
    - Identical model results, but run-times now back to 3.30.15.xx speeds!
- No other structural changes to the models

SRB requests at SRB018

SRB018 Req.4 (para. 24):

> *"The SRB REQUESTED an analysis of annual surplus production and the fraction of that production harvested."*

Surplus production

- 5 methods considered:
  1) Fitting surplus production models directly to survey indices
  2) ‘Standard’ surplus production based on all-ages biomass and fishing mortality
  3) Same calculation using Spawning biomass
  4) Decision table results presented each year
  5) Model-free ‘empirical harvest rates’ provided each year

1) Surplus production models (2014)

- Recruitment dynamics drive productivity
- Weak S-R relationship
- Survey index 1993+
- Useful exercise, but limited direct utility

2) ‘Standard’ surplus production (*S*)

- Based on assessment-estimated biomass (*B*) and all-ages catch (*C*) in each year (*y*):

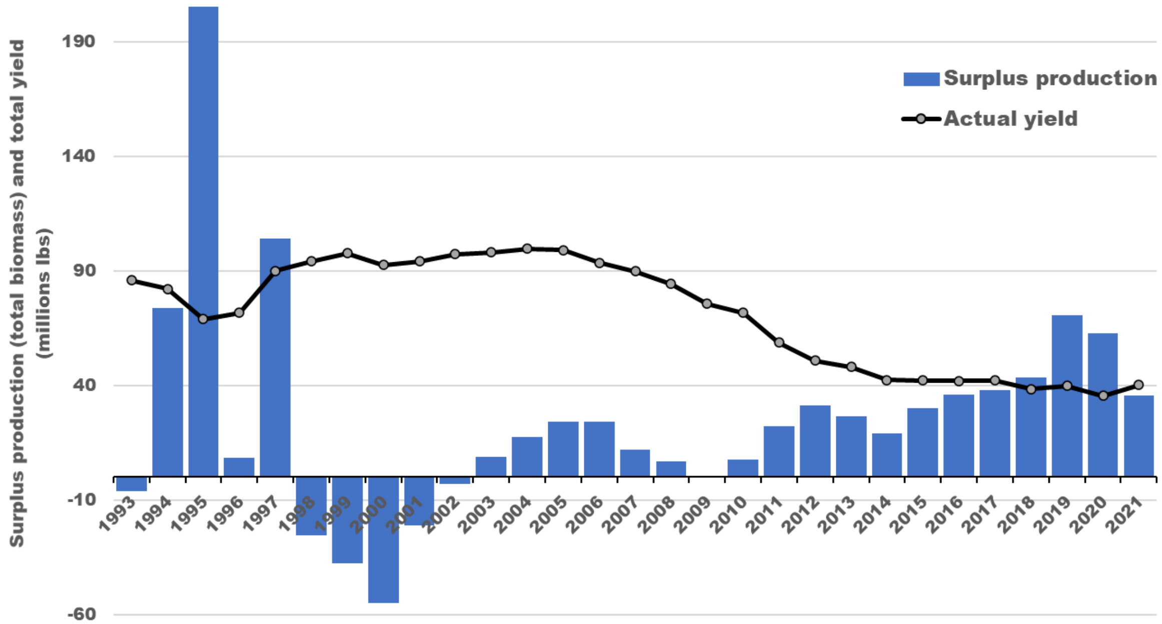
$$S_{y-1} = B_y - B_{y-1} + C_{y-1}$$

Defining ‘biomass’ is challenging due to multiple fleets with differing and time-varying selectivity (this is why we dropped the concept of ‘exploitable biomass’ several years ago in favor of SPR).

In addition, the IPHC’s interim management procedure is not intended to stabilize the biomass at any specific level.

2) 'Standard' surplus production

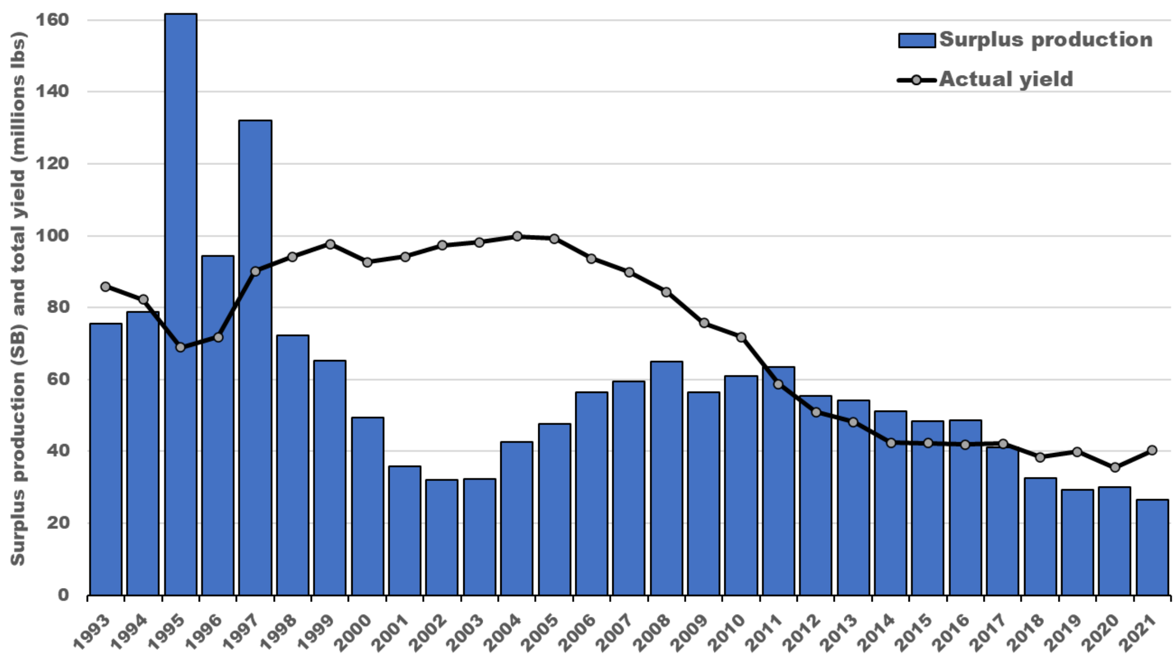
- All ages biomass:



Period of declining total biomass (from historically high levels) very clear.

3) 'Standard' surplus production

- Spawning biomass:



More consistent with reference points, same period of stock decline evident.

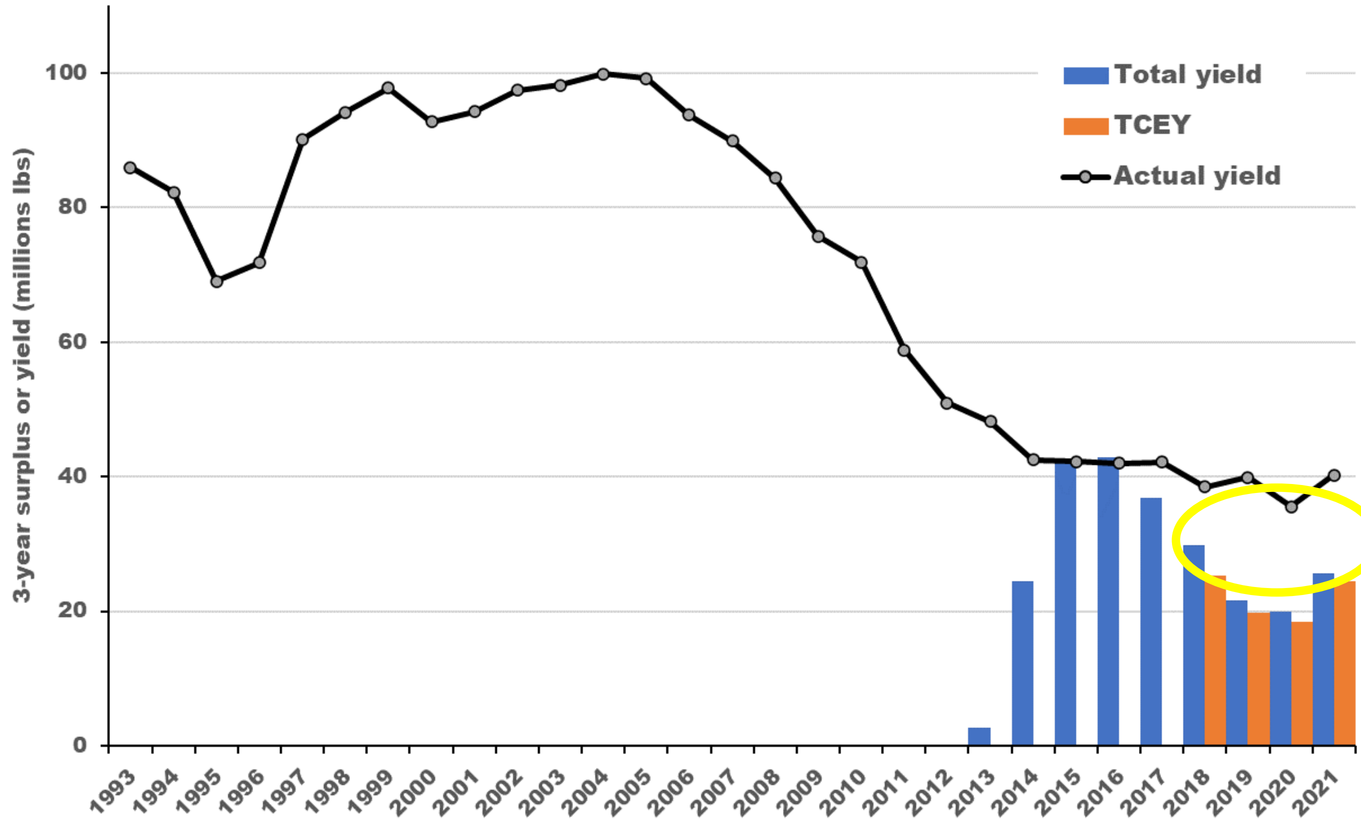
4) Surplus production – Decision table

- The yield that would produce a 50% chance of the same or greater spawning biomass after 3 years

2021 Alternative				3-Year Surplus		Status quo		Reference $F_{43\%}$					
Total mortality (M lb)			0.0	25.7	36.8	37.9	39.1	40.3	41.5	42.9	44.1	61.3	
TCEY (M lb)			0.0	24.4	35.5	36.6	37.8	39.0	40.3	41.6	42.8	60.0	
2021 fishing intensity			$F_{100\%}$	$F_{58\%}$	$F_{46\%}$	$F_{45\%}$	$F_{44\%}$	$F_{43\%}$	$F_{42\%}$	$F_{41\%}$	$F_{40\%}$	$F_{30\%}$	
Fishing intensity interval			--	39-76%	29-65%	29-64%	28-63%	27-62%	26-61%	26-60%	25-59%	18-49%	
Stock Trend (spawning biomass)	in 2022	is less than 2021	<1	42	61	62	64	65	66	67	69	82	a
		is 5% less than 2021	<1	7	32	34	36	39	41	44	46	66	b
	in 2023	is less than 2021	<1	51	62	63	64	65	66	67	69	81	c
		is 5% less than 2021	<1	32	53	54	55	56	57	59	59	74	d
	in 2024	is less than 2021	<1	50	60	61	62	63	64	66	67	80	e
		is 5% less than 2021	<1	40	55	56	57	57	58	59	60	74	f
Stock Status (Spawning biomass)	in 2022	is less than 30%	29	35	39	40	40	41	41	42	42	47	g
		is less than 20%	<1	<1	<1	<1	1	1	1	1	1	4	h
	in 2023	is less than 30%	23	32	39	40	40	41	42	43	43	49	i
		is less than 20%	<1	<1	2	2	3	3	4	5	5	19	j
	in 2024	is less than 30%	12	29	38	39	40	41	42	43	44	50	k
		is less than 20%	<1	<1	4	5	6	8	9	10	12	25	l

4) Surplus production – Decision table

(As calculated in each year's assessment)



Indicates a high probability of decrease in SB

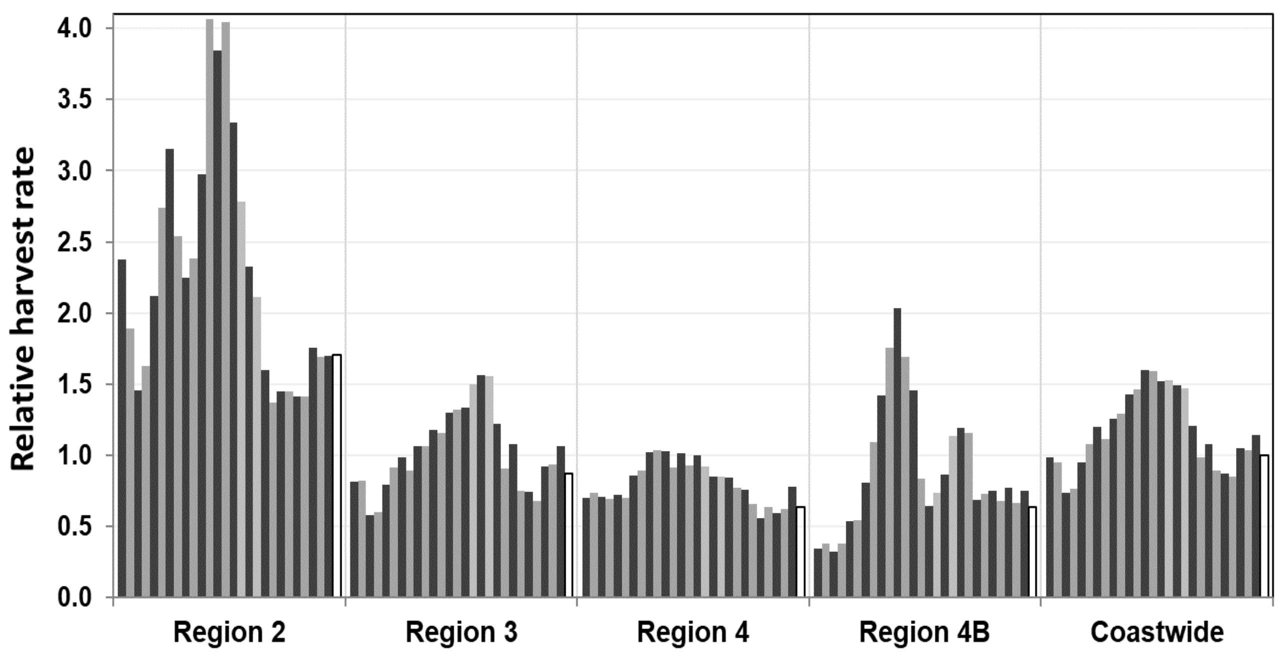
5) Empirical harvest rates (*U*)

- Model-free evaluation of yield vs production by year (*y*) and Biological Region (*r*)
- Assuming catchability is constant, catch (*C*), survey index (*I*) and an arbitrary constant (*k*) are all that is required:

$$\hat{U}_{y,r} = \frac{C_{y,r}}{I_{y,r}} k$$

5) Empirical harvest rates (*U*)

- Constant (*k*) is selected so that the coastwide value in the terminal year is 1.0



Surplus production conclusions

- Information provides clear results that yield exceeded annual production in the early 2000s, and again in the most recent 4 years.
- Recently, the choice to ‘fish down’ the stock using F46% (2017-2020) and then F43% (2021) has been explicit, and informed by MSE analyses

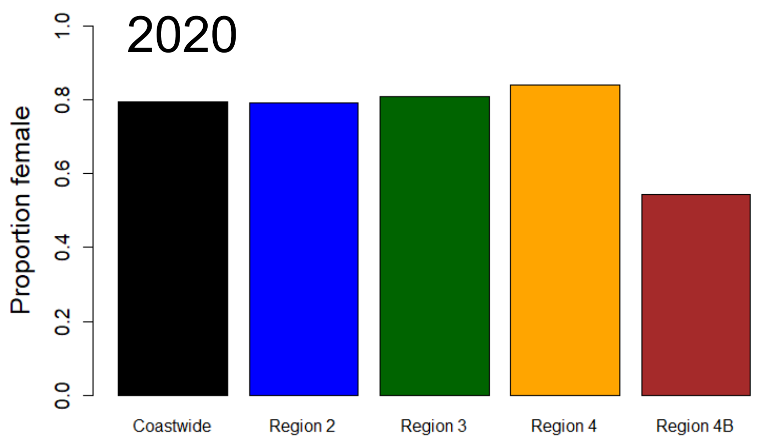
Preliminary data updates

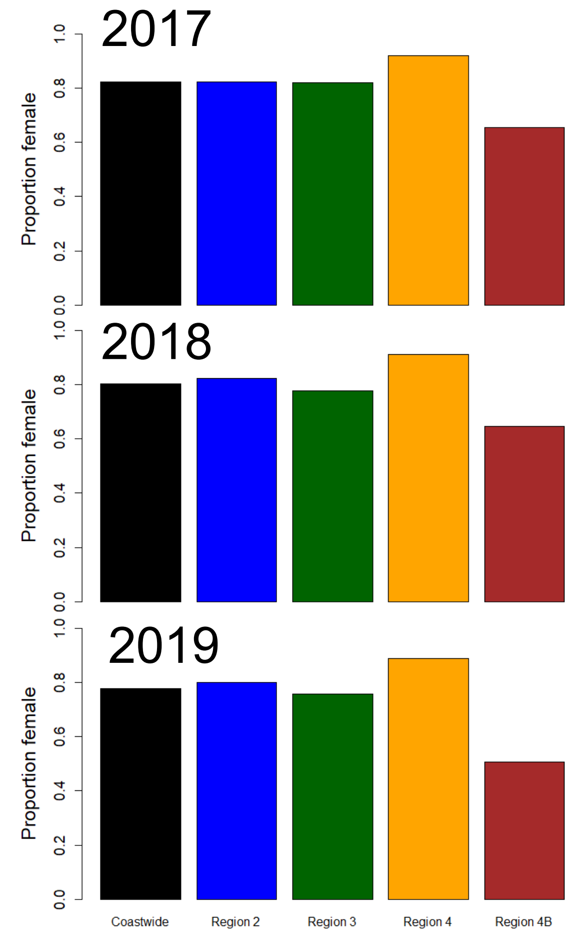
- 2020 Commercial fishery sex ratios at age completed in August 2021

Preliminary data updates

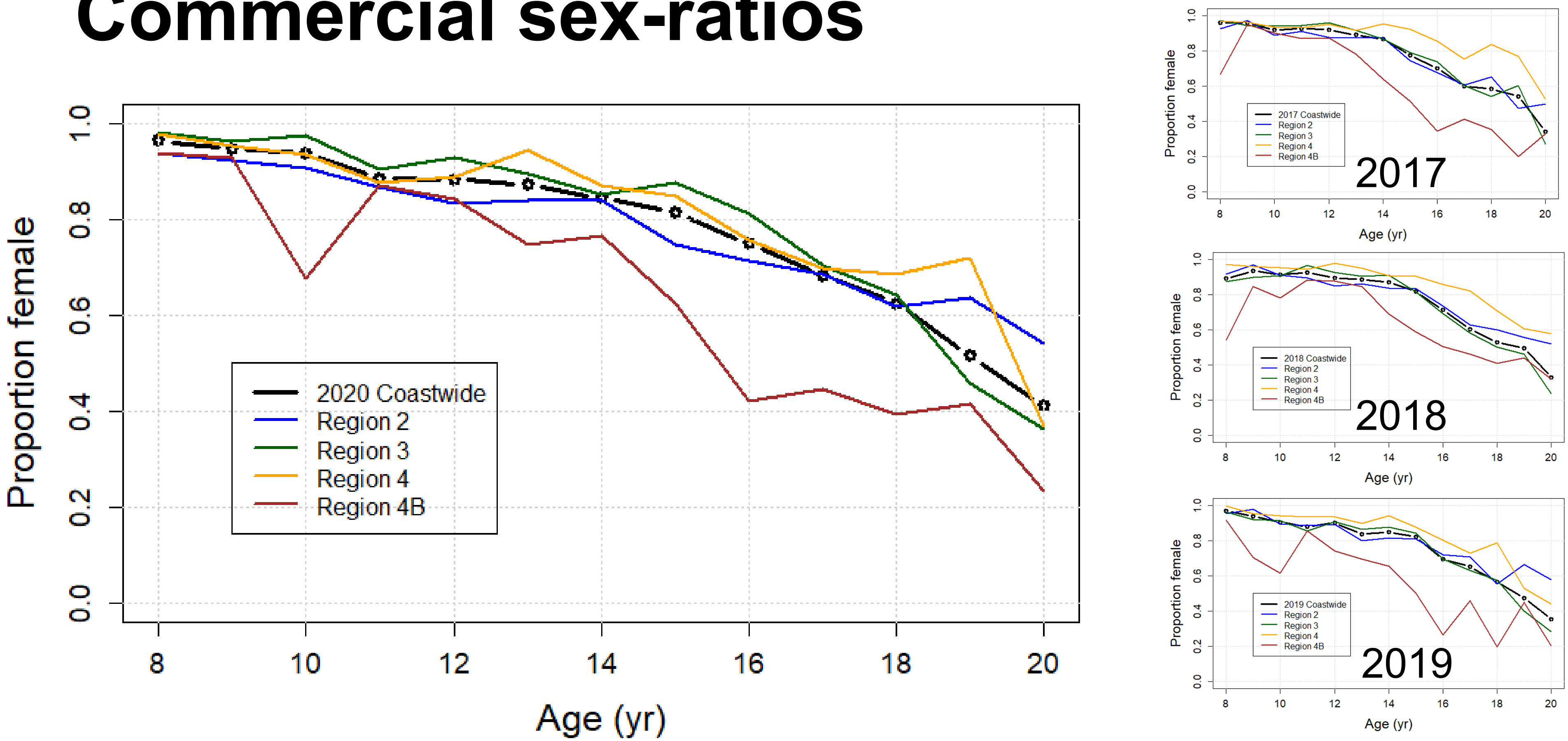
Commercial sex-ratios

	Coastwide % female	Region 2	Region 3	Region 4	Region 4B
2017	82%	82%	82%	92%	65%
2018	80%	82%	78%	91%	65%
2019	78%	80%	76%	89%	51%
2020	80%	79%	81%	84%	54%





Commercial sex-ratios



Preliminary data updates

- Commercial fishery whale depredation analysis is still in process

Standard data in the 2021 assessment

1) Modelled trend information including the 2021 FISS in all IPHC Regulatory Areas.
2) Age, length, individual weight, and average weight-at-age estimates from the 2021 FISS.
3) 2021 (and a small amount of 2020) Directed commercial fishery logbook trend information from all IPHC Regulatory Areas.
4) 2021 Directed commercial fishery biological sampling (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas.
5) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2020.
6) Updated mortality estimates from all sources for 2020 (where preliminary values were used) and estimates for all sources in 2021.

Recommendation/s

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-06 which provides a response to requests from SRB018 and an update on model development for 2021.

b) **RECOMMEND** any further changes to be included in the final 2021 stock assessment.

c) **REQUEST** any further analyses to be provided at SRB020, June 2022.

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MSE program of work and update

Agenda item 6

IPHC-2021-SRB019-07

(A. Hicks)

Topics

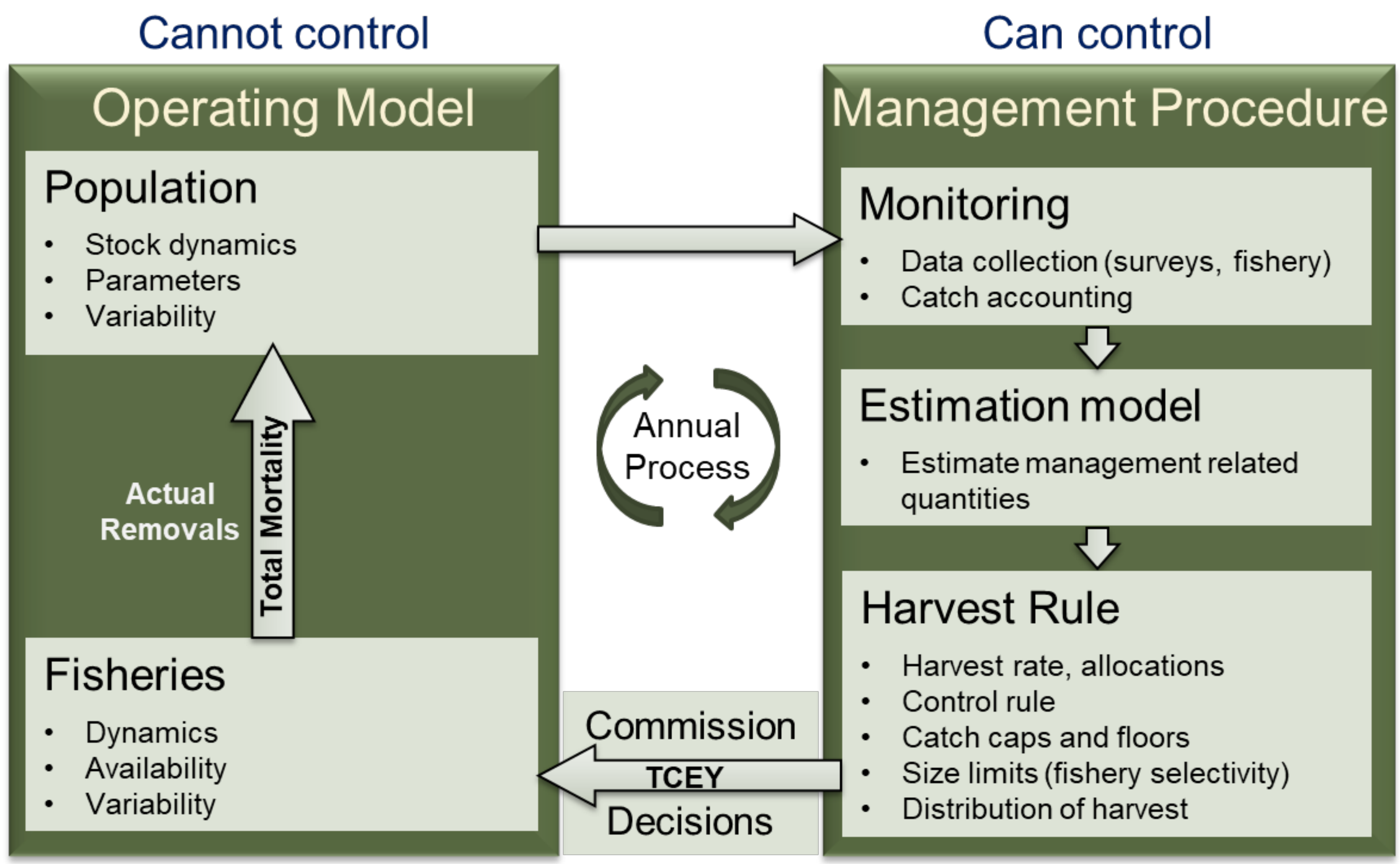
- Variability in the MSE framework
- MSE program of work for 2021-2023
- Preliminary investigation of an MP with multi-year assessments

SRB018 Request

IPHC-2021-SRB018-R, para. 30:

*"The SRB **REQUESTED** that the IPHC Secretariat present a revised system diagram of the MSE, showing components of variability and their implementation within MSE."*

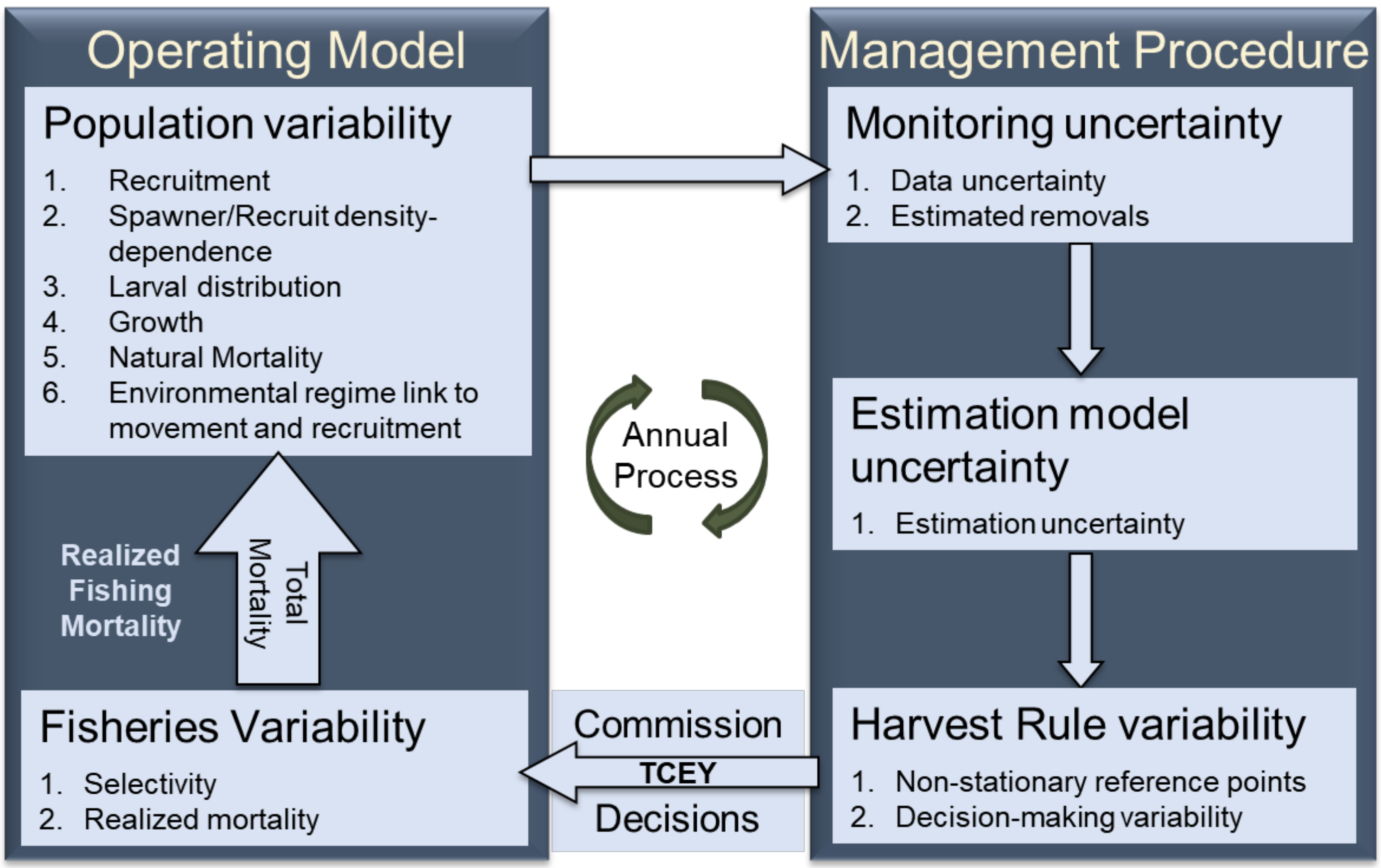
MSE framework



Categories of variability

	MSE Framework Element (Figure 2)				
Leach et al. (2014) Categories	**Population**	**Fisheries**	**Monitoring**	**Estimation Model**	**Harvest Rule**
Reference points					1. Non-stationary
Population structure	1. Recruitment 2. Spawner/Recruit relationship 3. Larval distribution • *Stock structure* • *Annual movement*				
Model	• *Number of bio-regions* • *Density-dependent processes (other than recruitment)*	1. Selectivity • *Number of fisheries* • *Catchability*	• *Data generation processes*	• *Estimation model structure*	
Management		• *Response of fisheries*	1. Uncertain data	1. Estimation uncertainty	2. Decision-making variability
Life History Traits	4. Growth 5. Natural mortality • *Maturation, fecundity, spawning*				
Environmental	6. Regimes 1. Movement, Recruitment • *Growth* • *Mortality* • *Climate change*	• *Effects on fisheries*	• *Effects on data collection*		• *Response of harvest rule*
Fishing mortality (catch)		2. Realized removals	2. Estimated removals		

Variability in the MSE framework



Movement and recruitment distribution

- Recent OM uses constant proportions of recruitment for each region across all years
- OM conditioned to mostly age 6+ fish from recent data
- Movement rates in current OM depart from rates determined from data
- Confounding between movement and recruitment distribution
- No data to inform recruitment distribution and mostly recent data informs movement
  - Although needs enough fish in early years in Region 2 to support catches

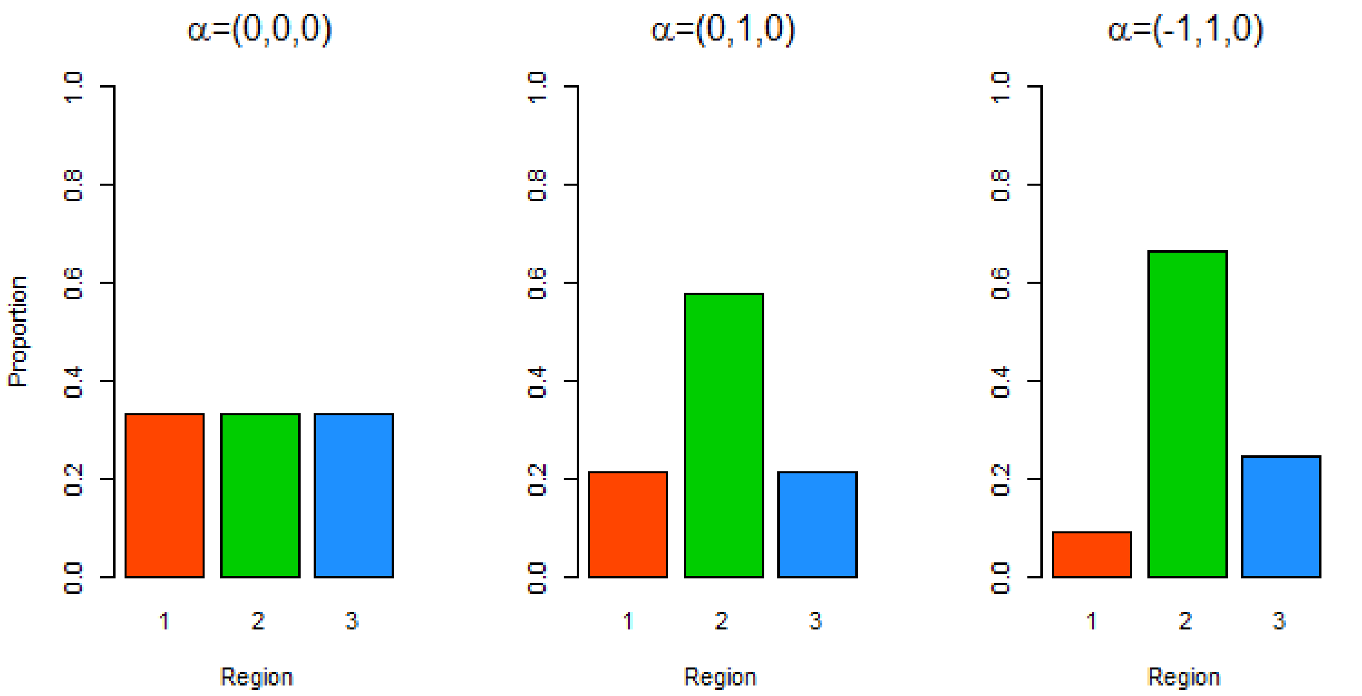
Variability in recruitment distribution

- Parameterize proportion of recruits settling in each region ($p_{t,r}^{R}$)
- $\sum p_{t,r}^{R}$ is 1.0
- Temporal covariate (x_t)
- $\eta_{t,r}^{R}$ in one region fixed at zero

$$p_{t,r}^{R} = \frac{e^{\eta_{t,r}^{R}}}{\sum_r e^{\eta_{t,r}^{R}}}$$

$$\eta_{t,r}^{R} = \alpha_r^R + \beta_r^R x_t + \gamma_r^R x_t^2$$

Parameterization of recruitment distribution



The parameters for $\boldsymbol{\beta}_r^R \boldsymbol{x}$ and $\boldsymbol{\gamma}_r^R$ are fixed at zero for all examples, therefore $\boldsymbol{\alpha} = \boldsymbol{\eta}$

Time-varying recruitment distribution

- Allow for nonlinear relationship with a temporal covariate
- Estimable parameters when conditioning
- Currently does not allow for random annual parameters over time

- Will experiment with time-varying recruitment distribution to examine effects on movement
- Develop scenarios for OM
  - Examine potential environmental variables or other covariates

SRB018 Request

IPHC-2021-SRB018-R, para. 36:

"The SRB **REQUESTED** that the IPHC Secretariat prioritize tasks for the MSE Program of Work that lead to adoption of a well-defined management procedure, taking into account interdependencies among tasks and presenting tasks as linked sets."

11th Special Session of the IPHC (SS011)

- Presented a list of tasks
- Commission prioritized a smaller set of tasks
  - Further development of operating model
  - Multi-year assessments
  - Size limits (begin development)
  - Communication of results

MSE Program of Work 2021-2023

ID	Category	Task	Deliverable
F.1	Framework	Develop migration scenarios	Develop OMs with alternative migration scenarios
F.2	Framework	Implementation variability	Incorporate additional sources of implementation variability in the framework
F.3	Framework	Develop more realistic simulations of estimation error	Improve the estimation model to more adequately mimic the ensemble stock assessment
F.5	Framework	Develop alternative OMs	Code alternative OMs in addition to the one already under evaluation.
M.1	MPs	Size limits	Identification, evaluation of size limits
M.3	MPs	Multi-year assessments	Evaluation of multi-year assessments
E.3	Evaluation	Presentation of results	Develop methods and outputs that are useful for presenting outcomes to stakeholders and Commissioners

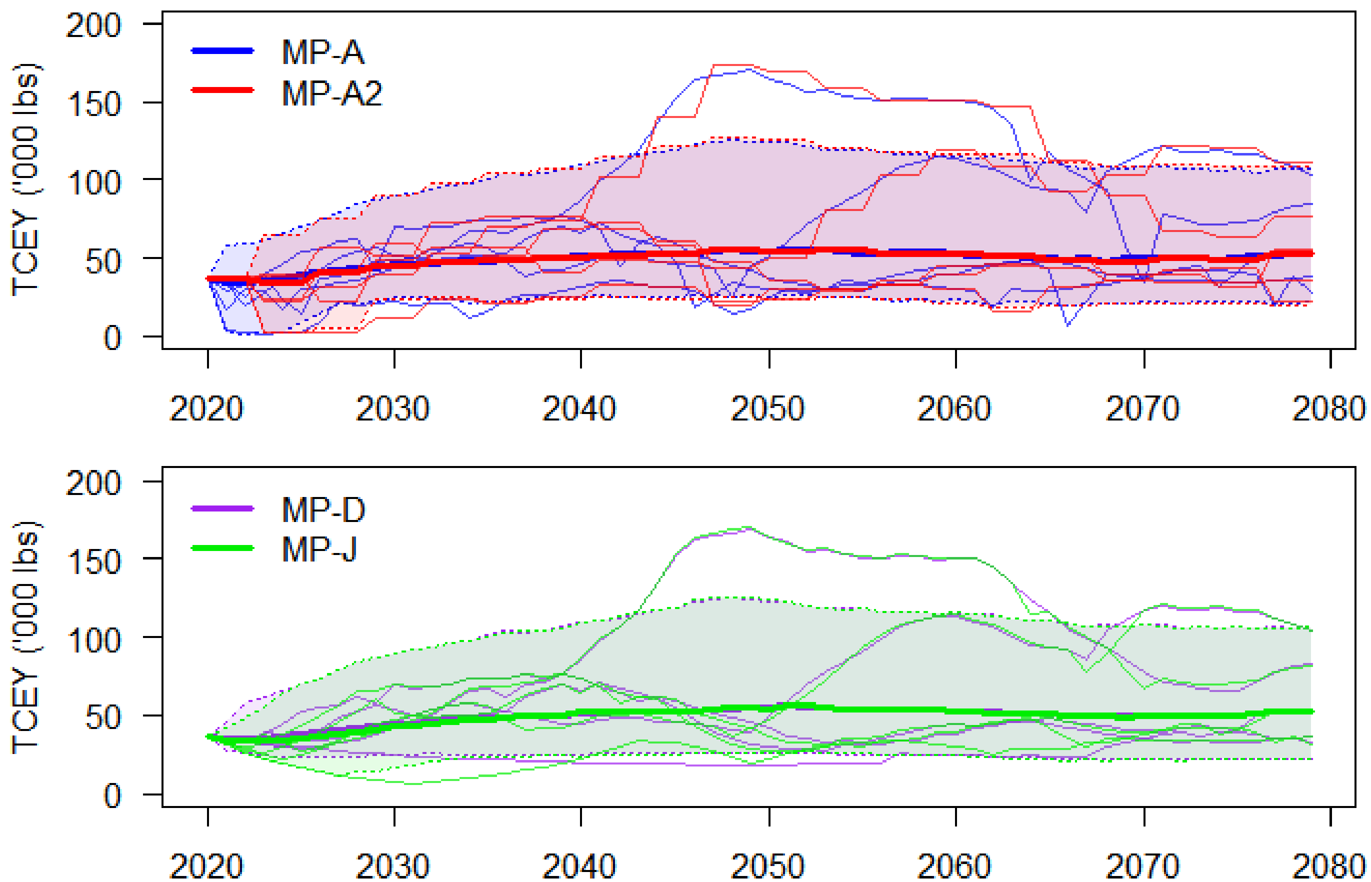
Biennial assessments

Element	MP-A	MP-A2	MP-D	MP-J
Maximum coastwide TCEY change of 15%				
Maximum Fishing Intensity buffer (SPR=36%)				
O32 stock distribution				
O32 stock distribution (5-year moving average)				
All sizes stock distribution				
Fixed shares updated in 5th year from O32 stock distribution				
Relative harvest rates of 1.0 for 2-3A, and 0.75 for 3B-4				
Relative harvest rates of 1.0 for 2-3, 4A, 4CDE, and 0.75 for 4B				
Relative harvest rates by Region: 1.0 for R2-R3, 0.75 for R4-R4B				
1.65 Mlbs fixed TCEY in 2A				
Formula percentage for 2B				
National Shares (2B=20%)				
Frequency of stock assessment & mortality limits (biennial)				

Mortality limits constant between assessments

SPR = 43% for all simulations

Simulated trajectories



Coastwide performance metrics

- Improved stability with a slightly smaller average TCEY
- Different SPR for MP-A2 may make it similar to MP-A

Management Procedure	A	A2	D	J
Biological Sustainability				
P(any RSB_y<20%)	<0.01	<0.01	0.01	<0.01
Fishery Sustainability				
P(all RSB<36%)	0.25	0.28	0.44	0.28
Median average TCEY (Mlbs)	39.92	38.31	40.22	37.90
P(any3 change TCEY > 15%)	0.44	0.36	0.10	0.00
Median AAV TCEY	12.1%	9.0%	5.9%	9.5%

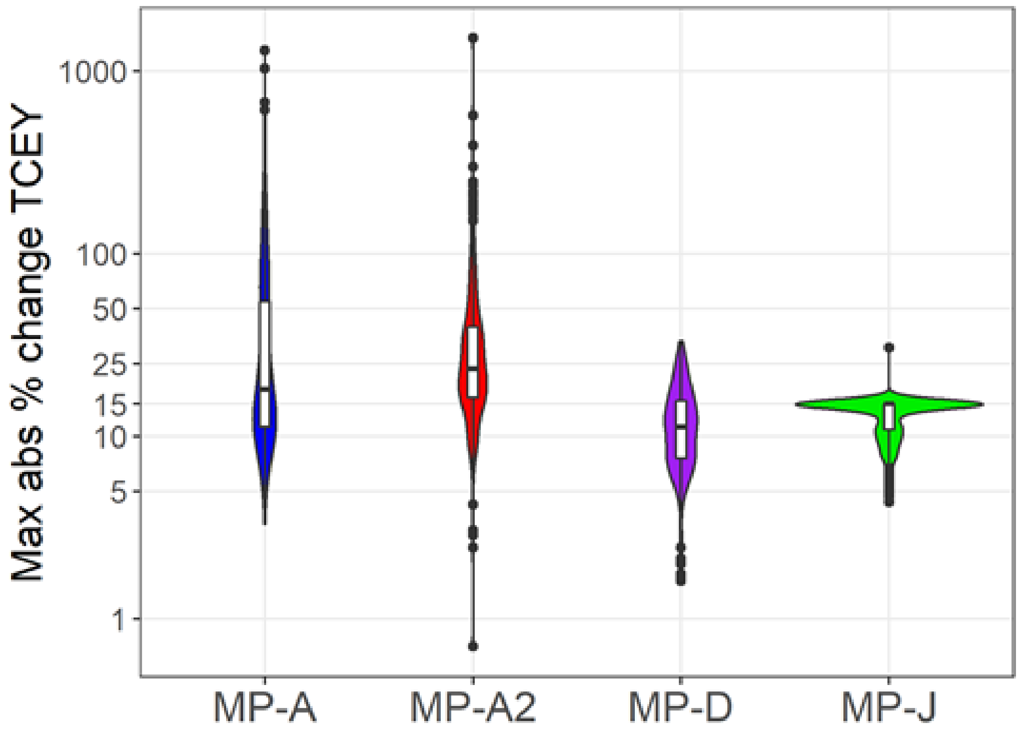
Alternative stability metrics

	Short-term				Long-term			
Management Procedure	A	A2	D	J	A	A2	D	J
Fishery Sustainability								
P(any1 change TCEY > 15%)	0.75	0.93	0.56	0.00	0.46	0.67	0.17	0.00
P(any2 change TCEY > 15%)	0.63	0.74	0.26	0.00	0.31	0.32	0.02	0.00
Median max absolute % change TCEY	18%	23%	11%	15%	13%	21%	9%	14%

Maximum absolute percent change

- Compressed distribution for MP-A2, with higher median
  - more often a higher maximum change in a ten-year period with A2

Short-term



Note: IPHC-2021-SRB019-07, Figure 5 showed long-term results

Multi-year assessment

- With a constant TCEY for two years
  - Trade-off between annual change and biennial stability
  - Fixing the TCEY or using further projections from stock assessment ignores data
  - Different SPR value may make results more similar
- Stability would increase with constant TCEY longer than two years
  - Would likely result in larger adjustments every 3rd year

Extensions to multi-year assessment MP

- Triennial assessment
- Empirical approaches in non-assessment years
  - Fix coastwide TCEY but update distribution
  - TCEY updated using trend of recent years
  - Use current FISS results to update TCEY and distribution

Recommendation/s

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-07 describing the MSE Program or Work for 2021–2023, sources of variability in the MSE framework, and results from simulations with a biennial mortality limit specification.

b) **RECOMMEND** MP specifications to investigate multi-year stock assessments or any other elements of interest as part of the MSE program of work for 2021-2023.

c) **REQUEST** any further analyses to be provided at SRB020, June 2022.

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Report on current and future biological and ecosystem science research activities

Agenda Item 7

IPHC-2021-SRB019-08

(J. Planas)

Outline

- SRB recommendations and requests from SRB018

2. Reproduction

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE
Reproduction	Histological maturity assessment	Updated maturity schedule	Scale biomass and reference point estimates	1. Biological input	Improve simulation of spawning biomass in the Operating Model
	Examination of potential skip spawning	Incidence of skip spawning			
	Fecundity assessment	Fecundity-at-age and -size information			
	Examination of accuracy of current field macroscopic maturity classification	Revised field maturity classification			

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SRB018–Req.13 (para. 44) The SRB **REQUESTED** that the analysis of seasonal patterns in gonad development be explicitly tied to the development/improvement of the maturity ogive (the vector of proportion mature at age that SA requires).

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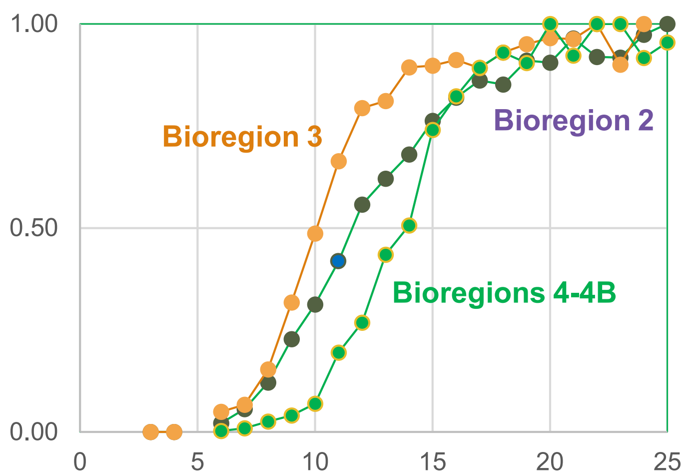
2. Reproduction

Maturity and fecundity sampling: FISS 2022-2023

- 2022 sampling will focus on morphometric vs. histological maturity estimation
- We will need to determine feasible sample sizes:

Step 1: which age-classes define the slope?

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BR2	0.02	0.06	0.12	0.23	0.31	0.42	0.56	0.62	0.68	0.76	0.82	0.86	0.85	0.91	0.91
BR3	0.05	0.07	0.15	0.32	0.49	0.66	0.79	0.81	0.89	0.90	0.91	0.89	0.93	0.95	0.97
BSAI	0.00	0.01	0.03	0.04	0.07	0.19	0.27	0.43	0.51	0.74	0.82	0.89	0.93	0.90	1.00
BR4	0.00	0.01	0.02	0.03	0.07	0.18	0.23	0.40	0.47	0.73	0.81	0.90	0.91	0.87	1.00
BR4B	0.00	0.01	0.03	0.05	0.07	0.21	0.31	0.47	0.54	0.75	0.83	0.89	0.95	0.94	1.00



Step 2: select desired data richness within target age-ranges

Expected sample sizes

	6	7	8	9	10	11	12	13	14	15	16	17	18	19
BR2	3	8	11	10	11	14	**17**	**21**	**21**	20	9	6	5	**3**
BR3	9	**18**	29	22	**20**	**20**	**31**	**34**	35	32	16	11	6	4
BR4	9	22	16	12	15	17	18	**20**	**19**	17	9	**6**	4	2
BR4B	8	15	17	16	14	14	18	**23**	**20**	14	6	**6**	6	2

Step 3+: determine sampling implications for FISS; adjust as necessary

Based on ages that define ~10-90% morphometric maturity:

	range	N Classes	Constrained Age	At N =	SamRt	Total	n/station
BR2	7-19	13	19	3	0.04	124	0.3
BR3	7-15	9	7	18	0.14	243	0.4
BR4	10-17	8	17	6	0.13	251	1.3
BR4B	10-17	8	17	6	0.40	287	2.9
					Grand Total:	905	

2. Reproduction

Maturity and fecundity sampling: FISS 2022-2023

- 2023 sampling will provide samples (whole ovaries) for fecundity estimation
  - Noting the whole ovaries may also be collected in 2022, if feasible

- The rate-selection process will be similar…

Select the desired data richness

Expected sample sizes

	6	7	8	9	10	11	12	13	14	15	16	17	18	19
BR2	3	8	11	10	11	14	**17**	**21**	**21**	20	9	6	5	**3**
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BR4	9	22	16	12	15	17	18	**20**	**19**	17	9	**6**	4	2
BR4B	8	15	17	16	14	14	18	**23**	**20**	14	6	**6**	6	2

Determine sampling implications for FISS

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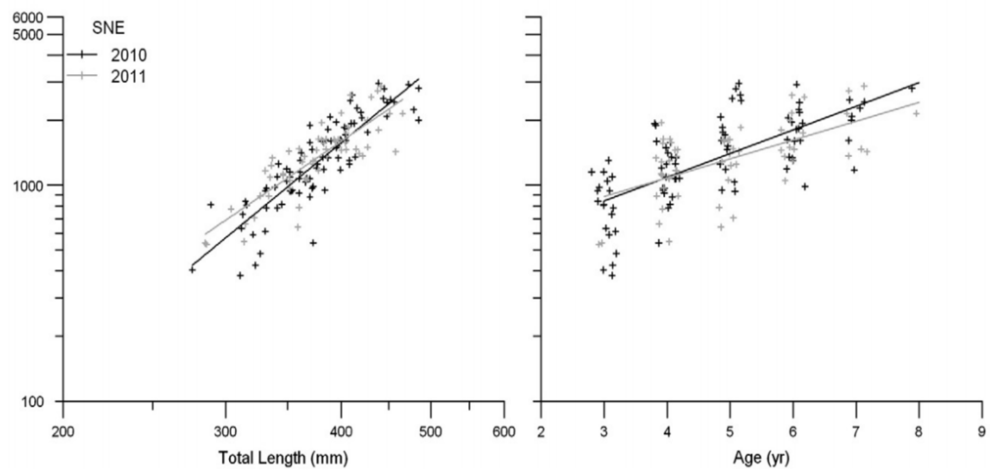
					Grand Total:	905	

… but with acceptable data-richness defined differently:

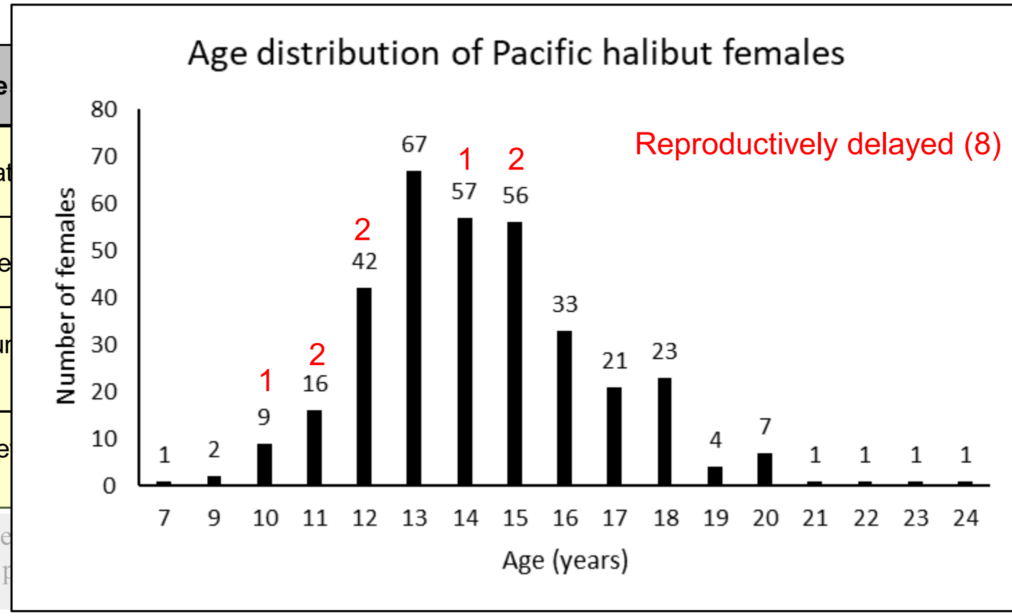
- based on sample sizes required for modeling length- and age-specific fecundity



From: McElroy et al., J. Sea Res **75**(2013):52-61
Fecundity in Winter flounder (*Pseudopleuronectes americanius*)

2. Reproduction

Research area	Research activities	Re	ce for MSE
Reproduction	Histological maturity assessment	Updat	imulation of biomass in ating Model
	Examination of potential skip spawning	Incide	
	Fecundity assessment	Fecun	
	Examination of accuracy of current field macroscopic maturity classification	Re	



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2. Reproduction: fecundity

- Objective: establish a fecundity –size (length/weight/age) relationship.
- Measure: potential annual fecundity as a measure of annual egg production.
- Whole ovaries from 3 females collected during FISS 2021.
- Fecundity assessment method testing planned for late 2021-early 2022.
- Selection of method for fecundity assessment by mid 2022.
- Collection of samples for fecundity assessment planned for FISS 2022

2. Reproduction

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE
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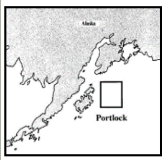
2. Reproduction

5-Yr Research Plan (2017-2021) | **(2022-2026)**

2017-2018 Field sample collection (central GOA)

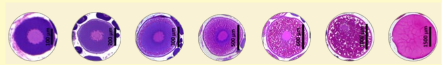


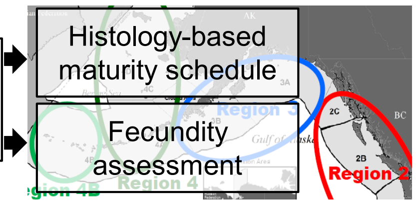
30♀/ month

♀>90 cm FL

Seasonal characterization of reproductive development

Histological samples → Characterization of oocyte stages → Classification of female developmental stages → Classification of reproductive phases → Appropriate timing of gonad collection in FISS → Histology-based maturity schedule; Fecundity assessment





Research outcomes:
- Group synchronous
- Batch spawner
- Determinate fecundity
- Annual cycle
- Spawning time
- Reproductive delays
- July/August

Macroscopic vs microscopic maturity staging

Macroscopic maturity scores; Ovary images ↔ Histology-based female developmental stages and reproductive phases → Assess accuracy of current field maturity classification criteria → Revise macroscopic staging criteria

Research outcomes:
- In progress

Staff involved: Teresa Fish, MSc candidate APU (2018-2020)
Funding: IPHC (2018-2020)
Publications: Fish et al. (2020) *J. Fish Biol*. **97**: 1880–1885 ; Fish et al. (in preparation)

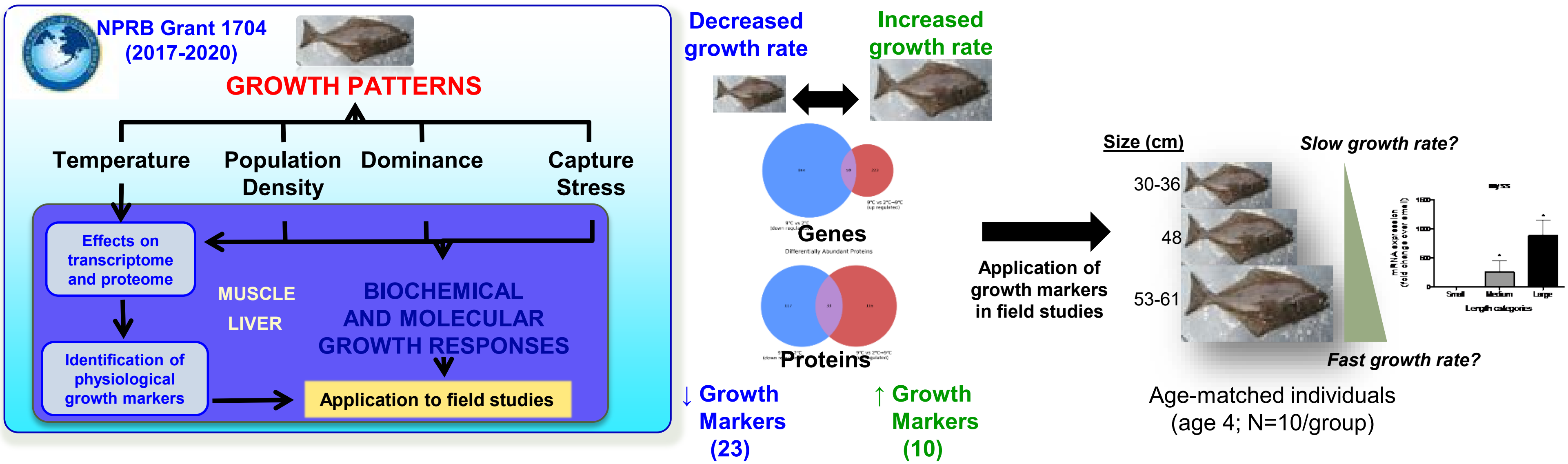
3. Growth

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
Growth	Identification and application of markers for growth pattern evaluation	Identification and application of markers for growth pattern evaluation	Scale stock productivity and reference point estimates		Improve simulation of variability and allow for scenarios investigating climate change	3. Biological parameterization and validation for growth projections
	Environmental influences on growth patterns	Environmental influences on growth patterns				
	Dietary influences on growth patterns and physiological condition	Dietary influences on growth patterns and physiological condition				

42. The SRB **NOTED** that growth marker genes identified in transcriptomic profiling studies can be informative in future genome scans. However, the SRB **REQUESTED** that the Secretariat explicitly describe how the gene regions identified as 'over' or 'under' expressed would be used. For example, research has yet to determine mechanisms for transcriptional differences other than there is over- or under-representation of mRNA transcripts associated with different treatment groups (e.g. warm vs. cool water) from a heterogeneous set of individuals collected from a single location. The Secretariat has not yet established that results can be generalized to other regions in the species range. Neither has the transcriptional patterns been generalized to individuals of different size/age. These questions should be investigated.

3. Growth

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
Growth	Identification and application of markers for growth pattern evaluation	Identification and application of markers for growth pattern evaluation	Scale stock productivity and reference point estimates		Improve simulation of variability and allow for scenarios investigating climate change	3. Biological parameterization and validation for growth projections
	Environmental influences on growth patterns	Environmental influences on growth patterns				
	Dietary influences on growth patterns and physiological condition	Dietary influences on growth patterns and physiological condition				



3. Growth

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
		Identification and application				

43. The SRB **REQUESTED** that the Secretariat use these gene regions and align sequences to the whole genome sequence data. Specifically, the Secretariat should investigate whether there is sequence variability within gene coding regions or in regions around gene coding regions that may be transcriptional modifiers (e.g. promoters). If genetic variation exists in or near these genes, these variable base pair position(s) (i.e. single nucleotide polymorphisms or SNPs) should be incorporated in other aspects of the Secretariat research; for example for research activities under the Migration and Population Dynamics Research area.

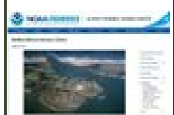
Transcript ID	Gene	Annotation	Non-coding	Coding	Five prime flanking
TRINITY_DN102963_c0_g1_i1	LOC118098571	glycine--tRNA ligase-like	86	11	94
TRINITY_DN98755_c4_g1_i1	LOC118105518	myosin heavy chain, fast skeletal muscle-like	60	39	30
TRINITY_DN88997_c0_g1_i1	LOC118110038	troponin I, slow skeletal muscle-like	52	6	94
TRINITY_DN105325_c2_g1_i1	LOC118118854	zinc finger protein 638-like	529	52	101
TRINITY_DN104023_c1_g2_i2	LOC118124806	asparagine synthetase [glutamine-hydrolyzing]-like	242	23	77
TRINITY_DN105033_c2_g1_i1	acta1a	actin alpha 1, skeletal muscle a	18	7	104
TRINITY_DN97221_c0_g3_i1	mylpfb	myosin light chain, phosphorylatable, fast skeletal muscle b	29	2	71
TRINITY_DN97789_c1_g1_i1	rhcga	Ammonium transporter, Rh family, C glycoprotein a	30	7	28
TRINITY_DN87895_c0_g1_i2	ttn.1	titin, tandem duplicate 1	420	205	124
TRINITY_DN106670_c2_g1_i1	ubp1	upstream binding protein 1	121	7	84

3. Growth

5-Yr Research Plan (2017-2021)

2016-2018 Age-0 summer collections (Kodiak)

Fish rearing at Hatfield Marine Science Center (Newport)



Identification and validation of physiological growth markers

Growth laboratory experiments

Temperature manipulations

Density manipulations

Handling manipulations

Transcriptomic and proteomic profiling

Temperature-responsive growth markers

Density-responsive growth markers

Handling-responsive growth markers

Validation studies

Environmental influences on growth patterns

Dietary influences on growth patterns and physiological condition

Research outcomes:
- Differentially-expressed genes
- Differentially-expressed proteins
- Putative growth markers

Environmental influences on growth patterns

Research outcomes:
- Effects of temperature on growth rates
- Temperature-specific molecular responses

Staff involved: Andy Jasonowicz, Anna Simeon
Funding: NPRB Grant#1704 (Sept. 2017-Feb. 2020)
Publications: Planas et al. (in preparation)

4. DMRs and Survival Assessment

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
Mortality and survival assessment	Discard mortality rate estimate: longline fishery	Experimentally-derived DMR	Improve estimates of unobserved mortality		Improve estimates of stock productivity	1. Fishery parameterization
	Discard mortality rate estimate: recreational fishery					2. Fishery parameterization
	Best handling practices: longline fishery	Guidelines for reducing discard mortality		2. Fishery yield		
	Best handling practices: recreational fishery	Guidelines for reducing discard mortality		3. Fishery yield		

- ***Guided recreational fishery***

NFWF National Fish and Wildlife Foundation

NPRB Grant No. 2009

1. Collect information on hook types and sizes and handling practices
2. **Investigate the relationship between gear types and capture conditions and size composition of captured fish**
3. **Injury profiles and physiological stress levels of captured fish**
4. **Assessment of mortality of discarded fish**

- Sitka: 21 – 27 May 2021
- Seward: 11 – 17 June 2021

4. DMRs and Survival Assessment

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
Mortality and survival assessment	Discard mortality rate estimate: longline fishery	Experimentally-derived DMR	Improve estimates of unobserved mortality		Improve estimates of stock productivity	1. Fishery parameterization
	Discard mortality rate estimate: recreational fishery					2. Fishery parameterization
	Best handling practices: longline fishery	Guidelines for reducing discard mortality		2. Fishery yield		
	Best handling practices: recreational fishery	Guidelines for reducing discard mortality		3. Fishery yield		

- ***Guided recreational fishery***

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4. **Assessment of mortality of discarded fish**

- Sitka: 21 – 27 May 2021

Size classes (cm)				
≤ 68	69-77	78-93	≥ 94	Total
63	**75**	**66**	**39**	**243**

- Two gear sizes: 12/0 and 16/0 hooks
- Observations and samples: hooking time, time on deck, weight, length, hook injury type and picture, viability, fat content, fish temperature, blood sample, fin clip, wire tag.

4. DMRs and Survival Assessment

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
Mortality and survival assessment	Discard mortality rate estimate: longline fishery	Experimentally-derived DMR	Improve estimates of unobserved mortality		Improve estimates of stock productivity	1. Fishery parameterization
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	Best handling practices: longline fishery	Guidelines for reducing discard mortality		2. Fishery yield		
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- ***Guided recreational fishery***

NFWF National Fish and Wildlife Foundation

UAF University of Alaska Fairbanks

Alaska Pacific University

NPRB Grant No. 2009

1. Collect information on hook types and sizes and handling practices
2. **Investigate the relationship between gear types and capture conditions and size composition of captured fish**
3. **Injury profiles and physiological stress levels of captured fish**
4. **Assessment of mortality of discarded fish**

- Seward, AK (3A): 11 – 17 June 2021

Types of tags		
Wire	sPATs	Total
38	80	118

- Two gear sizes: 12/0 and 16/0 hooks
- Observations and samples: hooking time, time on deck, weight, length, hook injury type and picture, viability, fat content, fish temperature, blood sample, fin clip, tag.

4. Mortality and Survival Assessment

5-Yr Research Plan (2017-2021)

Fall 2017 field experiment (GOA)

Discard mortality rate estimation: longline fishery

Capture and handling conditions
- Careful shake
- Gangion cut
- Hook strip

Injury and viability assessment

Physiological condition assessment

Analysis of capture-related variables

Survival assessment by tagging

Best handling practices in longline fishery

Research outcomes:
- Injury and viability profiles of hook release methods
- Physiological profile of fish under different capture and handling conditions
- Longline DMR

Summer 2021 field experiments (Sitka, AK Seward, AK)

Discard mortality rate estimation: charter recreational fishery

Capture and handling conditions
- 12/0 and 16/0 hooks

Injury, viability and physiological assessment

Survival assessment by tagging

Analysis of capture-related variables

Best handling practices in recreational fishery

Research outcomes:
- In progress

Staff involved: Tim Loher, Claude Dykstra, Allan Hicks, Ian Stewart

Funding: Saltonstall-Kennedy NOAA (Sept. 2017-Aug. 2020); National Fish and Wildlife Foundation (Apr. 2019-Nov. 2021)

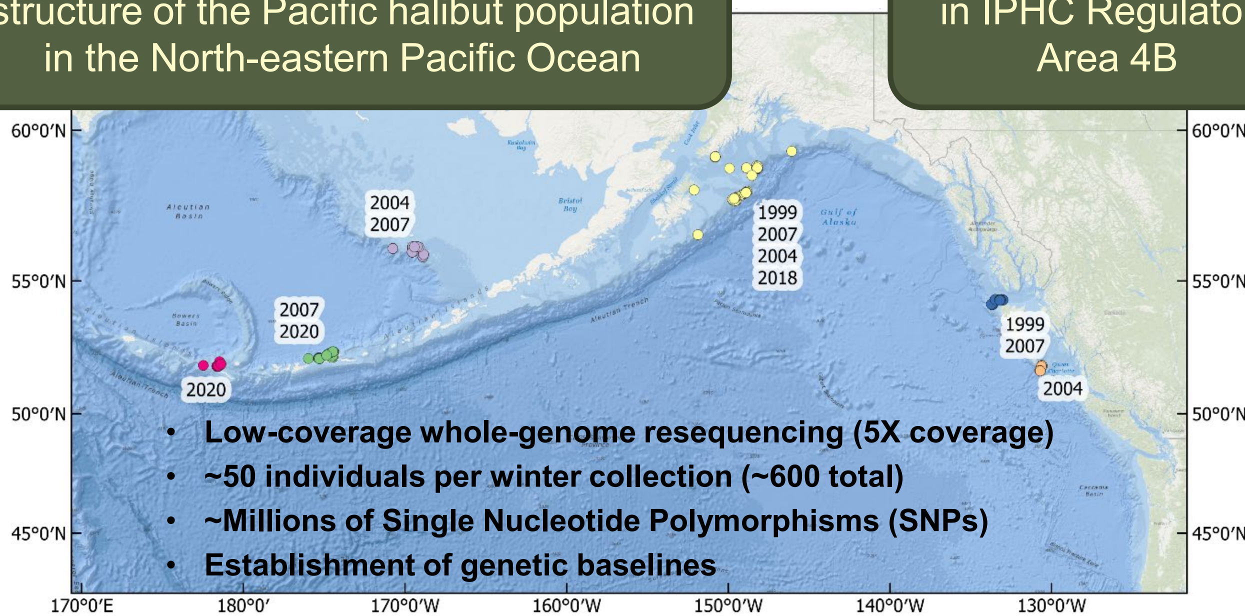
Publications: Kroska et al. (2021) *Conserv. Physiol.*; Loher et al. (in review) *North Amer. J. Fish. Manag.*

5. Genetics and Genomics

Research area	Research activities	Research outcomes	Relevance for stock assessment (SA)	SA Rank	Relevance for MSE	MSE Rank
Genetics and genomics	Population structure	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area	Altered structure of future stock assessments	2. Biological input	Improve parametization of the Operating Model	1. Biological parameterization and validation of movement estimates. 2. Biological parameterization and validation of recruitment distribution
		Assignment of individuals to				

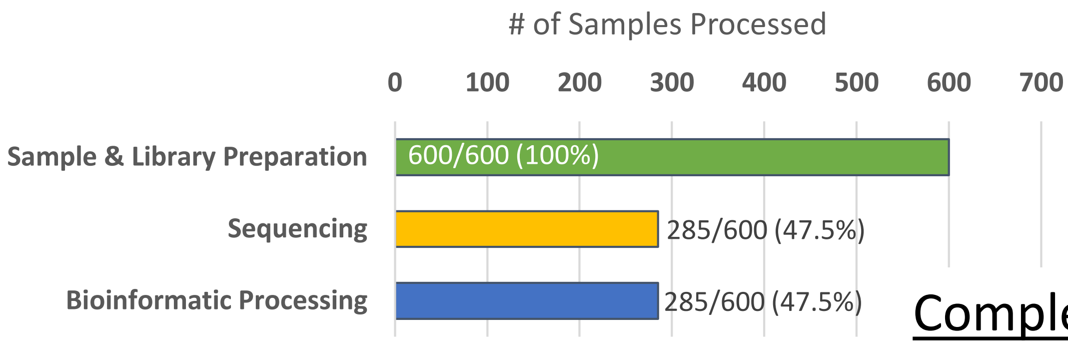
Revise our understanding of genetic structure of the Pacific halibut population in the North-eastern Pacific Ocean

Analysis of structure in IPHC Regulatory Area 4B



- **Low-coverage whole-genome resequencing (5X coverage)**
- **~50 individuals per winter collection (~600 total)**
- **~Millions of Single Nucleotide Polymorphisms (SNPs)**
- **Establishment of genetic baselines**

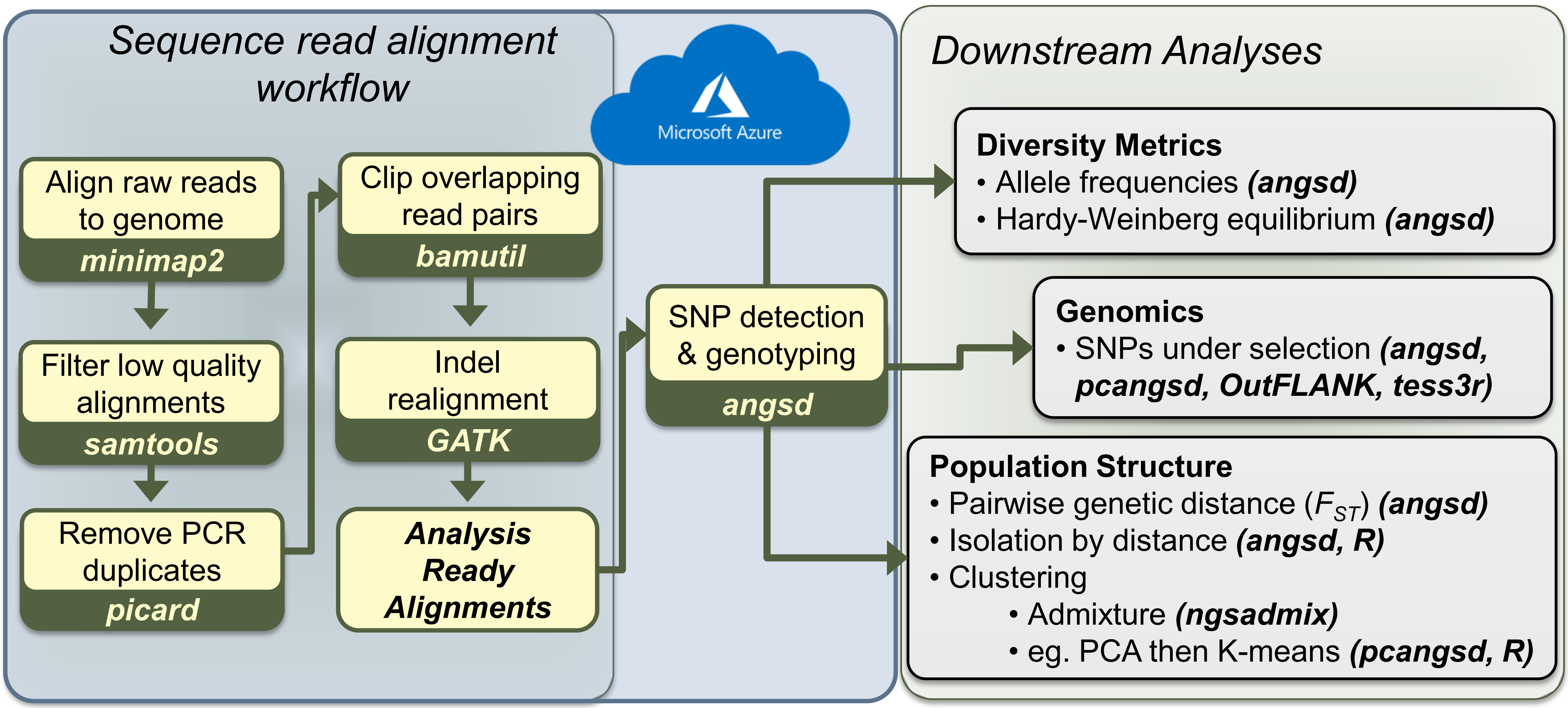
5. Genetics and Genomics



Completed sequencing runs to date:

	Run 1 (Sept 2020)	Run 2 (Feb 2021)
N	36	250
Sequencing Platform	Illumina HiSeq 4000	Illumina NovaSeq S4
Raw Reads Per Sample	26.5 million (21.8 - 42.9)	24.7 million (10.7 – 47.2)
Reads Retained	15.8 million (13 - 24.9) 60% (54% - 69%)	15.4 million (4.2 - 26.4) 63% (22% - 70%)
Coverage Per Sample	3.2x (2.6 – 5x)	3.5x (1.0 - 5.6x)

5. Genetics and Genomics



Methods

- ANGSD (v0.934) (Korneliussen et al. 2014)
  - global minor allele frequency (MAF) ≥ 0.01
  - p-value 1e-6 ≤ less for a site being variable
  - 214 out of 285 (~75%) of individuals

10,474,925 SNPs

- Removed SNPs in unplaced scaffolds, chr 9, and mt genome prior to analysis

10,039,557 SNPs

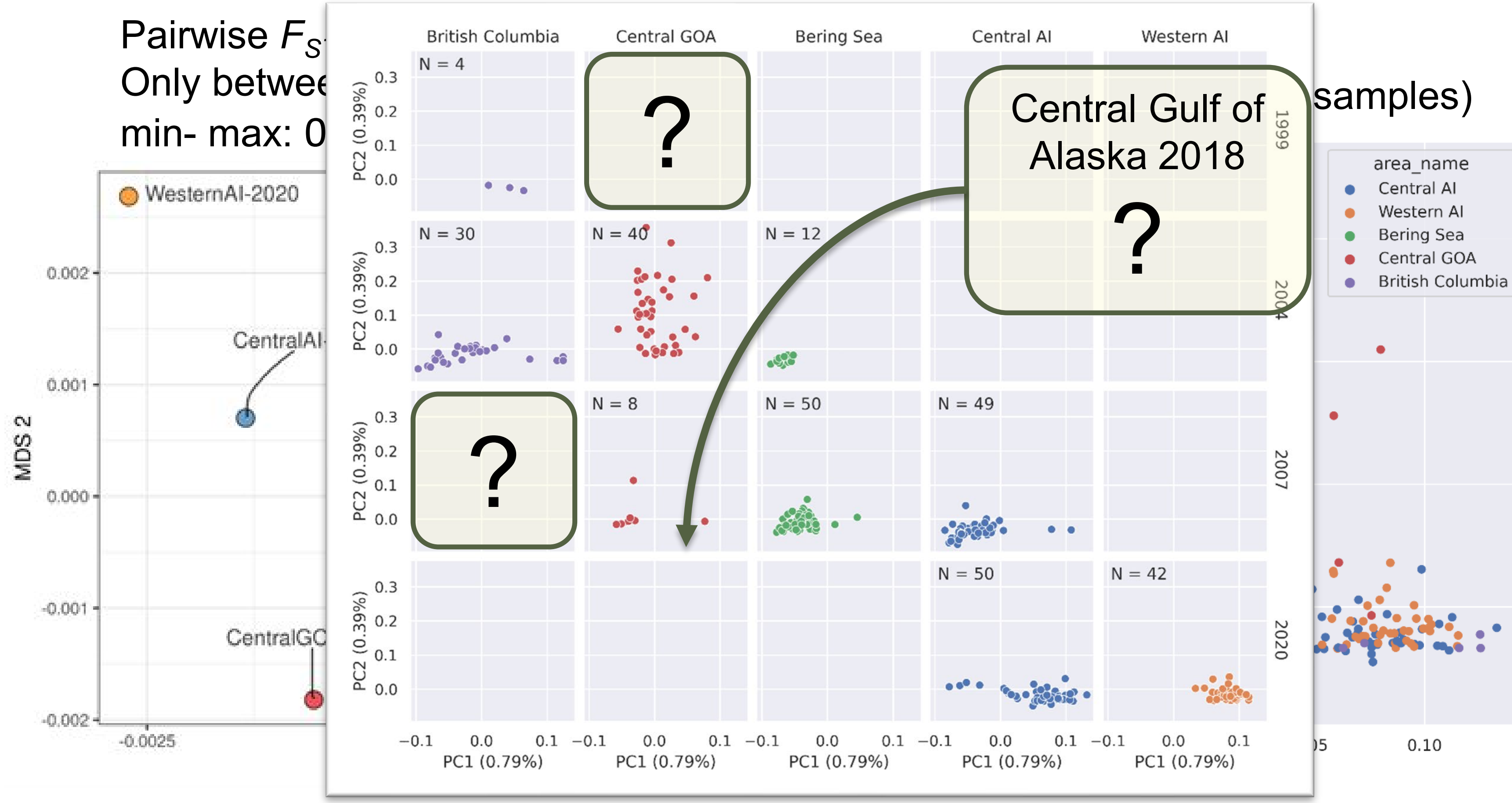
- PCangsd (v1.02) (Meisner & Albrechtsen 2018)
  - Default settings (MAF ≥ 0.05)

4,850,093 SNPs

Korneliussen, T. S., A. Albrechtsen, and R. Nielsen. 2014. ANGSD: Analysis of Next Generation Sequencing Data. BMC Bioinformatics 15(1):1–13.
Meisner, J., and A. Albrechtsen. 2018. Inferring Population Structure and Admixture Proportions in Low-Depth NGS Data. Genetics 210(2):719–731.

Population Structure (**preliminary*)

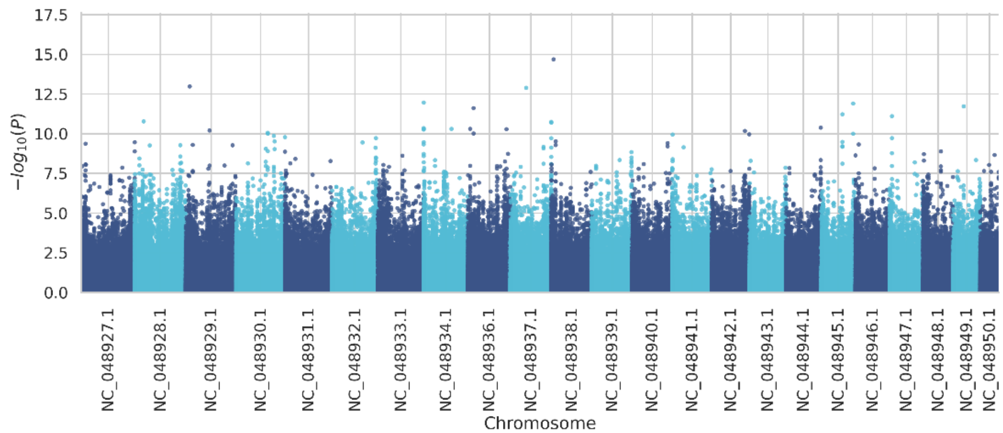
Pairwise F_{S}
Only betwee … samples)
min- max: 0



Signatures of Selection (**preliminary*)

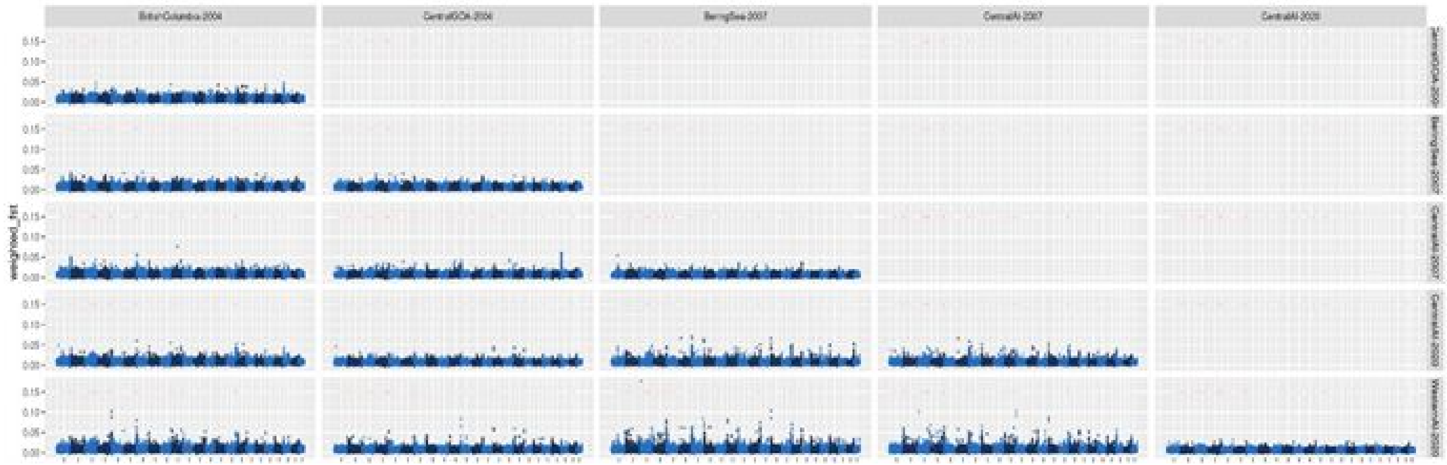
PCAngsd

- Min MAF 0.05
- 4,850,093 SNPs



Pairwise F_{ST}

- 10 kb windows, 5 kb step
- Only between collections where n ≥ 30
- 10,039,557 SNPs

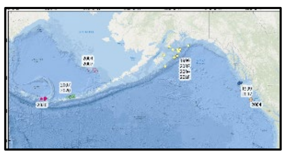


5. Genetics and Genomics

5-Yr Research Plan (2017-2021)

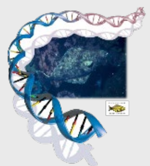
Collection of genetic samples of spawning aggregations spanning the Gulf of Alaska, Bering Sea and Aleutian Islands

(1999-2020)



Development and application of genomic approaches

Chromosome-level genome assembly



→ Development of methods based on low-coverage whole genome resequencing

→ Establishment of a bioinformatic pipeline in the cloud (Microsoft Azure)

→ Population structure analyses

→ Establishment of a baseline of genetic diversity

→ Delineation of fine-scale stock structure

Research outcomes:

- Sequenced genome (size=586 Mbp)
- Full annotation (NCBI) (27,422 genes)
- 24 chromosome-length scaffolds
- SNP detection and genotyping

Staff involved: Andy Jasonowicz

Funding: IPHC

Recommendation

That the SRB:

- **NOTE** paper IPHC-2021-SRB019-08 which outlines progress on the IPHC's 5-year Biological and Ecosystem Science Research Plan (2017-21).

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Pacific halibut multiregional economic impact assessment (PHMEIA):

update for SRB019

Agenda Item 8

IPHC-2021-SRB019-09

(B. Hutniczak)

Outline

1. **Economic impact**
   - Commercial fishing
   - Recreationaal fishing
   - Cross-regional effects

2. **Model setup**

   Social accounting matrix (SAM) approach with connected regional components

3. **Economic impact estimates**

   Interpreting PHMEIA model results

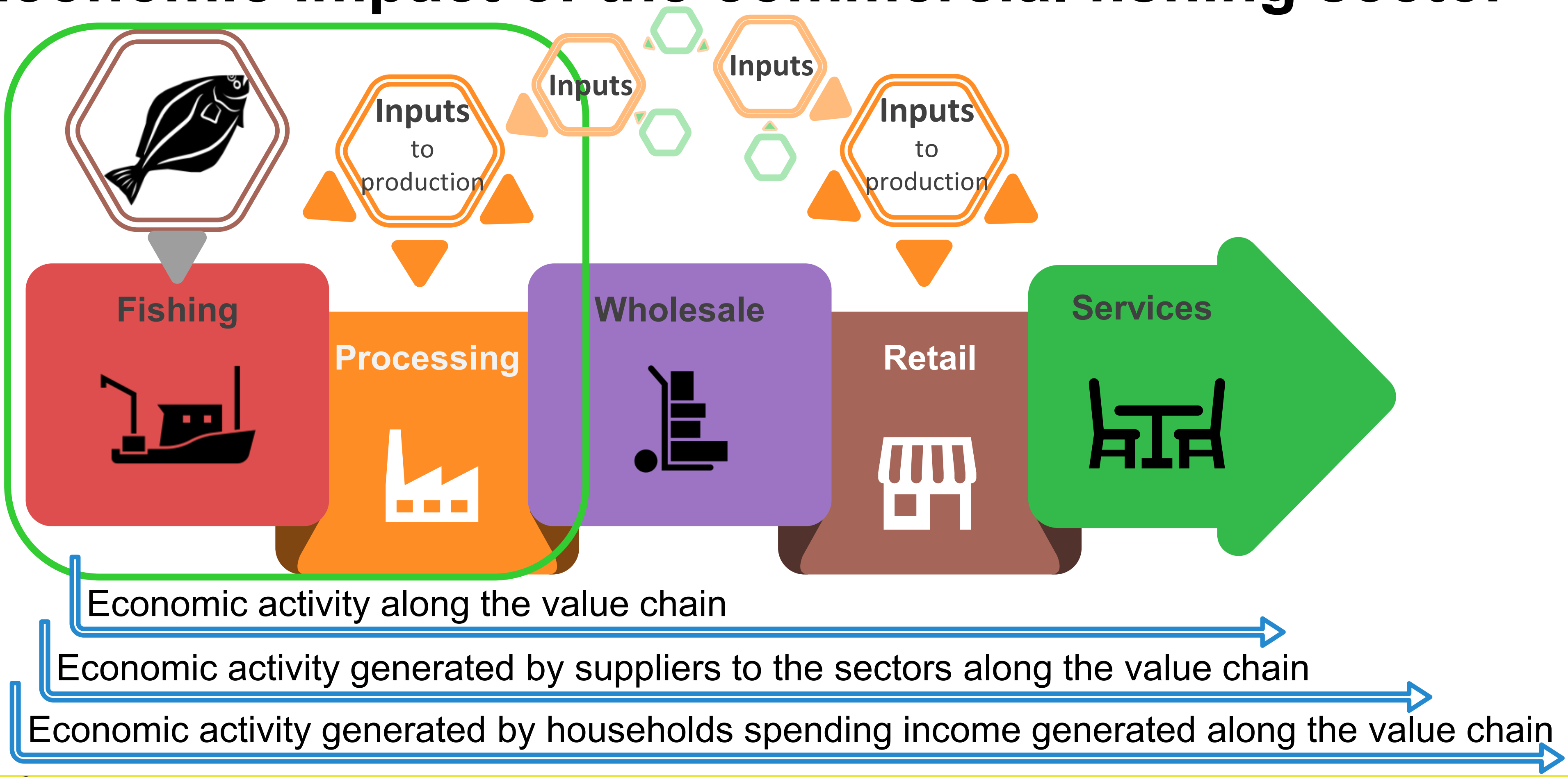
4. **Dissemination of results**

   Economic impact visualization tool

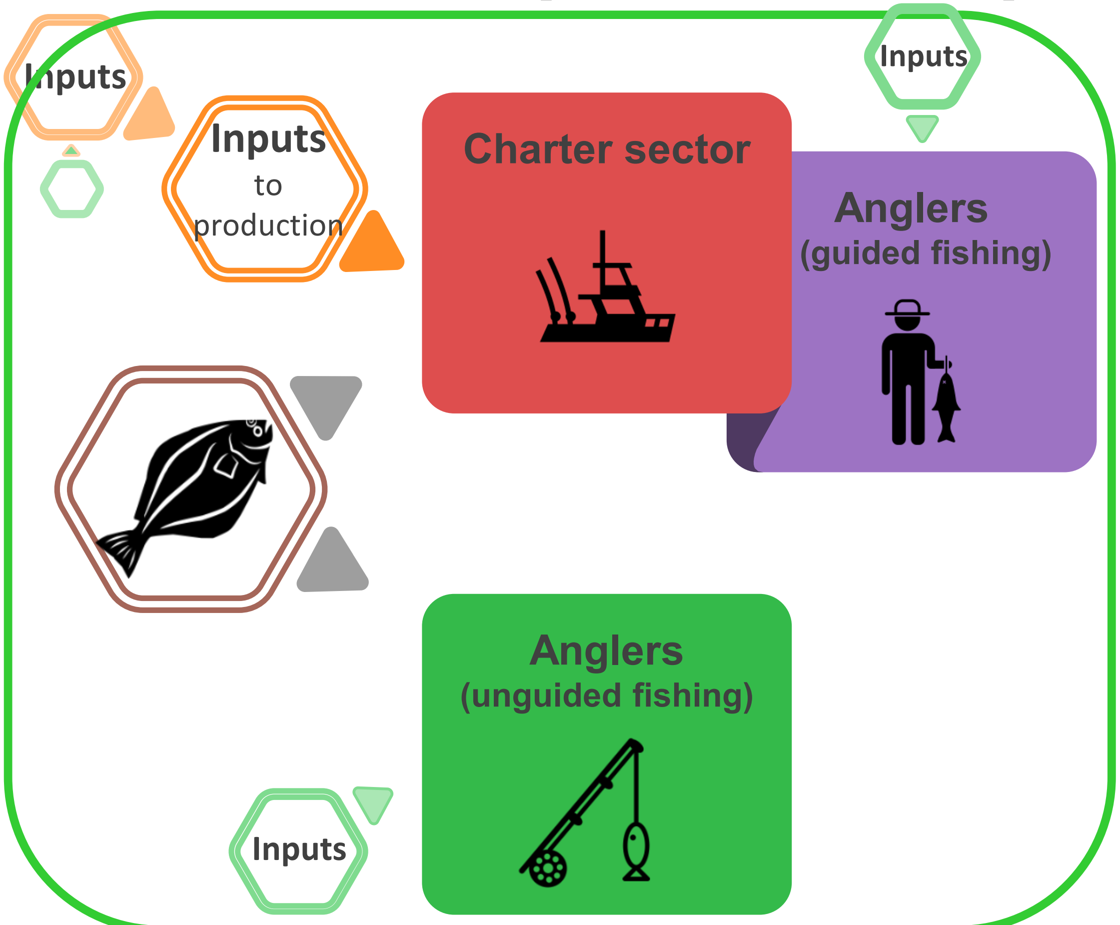
5. **Conclusions**

   Including recommendations for the SRB

Economic impact of the commercial fishing sector

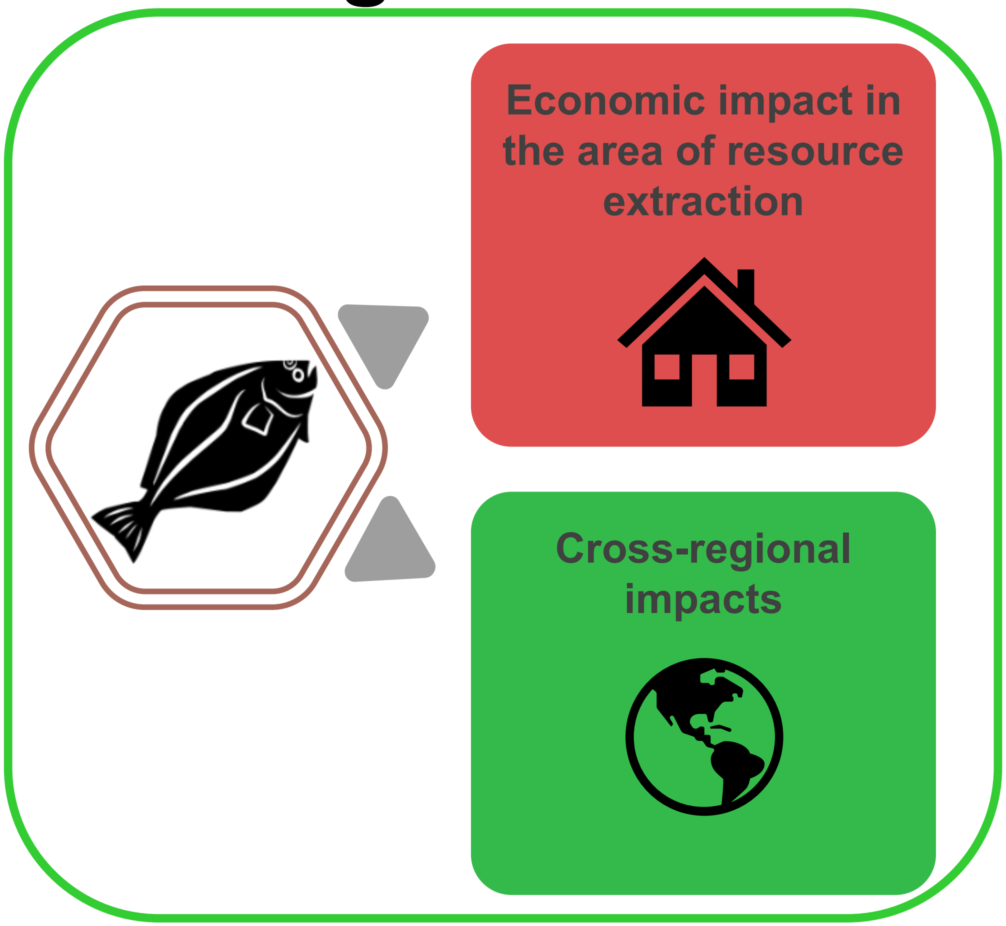


Economic impact of the sport fishing sector



- Economic activity of businesses directly dependent on the access to the resource
- Economic activity generated by suppliers to the resource-dependent businesses
- Economic activity generated by supplying anglers (guided and unguided)
- Economic activity generated by households spending income dependent on recreational fishing (guided and unguided)

Multiregional effects



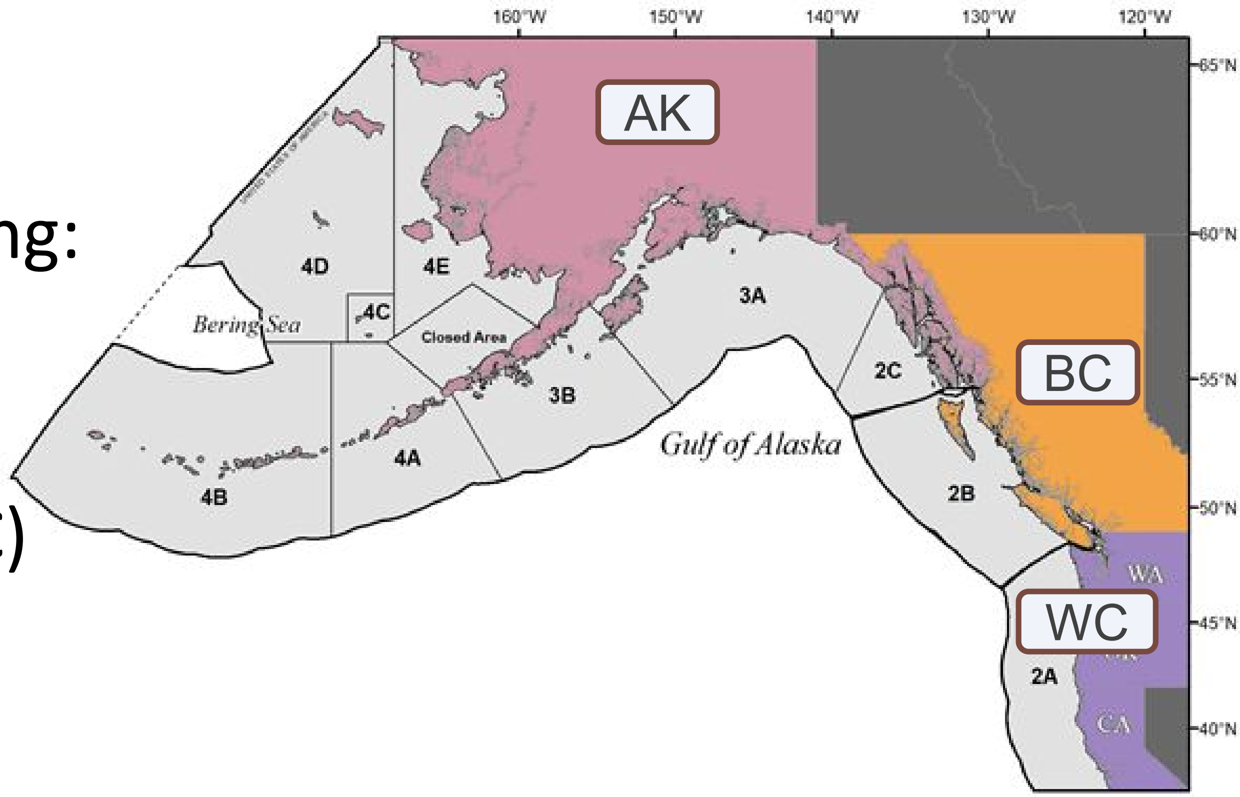
- Monetary flows related to inputs to production / import of inputs
- Monetary flows related to final consumption / export of services
- Wages earned by residents vs. non-residents
- Profit from ownership of residents vs. non-residents

Regions

Pacific halibut producing:

- Alaska (AK)
- West Coast (WC)
- British Columbia (BC)

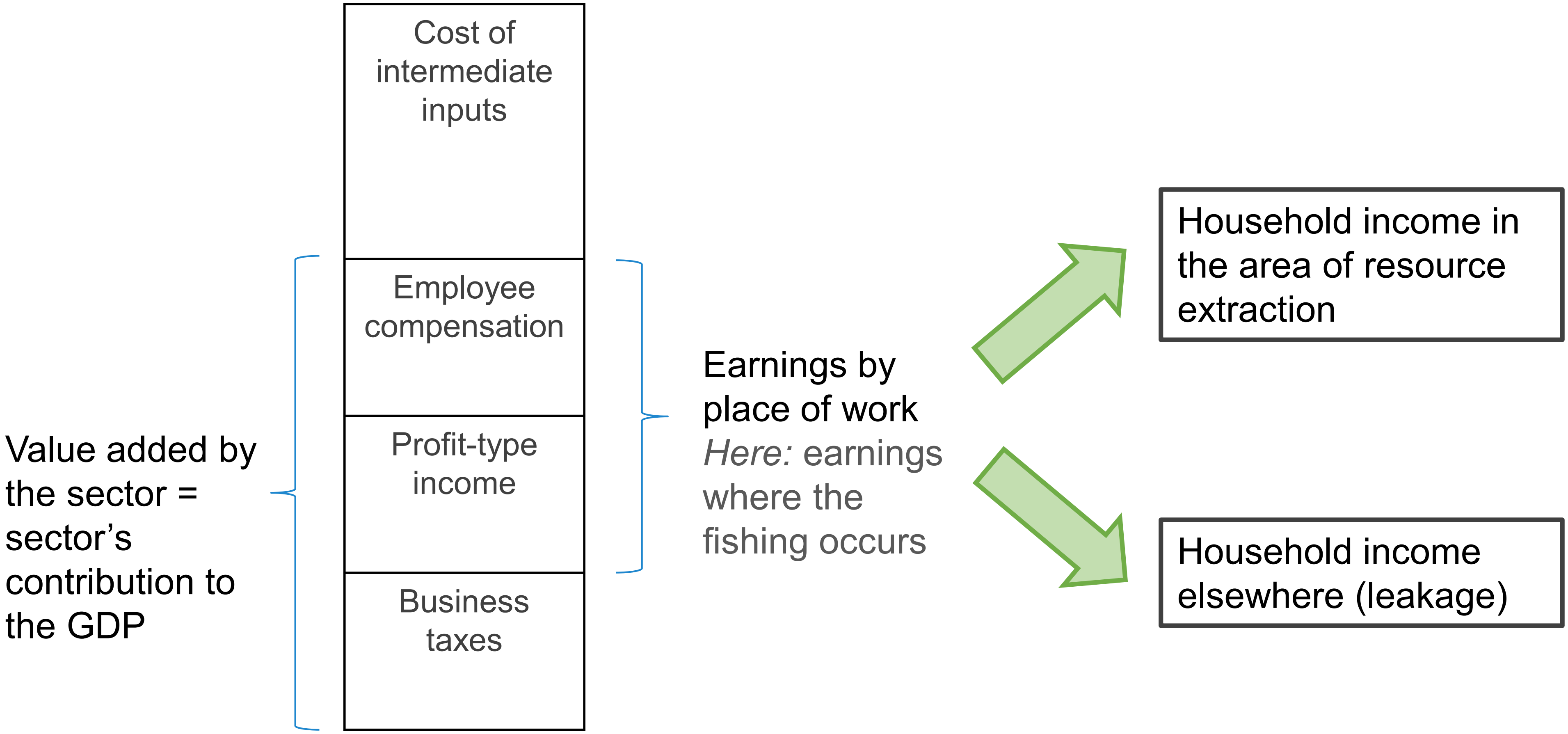
- Rest of the US (RUS)
- Rest of Canada (ROC)
- Rest of the world (ROW)*



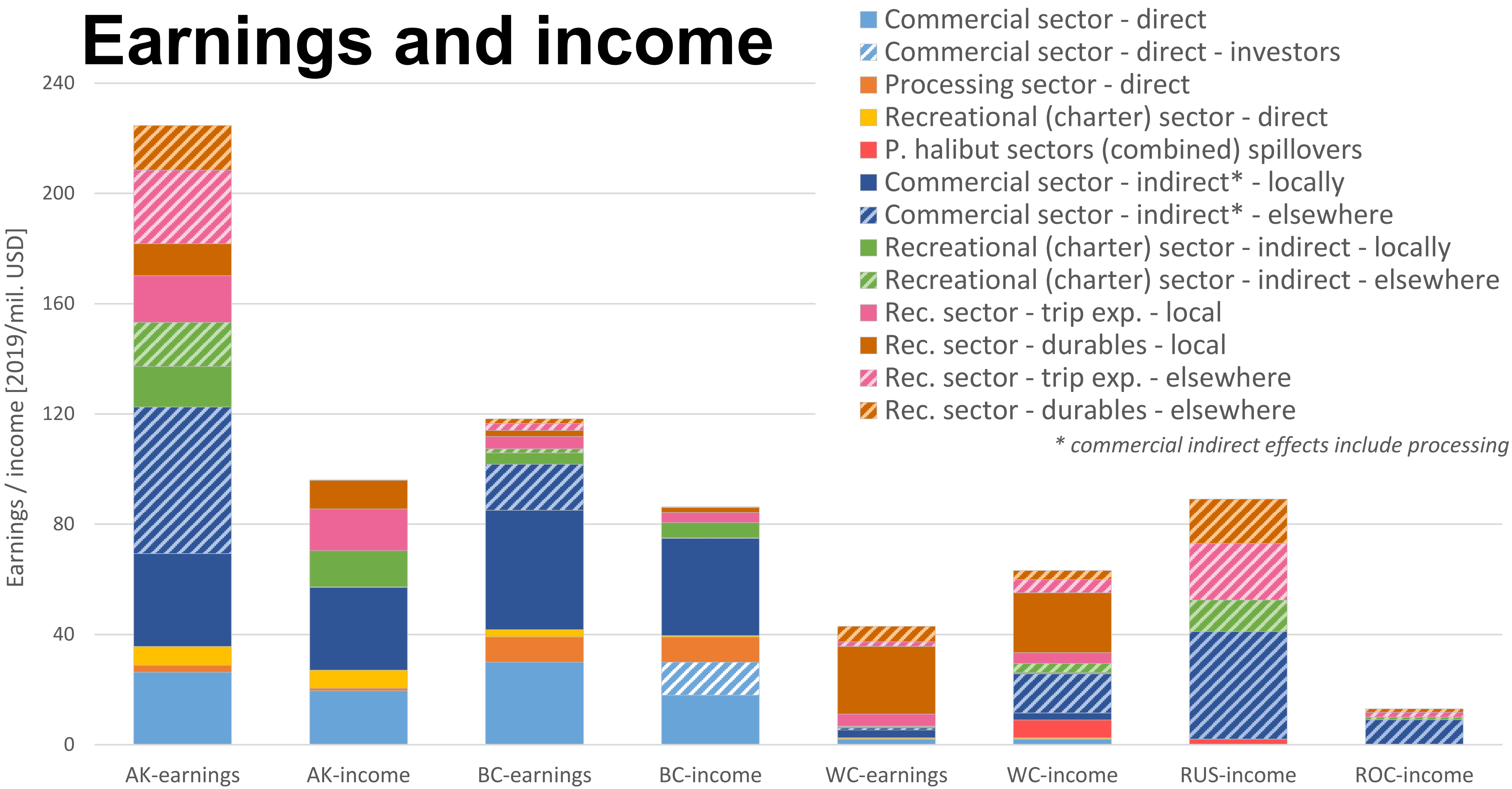
Multiregional social accounting matrix/SAM-based approach

*treated as exogenous

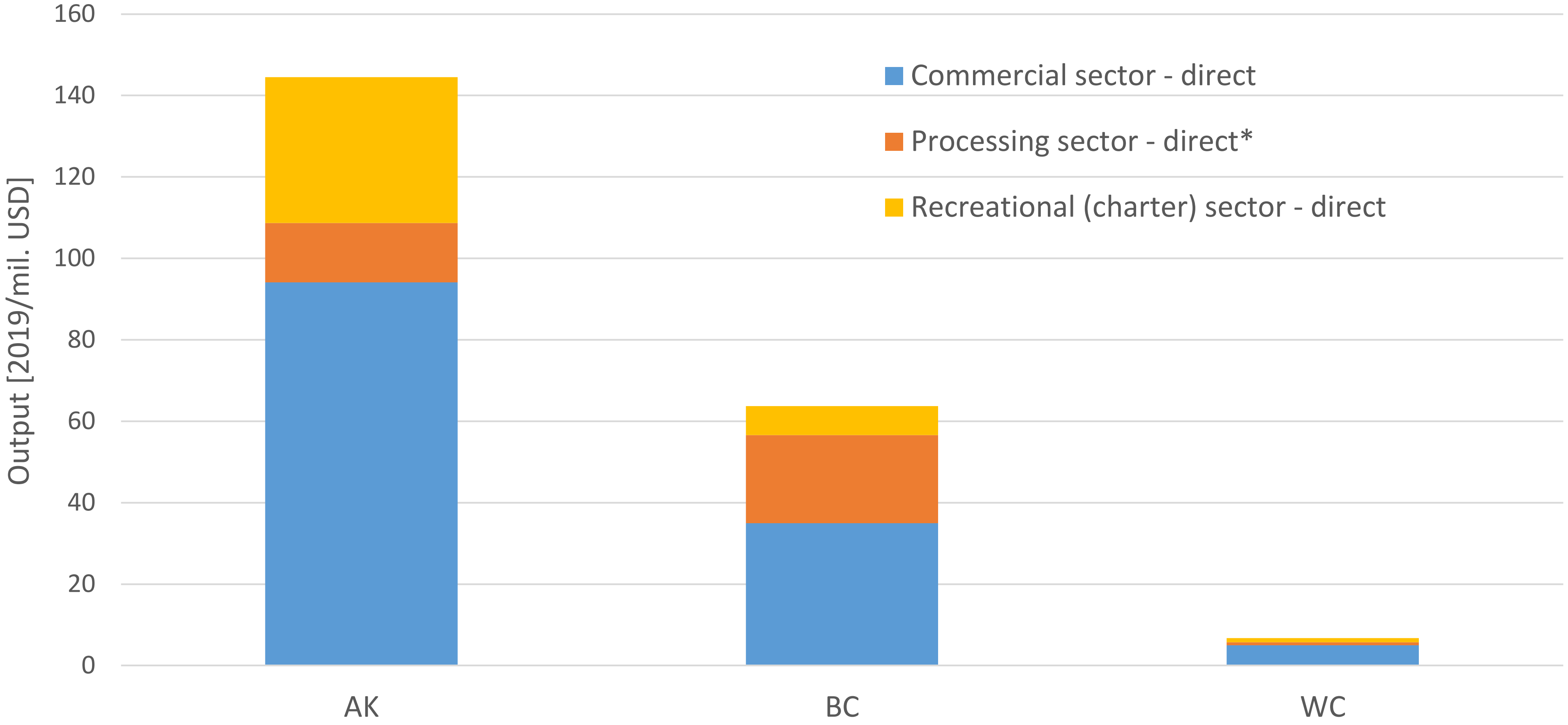
Direct earnings & income



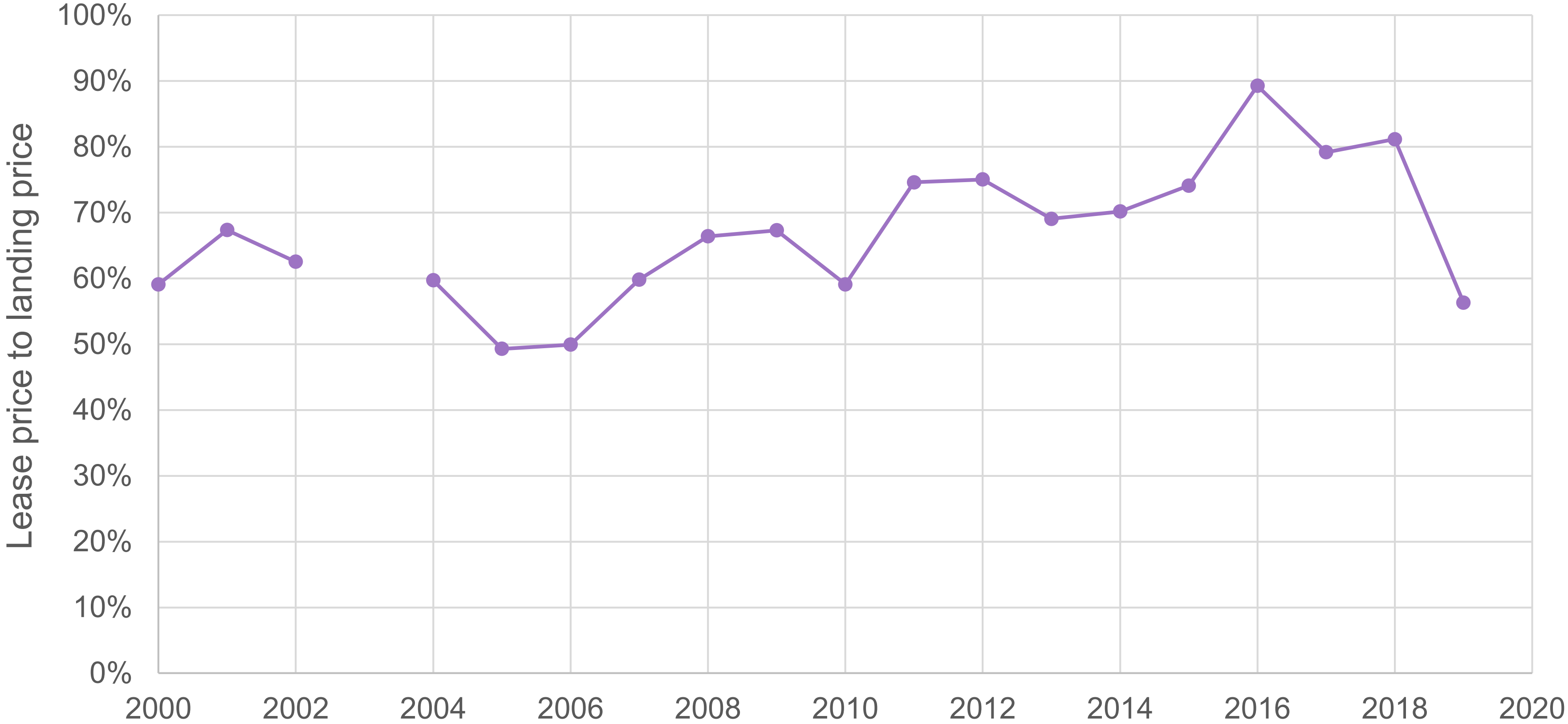
Earnings and income



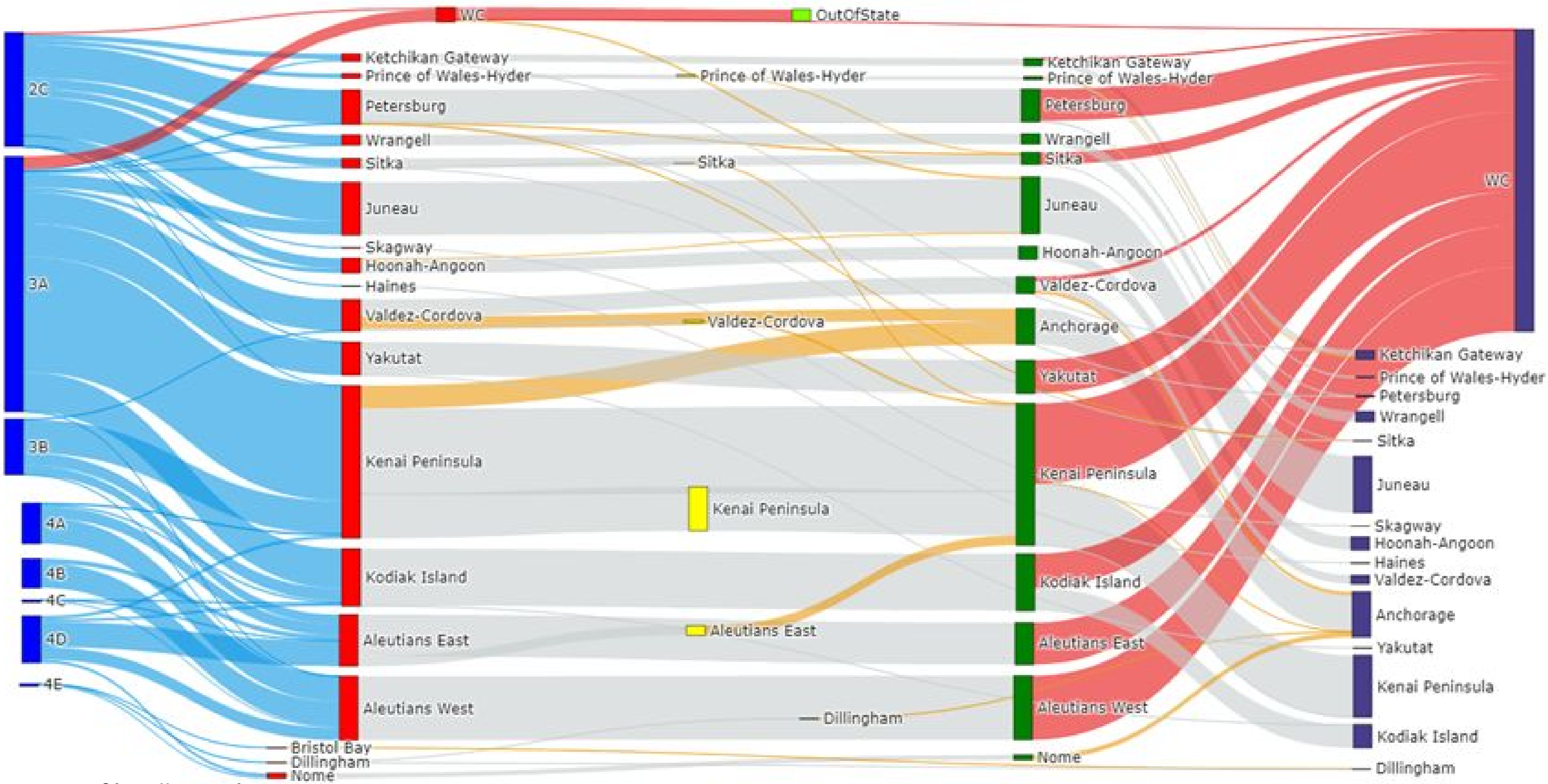
Output by sector / direct impact



Lease price to landing price in BC



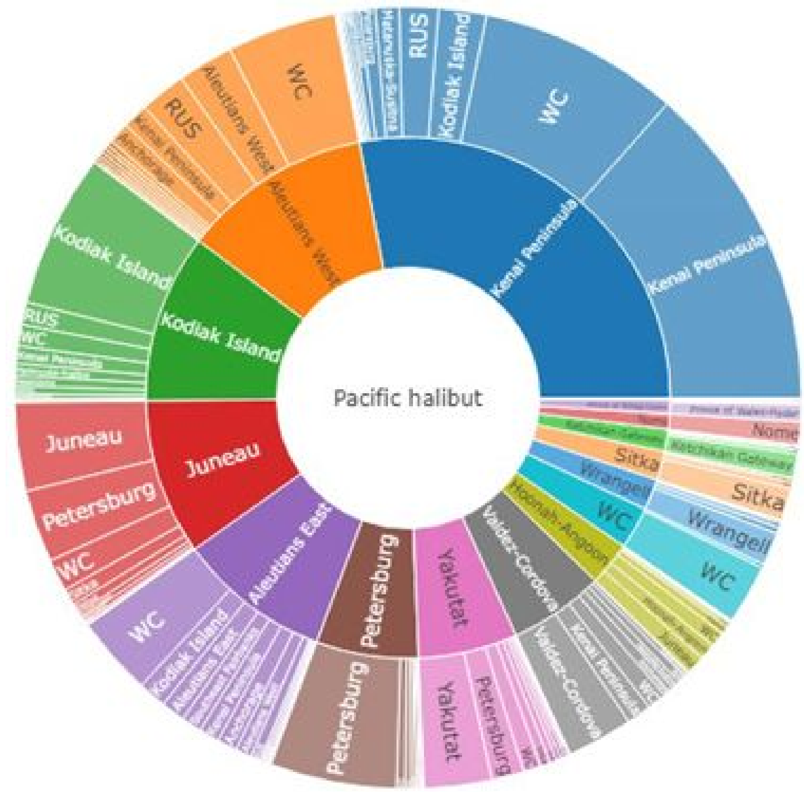
Flows in the commercial sector (1/2)



Flows in terms of landing value

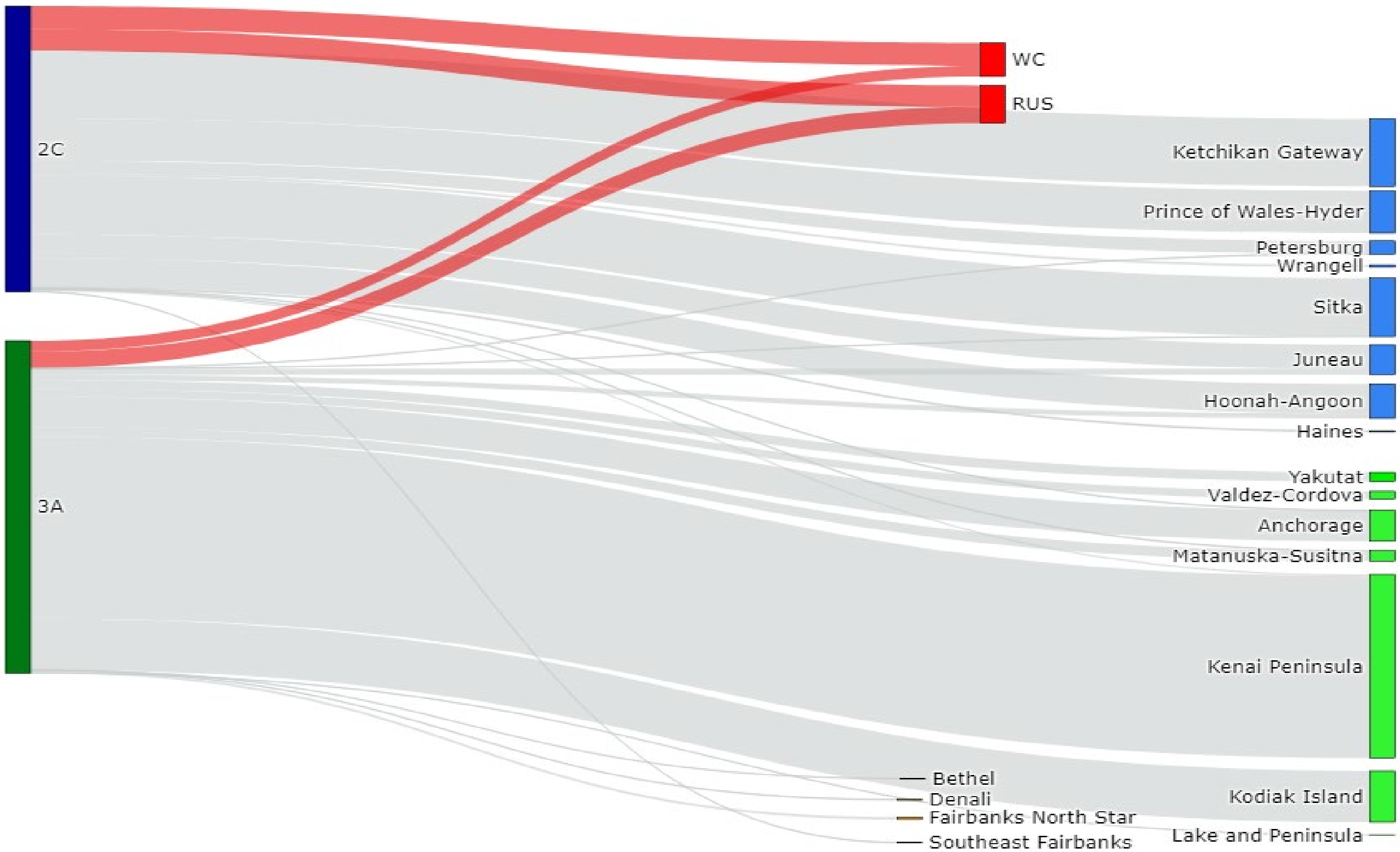
Flows in the commercial sector (2/2)

(1) Landing area vs. vessel owner residence



(2) Landing area vs. permit owner residence

Flows in the charter sector

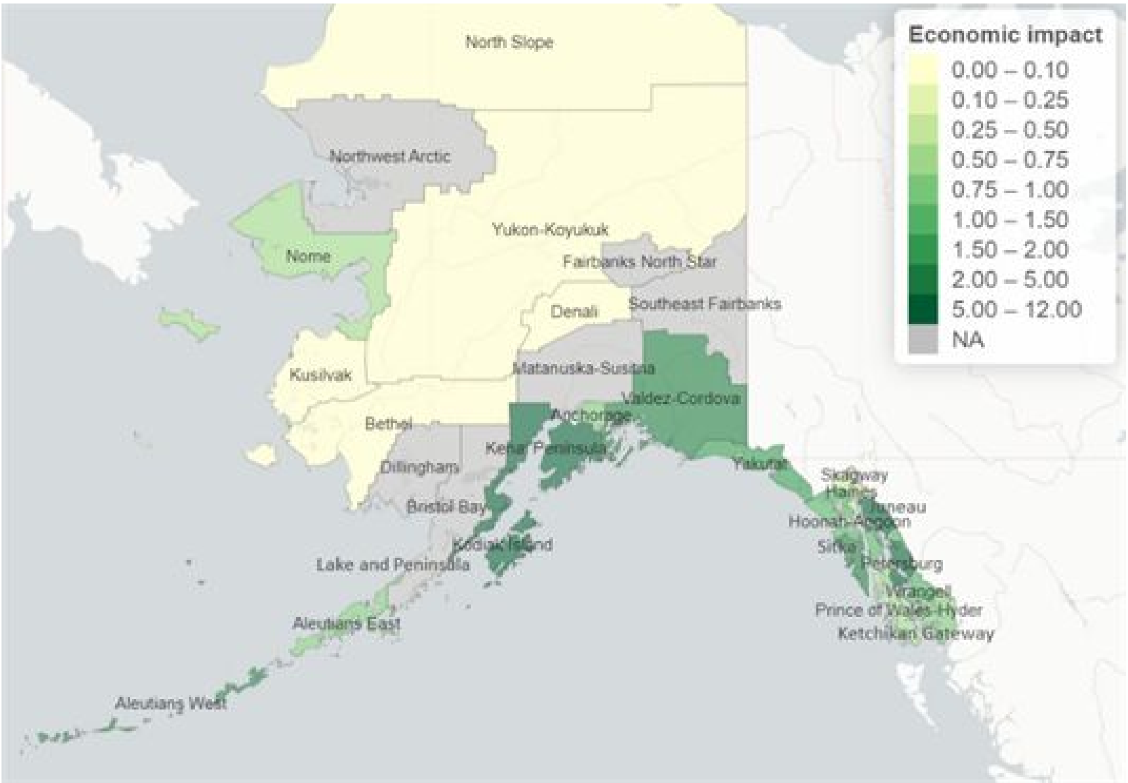


Flows in terms of the number of endorsed anglers

Comparison of the results between sectors (2019)

	Unit	Charter	Commercial
EI on households	Total in mil. USD	34.1	106.4
EI on households in Alaska	Total in mil. USD	19.7	50.6
EI on households	USD per 1 USD of output	0.95	1.13
EI on households in Alaska	USD per 1 USD of output	0.55	0.54
EI on households	USD per 1 lb of removals	12.02	5.81
EI on households in Alaska	USD per 1 lb of removals	6.93	2.76

Community impacts



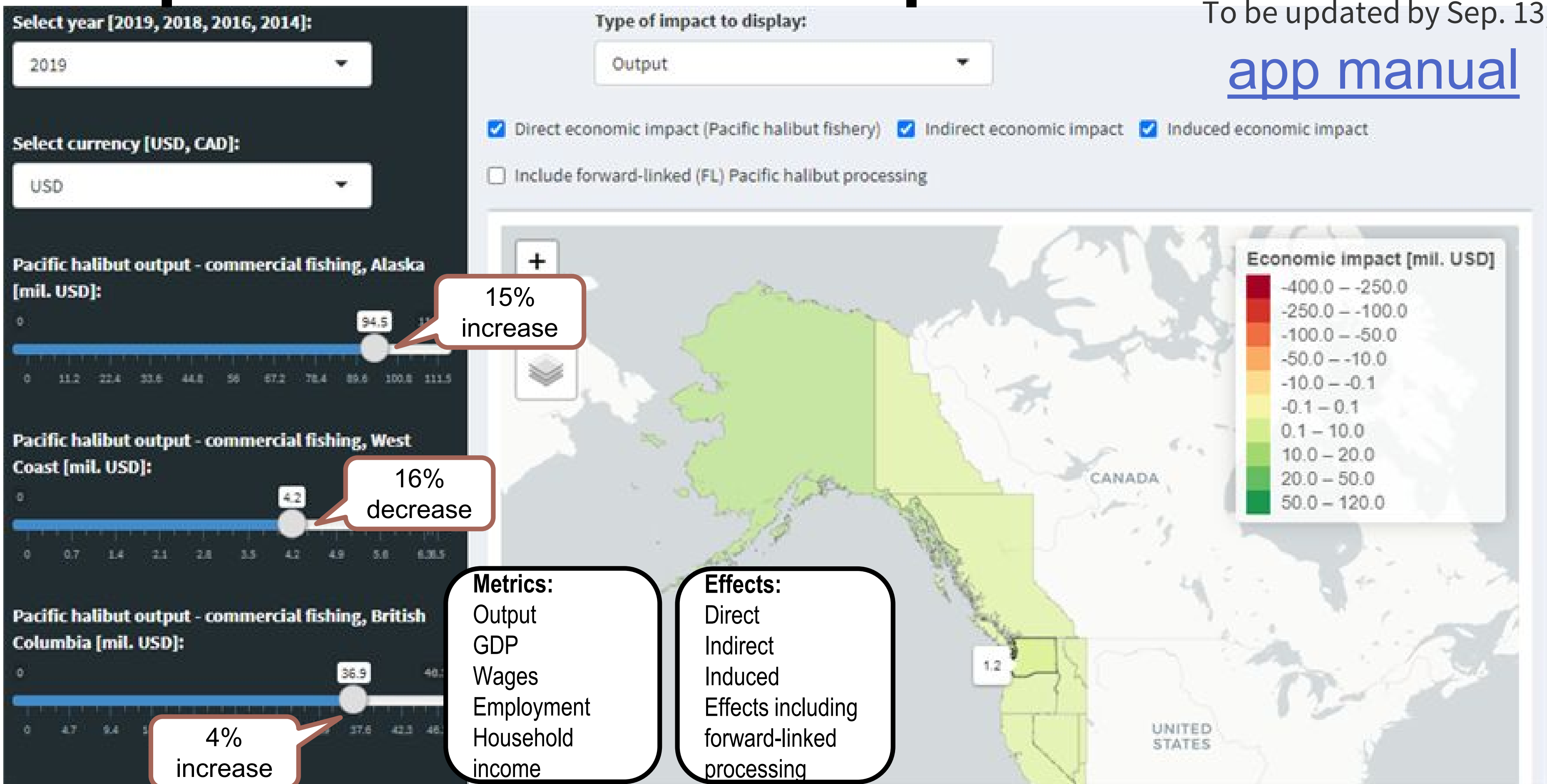
County-level economic impact estimates for Alaska [2019]

Map of the economic impact

[web-based tool](#)

To be updated by Sep. 13, 2021

[app manual](#)



Conclusions

- Comprehensive understanding of the impact of the Pacific halibut resource
- The results suggest that the revenue generated by Pacific halibut at the harvest stage accounts for only a fraction of economic activity that would be forgone if the resource was not available to fishers (commercial and recreational)
- Economic impacts are highly heterogenous, vary significantly by region and sector
- PHMEIA model results can inform the community impacts of the Pacific halibut resource throughout its range and highlight communities particularly dependent on Pacific halibut fishing-related economic activities

Way forward

The Secretariat continues improving the Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) with an intention to inform stakeholders on the importance of the Pacific halibut resource and fisheries to their respective communities, but also broader regions and nations, and contribute to a wholesome approach to Pacific halibut management that is optimal from both biological and socioeconomic perspective.

Additional effort is planned to develop an improved strategy for primary data collection following the 2021 fishing season.

Tasks enhancing the PHMEIA usability to the Commission are included in the IPHC 5-year Program of Integrated Science and Research (2021-26)

Recommendations

That the SRB:

a) **NOTE** paper IPHC-2021-SRB019-09 which provides an update on the development of the Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) and responds to comments made during the SRB18.

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