INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC–2023–SRB022–00
Last Update: 22 May 2023

22nd Session of the IPHC Scientific Review Board (SRB022) – *Compendium of meeting documents*

20-22 June 2023, Seattle, WA, USA

Commissioners

Canada	United States of America
Paul Ryall	Jon Kurland
Neil Davis	Robert Alverson
Peter DeGreef	Richard Yamada

Executive Director

David T. Wilson, Ph.D.

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LAST UPDATE: 22 May 2023

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

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PROVISIONAL: AGENDA & SCHEDULE FOR THE 22th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB022)

Date: 20-22 June 2023
Location: Seattle, WA, USA, & Electronic Meeting
Venue: IPHC HQ & Adobe Connect
Time: 12:30-17:00 (20th), 09:00-17:00 (21-22nd) PDT
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

3. IPHC PROCESS
- 3.1. SRB annual workflow (D. Wilson)
- 3.2. Update on the actions arising from the 21st Session of the SRB (SRB021) (D. Wilson)
- 3.3. Outcomes of the 99th Session of the IPHC Annual Meeting (AM099) (D. Wilson)
- 3.4. Observer updates (e.g. Science Advisors)

4. INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED RESEARCH AND MONITORING (2022-26)

4.1. RESEARCH
- 4.1.1. Pacific halibut stock assessment
- 4.1.2. Management strategy evaluation
- 4.1.3. Biology and ecology

4.2. MONITORING
- 4.2.1. Fishery-dependent data
- 4.2.2. Fishery-independent data
  - IPHC Fishery-Independent Setline Survey (FISS)
    - 2024 FISS design evaluation (R. Webster)
    - Updates to space-time modelling (R. Webster)

5. MANAGEMENT SUPPORTING INFORMATION

6. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 22nd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB022)

SCHEDULE FOR THE 22nd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB022)

Tuesday, 20 June 2023		
Time	**Agenda item**	**Lead**
12:00-12:30	*Lunch – Meet and greet *Electronic meeting platform - Participants encouraged to call in and test connection	
12:30-12:35	1. OPENING OF THE SESSION 2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION	S. Cox & D. Wilson
12:35-13:00	3. IPHC PROCESS 3.1 SRB annual workflow (D. Wilson) 3.2 Update on the actions arising from the 21st Session of the SRB (SRB021) 3.3 Outcomes of the 99th Session of the IPHC Annual Meeting (AM099) 3.4 Observer updates (e.g. Science Advisors)	D. Wilson
13:00-13:10	4. INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED RESEARCH AND MONITORING (2022-26)	D. Wilson
13:10-16:00	4.1 RESEARCH 4.1.1 Pacific halibut stock assessment 4.1.2 Management strategy evaluation 4.1.3 Biology and ecology	 I. Stewart A. Hicks J. Planas
16:00-17:00	SRB drafting session	SRB members
Wednesday, 21 June 2023		
Time	**Agenda item**	**Lead**
09:00-09:30	Review of Day 1 and discussion of SRB Recommendations from Day 1	Chairperson
09:30-12:30	4.1 continued.	

12:30-13:30	Lunch	
13:30-16:00	4.2 MONITORING 4.2.1 Fishery-dependent data 4.2.2 Fishery-independent data • IPHC Fishery-Independent Setline Survey (FISS) ○ 2024 FISS design evaluation (R. Webster) ○ Updates to space-time modelling (R. Webster)	D. Wilson R. Webster K. Ualesi
16:00-17:00	SRB drafting session	SRB members
Thursday, 22 June 2023		
Time	**Agenda item**	**Lead**
09:00-09:30	Review of Day 2 and discussion of SRB Recommendations from Day 2	Chairperson
09:30-12:30	5. MANAGEMENT SUPPORTING INFORMATION	As needed
12:30-13:30	Lunch	
13:30-14:30	SRB drafting session	SRB members
14:30-17:00	6. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 22nd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB022)	S. Cox

LIST OF DOCUMENTS FOR THE 22nd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB022)

Document	Title	Availability
IPHC-2023-SRB022-01	Agenda & Schedule for the 22nd Session of the Scientific Review Board (SRB022)	✓ 13 Mar 2023
IPHC-2023-SRB022-02	List of Documents for the 22nd Session of the Scientific Review Board (SRB022)	✓ 17 May 2023
IPHC-2023-SRB022-03	Update on the actions arising from the 21st Session of the SRB (SRB021) (IPHC Secretariat)	✓ 17 May 2023
IPHC-2023-SRB022-04	Outcomes of the 99th Session of the IPHC Annual Meeting (AM099) (D. Wilson)	✓ 17 May 2023
IPHC-2023-SRB022-05	International Pacific Halibut Commission 5-Year program of integrated research and monitoring (2022-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, R. Webster, & B. Hutniczak)	✓ 17 May 2023
IPHC-2023-SRB022-06	2023-25 FISS design evaluation (R. Webster)	✓ 20 May 2023
IPHC-2023-SRB022-07	IPHC Secretariat MSE Program of Work (2023) and an update on progress (A. Hicks & I. Stewart)	✓ 18 May 2023
IPHC-2023-SRB022-08	Development of the 2023 Pacific halibut (*Hippoglossus stenolepis*) stock assessment (I. Stewart & A. Hicks)	✓ 18 May 2023
IPHC-2023-SRB022-09	Report on current and future biological and ecosystem science research activities (J. Planas)	✓ 17 May 2023
Information papers		
Nil to-date	Nil to-date	-

UPDATE ON THE ACTIONS ARISING FROM THE 21ST SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB021)

PREPARED BY: IPHC SECRETARIAT (17 MAY 2023)

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 SRB021.

BACKGROUND

At the SRB021, the members recommended/requested a series of actions to be taken by the IPHC Secretariat, as detailed in the SRB021 meeting report (IPHC-2022-SRB021-R) available from the IPHC website, and as provided in Appendix A.

DISCUSSION

During the 21st Session of the SRB (SRB021), 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-2023-SRB022-03, 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 (SRB021).
2) **AGREE** to consider and revise the actions as necessary, and to combine them with any new actions arising from SRB022.

APPENDICES

Appendix A: Update on actions arising from the 21st Session of the IPHC Scientific Review Board (SRB021)

APPENDIX A
Update on actions arising from the 21st Session of the IPHC Scientific Review Board (SRB021)

RECOMMENDATIONS

Action No.	Description	Update
SRB021–Rec.01 (para. 14)	***International Pacific Halibut Commission 5-year program of integrated research and monitoring (2022-26)*** The SRB **RECOMMENDED** that the Secretariat and Commission take a more deliberate and explicit approach in deciding which research programs to fund internally or externally, since internally funded research can: (i) utilize milestones and interim evaluations as possible "kill points" where a project may be discontinued if the marginal costs outweigh the benefits of a particular research stream or project; (ii) provide pilot data to support external research proposals; and (iii) support critical applied research that falls outside typical funding agency interests.	**Ongoing** **Update**: See paper **IPHC-2023-SRB022-05** which now contains a cover page that includes a first attempt to meet this recommendation. Feedback is requested from the SRB022 on formatting and content.
SRB021–Rec.02 (para. 18)	***IPHC Fishery-independent setline survey (FISS)*** **NOTING** that the coefficient of variation (CV) for IPHC Regulatory Area 4B continued to exceed the 15% threshold in 2021, the SRB **RECOMMENDED** continuing to investigate potential means to mitigate these effects. For example, by increasing the pool of potential bidders by including vessel using snap-gear.	***Completed*** **Update**: Charter bids were open to vessels fishing snap gear in 2023 and we expect some use of this gear on the 2023 FISS.
SRB021–Rec.03 (para. 20)	***Updates to space-time modelling*** **NOTING** that the 'hurdle' model structure (separate modeling of presence/absence and abundance conditional on presence) of the space-time model used to analyze the FISS may not be the most efficient approach, the SRB **RECOMMENDED** that the Secretariat explore other approaches such as the use of mixture models or the 'Tweedie' distribution.	***In Progress*** **Update**: We have had some success fitting the Tweedie model and intend to present results at SRB023. See paper **IPHC-2023-SRB022-06**
SRB021–Rec.04 (para. 22)	**NOTING** increasingly long computing times, limited available distributions, and space-time model instability in some cases, the SRB **RECOMMENDED** exploring alternatives to the R-INLA software package.	***In Progress*** **Update**: To be discussed at SRB023. See paper **IPHC-2023-SRB022-06**

Action No.	Description	Update
SRB021–Rec.05 (para. 26)	***Management Strategy Evaluation: update*** **NOTING** the MSE results for size limit scenarios presented, the SRB **RECOMMENDED** further analysis of the economic implications of harvesting smaller fish (e.g. reduced yield and/or increased processing costs, changes in efficiency, and potential lower value for smaller fish).	***Completed*** **Update**: MSE results related to size limits were presented to the Commission at AM099, and the Commission agreed that sufficient analysis has been completed (see paragraphs 82-84 of IPHC-2023-AM099-R).
SRB021–Rec.06 (para. 27)	The SRB **RECOMMENDED** evaluating additional performance metrics including, for example, discard mortality and change in TCEY in assessment years for multi-year assessment MPs.	***In Progress*** **Update**: Although the Commission has agreed to a short list of priority performance metrics, additional performance metrics of interest will be discussed at MSAB018.
SRB021–Rec.07 (para. 34)	***Pacific halibut stock assessment: 2022*** The SRB **RECOMMENDED** not implementing MASE weighting for the 2022 stock assessment advice and, instead, continuing to use the equal weighting approach to the ensemble components.	***Completed*** **Update**: No change in weighting was applied in 2022. Research on MASE continues.
SRB021–Rec.08 (para. 35)	**NOTING** the integration between the stock assessment and biological research in evaluating the impact of genetic sex composition data (and the one-year lag in providing these data) on assessment results along with the resourcing implications, the SRB **RECOMMENDED** continued evaluation of the impact on stock assessment output of analyzing this genetic sex composition data on 1, 2, or 3 year intervals.	***In Progress*** **Update**: An update on this evaluation will be provided for SRB022. See paper **IPHC-2023-SRB022-08**.
SRB021–Rec.09 (para. 41)	***Biological and ecosystem sciences – Project updates*** **NOTING** the information on recent wire tagging of Pacific halibut as part of the recreational DMR study and intent to characterize movements of Pacific halibut among IPHC Regulatory Areas, the SRB **RECOMMENDED** that the data available be summarized to map and analyze existing trends in the data.	***In Progress*** **Update**: A summary of Pacific halibut movement from available data generated during the recreational DMR study will be provided for SRB022. See paper **IPHC-2023-SRB022-09**.

Action No.	Description	Update
SRB021–Rec.10 (para. 44)	**NOTING** the Secretariat's interest in applications of molecular markers for somatic growth and evaluation of growth patterns, the SRB **RECOMMENDED** that the Secretariat devote attention to annotation of sequence data that may be relevant to understanding spatial, temporal, and demographic (size/age) variation growth and maturation.	***Pending*** **Update**: The Secretariat is discussing avenues to address the SRB recommendation.
SRB021–Rec.11 (para. 47)	**NOTING** the flow chart presented in Figure 1 of paper IPHC-2022-SRB021-09, the SRB **RECOMMENDED** that (i) additional analyses be conducted in areas of unsupervised clustering for individuals, and (ii) estimate measures of genetic variation among individuals within and among sampling groups to characterize inter-individual relationships, which could provide further indication of admixture. The coefficients of relationship among individuals within sampling location and levels of pair-wise variance in SNP allele frequency between sampling locations can be used to identify 'source' and 'sink' regions.	***In Progress*** **Update**: A summary of progress on K-means clustering and model selection criteria will be presented at SRB022. See paper **IPHC-2023-SRB022-09**.
SRB021–Rec.12 (para. 48)	The SRB **NOTED** that in the sub-area of Population Genetics and Structure, the Secretariat intends to use Site Frequency Spectral (SFS) analyses. Both selection and population growth can produce similar SFS patterns in data. As such, the SRB **RECOMMENDED** testing using a 'Tajima D' analysis and estimate levels of excess of low frequency SNP alleles within sampling areas (or reporting units).	***In Progress*** **Update**: The IPHC Secretariat has begun incorporating the estimation of Tajima's D for each collection in their analysis of low-coverage whole genome resequencing data. See paper **IPHC-2023-SRB022-09**.

Action No.	Description	Update
SRB021–Rec.13 (para. 49)	**NOTING** that Secretariat's intention to use Multiple Dimensional Scaling to visualise inter-individual and inter-location genetic similarity, the SRB **RECOMMENDED** that the Secretariat develop a data baseline of background information at the individual level to better develop hypotheses to explain visual patterns in data.	***In Progress*** **Update**: The biological data and sample attributes for the individuals used for low-coverage whole genome resequencing are being used for this purpose. Relationships between these attributes and the results obtained from ordination methods (e.g. PCA & MDS) are being investigated to assist with the interpretation of the resulting visual patterns. See paper **IPHC-2023-SRB022-09**.
SRB021–Rec.14 (para. 50)	**NOTING** the Secretariat's interest in describing linkage relationships, and that descriptions of linkage disequilibrium can be fraught with difficulty in situations of admixture and due to vagaries in breeding structure, the SRB **RECOMMENDED** that the Secretariat explore other literature not cited in IPHC-2022-SRB021-09 in this area.	***Completed*** **Update**: The IPHC Secretariat acknowledges this and is exploring additional literature pertaining to this issue to ensure that these analyses are consistent with current published literature.
SRB021–Rec.15 (para. 51)	The SRB **RECOMMENDED** that the Secretariat (i) develop a rapid screening panel of SNP markers (e.g. GTseq, RADcapture) for future use in Close-Kin Mark recapture (CKMR), population assignment, or other applications (CKMR applications may necessitate the development of microhaplotypes to achieve adequate accuracy in multi-generational pedigree analyses), and (ii) begin developing potential SNP panels and evaluate accuracy of population-based or pedigree-based assignment under scenarios likely to be encountered in future IPHC applications.	***Pending*** **Update**: The low-coverage whole genome resequencing dataset that the IPHC Secretariat has recently generated will be leveraged to develop application-specific marker panels in the future.

REQUESTS

Action No.	Description	Update
SRB021–Req.01 (para. 15)	***International Pacific Halibut Commission 5-year program of integrated research and monitoring (2022-26)*** The SRB **RECALLED** SRB020–Rec.05 (para. 36) (shown below) and **REQUESTED** that the Secretariat evaluate data collected during the FISS or other IPHC research programs that might be useful for the broader scientific community and potential existing external repositories that might house these data. SRB020–Rec.05 (para. 36) "*The SRB **NOTED** the exceptional level of transparency and commitment to the principles of open science represented by the Secretariat's data and code-sharing practices and, therefore, **RECOMMENDED** that the Secretariat consider producing peer-reviewed data report publications, which would (a) enhance outreach to potential external data users and (b) allow for tracking external use of IPHC data and resources.*"	***In Progress*** **Update**: The Secretariat is researching potential data publication resources, including in-house options, to further improve transparency and visibility.
SRB021–Req.02 (para. 30)	***Management Strategy Evaluation: update*** The SRB **REQUESTED** that the Secretariat examine MPs based on a three-year assessment cycle with annual TCEY changes proportional to changes in the FISS index because (i) this approach would be simpler and more transparent than a model, which has not yet been developed); (ii) the high benefit to cost ratio for multi-year TCEYs; (iii) it matches the current three-year full assessment cycle; and (iv) the general approach has precedents in other fishery commissions (e.g. Southern Bluefin Tuna).	***In Progress*** **Update**: The Secretariat presented MSE results for a three-year assessment cycle to the Commission at AM099. The Commission agreed that there is utility in continuing to explore multi-year stock assessment management procedures. See paper **IPHC-2023-SRB022-07**.
SRB021–Req.03 (para. 32)	***Pacific halibut stock assessment: 2022*** The SRB **RECALLED** SRB020–Rec.02 (para. 23) and SRB020-Rec.04 (para. 25) (shown below), and **REQUESTED** an update at SRB022: SRB020–Rec.02 (para. 23) "*The SRB **NOTED** that most models within the ensemble produced reasonable and well-constrained estimates of natural mortality (M) and **RECOMMENDED** that estimation of M should be adopted in the short AAF assessment model with consideration in*	***In Progress*** **Update**: M was estimated in the short AAF model in 2022. Evaluation of 2022 M estimates relative to preliminary estimates to be provided for SRB022 along with further exploration of marine mammal depredation.

Action No.	Description	Update
	other models as part of the stock assessment research program." SRB020–Rec.04 (para. 25) "*The SRB **NOTED** apparent discrepancies in marine mammal prevalence among anecdotal reports, FISS observations, and preliminary evaluation of logbook data, and therefore **RECOMMENDED** further investigation of methods to better estimate marine mammal prevalence and impacts on the fishery.*"	See paper **IPHC-2023-SRB022-08**.
SRB021–Req.04 (para. 33)	**NOTING** the substantial interannual variation in MASE weightings of the four assessment models, the SRB **AGREED** that one-step-ahead predictive skill is a potentially promising basis for model weighting, and **REQUESTED** continued research into MASE weightings averaged over longer time periods as well as comparing these to alternative weighting metrics, for example, via cross-validation.	***In Progress*** **Update**: Further exploration on MASE weighting will be provided for SRB022. See paper **IPHC-2023-SRB022-08**.
SRB021–Req.05 (para. 37)	***Biological and ecosystem sciences – Project updates*** The SRB **REQUESTED** that the Secretariat amend the priorities under bullet "2. Reproduction" (IPHC-2022-SRB021-09) to include other avenues of investigations such as size/age specific fecundity and spatial variation in same.	***Completed*** **Update**: Fecundity estimations by size/age and spatial variation are now incorporated as priorities for the research area of Reproduction.
SRB021–Req.06 (para. 39)	The SRB **NOTED** and **APPRECIATED** details provided concerning ongoing or anticipated statistical analyses of data that enhanced the SRB's ability to understand and critique methods to expected research outcomes and **REQUESTED** continued consistency in the presentation in these areas.	***Completed*** **Update**: The Secretariat will continue efforts to provide details of data analysis approaches used and planned.
SRB021–Req.07 (para. 40)	**NOTING** the progress update on Migration and Distribution and the specific research goal of creating a map of suitable juvenile Pacific halibut settlement habitat, the SRB **REQUESTED** (i) a clearer statement of the relevance of this research to management, MSE, and/or the stock assessment and (ii) clarification regarding the types of data to be collected and used to determine occupancy (and preference), and by what data sources.	***Completed*** **Update**: The Secretariat will clarify the relevance and data sources and types used for mapping suitable juvenile habitat in SRB022.

Action No.	Description	Update
SRB021–Req.08 (para. 43)	**NOTING** the Secretariat's interest in growth and size-at-age relationships, the SRB **REQUESTED** clarification of narrative regarding collection of environmental covariate data for projecting future short-term size-at-age trends.	***In Progress*** **Update**: The Secretariat is working towards better defining future work on the influence of environmental covariate data on size-at-age trends.
SRB021–Req.09 (para. 45)	**NOTING** the Secretariat's interest in identification of evidence for spatial population structure, and given the IPHC manages stocks on the basis of biological reporting regions, the SRB **REQUESTED** clarification on how the Secretariat may alter assessments if 'functionally isolated components of the population are found'.	***Completed*** **Update**: Summary of this topic included in **IPHC-2022-SRB022-08**.

INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC-2023-SRB022-04

OUTCOMES OF THE 99TH SESSION OF THE IPHC ANNUAL MEETING (AM098)

PREPARED BY: IPHC SECRETARIAT (D. WILSON, 17 MAY 2023)

PURPOSE

To provide the SRB with the outcomes of the 99th Session of the IPHC Annual Meeting (AM099), relevant to the mandate of the SRB.

BACKGROUND

The agenda of the Commission's Annual Meeting (AM099) included several agenda items relevant to the SRB:

3. IPHC PROCESS

- *3.1 Update on actions arising from the 98th Session of the IPHC Annual Meeting (AM098), 2022 Special Sessions, intersessional decisions, and the 98th Session of the IPHC Interim Meeting (IM098) (D. Wilson)*
- *3.2 Report of the IPHC Secretariat (2022) (D. Wilson & B. Hutniczak)*
- *3.3 2nd IPHC Performance Review (PRIPHC02): Implementation of recommendations (D. Wilson)*
- *3.4 International Pacific Halibut Commission 5-year program of Integrated Research and Monitoring (2022-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, R. Webster, B. Hutniczak, & J. Jannot)*
- *3.5 Report of the 23rd Session of the IPHC Research Advisory Board (RAB023) (D. Wilson, J. Planas)*
- *3.6 Reports of the IPHC Scientific Review Board (SRB Chairperson)*

4. FISHERY MONITORING

- *4.1 Fishery-dependent data overview (2022) (J. Jannot)*
- *4.2 Fishery-independent data overview (2022)*
  - *4.2.1 IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2022 (K. Ualesi)*

5. STOCK STATUS OF PACIFIC HALIBUT (2022) AND HARVEST DECISION TABLE 2023

- *5.1 Space-time modelling of survey data (R. Webster)*
- *5.2 2023-25 FISS design evaluation (R. Webster)*
- *5.3 Stock Assessment: Data overview and stock assessment (2022), and harvest decision table (2023) (I. Stewart, A. Hicks, R. Webster, D. Wilson, & B. Hutniczak)*
- *5.4 Pacific halibut mortality projections using the IPHC mortality projection tool (2023) (I. Stewart)*

6. BIOLOGICAL AND ECOSYSTEM SCIENCES – PROJECT UPDATES

- *6.1 Report on Current and Future Biological and Ecosystem Science Research Activities (J. Planas)*

7. MANAGEMENT STRATEGY EVALUATION

- *7.1 Report of the 17th Session of the IPHC Management Strategy Advisory Board (MSAB017) (Co-Chairpersons)*
- *7.2 IPHC Management Strategy Evaluation: update (A. Hicks)*

DISCUSSION

During the course of the 99th Session of the IPHC Annual Meeting (AM099) 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-2023-SRB022-04 which details the outcomes of the 99th Session of the IPHC Annual Meeting (AM099), relevant to the mandate of the SRB.

APPENDICES

Appendix A: Excerpts from the 99th Session of the IPHC Annual Meeting (AM099) Report (IPHC-2023-AM099-R).

APPENDIX A
Excerpt from the 99th Session of the IPHC Annual Meeting (AM099) Report (IPHC-2023-AM099-R)

RECOMMENDATIONS

International Pacific Halibut Commission 5-year program of Integrated Research and Monitoring (2022-26)

AM099–Rec.01 (para. 12) The Commission **RECOMMENDED** that the Secretariat annually present potential changes to the Plan at the IPHC Interim Meeting. The Commission would then have the opportunity to provide any redirection based on Commission priorities and available funding. To assist in making that assessment, the Secretariat will be preparing a progress report annually.

IPHC Management Strategy Evaluation: update

AM099–Rec.02 (para. 76) The Commission **RECOMMENDED** that for the purpose of a comprehensive and intelligible Harvest Strategy Policy (HSP), four coastwide objectives should be documented within the HSP, in priority order:

a) Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point (B20%) at least 95% of the time.

b) Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point (B36%) 50% or more of the time.

c) Optimise average coastwide TCEY.

d) Limit annual changes in the coastwide TCEY.

AM099–Rec.03 (para. 84) The Commission **AGREED** sufficient analysis has been completed and **RECOMMENDED** not to change the current 32 inch size limit.

REQUESTS

2023-25 FISS design evaluation

AM099–Req.01 (para. 35) The Commission **REQUESTED** a desktop review to determine if reducing bait size on the FISS would substantially reduce costs, while not reducing catch rates and associated fish sale revenue to any large degree.

AM099–Req.02 (para. 44) The Commission **REQUESTED** that the Secretariat provide a breakdown of costs associated with the FISS over the last three (3) years and what is projected for the 2023 FISS, and for this to be presented at the 13th Special Session of the Commission (SS013).

Pacific halibut mortality projections using the IPHC mortality projection tool (2023)

AM099–Req.03 (para. 61) The Commission **REQUESTED** a table be prepared annually that details the historical TCEY decisions, that is currently published on the IPHC website [https://www.iphc.int/uploads/data/time-series-datasets/excel/iphc-2023-tsd-017.xlsx]

Report on current and future biological and ecosystem science research activities

AM099–Req.04 (para. 66) The Commission **REQUESTED** that the Secretariat provide a summary of the proposed and ongoing research projects at the Secretariat, including status updates, suggestions for potential priority setting by the Commission, links to the IPHC's mandate and how the research will inform decision-making, guidance on types of research that should be considered for internal funding versus types of research that would be contingent on the availability of external funding or partnerships, among other criteria that may be requested by the Commission.

AM099–Req.05 (para. 67) The Commission **REQUESTED** that the Secretariat highlight the elements of its 5YRPIRM (the Plan) that will inform its understanding of the impacts of climate change on Pacific halibut in its annual presentations of the research Plan to the Commission.

IPHC Management Strategy Evaluation: update

AM099–Req.06 (para. 88) **NOTING** paragraph 60 from the 21st Session of the SRB (SRB021), the Commission **REQUESTED** the Secretariat develop a description of options to responding to exceptional circumstances that would trigger a stock assessment in non-assessment years and additional MSE analyses.

IPHC-2022-SRB021-R, para 60: *The SRB RECOMMENDED that Exceptional Circumstances be defined to determine whether monitoring information has potentially departed from their expected distributions generated by the MSE. Declaration of Exceptional Circumstances may warrant re-opening and revising the operating models and testing procedures used to justify a particular management procedure.*

INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED RESEARCH AND MONITORING (2022-26)

PREPARED BY: IPHC SECRETARIAT (D. WILSON, J. PLANAS, I. STEWART, A. HICKS, B. HUTNICZAK, R. WEBSTER; 17 MAY 2023)

PURPOSE

To provide the SRB with the IPHC 5-year Program of Integrated Research and Monitoring (2022-26), including a draft research tracking tool.

BACKGROUND

Recalling that:

a) the IPHC Secretariat conducts activities to address key issues identified by the Commission, its subsidiary bodies, the broader stakeholder community, and the IPHC Secretariat;

b) the process of identifying, developing, and implementing the IPHC's science-based activities involves several steps that are circular and iterative in nature, but result in clear project activities and associated deliverables;

c) the process includes developing and proposing projects based on direct input from the Commission, the experience of the IPHC Secretariat given its broad understanding of the resource and its associated fisheries, and concurrent consideration by relevant IPHC subsidiary bodies, and where deemed necessary, including by the Commission, additional external peer review;

d) the IPHC Secretariat commenced implementation of the new Plan in 2022 and will keep the Plan under review on an ongoing basis.

Also recalling that an overarching goal of the IPHC 5-year Program of Integrated Research and Monitoring (2022-26) is to promote integration and synergies among the various research and monitoring activities of the IPHC Secretariat in order to improve knowledge of key inputs into the Pacific halibut stock assessment, and Management Strategy Evaluation (MSE) processes, thereby providing the best possible advice for management decision making processes.

SRB021: At SRB021 in September 2023, the SRB made the following recommendation:

SRB021–Rec.01 (para. 14) *The SRB RECOMMENDED that the Secretariat and Commission take a more deliberate and explicit approach in deciding which research programs to fund internally or externally, since internally funded research can: (i) utilize milestones and interim evaluations as possible "kill points" where a project may be discontinued if the marginal costs outweigh the benefits of a particular research stream or project; (ii) provide pilot data to support external research proposals; and (iii) support critical applied research that falls outside typical funding agency interests.*

SS013: Subsequently, the Commission provided the following directive to the Secretariat based on their interpretation of SRB021-Rec.01:

Budget Estimates: FY2024 (for approval): Fund 20 – Research: Biological and Ecosystem Sciences annual reporting

SS013-Req.01 (para. 9) *The Commission* ***REQUESTED*** *that, as part of the annual reporting to the Commission on the Biological and Ecosystem Science Branch activities, that the Secretariat provide a summary table that incorporates the following elements for Commission review:*

a) Current project abstract, including objectives, links to IPHC's core mandate and how it will inform Commissioner's decisions;
b) Related Commission decisions and directives;
c) Timeline for deliverables;
d) Funding sources;
e) Progress report.

DISCUSSION

The SRB should note that:

a) the intention is to ensure that the new integrated plan is kept as a '*living plan*', and is reviewed and updated annually based on the resources available to undertake the work of the Commission (e.g. internal and external fiscal resources, collaborations, internal expertise);

b) the plan focuses on core responsibilities of the Commission; and any redirection provided by the Commission;

c) each year the SRB may choose to recommend modifications to the current Plan, and that any modifications subsequently made would be documented both in the Plan itself, and through reporting back to the SRB and then the Commission.

RECOMMENDATION

That the SRB:

1) **NOTE** paper IPHC-2023-SRB022-05 which provides the IPHC 5-year program of Integrated Research and Monitoring (2022-26), including a draft research tracking tool.

APPENDICES

Appendix A: Commission proposed template for research activities within the 5-YPIRM

Appendix B: IPHC 5-Year Program of Integrated Research and Monitoring (2022-26) (D. Wilson, J. Planas, I. Stewart, A. Hicks, B. Hutniczak, & R. Webster)

Appendix A
Commission proposed template for research activities within the 5-YPIRM

Priority level	**Theme**	**Project ID and Title**	**Abstract (inc. objective, link to IPHC core mandate and informing Commissioner management decision, method/expected result)**	**Timeframe, including deliverable milestones**	**Funding details (amount required per year, funding source)**	**Commissioner decision**	**Status**
E.g. 1, 2, 3	*E.g. Migration, Genomics, etc.*		*E.g. similar to typical science abstract to summarize project, with links to IPHC core mandate and decision-making*	*E.g. 3 year program; specify deliverable in yr 1 vs 2 vs 3*	*E.g. 2023: $XX,XXX; 2024:…; funded internally or externally for XX reason*	*E.g. Adopted, Not adopted, supported by US only, supported by CAN only*	*E.g. Specify status similar to what is done to report on PR; status to be linked to milestones*
NEW PROJECTS - FOR DECISION							
…							
PREVIOUSLY PITCHED PROJECTS (including adopted and not adopted)							
…							

APPENDIX B

INTERNATIONAL PACIFIC HALIBUT COMMISSION

5-YEAR PROGRAM OF INTEGRATED RESEARCH AND MONITORING

(2022 - 2026)

INTERNATIONAL PACIFIC

HALIBUT COMMISSION

Commissioners

Canada	United States of America
Paul Ryall	Jon Kurland
Neil Davis	Robert Alverson
Peter DeGreef	Richard Yamada

Executive Director

David T. Wilson, Ph.D.

BIBLIOGRAPHIC ENTRY

IPHC 2023. International Pacific Halibut Commission 5-Year program of integrated research and monitoring (2022-26). Seattle, WA, U.S.A. *IPHC–2023-5YPIRM, 52 pp.*

INTERNATIONAL PACIFIC HALIBUT COMMISSION

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ACRONYMS

AM	Annual Meeting
CB	Conference Board
DMR	Discard Mortality Rate
FAC	Finance and Administration Committee
FISS	Fishery-Independent Setline Survey
FSC	First Nations Food, Social, and Ceremonial [fishery]
IM	Interim Meeting
IPHC	International Pacific Halibut Commission
MSAB	Management Strategy Advisory Board
MSE	Management Strategy Evaluation
OM	Operating Model
PAB	Processor Advisory Board
PDO	Pacific Decadal Oscillation
PHMEIA	Pacific halibut multiregional economic impact assessment [model]
QAQC	Quality assurance/quality control
RAB	Research Advisory Board
SHARC	Subsistence Halibut Registration Certificates
SRB	Scientific Review Board
TCEY	Total Constant Exploitation Yield
U.S.A.	United States of America
WM	Work Meeting

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

EXECUTIVE SUMMARY

An overarching goal of the *IPHC 5-Year Program of Integrated Research and Monitoring (2022-26)* is to promote integration and synergies among the various research and support 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, and to provide the best possible advice for management decision-making processes.

Along with the implementation of the short- and medium-term activities contemplated in this *IPHC 5-Year Program of Integrated Research and Monitoring (2022-26)*, and in pursuit of the overarching objective, the IPHC Secretariat will also aim to:

1) undertake cutting-edge research programs in fisheries research in support of Pacific halibut fisheries management;
2) undertake groundbreaking methodological research;
3) undertake applied research;
4) establish new collaborative agreements and interactions with research agencies and academic institutions;
5) promote the international involvement of the IPHC by continued and new participation in international scientific organizations and by leading international science and research collaborations;
6) effectively communicate IPHC research outcomes;
7) incorporate talented students and early researchers in research activities contemplated.

The research and monitoring activities conducted by the IPHC Secretariat are directed towards fulfilling the following four (4) objectives within areas of data collection, biological and ecological research, stock assessment, and Management Strategy Evaluation (MSE). In addition, the IPHC responds to Commission requests for additional inputs to management and policy development which are classified under management support.

The Secretariat's success in implementing the *IPHC 5-Year Program of Integrated Research and Monitoring (2022-26)* will be measured according to the following criteria relevant to the stock assessment, the MSE and for all inputs to IPHC management:

1) Timeliness – was the research conducted, analyzed, published, and provided to the Commission at the appropriate points to be included in annual management decisions?
2) Accessibility – was the research published and presented in such a way that it was available to other scientists, stakeholders, and decision-makers?
3) Relevance – did the research improve the perceived accuracy of the stock assessment, MSE, or decisions made by the Commission?
4) Impact – did the research allow for more precision or a better estimate of the uncertainty associated with information for use in management?
5) Reliability – has research resulted in more consistent information provided to the Commission for decision-making.

1. Introduction

The International Pacific Halibut Commission (IPHC) is a public international organization so designated via Presidential Executive Order 11059 and established by a Convention between Canada and the United States of America. The IPHC Convention was signed on 2 March 1923, ratified on 21 July 1924, and came into effect on 21 October 1924 upon exchange. 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 1979 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 fisheries are conducted, and redefined the role of IPHC in the management of the fishery. 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, U.S.A. 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.***

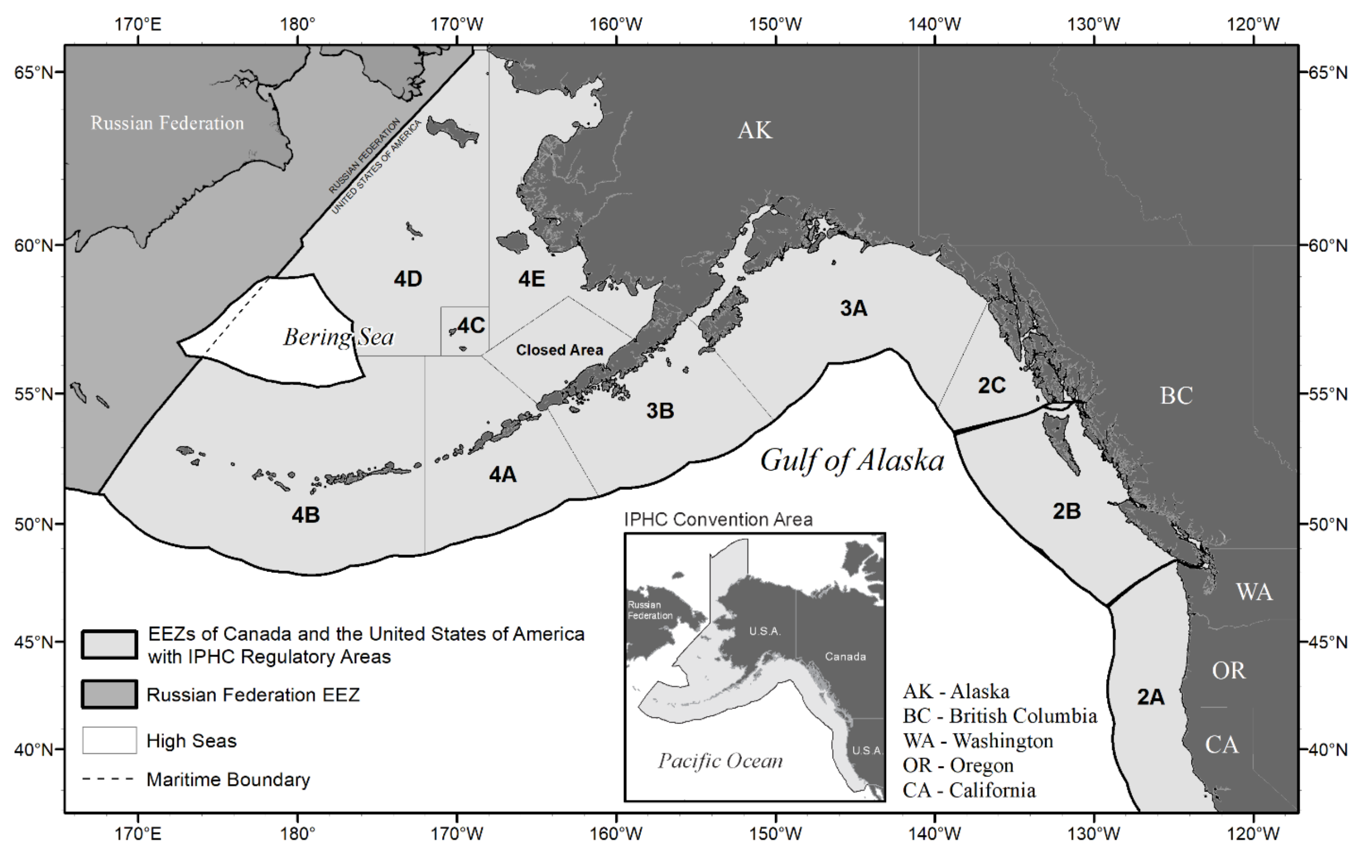

Figure 1. Map of the IPHC Convention Area (map insert) and IPHC Regulatory Areas.

2. *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 research 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.

Over the last five years (2017-2021), the research conducted by the IPHC Secretariat has been guided by a 5-Year Biological and Ecosystem Science Research Plan (IPHC–2019–BESRP-5YP) that aimed at improving knowledge on the biology of Pacific halibut in order to improve the accuracy of the stock assessment and in the management strategy evaluation (MSE) process. The IPHC-2019-BESRP-5YP contemplated research activities in five focal areas, namely Migration and Distribution, Reproduction, Growth and Physiological Condition, Discard Mortality Rates and Survival, and Genetics and Genomics. Research activities were highly integrated with the needs of stock assessment and MSE by their careful alignment with biological uncertainties and parameters, and the resulting prioritization (Appendix I). The outcomes of the IPHC-2019-BESRP-5YP have provided key inputs into stock assessment and the MSE process and, importantly, have provided foundational information for the successful pursuit of continuing and novel objectives within the new 5-Year Program of Integrated Research and Monitoring (2022-2026) (5YPIRM) (Appendix I).

The 2nd Performance Review of the IPHC (IPHC-2019-PRIPHC02-R), carried out over the course of 2019, also provided a range of recommendations to the Commission on ways in which it could continue to improve on the quality of scientific advice being provided to the Commission. There were nine (9) specific recommendations as provided below:

Science: Status of living marine resources

PRIPHC02–Rec.03 (para. 44) The PRIPHC02 ***RECOMMENDED*** *that opportunities to engage with western Pacific halibut science and management agencies be sought, to strengthen science links and data exchange. Specifically, consider options to investigate pan-Pacific stock structure and migration of Pacific halibut.*

PRIPHC02–Rec.04 (para. 45) The PRIPHC02 ***RECOMMENDED*** *that:*

a) further efforts be made to lead and collaborate on research to assess the ecosystem impacts of Pacific halibut fisheries on incidentally caught species (retained and/or discarded);
b) where feasible, this research be incorporated within the IPHC's 5-Year Research Plan (https://www.iphc.int/uploads/pdf/besrp/2019/iphc-2019-besrp-5yp.pdf);
c) findings from the IPHC Secretariat research and that of the Contracting Parties be readily accessible via the IPHC website.

Science: Quality and provision of scientific advice

PRIPHC02–Rec.05 (para. 63) The PRIPHC02 ***RECOMMENDED*** *that simplified materials be developed for RAB and especially MSAB use, including training/induction materials.*

PRIPHC02–Rec.06 (para. 64) The PRIPHC02 ***RECOMMENDED*** *that consideration be given to amending the Rules of Procedure to include appropriate fixed terms of service to ensure SRB peer review remains independent and fresh; a fixed term of three years seems appropriate, with no more than one renewal.*

PRIPHC02–Rec.07 (para. 65) The PRIPHC02 ***RECOMMENDED*** *that the peer review process be strengthened through expanded subject specific independent reviews including data quality and standards, the FISS, MSE, and biological/ecological research; as well as conversion of "grey literature" to primary literature publications. The latter considered important to ongoing information outreach efforts given the cutting-edge nature of the Commission's scientific work.*

PRIPHC02–Rec.08 (para. 66) The PRIPHC02 ***RECOMMENDED*** *that the IPHC Secretariat develop options for simple graphical summaries (i.e. phase plot equivalents) of fishing intensity and spawning stock biomass for provision to the Commission.*

Conservation and Management: Data collection and sharing

PRIPHC02–Rec.09 (para. 73) The PRIPHC02 ***RECOMMENDED*** *that observer coverage be adjusted to be commensurate with the level of fishing intensity in each IPHC Regulatory Area.*

Conservation and Management: Consistency between scientific advice and fishery Regulations adopted

PRIPHC02–Rec.10 (para. 82) The PRIPHC02 ***RECOMMENDED*** *that the development of MSE to underpin multi-year (strategic) decision-making be continued, and as multi-year decision making is implemented, current Secretariat capacity usage for annual stock assessments should be refocused on research to investigate MSE operating model development (including consideration of biological and fishery uncertainties) for future MSE iterations and regularised multi-year stock assessments.*

PRIPHC02–Rec.11 (para. 83) The PRIPHC02 ***RECOMMENDED*** *that ongoing work on the MSE process be prioritised to ensure there is a management framework/procedure with minimal room for ambiguous interpretation, and robust pre-agreed mortality limit setting frameworks.*

The work outlined in this document builds on the previous a 5-Year Biological and Ecosystem Science Research Plan (IPHC–2019–BESRP-5YP), closing completed projects, extending efforts where needed, and adding new avenues in response to new information. Appendix I provides a detailed summary of the previous plan and the status of the work specifically undertaken. Key highlights relevant to the stock assessment and MSE include:

- Completion of the genetic assay for determining sex from tissue samples, processing of commercial fishery samples collected during 2017-2020, inclusion of this information in the 2019 and subsequent stock assessments, and transfer of this effort from research to ongoing monitoring.
- Incremental progress toward population-level sampling and analysis of maturity and fecundity.
- Continued development of the understanding of physiological and environmental mechanisms determining growth for future field application.
- Published estimates of discard mortality rates for use in data processing and management accounting.
- Collection of genetic samples and genome sequencing to provide a basis for ongoing evaluation of stock structure at population-level and finer scales.

All previously described research areas continue to represent critical areas of uncertainty in the stock assessment and thus are closely linked to management performance. The previous 5-year plan was successful in either providing direct new information to the stock assessment or building the foundation for the collection/analysis of such information in this updated plan. As noted below, some new priorities have emerged, and others have evolved based on the work completed to date. The incorporation of research objectives in the 5YPIRM that address climate change as a factor influencing Pacific halibut biology and ecology as well as fishery performance and dynamics constitutes a timely and relevant contribution towards advancing IPHC-led research to the forefront of fisheries science.

An **overarching goal** of the *IPHC 5-Year Program of integrated research and monitoring (2022-26)* is therefore to promote integration and synergies among the various research and support activities of the IPHC Secretariat in order to improve our knowledge of key inputs into the Pacific halibut stock assessment and MSE processes, in order to provide the best possible advice for management decision-making processes.

Along with the implementation of the short- and medium-term activities contemplated in this *IPHC 5-Year Program of Integrated Research and monitoring (2022-26)*, and in pursuit of the overarching objective, the IPHC Secretariat will also aim to:

1) undertake cutting-edge research programs in fisheries research in support of fisheries management of Pacific halibut;
2) undertake groundbreaking methodological research;
3) undertake applied research;
4) establish new collaborative agreements and interactions with research agencies and academic institutions;
5) promote the international involvement of the IPHC by continued and new participation in international scientific organizations and by leading international science and research collaborations.
6) effectively communicate IPHC research outcomes
7) incorporate talented students and early researchers in research activities contemplated.

The research and monitoring activities conducted by the IPHC Secretariat are directed towards fulfilling the following four (4) **objectives** within areas of data collection, biological and ecological research, stock assessment, and MSE. In addition, the IPHC responds to Commission requests for additional inputs to management and policy development which are classified under management support. The overall aim is to provide a program of integrated research and monitoring (Fig 2):

Research

1) **Stock assessment**: apply the resulting knowledge to improve the accuracy and reliability of the current stock assessment and the characterization of uncertainty in the resultant stock management advice provided to the Commission;
2) **Management Strategy Evaluation (MSE)**: to develop an accurate, reliable, and informative MSE process to appropriately characterize uncertainty and provide for the robust evaluation of the consequences of alternative management options, known as harvest strategies, using defined conservation and fishery objectives;
3) **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;

Monitoring

4) **Monitoring**: collect representative fishery dependent and fishery-independent data on the distribution, abundance, biology, and demographics of Pacific halibut through ongoing monitoring activities;

Integrated management support

5) **Additional inputs**: respond to Commission requests for any additional information supporting management and policy development.

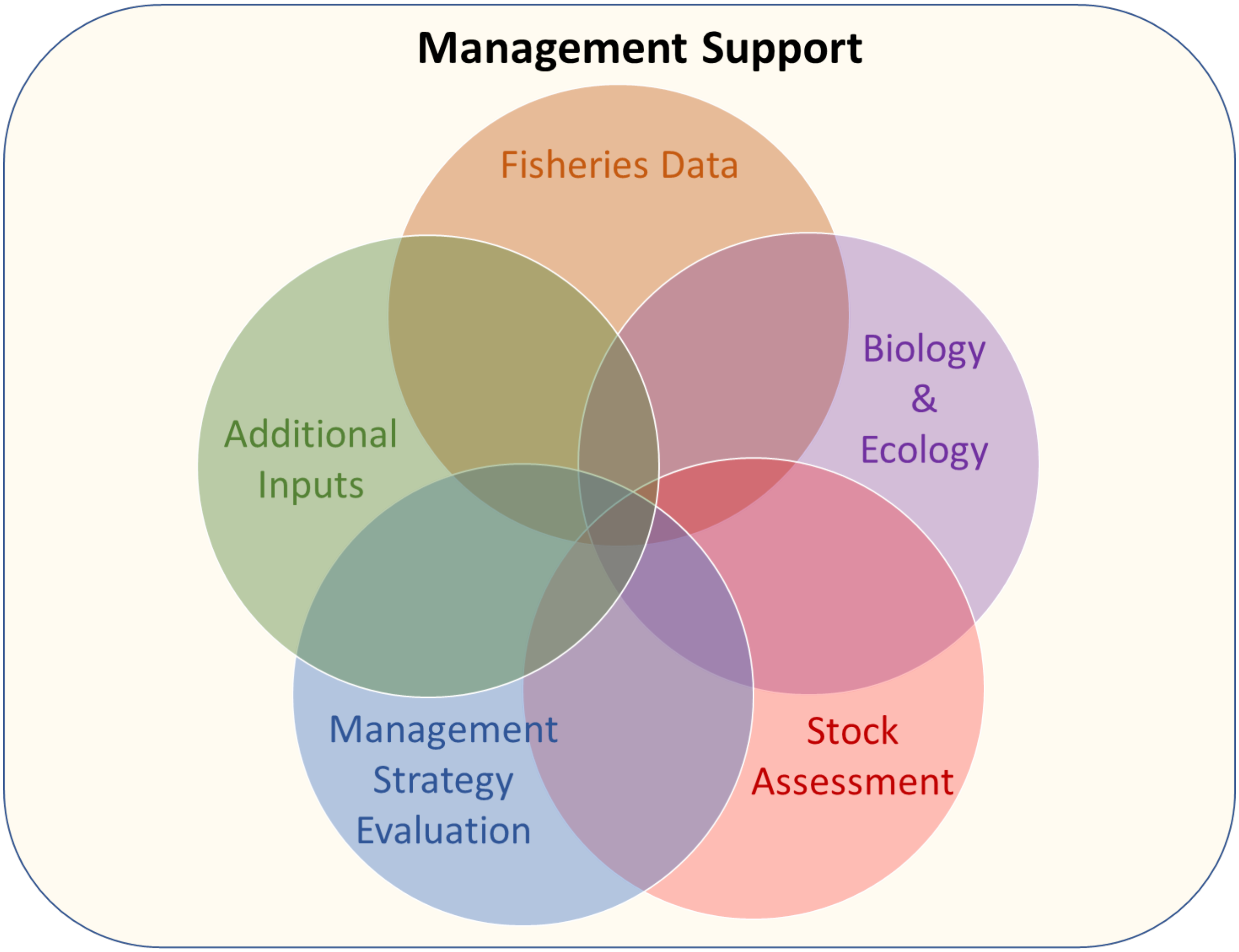

Figure 2. Core areas of the IPHC's program of integrated research and monitoring providing management support.

3. Strategy

The IPHC Secretariat has five (5) enduring strategic goals in executing our mission, including our overarching goal and associated science and research objectives, as articulated in our Strategic Plan (IPHC Strategic Plan (2019-23)): 1) To operate in accordance with international best practice; 2) Be a world leader in scientific excellence and science-based decision making; 3) To foster collaboration (within Contracting Parties and internationally) to enhance our science and management advice; 4) Create a vibrant IPHC culture; and 5) Set the standard for fisheries commissions globally.

Although priorities and tasking will change over time in response to events and developments, the Strategic 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, will be operationalised through a multi-year tactical activity matrix 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 will be involved in project development and ongoing review.

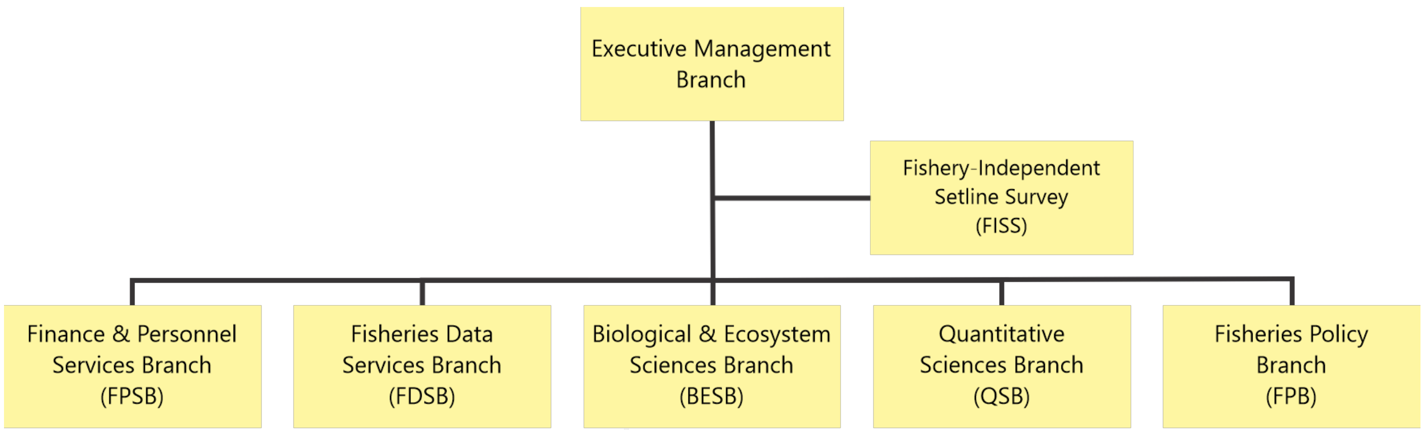

Figure 3. IPHC Secretariat organisation chart (2022).

4. Measures of Success

The Secretariat's success in implementing the *IPHC 5-Year Program of Integrated Research and Monitoring (2022-26)* will be measured according to the following criteria relevant to the stock assessment, the MSE and for all inputs to IPHC management:

1) Timeliness – was the research conducted, analyzed, published, and provided to the Commission at the appropriate points to be included in annual management decisions?
2) Accessibility – was the research published and presented in such a way that it was available to other scientists, stakeholders, and decision-makers?
3) Relevance - did the research improve the perceived accuracy of the stock assessment, MSE or decisions made by the commission?
4) Impact – did the research allow for more precision or a better estimate of the uncertainty associated with information for use in management?
5) Reliability - has research resulted in more consistent information provided to the Commission for decision-making.

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 Communication

The IPHC Secretariat will disseminate information about the activities contemplated in the IPHC 5-Year Program of Integrated Research and Monitoring (2022-2026) and the resulting products to Contracting Parties, stakeholders, the scientific community, and the general public through a variety of channels:

1) IPHC website (www.iphc.int);
2) Formal documentation provided for IPHC meetings (Interim and Annual Meetings, Subsidiary Body meetings, etc.);
3) Presentations at national and international scientific conferences;
4) Published reports and peer-reviewed publications (section 4.4);
5) Outreach events;
6) Social media outlets (e.g. Facebook, Twitter, LinkedIn, etc.);
7) Informal presentations and interactions with partners, stakeholders, and decision-makers at varied times and venues when needed.

4.3 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. Continuing the successful funding-recruitment strategy adopted during the previous 5-yr research plan (IPHC–2019–BESRP-5YP) (Appendix I), the Secretariat will identify and select external funding opportunities that are timely and that aim at addressing key research objectives (as outlined in Appendix II) that have important implications for stock assessment and the MSE process. The IPHC Secretariat has the necessary expertise to propose novel and important research questions to funding agencies and to recruit external collaborators from research agencies and universities as deemed necessary. The IPHC Secretariat will continue to capitalize on the strong analytical contributions of quantitative scientists to the development of biological research questions within the framework of research projects funded by external as well as internal funding sources.

4.4 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. In the sections that follow, the expected publications from each research stream and cross-stream are defined.

5. Core focal areas – Background

The goals of the main activities of the *5-Year program of integrated research and monitoring (2022-26)* are integrated across the organisation, involving 1) monitoring (fisheries-dependent and –independent data collection), and 2) research (biological, ecological), modelling (FISS and stock assessment), and MSE, as outlined in the following sub-sections. These components are closely linked to one another, and all feed into management decision-making (Fig. 4). Additionally, management-supporting information constitute a range of additional decision-making drivers within and beyond IPHC's current research and monitoring programs. 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 I.

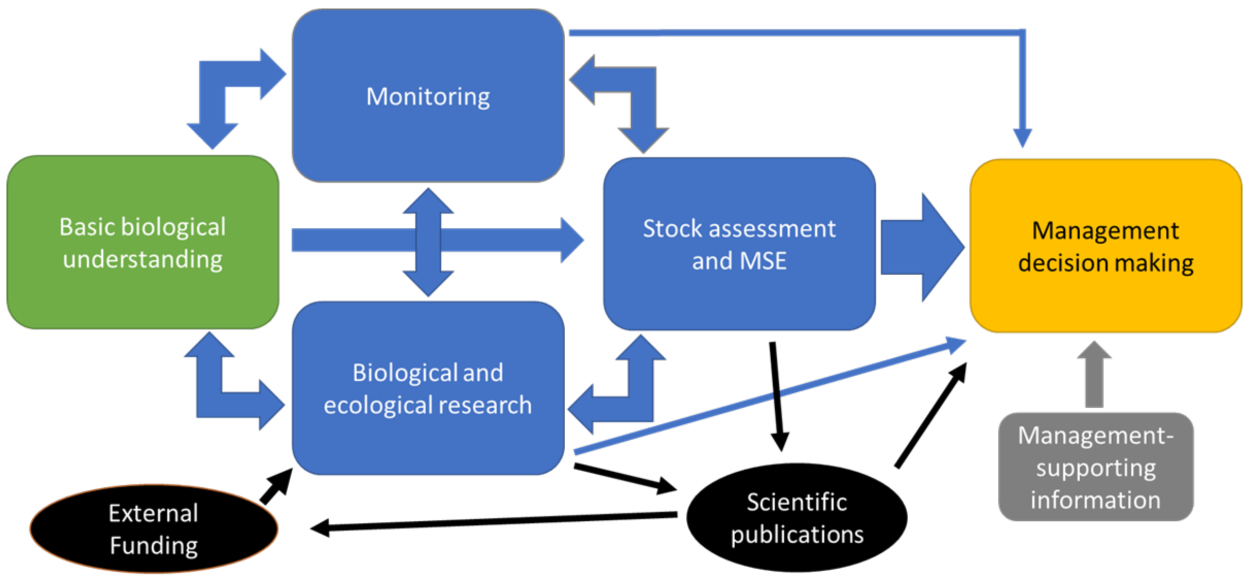

Figure 4. Flow of information from basic biological understanding of the Pacific halibut resource, through IPHC research components (monitoring, biological and ecological research, stock assessment, and MSE) to management decision-making. Management-supporting information (grey) constitute a range of additional decision-making drivers within and beyond IPHC's current research and monitoring programs. Arrows indicate the strength (size of the arrow) and direction of information exchange. Also identified (in black) are the external links from funding and scientific publications which supplement the IPHC's internal process.

5.1 Research

5.1.1 Stock Assessment

Focal Area Objective	To improve accuracy and reliability of the current stock assessment and the characterization of uncertainty in 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 2021 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 IPHC's 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 four categories:

1) Assessment data collection and processing;
2) technical development;
3) biological inputs; and
4) 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 described in the sections below.

5.1.2 Management Strategy Evaluation (MSE)

Focal Area Objective	To develop an accurate, reliable, and informative MSE process to appropriately characterize uncertainty and provide for the robust evaluation of the consequences of alternative management options, known as harvest strategies, using defined conservation and fishery objectives.
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 continue to 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 Total Constant Exploitation Yields (TCEY) 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 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 socioeconomics.

5.1.3 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. 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 that are 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 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, 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 the IPHC aim to provide information on 1) 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); 2) the spawning (female) population (e.g. reproductive maturity, skipped spawning, reproductive migrations); and 3) resulting changes in population dynamics. Furthermore, the research activities of IPHC also aim to provide 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 reduce 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.

5.2 Monitoring

Focal Area Objective	To collect fishery-dependent and fishery-independent data on the distribution, abundance, and demographics 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 • https://www.iphc.int/datatest/data/water-column-profiler-data

5.2.1 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 are described below.

5.2.1.1 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 2022). 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 (U.S.A.) and observer data (Canada).

5.2.1.2 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 analyses. 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. Non-directed fisheries off Canada British Columbia are monitored and 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.

5.2.1.3 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.

5.2.1.4 Recreational fisheries data

Recreational removals of Pacific halibut, including estimated recreational discard mortality, are provided by National/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.

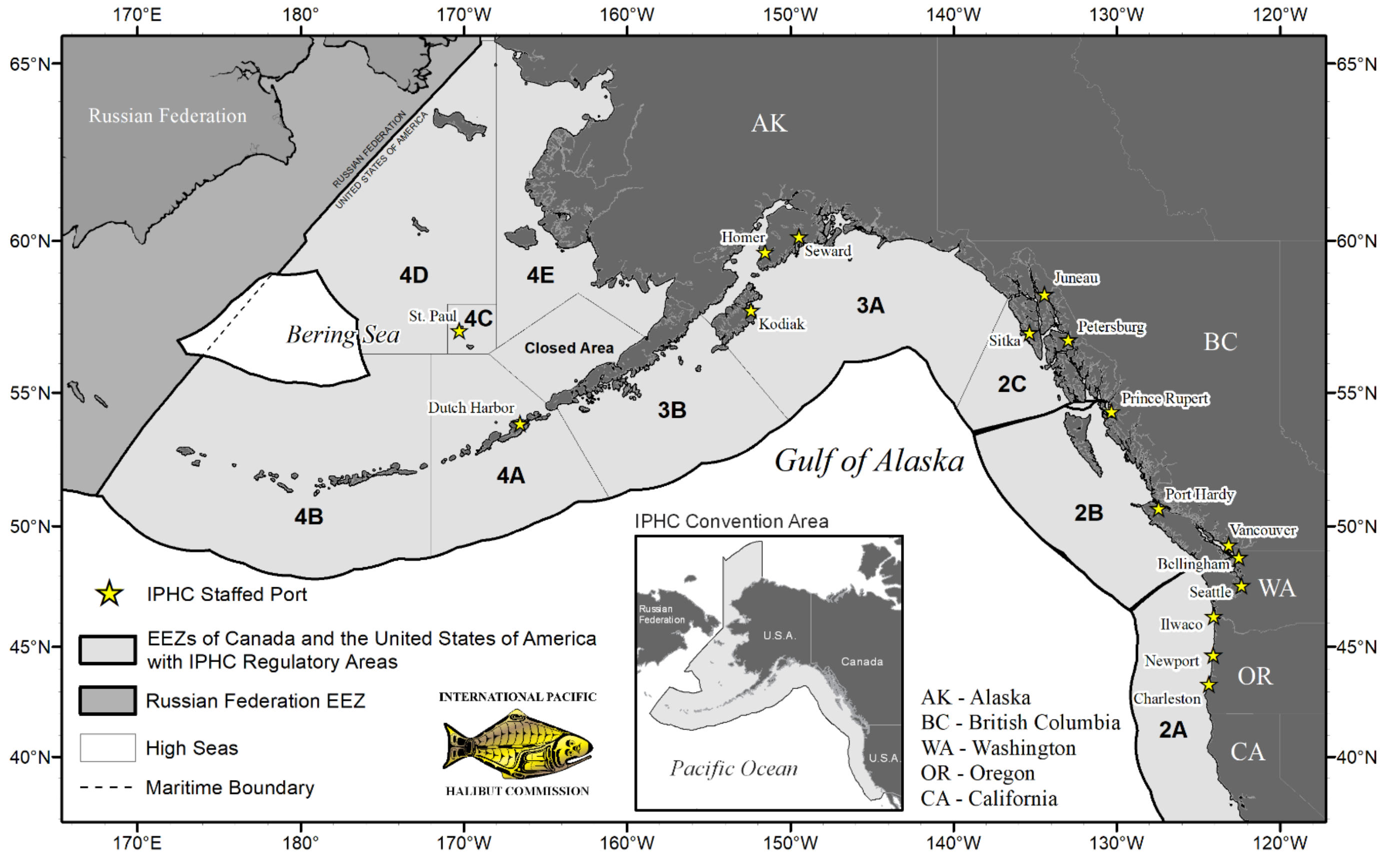

Figure 5. Ports where the IPHC has sampled directed commercial landings throughout the fishing period in recent years (note: ports sampled may change from year-to-year for operational reasons).

5.2.2 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.

5.2.2.1 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, 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 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 of Pacific halibut) are used to monitor changes in biomass, growth, and mortality. 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. Environmental data are also collected including water column temperature, salinity, dissolved oxygen, pH, and chlorophyll concentration to help identify the conditions in which the fish were caught, and these data can serve as co-variates in space-time modeling used in the stock assessment. 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 2022).

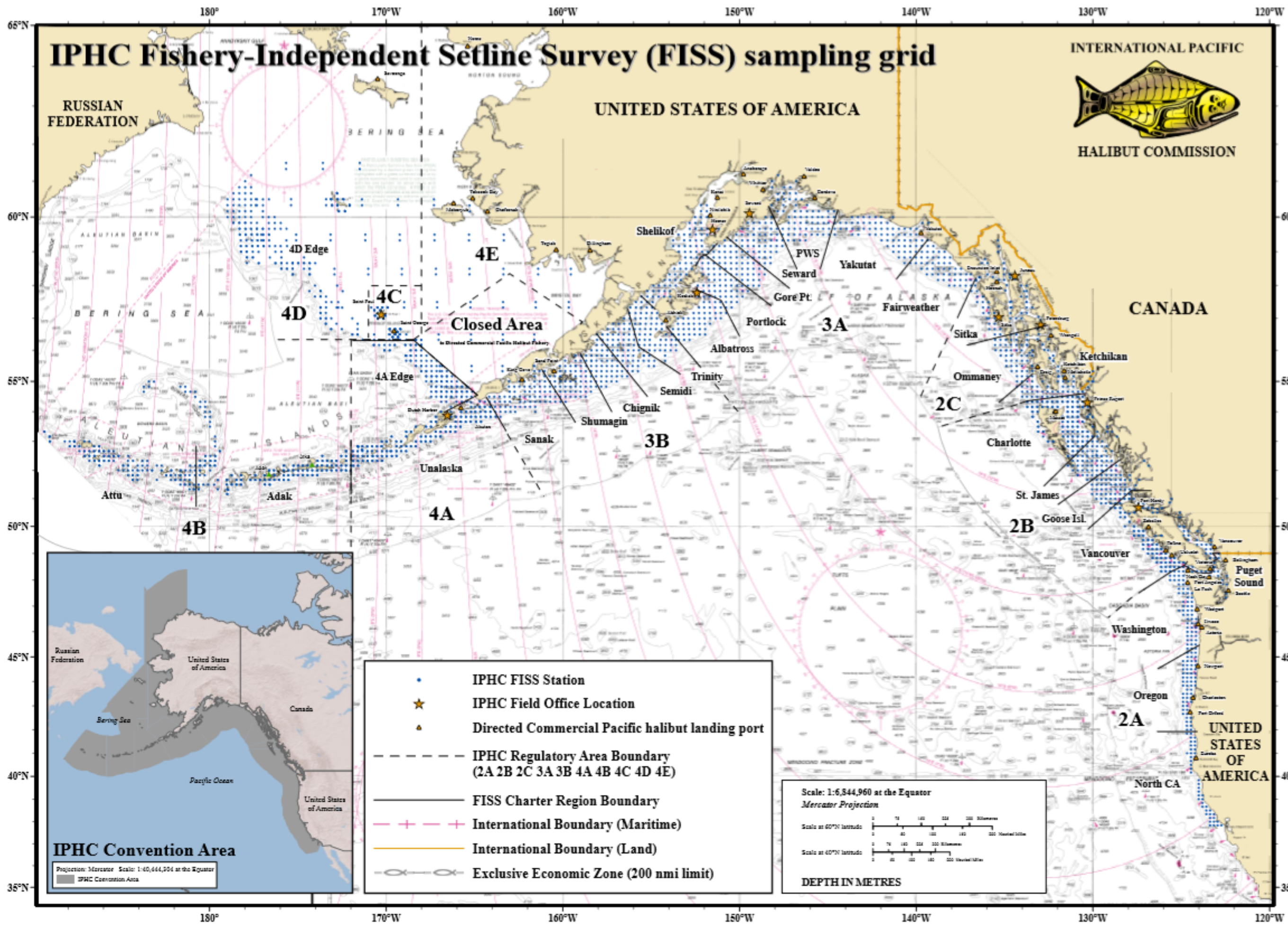

Figure 6. IPHC Fishery-Independent Setline Survey (FISS) with full sampling grid shown.

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 density indices would be estimated with high precision and low potential for 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 (SRB) meetings 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).

5.2.2.2 Fishery-independent Trawl Survey (FITS)

The IPHC has participated routinely in the NOAA Fisheries trawl surveys operating in the Bering Sea (Fig. 7, annually since 1998), Aleutian Islands (intermittently since 1997) and Gulf of Alaska (since 1996). 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, distribution, and age composition of young Pacific halibut.

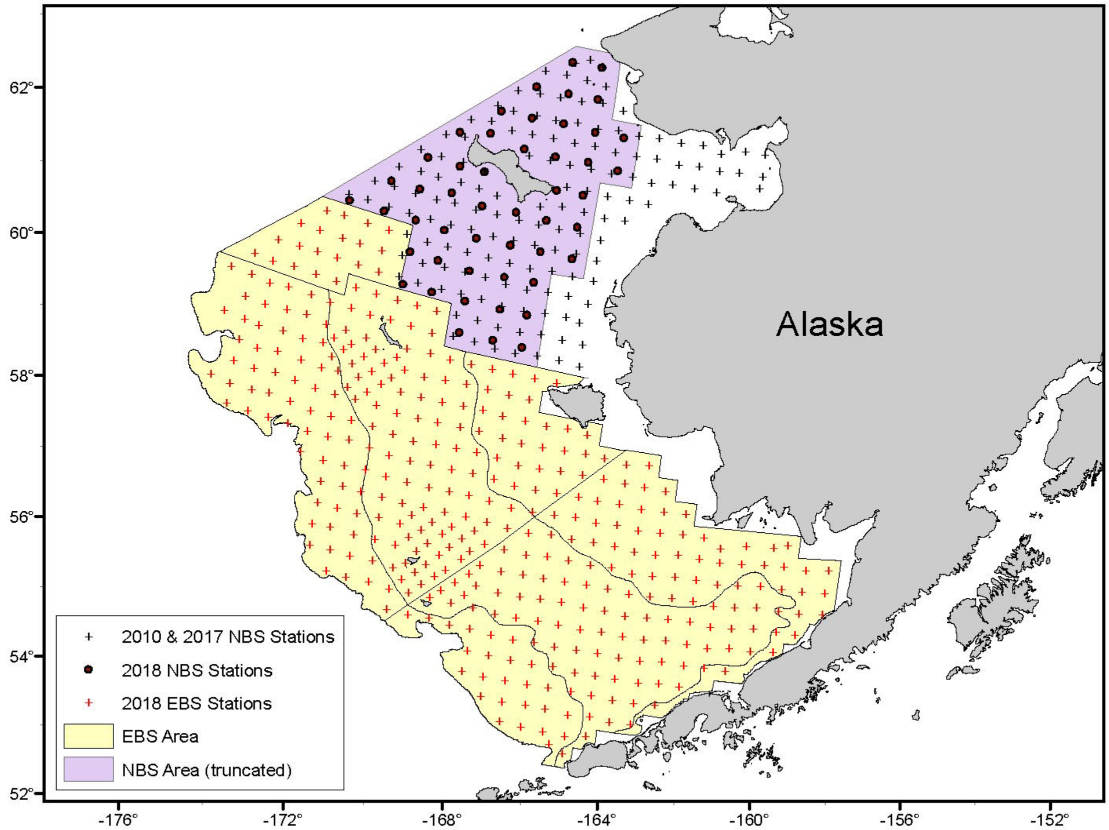

Figure 7. Sampling station design for the 2018 NOAA Bering Sea bottom trawl survey. Black dots are stations sampled in the 2018 "rapid-response" Northern Bering Sea trawl survey and black plus signs are stations sampled in standardized Northern Bering Sea trawl survey.

5.3 Management-supporting information

Successful fisheries management requires rigorous application of the scientific method of problem solving in the development of strategic alternatives and their evaluation on the basis of objectives that integrate ecosystem and human dynamics across space and time into management decision-making (Lane and Stephenson, 1995). This points to the importance of understanding a broad range of factors to deliver on the Commission's objective to develop the stocks of Pacific halibut to the levels that permit the optimum yield from the fishery over time. Management-supporting information beyond IPHC's current research and monitoring programs relate to, among others, socioeconomic considerations, community development, political constraints, and operational limitations.

Responding to the Commission's "*desire for more comprehensive economic information to support the overall management of the Pacific halibut resource in fulfillment of its mandate*" (economic study terms of reference adopted at FAC095 and endorsed at AM095 in 2019), between 2019 and 2021 the IPHC conducted a socioeconomic study. The study's core product, Pacific halibut multiregional economic impact assessment (PHMEIA) model, describes economic interdependencies between sectors and regions to bring a better understanding of the role and importance of the Pacific halibut resource to regional economies of Canada and the United States of America (see project report). The model details the within-region production structure of the Pacific halibut sectors (fishing, processing, charter) and cross-regional flows of economic benefits. The model also accounts for economic activity generated through sectors that supply fishing vessels, processing plants, and charter businesses with inputs to production, by embedding Pacific halibut sectors into the model of the entire economy of Canada and the USA. The PHMEIA model fosters stakeholders' better understanding of a broad scope of regional impacts of the Pacific halibut resource. The results highlight that the harvest stage accounts for only a fraction of economic activity that would be forgone if the resource was not available to fishers in the Pacific Northwest. Moreover, the study informs on the vulnerability of communities to changes in the state of the Pacific halibut stock throughout its range, highlighting regions particularly dependent on economic activities that rely on Pacific halibut. Leveraging multiple sources of socioeconomic data, the project provides complementary input for designing policies with desired effects depending on regulators' priorities which may involve balancing multiple conflicting objectives. 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.

The economic impact assessment is supplemented by an analysis of the formation of the price paid for Pacific halibut products by final consumers (end-users) that is intended to provide a better picture of Pacific halibut contribution to the gross domestic product (GDP) along the entire value chain, from the hook-to-plate. This supplemental material is available in IPHC's Pacific halibut market analysis.

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

Research at IPHC can be classified as "use-inspired basic research" (Stokes 1997) which combines knowledge building with the application of existing and emerging knowledge to provide for the management of Pacific halibut. The four core focal areas: stock assessment, management strategy evaluation, management supporting information, and biology & ecology, all interact with each other as well as with fisheries monitoring activities in the IPHC program of integrated research and monitoring. Progress and knowledge building in one focal area influences and informs application in other core focal areas, also providing insight into future research priorities. The circular feedback loop is similar to the scientific method of observing a problem, creating a hypothesis, testing that hypothesis through research and analysis, drawing conclusions, and refining the hypothesis.

The IPHC Secretariat has been working with IPHC advisory bodies, such as the Scientific Review Board (SRB), and the Commission to conduct scientific research in a way that utilizes the scientific method. Problems are often identified by an advisory body or Commission and hypotheses are developed by the IPHC Secretariat. Research is reviewed by the SRB and refined hypotheses are presented to advisory bodies and the Commission. This process occurs via an annual schedule of meetings, as shown in Fig. 8. In May, an MSE informational session may be held if there is significant progress in the MSE such that it would be useful to prepare stakeholders for the Management Strategy Advisory Board (MSAB) meeting in October. Recommendations related to the MSE, and development of a harvest strategy directed to the Commission are a result of the MSAB meeting. The SRB holds two meetings each year: one in June where requests are typically directed to IPHC Secretariat, and one in September where recommendations are made to the Commission. The June SRB meeting has a focus on research; the September meeting represents a final check of science products to be presented to the Commission for use in management. The Research Advisory Board (RAB) meets in November to discuss ongoing research, provide guidance and recommend new research projects. The Work Meeting (WM) is held in September and is a working session with IPHC Secretariat and the Commission to prepare for the Interim Meeting (IM) held in November and the Annual Meeting (AM) held in January. Outcomes from the AM include mortality limits (coastwide and by IPHC Regulatory Area), directed fishery season dates, domestic regulations, and requests and recommendations for the IPHC Secretariat. In conjunction with the AM are meetings of the Finance and Administration Committee (FAC), the Conference Board (CB), and the Processor Advisory Board (PAB). The Commission may also hold Special Sessions (SS) throughout the year to take up and make decisions on specific topics.

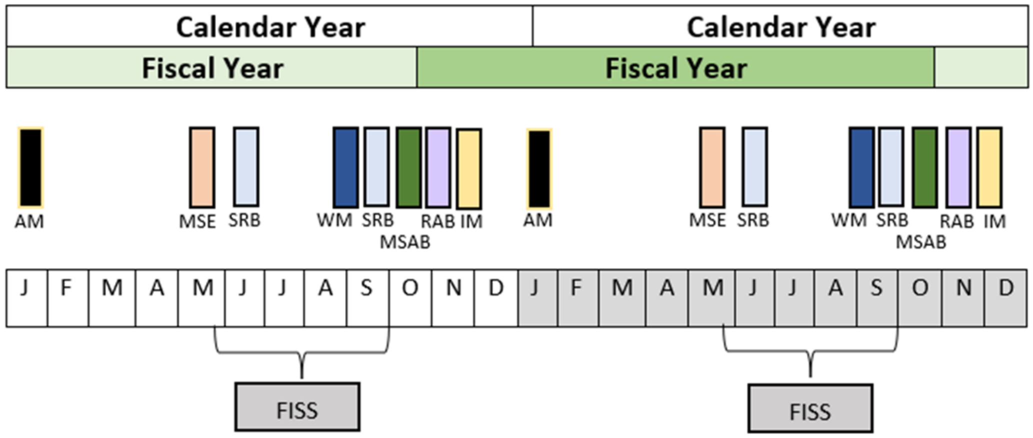

Figure 8. The typical IPHC annual meeting schedule with the calendar year and fiscal year shown. The meetings, shown in the middle row are: Annual Meeting where the Commission makes many final decisions for that year (AM), an MSE informational session (MSE), Scientific Review Board meetings (SRB), the Commission Work Meeting (WM), the Management Strategy Advisory Board meeting (MSAB), the Research Advisory Board Meeting (RAB), and the Interim Meeting (IM). The annual FISS schedule is also shown.

In addition to the annual meeting process at IPHC, individual core focal areas of research may identify and prioritize research for other core focal areas. For example, stock assessment research often identifies gaps in the knowledge of Pacific halibut biology and ecology, which then identifies priority research for the Biology and Ecology core area. Vice versa, basic biological and ecological research can identify concepts that could be better understood and result in improved implementation in any of the core areas. Furthermore, Management Strategy Evaluation can often be used to identify priority research topics for any core areas by simulation testing to identify research that may have the largest benefit to improving the management of Pacific halibut.

The top priorities of research for various categories in each of the core focal areas are provided below. The top priorities are a subset of the potential research topics in each core focal area. More exhaustive and up-to-date lists of research topics, that may extend beyond a five-year timeframe, can be found in recent meeting documents related to each core focal area.

6.1 Research

6.1.1 Stock Assessment

Within the four assessment research categories, the following topics have been identified as top 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.

6.1.1.1 Stock Assessment data collection and processing

6.1.1.1.1 Commercial fishery sex-ratio-at-age via genetics

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 four years (2017-20) of commercial sex-ratio-at-age information available for the 2021 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. This assessment priority directly informs *6.1.3.2 Reproduction* as described below.

6.1.1.1.2 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 harvesters. 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. This assessment priority directly informs *6.1.3.4 Mortality and Survival Assessment* as described below.

6.1.1.2 Stock Assessment technical development

6.1.1.2.1 Maintaining coordination with the MSE

The stock assessment and MSE operating models have been developed in close coordination, in order to identify plausible hypotheses regarding the processes governing Pacific halibut population dynamics. Important aspects of Pacific halibut dynamics include recruitment (possibly related to extrinsic environmental factors in addition to spawning biomass), size-at-age, movement/migration and spatial patterns in fishery catchability and selectivity. Many approaches developed as part of the tactical stock assessment have been explored in the MSE operating model, and conversely, the MSE operating model has highlighted areas of data uncertainty or alternative hypotheses for exploration in the assessment (e.g. movement rates). Although these two modelling efforts target differing objectives (tactical vs. strategic) continued coordination is essential to ensure that the stock assessment and the MSE represent the Pacific halibut similarly and provide consistent and useful advice for tactical and strategic decision-making.

6.1.1.2.2 Data weighting

The stock assessment currently relies on iterative "Francis" weighting of the age compositional data using a multinomial likelihood formulation (Francis 2011) based on the number of samples available in each year. Exploration of a stronger basis for input sample sizes through analysis of sampling design, estimation of sample weighting and alternative likelihoods may all provide for a more stable approach and a better description of the associated uncertainty.

6.1.1.2.3 Environmental covariates to recruitment

The two long time-series models included in the stock assessment ensemble allow for the Pacific Decadal Oscillation (PDO; Mantua et al. 1997) to be a binary covariate indicating periods of higher or lower average recruitment. This relationship has been observed to be consistent since its development over 20 years ago (Clark et al 1999) and is re-estimated in each year's stock assessment models. With additional years of data, evaluation of the strength of this relationship, as compared to other metrics of the PDO (e.g., annual deviations, running averages) or other indicators of NE Pacific Ocean productivity should be undertaken in order to provide the best estimates and projections of Pacific halibut recruitment and to provide for alternative hypotheses for use in the MSE. This assessment priority partially informs *6.1.3.2 Reproduction* as described below.

6.1.1.2.4 'Leading' parameter estimation

Stock assessments are generally very sensitive to the estimates of leading parameters (stock-recruitment parameters, natural mortality, sex-specific dynamics, etc.). For Pacific halibut some of these are fully integrated into the estimation uncertainty (average unexploited recruitment), or partially integrated (e.g. estimation of natural mortality in two of the four models). As time-series of critically informative data sources like the FISS and the sex-ratio of the commercial landings grow longer it may be possible to integrate additional leading parameters directly in the assessment models and/or include them as nested models within the ensemble.

6.1.1.3 Stock Assessment biological inputs

6.1.1.3.1 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 the 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 processes 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. This assessment priority directly informs *6.1.3.2 Reproduction* as described below.

6.1.1.3.2 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 and Webster 2022). 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. This assessment priority directly informs *6.1.3.1 Migration and Population Dynamics* as described below.

6.1.1.3.3 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. This assessment priority directly informs *6.1.3.1 Migration and Population Dynamics* as described below.

6.1.1.4 Stock Assessment fishery yield

6.1.1.4.1 Biological interactions with fishing gear

In 2020, 16% of the total fishing mortality of Pacific halibut was discarded (Stewart et al. 2021). 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. This assessment priority directly informs *6.1.3.4 Mortality and Survival Assessment* as described below.

6.1.1.4.2 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, lead to greater retained yield, and reduce the potential uncertainty associated with large quantities of estimated mortality due to discarding. This assessment priority directly informs *6.1.3.4 Mortality and Survival Assessment* as described below.

Outside of the four general assessment categories, the IPHC has recently considered adding close-kin genetics (e.g., Bravington et al. 2016) to its ongoing research program (see section 6.1.3.1). 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 into 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 from the FISS since 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. This five-year plan should consider a pilot evaluation, such that a broader study could be undertaken in the future, providing the likely results would meet the Commission's objectives and prove possible given financial constraints. Research related to close-kin genetics would be pursued under *6.1.3.1 Migration and Population Dynamics* as described below.

6.1.2 Management Strategy Evaluation

MSE priorities have been subdivided into three categories: 1) biological parameterisation, 2) fishery parameterization, and 3) technical development. Research provides specifications for the MSE simulations, such as inputs to the Operating Model (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. The following topics have been identified as top priorities.

6.1.2.1 MSE Biological and population parameterization

6.1.2.1.1 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 MSE objectives to reflect reality and plausible outcomes. Research under Section 6.1.3.1 will inform this MSE priority.

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 regarding 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.

6.1.2.1.2 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. Research under Sections 6.1.3.1 and 6.1.3.2 will inform this MSE priority.

6.1.2.1.3 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. Research under Section 6.1.3.3 will inform this MSE priority.

6.1.2.1.4 MSE 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. Research under Sections 6.1.3.4 and 6.1.3.5 will inform this MSE priority.

6.1.2.2 MSE technical development

Technical improvements to the MSE framework will allow for rapid development of alternative operating models and efficient simulation of management strategies for future evaluation. Coordination with the technical development of the stock assessment (Section 6.1.1.2.1) is necessary to ensure consistent assumptions and hypotheses for tactical (i.e. stock assessment) and strategic (i.e. MSE) models. Investigations done in the stock assessment will inform the stock assessment, which will then be informed by investigations using the closed-loop simulation framework. Multi-year assessments may allow for additional opportunity to coordinate between stock assessment and MSE.

6.1.2.2.1 Alternative migration scenarios

Including alternative migration hypotheses in the MSE simulations will assist in identifying management procedures that are robust to this uncertainty. This exploration will draw on general research on the movement and migration of Pacific halibut, observations from FISS and fisheries data, and outcomes of the stock assessment. Identification of reasonable hypotheses for the movement of Pacific halibut is essential to the robust investigation of management procedures. Research under Section 6.1.3.1 will inform this MSE priority.

6.1.2.2.2 Realistic simulations of estimation error

Closed loop simulation uses feedback from the management procedure to update the population in the projections. The management procedure consists of data collection, an estimation model, and harvest rules; currently IPHC uses a stock assessment as the estimation model. Future development of an efficient simulation process to mimic the stock assessment will more realistically represent the current management process. This involves using multiple estimation models to represent the ensemble and appropriately adding data and updating those models in the simulated projections. Improvements to the current MSE framework include adding additional estimation models to better represent the ensemble stock assessment, ensuring that the simulated estimation accurately represent the stock assessment now and, in the future, and speeding up the simulation process.

6.1.2.2.3 Incorporate additional sources of implementation uncertainty

Implementation uncertainty consists of three subcategories: 1) decision-making uncertainty, 2) realized uncertainty, and 3) perceived uncertainty. Decision-making uncertainty is the difference between mortality limits determined from the management procedure and those adopted by the Commission. This uncertainty is currently not implemented in the MSE framework but has been requested by the SRB and the independent peer review of the MSE. Realized uncertainty is the difference between the mortality limit set by the Commission and the actual mortality realized by the various fisheries. This type of uncertainty is currently partially implemented in the MSE framework. Finally, perceived uncertainty is the difference between the realized mortality and the estimated mortality limits from the various fisheries, which would be used in the estimation model. This third type of implementation uncertainty has not been implemented in the MSE framework. Implementing decision-making uncertainty is a priority for the MSE and will assist in understanding the performance of management procedures when they may not be followed exactly.

6.1.2.3 MSE Program of Work for 2021–2023

Following the 11th 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 2021–23.

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

6.1.2.4 Potential Future MSE projects

Management Strategy Evaluation is an iterative process where new management procedures may be evaluated, current management procedures may be re-evaluated under different assumptions, and the understanding of the population, environment, and fisheries may be updated with new information stemming from the stock assessment and biological/ecological research. The current Program of Work (Table 1) focuses on two elements of Management Procedures, but in the future other elements may be of interest, such as distribution procedures. The research being done now will inform the development of the MSE in the future to ensure a robust evaluation of any management procedure.

6.1.3 Biology and Ecology

Capitalizing on the outcomes of the previous 5-year plan (IPHC–2019–BESRP-5YP) (Appendix I), the IPHC Secretariat has identified five research areas that will provide key inputs for stock assessment and the MSE process. In addition to linking genetics and genomics with migration and distribution studies in the newly coined area of Migration and Population Dynamics, the IPHC Secretariat has incorporated a novel research area on Fishing Technology. A series of key objectives for each the five research areas have been identified.

6.1.3.1 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.
- Exploration and development of alternative methods for aging Pacific halibut based on genetic analyses of DNA methylation patterns in tissues (fin clips).
- Exploration of methods for individual identification based on computer-assisted tail image matching systems as an alternative for traditional mark and recapture tagging.

6.1.3.2 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.

6.1.3.3 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.

6.1.3.4 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 improved estimation of depredation mortality from marine mammals.

6.1.3.5 Fishing Technology

Studies aimed at developing methods that involve modifications of fishing gear with the purpose of reducing Pacific halibut depredation and bycatch. Specific objectives in this area include:

- Investigate new methods for whale avoidance and/or deterrence for the reduction of Pacific halibut depredation by whales (e.g. catch protection methods).
- Investigate physiological and behavioral responses of Pacific halibut to fishing gear in order to reduce bycatch.

6.2 Monitoring

The Commission's extensive monitoring programs include both direct data collection and coordination with domestic agencies to produce both fishery-dependent and fishery-independent information on the stock and fishery trends, and other information. These critical sources include estimates of fishing mortality from all fisheries encountering Pacific halibut, biological sampling from these fisheries as well as catch-rates and biological sampling from longline and trawl surveys. Monitoring data provide the basis for stock assessment and MSE analysis, many biological research studies, and some inputs directly to the decision-making process (Figure 4). While not the primary focus of this 5-year plan, a basic summary of the components led by the IPHC and those that are provided by domestic agencies is provided below.

6.2.1 Fishery-dependent data

Data collection and monitoring activities aimed at providing standardised time-series of mortality, fishery, and biological data from both direct target fisheries as well as fisheries that incidentally catch Pacific halibut. Directed commercial fisheries data are managed by IPHC. Non-directed commercial discard mortality data, subsistence fisheries data, and recreational fisheries data are managed by Contracting Party domestic agencies.

6.2.1.1 Directed commercial fisheries data

6.2.1.2 Annually review the spatial distribution of sampling effort among ports, data collection methods, sampling rates, and quality assurance/quality control (QAQC) processes, including in-season review of port sampling activities

Ensure current data collection efforts meet current and future needs of stock assessment, MSE and management. Collaborate and coordinate with other Secretariat functions to develop methods and procedures for incorporating promising research results into long-term monitoring program. The IPHC relies on domestic and Tribal agency programs to report annual mortality from incidental catches in non-directed commercial fisheries, catches from subsistence fisheries, and catches from recreational fisheries. Non-directed commercial discard mortality data

Annually collaborate with observer programs and other partners to ensure robust data collection and sampling, QAQC processes, and reporting of incidental catch and mortality, as well as biological sampling.

6.2.1.3 Subsistence fisheries data

Annually collaborate with Tribal, State and Federal agencies of each Contracting Party to ensure high quality data collection, sampling, and reporting in the subsistence fisheries in Canada and the United States of America.

6.2.1.4 Recreational fisheries data

Annually collaborate with National/State agencies of each Contracting Party to ensure and validate high quality data and reporting of recreational fishery mortality estimates and biological data.

6.2.2 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.

6.2.2.1 Fishery-independent setline survey (FISS)

An annual review process for the FISS station design has been developed (Fig. 9) and is expected to continue in coming years. This process involves scientific review of proposed FISS designs by the Scientific Review Board and includes input from stakeholders prior to review and approval of designs by the Commissioners.

Direct weighing of Pacific halibut has been integrated into the annual FISS sampling since 2019 and will continue into the future to ensure accurate estimation of WPUE and other weight-derived quantities. Sample rates for genetic monitoring will need to be determined for future sampling. Sampling rates of otoliths for aging, archive otoliths and tagged fish will continue to be reviewed annually to ensure the data needs of the IPHC stock assessment and research program are met. Annual FISS sampler training and data QAQC (including at point of data collection and during post-sampling review) will ensure high quality data from the FISS program. Procedures are reviewed annually.

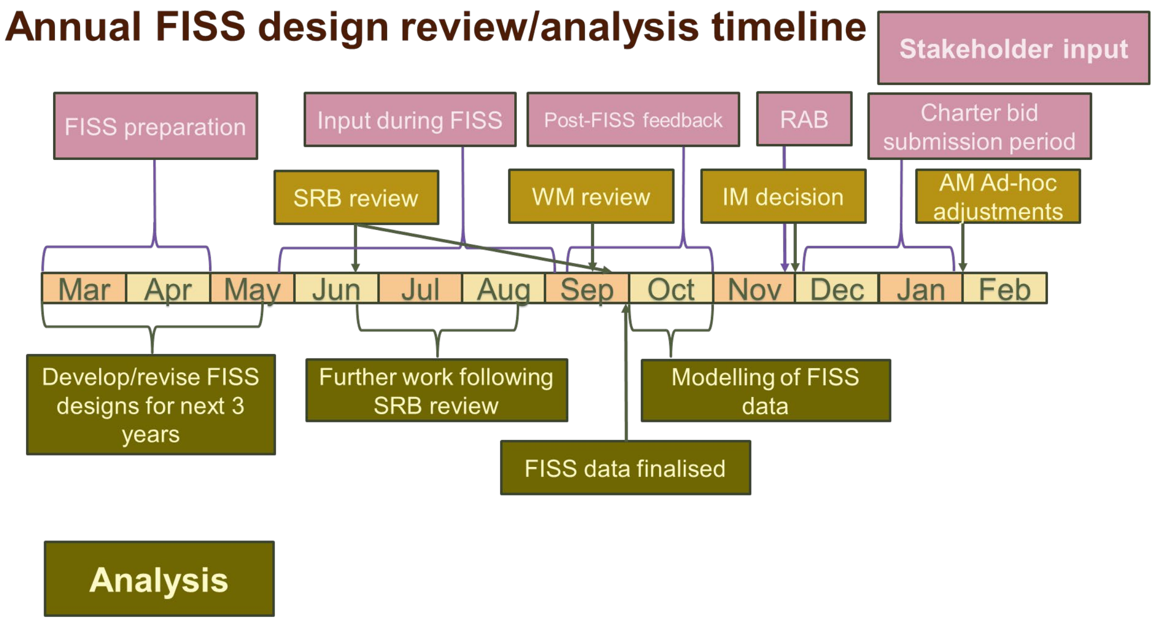

Figure 9. Timeline of annual FISS design review process.

6.2.2.2 Fishery-independent Trawl Survey (FITS)

The IPHC will continue to collaborate with NMFS on sampling procedures for Pacific halibut on the placement of an IPHC sampler onboard a survey vessel for the collection of biological data.

6.3 Potential of integrating human dynamics into management decision-making

Understanding the complexity of human dimension of the fisheries sectors is becoming increasingly important in the context of globalization. Local products compete on the market with a large variety of imported seafood. High exposure to international markets makes seafood accessibility fragile to perturbations, as shown by the COVID-19 pandemic (OECD 2020). Seafood production is also highly dependent on the production and price of imports. The IPHC's socioeconomic study showed that Pacific halibut contribution to households' income dropped by a quarter throughout the pandemic. While signs of strong recovery were present in 2021 (Fry 2021), the study called attention to Pacific halibut sectors' exposure to external factors beyond stock condition and the need for expanding the scope of management-supporting information the IPHC provides.

It is also unclear how small remote communities can capitalize on the high prices that the final customers are paying for premium seafood products. In 2021, fresh Alaskan Pacific halibut fillets routinely sold for USD 24-28 a pound, and often more, in downtown Seattle (e.g. USD 38 at Pike Place Market). Pacific halibut dishes at the restaurants typically sell for USD 37-43 for a dish including a 6oz fish portion. The IPHC's socioeconomic study detailed the geography of impacts of the Pacific halibut fisheries, providing a coherent picture of the exposure of fisheries-dependent households by location to changes in resource availability, but paying closer attention to quantifying leakage of economic benefits from communities strongly involved in fisheries, highlighted that the local earnings often do not align with how much fishing occurs within the community. This suggests the need for research focused on how to operationalize social equity in the context of the globalized market dynamics and the pursuit of stock sustainability.

In addition, fisheries are at the forefront of exposure to the accelerating impacts of climate change. For example, a rapid increase in water temperature off the coast of Alaska in 2014-16, termed *the blob*, affected fisheries (Cheung and Frölicher 2020) and may have a long-term impact on Pacific halibut distribution. The consequences may include shifts in the distribution of benefits, but possibly go further, affecting the stability of agreements over allocation of a shared resource. Research on decision quality under fast-progressing climate-induced changes to stock distribution may be warranted.

Conflicting objectives among stakeholders regarding the use of limited resource in the context of globalization, calls for social equity and climate change are a major challenge of decision-making in fisheries management. Integrating approaches aimed at understanding the human dynamics and external factors with stock assessment and MSE can assist fisheries in bridging the gap between the current and the optimal performance without compromising the stock biological sustainability. For example, socioeconomic performance metrics presented alongside already developed biological/ecological performance metrics would supplement IPHC's portfolio of tools for assessing policy-oriented issues (as requested by the Commission, IPHC-2021-AM097-R, AM097-Req.02) and support decision-making. Moreover, continuing investment in understanding the human dimension of Pacific halibut fishing can also inform on other drivers such as human behavior or human organization that affect the dynamics of fisheries, and thus contribute to improved accuracy of the stock assessment and the MSE (Lynch et al.2018). As such, it can contribute to research integration at the IPHC and provide a complementary resource for the development of harvest control rules.

Lastly, Pacific halibut 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. Recognizing and adopting such an all-encompassing definition of the Pacific halibut resource contribution, the IPHC 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.

7. Amendment

The intention is to ensure the plan is kept as a '*living plan*', that is reviewed and updated annually based on the resources available to undertake the work of the Commission (e.g. internal and external fiscal resources, collaborations, internal expertise). The IPHC Secretariat is committed to ensuring an exceptional level of transparency and commitment to the principles of open science.

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APPENDICES

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

Appendix II: Proposed schedule of outputs

Appendix III: Proposed schedule with funding and staffing indicators

APPENDIX I

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.

1.1. 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*. 2021. 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.

Integration with Stock Assessment and MSE: The relevance of research outcomes from activities in this research area for stock assessment is in the improvement of estimates of productivity. 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 stock assessment. The relevance of these research outcomes for MSE is in the improvement of the parametrization of the Operating Model and represent the top ranked biological input into the MSE.

2. Reproduction.

2.1 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.

2.2 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, T., Wolf, N., Smeltz, T. S., Harris, B. P., and Planas, J. V. Reproductive Biology of Female Pacific Halibut (*Hippoglossus stenolepis*) in the Gulf of Alaska. *Frontiers in Marine Science* 2022. 9:801759. doi: 10.3389/fmars.2022.801759.

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.

Integration with Stock Assessment and MSE: 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 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 stock assessment and represent the most important biological inputs for stock assessment. The relevance of these research outcomes for MSE is in the improvement of the simulation of spawning biomass in the Operating Model.

3. Growth.

3.1 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. 2022. 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.

3.2 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. 2022. 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.

Integration with Stock Assessment and MSE: 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 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. The relevance of these research outcomes for MSE is in the improvement of the simulation of variability and to allow for scenarios investigating climate change.

4. Mortality and Survival Assessment.

4.1 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.
- Mortality 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*). *Conservation Physiology* 2021. 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 postrelease longline mortality in Pacific halibut using acceleration-logging tags. *North American Journal of Fisheries Management*. 2022. 42: 37-49. DOI: https://doi.org/10.1002/nafm.10711.

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.

4.2 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.

Integration with Stock Assessment and MSE: The relevance of research outcomes from these activities for stock assessment 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. The relevance of these research outcomes for MSE is in fishery parametrization

5. Genetics and genomics.

5.1 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 602 Mb and contains 24 chromosome-size scaffolds covering 99.8% of the complete assembly with a N50 scaffold length of 27 Mb at a coverage of 91x.
- The Pacific halibut genome has been annotated by NCBI and is available as NCBI Hippoglossus stenolepis Annotation Release 101 (https://www.ncbi.nlm.nih.gov/assembly/GCA_022539355.2/).
- 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, A.C., Simeon, A., Zahm, M., Cabau, C., Klopp, C., Roques, C., Iampietro, C., Lluch, J., Donnadieu, C., Parrinello, H., Drinan, D.P., Hauser, L., Guiguen, Y., Planas, J.V. Generation of a chromosome-level genome assembly for Pacific halibut (*Hippoglossus stenolepis*) and characterization of its sex-determining genomic region. *Molecular Ecology Resources. 2022. In Press*. doi: https://doi.org/10.1111/1755-0998.13641.

Jasonowicz et al. 2022. In Preparation.

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

- Genome-wide analysis of stock structure and composition.

5.2 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.

Integration with Stock Assessment and MSE: The relevance of research outcomes from these activities for stock assessment resides 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 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 stock assessment. Furthermore, the relevance of these research outcomes for MSE is in biological parametization and validation of movement estimates and of recruitment distribution.

B. List of ranked biological uncertainties and parameters for stock assessment (SA) and their links to research areas and activities contemplated in the IPHC 5-Year Biological and Ecosystem Science Research Plan (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

C. List of ranked biological uncertainties and parameters for management strategy evaluation (MSE) and their links to research areas and activities contemplated in the IPHC 5-Year Biological and Ecosystem Science Research Plan (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

D. External funding received during the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21):

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 industry	$98,902	Bycatch estimates	April 2019 – November 2021
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
7	**Bycatch Reduction Engineering Program - NOAA**	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries (NA21NMF4720534)	IPHC	Deep Sea Fishermen's Union, Alaska Fisheries Science Center-NOAA, industry representatives	$99,700	Mortality estimations due to whale depredation	November 2021 – October 2022
8	**North Pacific Research Board**	Pacific halibut population genomics (NPRB Award No. 2110)	IPHC	Alaska Fisheries Science Center-NOAA	$193,685	Stock structure	December 2021- January 2024
				Total awarded ($)	**$1,020,801**		

E. Publications in the peer-reviewed literature resulting from the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21):

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*). *Conservation Physiology* 2021. 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*. 2021. 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.

2022:

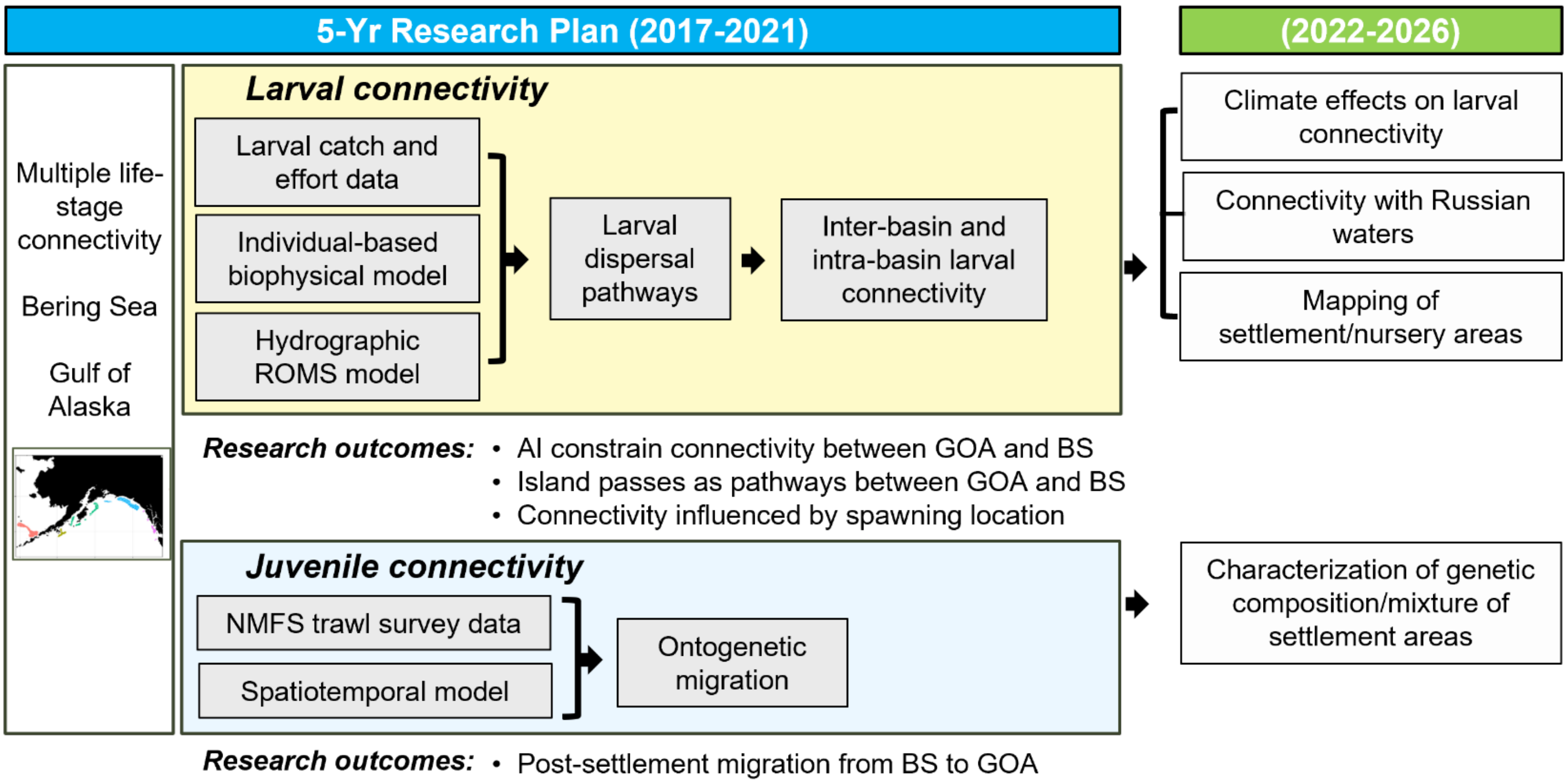
Fish, T., Wolf, N., Smeltz, T. S., Harris, B. P., and Planas, J. V. Reproductive Biology of Female Pacific Halibut (*Hippoglossus stenolepis*) in the Gulf of Alaska. *Frontiers in Marine Science* 2022. 9:801759. doi: 10.3389/fmars.2022.801759.

Jasonowicz, A.C., Simeon, A., Zahm, M., Cabau, C., Klopp, C., Roques, C., Iampietro, C., Lluch, J., Donnadieu, C., Parrinello, H., Drinan, D.P., Hauser, L., Guiguen, Y., Planas, J.V. Generation of a chromosome-level genome assembly for Pacific halibut (*Hippoglossus stenolepis*) and characterization of its sex-determining genomic region. *Molecular Ecology Resources.* 2022. In Press. doi: https://doi.org/10.1111/1755-0998.13641.

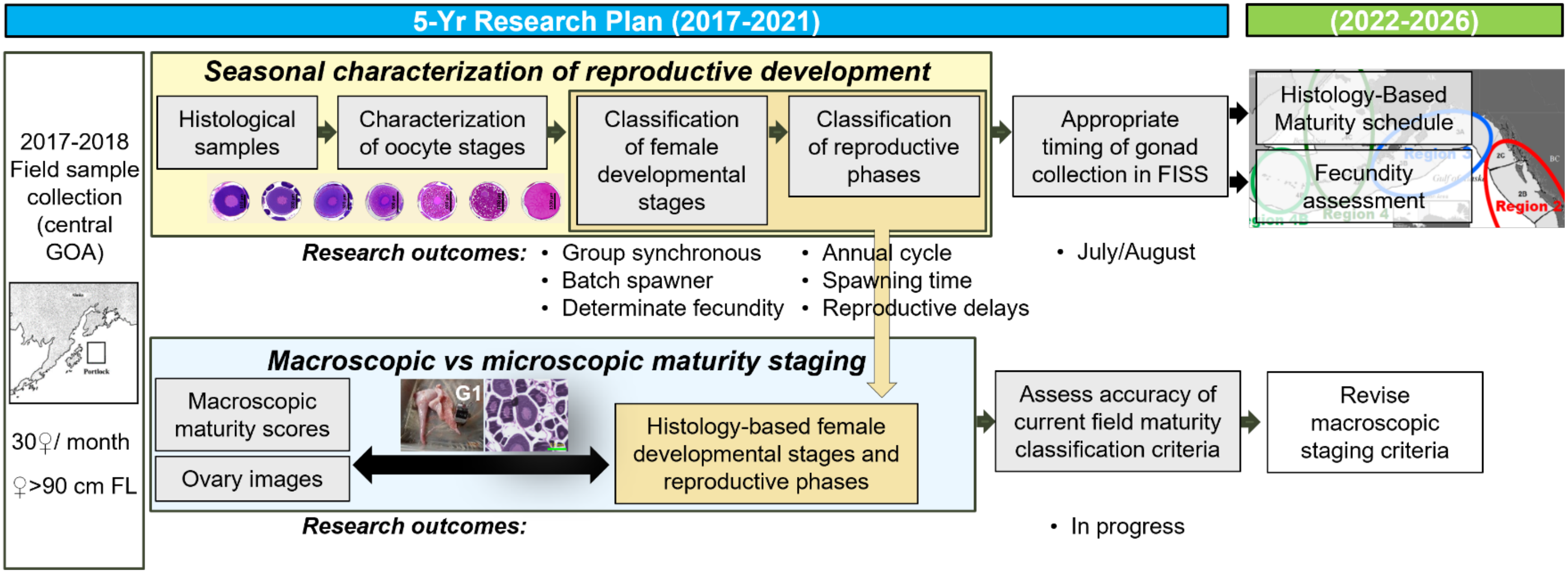
Loher, T., Dykstra, C.L., Hicks, A., Stewart, I.J., Wolf, N., Harris, B.P., Planas, J.V. Estimation of postrelease longline mortality in Pacific halibut using acceleration-logging tags. *North American Journal of Fisheries Management*. 2022. 42: 37-49. DOI: http://dx.doi.org/10.1002/nafm.10711.

F. Flow chart of progress resulting from the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21) by research area leading to the IPHC 5-Year Program of Integrated Research and Monitoring (2022-2026)

1. Migration and Distribution

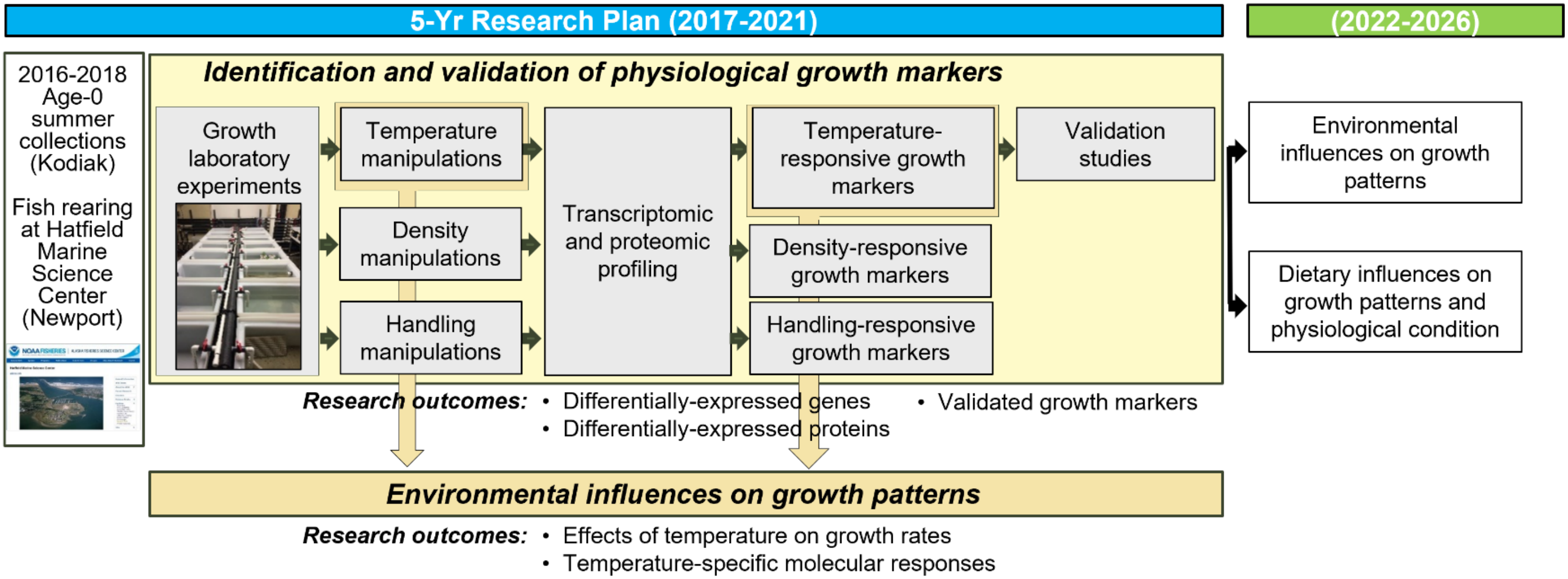


2. Reproduction



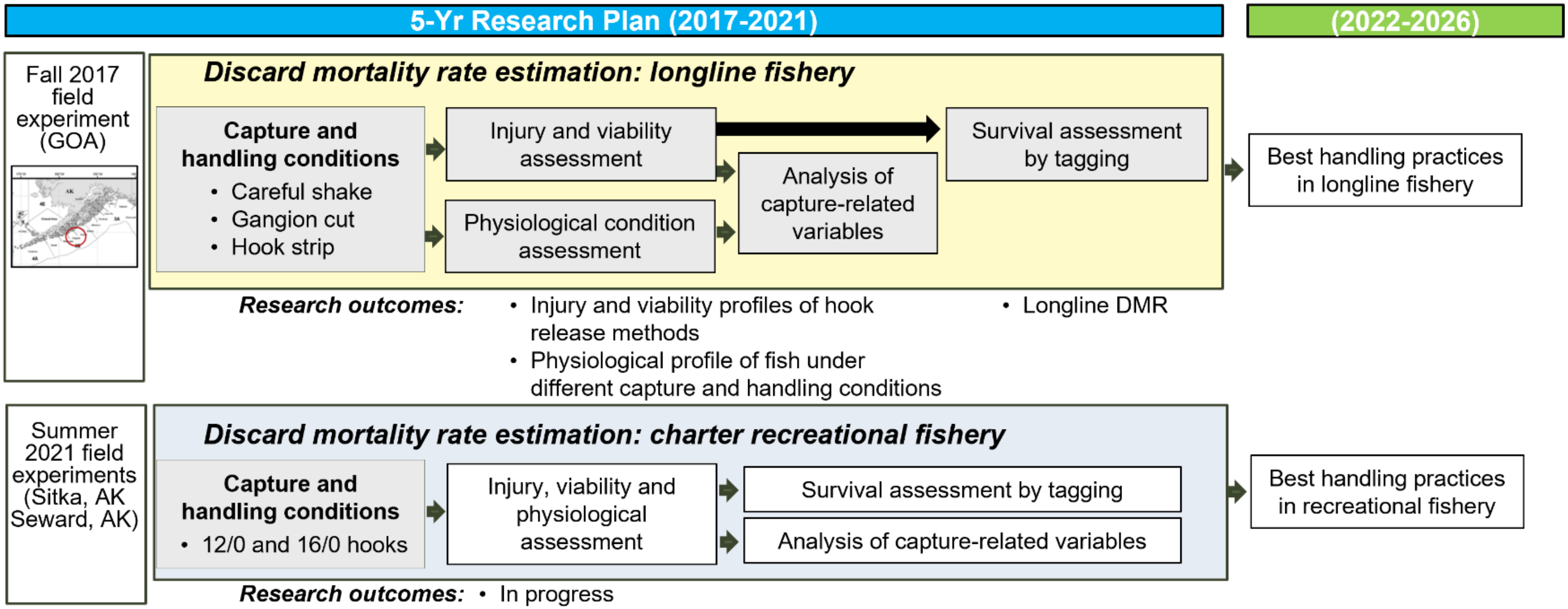
Staff involved: Teresa Fish, MSc APU (2018-2020), Crystal Simchick, Ian Stewart, Allan Hicks, Josep Planas
Funding: IPHC (2018-2020)
Publications (2): Fish et al. (2020) *J. Fish Biol*. **97**: 1880–1885 ; Fish et al. (2022) Front. Mar. Sci. 9:801759

3. Growth



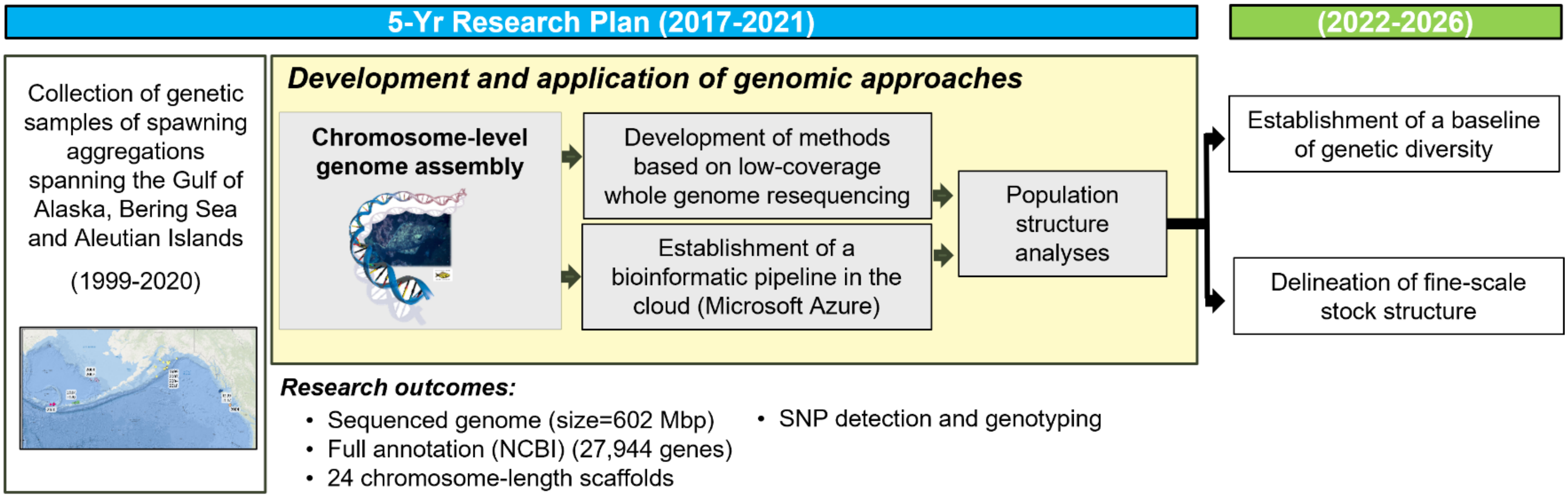
Staff involved: Andy Jasonowicz, Crystal Simchick, Josep Planas
Funding: NPRB Grant#1704 (Sept. 2017-Feb. 2020)
Publications: Planas et al. (in preparation)

4. Mortality and Survival Assessment



Staff involved: Claude Dykstra, Allan Hicks, Ian Stewart, Josep Planas
Funding (3): Saltonstall-Kennedy NOAA (Sept. 2017-Aug. 2020); NFWF (Apr. 2019-Nov. 2021); NPRB#2009 (Jan. 2021-Mar. 2022)
Publications (2): Kroska et al. (2021) *Conserv. Physiol.*; Loher et al. (2022) *North Amer. J. Fish. Manag. 42: 37-49*

5. Genetics and Genomics



Staff involved: Andy Jasonowicz, Josep Planas
Funding: IPHC, NPRB#2110
Publications: Jasonowicz et al. (2022) *Mol. Ecol. Resour. (In Review)*

APPENDIX II

Proposed schedule of outputs

	2022		2023		2024		2025		2026	
Biology and Ecology										
Migration and population dynamics										
Reproduction										
Growth										
Mortality and survival assessment										
Fishing technology										
Stock Assessment										
Management Strategy Evaluation										
Monitoring										

APPENDIX III

Proposed schedule of funding and staffing indicators: Biology and Ecology

Research areas	Research activities	Required FTEs/Year	IPHC FTEs/Year	2022	2023	2024	2025	2026	IPHC Funds	Grant Funds
Migration and Population Dynamics	Larval and juvenile connectivity and early life history studies	0.45	0.45		RB1	RB2			Yes	NPRB #2100
	Population structure	0.4	0.8		RB1				No	NPRB #2110
	Adult migration and distribution	0.4							No	NPRB #2110
	Close-kin mark-recapture studies	1	0						No	Planned
	Seascape genomics	1	0						No	Planned
	Genome-wide association analyses	1	0						No	Planned
	Genomic-based aging methods	1	1		RS 1				Yes	No
Reproduction	Maturity-at-age estimations	0.75	0						Yes	No
	Fecundity assessment	0.5	0.25			RB4	RS 2		Yes	No
	Examination of accuracy of current field macroscopic maturity classification	0.25							Yes	No
	Sex ratio of current commercial landings	0.5	0.75	LT					Yes	No
	Recruitment strength and variability	0.5	0				RS 2		Yes	Planned
Growth	Environmental influences on growth patterns	0.5	0.5			MSc student			No	Planned
	Dietary influences on growth patterns and physiological condition	0.5	0.2		RB3				No	Planned
Mortality and survival assessment	Discard mortality rate estimate: recreational fishery	0.5	1						No	NPRB #2009
	Best handling practices: recreational fishery	0.5		RB 3					No	NPRB #2009
	Whale depredation accounting and tools for avoidance	0.5							No	BREP
	Biological interactions with fishing gear	0.5							No	BREP

IPHC staff (Planned):

RS1: Research Scientist 1(PhD; Life History Modeler I). Full time temporary position (100% research;
RS2: Research Scientist 1(PhD; Life History Modeler II). Full time temporary position (100% research;
RB1: Research Biologist 1 (Geneticist; MSc). Full time temporary position (until April 2022; 1 FTE). 55% of salary covered by Grant NPRB#2110.
RB2: Research Biologist 2 (Early Life History; MSc). Full time permanent position (40% research; 0.4 FTE)
RB3: Research Biologist 3 (DMR; MSc). Full time permanent position (100% research; 1 FTE)
RB4: Research Biologist 4 (Maturity and Fecundity; MSc). Full time permanent position (100% research; 1 FTE)
LT: Laboratory Technician (MSc). Full time temporary position (100% research; 1 FTE)

2024-26 FISS design evaluation

PREPARED BY: IPHC SECRETARIAT (R. A. WEBSTER; 20 MAY 2023)

PURPOSE

To present the proposed designs for the IPHC's Fishery-Independent Setline Survey (FISS) for the 2024-26 period, and an evaluation of those designs, for review by the Scientific Review Board.

BACKGROUND

The IPHC's Fishery-Independent Setline Survey (FISS) provides data used to compute indices of Pacific halibut density for use in monitoring stock trends, estimating stock distribution, and as an important input in the stock assessment. Stock distribution estimates are based on the annual mean weight per unit effort (WPUE) for each IPHC Regulatory Area, computed as the average of WPUE of all Pacific halibut and for O32 (greater than or equal to 32" or 81.3cm in length) Pacific halibut estimated at each station in an area. Mean numbers per unit effort (NPUE) is used to index the trend in Pacific halibut density for use in the stock assessment models.

FISS history 1993-2019

The IPHC has undertaken FISS activity since the 1960s. However, methods were not standardized to a degree (e.g., the bait and gear used) that allows for simple combined analyses until 1993. From 1993 to 1997, the annual design was a modification of a design developed and implemented in the 1960s, and involved fishing triangular clusters of stations, with clusters located on a grid (IPHC 2012). Coverage was limited in most years and was generally restricted to IPHC Regulatory Areas 2B through 3B. The modern FISS design, based on a grid with 10 nmi (18.5 km) spacing, was introduced in 1998, and over the subsequent two years was expanded to include annual coverage in parts of all IPHC Regulatory Areas within the depth ranges of 20-275 fathoms (37-503 m) in the Gulf of Alaska and Aleutian Islands, and 75-275 fathoms (137-503 m) in the Bering Sea (IPHC 2012). Annually-fished stations were added around islands in the Bering Sea in 2006, and in the same year, a less dense grid of paired stations was fished in shallower waters of the southeastern Bering Sea, providing data for a calibration with data from the annual National Marine Fishery Service (NMFS) bottom trawl survey (Webster et al. 2020).

Through examination of commercial logbook data and information from other sources, it became clear by 2010 that the historical FISS design had gaps in coverage of Pacific halibut habitat that had the potential to lead to bias in estimates derived from its data. These gaps included deep and shallow waters outside the FISS depth range (0-20 fathoms and 275-400 fathoms), and unsurveyed stations on the 10 nmi grid within the 20-275 fathom depth range within each IPHC Regulatory Area. This led the IPHC Secretariat to propose expanding the FISS to provide coverage of the unsurveyed habitat with United States and Canadian waters. In 2011 a pilot expansion was undertaken in IPHC Regulatory Area 2A, with stations on the 10 nmi grid added to deep (275-400 fathoms) and shallow (10-20 fathoms) waters, the Salish Sea, and other, smaller gaps in coverage. (The 10 fathom limit in shallow waters was due to logistical difficulties in standardized fishing of longline gear in shallower waters.) A second expansion in IPHC Regulatory Area 2A was completed in 2013, with a pilot California survey between latitudes of 40-42°N.

The full expansion program began in 2014 and continued through 2019, resulting in the sampling of the entire FISS design of 1890 stations in the shortest time logistically possible. The FISS expansion program allowed us to build a consistent and complete picture of Pacific halibut density throughout its range in Convention waters. Sampling the full FISS design has reduced bias as noted above, and, in conjunction with space-time modelling of survey data (see below), has improved precision and fully quantified the uncertainty associated with estimates based on partial annual sampling of the species range. It has also provided us with a complete set of observations over the full FISS design (Figure 1) from which an optimal subset of stations can be selected when devising annual FISS designs. This station selection process began in 2019 for the 2020 FISS and continues with the current review of design proposals for 2024-26. Note that in the Bering Sea, the full FISS design does not provide complete spatial coverage, and FISS data are augmented with calibrated data from National Marine Fisheries Service (NMFS) and Alaska Department of Fish and Game (ADFG) trawl surveys (stations can vary by year – 2019 designs are shown in Figure 1). Both supplementary surveys have been conducted approximately annually in recent years.

Space-time modelling

In 2016, a space-time modelling approach was introduced to estimate time series of weight and numbers-per-unit-effort (WPUE and NPUE), and to estimate the stock distribution of Pacific halibut among IPHC Regulatory Areas. This represented an improvement over the largely empirical approach used previously, as it made use of additional information within the survey data regarding the degree of spatial and temporal of Pacific halibut density, along with information from covariates such as depth (see Webster 2016, 2017). It also allowed a more complete of accounting of uncertainty; for example, prior to the use of space-time modelling, uncertainty due to unsurveyed regions in each year was ignored in the estimation. Prior to the application of the space-time modelling, these unsampled regions were either filled in using independently estimated scalar calibrations (if fished at least once), or catch-rates at unsampled stations were assumed to be equal to the mean for the entire Regulatory Area. The IPHC's Scientific Review Board (SRB) has provided supportive reviews of the space-time modelling approach (e.g., IPHC-2018-SRB013-R), and the methods have been published in a peer-review journal (Webster et al. 2020). Similar geostatistical models are now routinely used to standardize fishery-independent trawl surveys for groundfish on the West Coast of the U.S. and in Alaskan waters (e.g., Thorson et al. 2015 and Thorson 2019). The IPHC space-time models are fitted through the R-INLA package in the R software.

FISS design objectives

The primary purpose of the annual FISS is to sample Pacific halibut to provide data for the stock assessment (abundance indices, biological data) and estimates of stock distribution for use in the IPHC's management procedure. The priority of the current rationalized FISS is therefore to maintain or enhance data quality (precision and bias) by establishing baseline sampling requirements in terms of station count, station distribution and skates per station. Potential considerations that could add to or modify the design are logistics and cost (secondary design layer), and FISS removals (impact on the stock), data collection assistance for other agencies, and IPHC policies (tertiary design layer). These priorities are outlined in Table 1.

Table 1. Prioritization of FISS objectives and corresponding design layers.

Priority	Objective	Design Layer
Primary	Sample Pacific halibut for stock assessment and stock distribution estimation	Minimum sampling requirements in terms of: • Station distribution • Station count • Skates per station
Secondary	Long term revenue neutrality	Logistics and cost: operational feasibility and cost/revenue neutrality
Tertiary	Minimize removals, and assist others where feasible on a cost-recovery basis.	Removals: minimize impact on the stock while meeting primary priority Assist: assist others to collect data on a cost-recovery basis IPHC policies: ad-hoc decisions of the Commission regarding the FISS design

Design review and finalisation process

Since completion of the FISS expansions, a review process has been developed for annual FISS designs created according to the above objectives:

- The Secretariat presents design proposals based only on primary objectives (Table 1) to the SRB for three subsequent years at the June meeting (recognizing that data from the current summer FISS will not be available for analysis prior to the September SRB meeting);
- These design proposals, revised (if necessary) based on June SRB input, are then reviewed by Commissioners at the September work meeting;
- At their September meeting, the SRB reviews revisions to the design proposals made to account for secondary and tertiary objectives

Following the review process, designs may be further modified to account for any updates based on secondary and tertiary objectives before being finalized during the Interim and Annual meetings and the period prior to implementation:

- Presentation of FISS designs for 'endorsement' by the Commission occurs at the November Interim Meeting;
- Ad hoc modifications to the design for the current year (due to unforeseen issues arising) are possible at the Annual Meeting;
- The endorsed design for current year is then modified (if necessary) to account for any additional tertiary objectives prior to summer implementation (February-April).

Consultation with industry and stakeholders occurs throughout the FISS planning process, at the Research Advisory Board meeting (late November) and particularly in finalizing design details as part of the FISS charter bid process, when stations can be added and other adjustments made to provide for improved logistical efficiency. We also note the opportunities for stakeholder input during public meetings (Interim and Annual Meetings).

Note that while the review process examines designs for the next three years, revisions to designs for the second and third years are expected during subsequent review periods as additional data are collected. Having design proposals available for three years instead of the next year only assists the IPHC with medium-term planning of the FISS, and allows reviewers (SRB, IPHC Commissioners) and stakeholders to see more clearly the planning process for sampling the entire FISS footprint over multiple years. Extending the proposed designs beyond three years is not considered worthwhile, as we expect further evaluation undertaken following collection of data during the one to three-year period to influence design choices for subsequent years.

PROPOSED DESIGNS FOR 2024-26

The designs proposed for 2024-26 (Figures 2 to 4) 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, historically a logistically feasible footprint for the annual FISS.

In 2022, designs for 2024-25 were also endorsed subject to later revision (IPHC-2022-IM098-R). However, the original proposed design for 2023 (IPHC-2022-SRB020-05) was not endorsed by the Commissioners. To meet the secondary objective of long-term revenue neutrality, they instead endorsed a spatially-reduced design with minimal sampling in IPHC Regulatory Areas 2A, 4A and 4B (16 FISS grid station per area), and no sampling in IPHC Regulatory Area 4CDE (IPHC-2022-IM098-R). For this reason, almost all stations in IPHC Regulatory Areas 2A, 4A, 4B and 4CDE that were proposed but not endorsed for 2023 are again proposed for the 2024 FISS. The one exception is in IPHC Regulatory Area 4A, where the sample timing of two subareas has been switched.

Thus, the following changes from the previous 2024 proposal presented at SRB020 have been made (see Figure 2):

- IPHC Regulatory Area 2A: Sample the highest-density waters of IPHC Regulatory 2A in northern Washington and central/southern Oregon and add the moderate density waters

of southern Washington/northern Oregon and northern California **(original 2023 SRB proposal)**.
- IPHC Regulatory Area 4A: Sample both the higher-density western subarea of IPHC Regulatory Area 4A and the lower-density southeastern subarea in 2024 **(previous 2025 SRB proposal)**.
- IPHC Regulatory Area 4B: Sample the high-density eastern subarea and the western subarea in 2024 **(original 2023 SRB proposal)**.

One change was made to last year's 2025 proposal (Figure 3):

- IPHC Regulatory Area 4A: Sample both the higher-density western subarea of IPHC Regulatory Area 4A and the medium-density Bering Sea shelf subarea in 2025 **(previous 2023 SRB proposal)**.

The 2026 proposal (Figure 4) includes sampling in the high-density subareas of IPHC Regulatory Areas 2A, 4A, and 4B, along with full sampling of FISS stations in IPHC Area 4CDE.

Stations in the moderate-density waters of IPHC Regulatory 2A proposed for 2024 sampling have not been sampled since 2017 (California) or 2019 (WA/OR), and thus 2024 sampling will occur 5-7 years since they were last sampled. We have also received anecdotal reports of increasing recreational catch rates in northern California, providing additional motivation for sampling in those waters.

A review of commercial catch data shows moderate catch rates in recent years in southeast IPHC Regulatory 4A. With these stations last sampled in 2019, sampling in 2024 will provide an updated understanding of Pacific halibut density in this subarea and inform future decisions on sampling frequency in IPHC Regulatory Area 4A. Note that several stations on the IPHC Regulatory Area 4A shelf edge overlap the NMFS bottom trawl survey (in purple in Figure 3), and are not proposed for FISS sampling in the foreseeable future.

In the most recent surveys of IPHC Regulatory Area 4B, the eastern subarea had by far the highest catch rates and is the priority for frequent sampling. The western and central subareas were approved for sampling in 2022, but only the central subarea was sampled due to a lack of charter vessel bids for the western subarea. Thus, the western subarea has been added to the 2024 proposal to reduce the risk of bias due to the potential for otherwise unmonitored changes in density.

Following this three-year period, the only remaining waters unsampled since FISS rationalization began in 2020 will be:

- Zero-to-low density waters in IPHC Regulatory Area 2A comprising deep (>275 ftm) and shallow (<20 ftm) stations and northern California south of 40°N (sampled comprehensively in 2017), and low-density waters of the Salish Sea (previously sampled in 2018).
- Near-zero density waters in the Salish Sea in IPHC Regulatory Area 2B (sampled in 2018 only).

We anticipate proposing these stations for sampling in 2027-28, 10-11 years after previous FISS sampling, so that the entire 1890-station FISS grid will have been fished from 2020-28.

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. Ongoing oceanographic (e.g., sea ice and bottom temperatures) and ecosystem (e.g., prey species abundance and distribution) changes in this Regulatory Area highlight the potential for changes in the biology and abundance of Pacific halibut in the Bering Sea. Despite prioritizing comprehensive sampling of this Regulatory Area in 2020-22, in each year logistical challenges have precluded achieving the full design in a single year, although it was fished over in two parts over the 2021-22 period. Therefore, it is retained throughout the current three-year plan, to be re-evaluated when and if sampling is successful.

While the proposed designs continue to rely on randomized subsampling of stations within the core IPHC Regulatory Areas (2B, 2C, 3A and 3B) and logistically efficient subarea designs elsewhere, other designs have been considered and remain as options (Webster 2021, Appendix A). Thus, we invite the SRB's discussion of alternative designs such as randomized cluster sampling or the use of subarea sampling in the core areas as more operationally efficient alternatives.

FISS DESIGN EVALUATION

Precision targets

In order to maintain the quality of the estimates used for the assessment and for estimating stock distribution, the IPHC Secretariat has set a target range of less than 15% for the coefficient of variation (CV) of mean O32 and all sizes WPUE for all IPHC Regulatory Areas. We also established precision targets of IPHC Biological Regions and a coastwide target (IPHC-2020-AM096-07), but achievement of the Regulatory Area targets has resulted in meeting targets for the larger geographic units.

We examined the effect of subsampling the FISS stations for a management unit on precision as follows:

- Where a randomized design is not used, identify logistically efficient subareas within each management unit and select priorities for future sampling.
- Generate simulated data for all FISS stations based on the output from the most recent space-time modelling.
- Fit space-time models to the observed data series augmented with 4 additional years of simulated data (current calendar year plus three years for proposed designs), where the FISS designs reflect the sampling priorities identified above.
- Project precision estimates and quantify bias potential of proposed designs.

At the time of writing, it has become clear that the endorsed FISS design in IPHC Areas 4A and 4B did not receive viable bids, and our analysis therefore assumes a design with no 2023 sampling in these areas.

Table 2 shows projected CVs following completion of the proposed 2024-26 FISS designs together with the expected 2023 FISS sampling. With these designs, we are projected to maintain CVs within the target range in all years. Estimates from the terminal year are most informative for management decisions, but they also typically have the largest CVs (all else being equal; these are then reduced in subsequent years as observations are available in both adjacent years, due to the temporal correlation). The final column in Table 2 shows the CV projections immediately following the 2024 FISS, which are also within the target range.

Table 2. Projected CVs (%) for 2023-26 for O32 WPUE estimated after completion of the proposed 2024-26 FISS designs, and (final column) after completion of the proposed 2024 FISS design only.

Reg. Area	2023	2024	2025	2026	**2024** (After 2024 FISS)
2A	12	11	12	14	12
4A	14	9	9	12	10
4B	16	9	10	12	9

Reducing the potential for bias
In IPHC Regulatory Areas in which stations are not subsampled randomly (IPHC Regulatory Areas 2A, 4A and 4B), sampling a subset of the full data frame in any area or region brings with it the potential for bias. This is due to trends in the unsurveyed portion of a management unit (Regulatory Area or Biological Region) potentially differing from those in the surveyed portion. Therefore, we also examine how frequently part of an area (subarea) should be surveyed in order to reduce the likelihood of appreciable bias. For this, we use a threshold of a 10% absolute change in biomass percentage: our goal is to sample frequently enough so that each subarea's biomass proportion has a low chance of changing by more than 10% between successive surveys of the subarea. (The 10% value was chosen to provide a threshold that was meaningful in terms of bias without either resulting in large unmonitored change - e.g., 20% or more - or change so small it would require annual sampling of all stations – e.g., 5% or less - to detect reliably.

At SRB021, we presented a new method for quantifying the risk of bias due to not sampling a particular subregion of an IPHC Regulatory Area for a specified number of years (see IPHC-2022-SRB021-06). The method uses samples from the posterior predictive distribution from the space-time modelling to estimate the probability of at least a 10% absolute change in a subarea's biomass proportion over a period of time equal to the number of years since it was last sampled. We denote this probability by q_{sy}, where s is the subarea and y is the number of years since last sampling. q_{sy} is estimated for all possible years in the historical time series, but greatest interest is in the most recent values, which are most relevant for current FISS design proposals.

IPHC REGULATORY AREA 2A:

Figure 5 shows q_{s2} by year for all three subareas of IPHC Regulatory Areas 2A. Subarea 1 is the one with greatest Pacific halibut density, and by 2024 it will have been largely unsampled for just two years (hence y=2 in the q subscript). The subarea 1 plot (top panel) shows a modest risk ($q_{1,2}$≈20-30%) of two-year changes of at least 10% in biomass proportion for this area over the three most recent years. We could accept this risk and not propose sampling subarea 1, but as it comprises the core of the area's stock, it is the most important area to sample to monitor the overall trend and maintain high precision.

Subarea 2 was last sampled in 2019 (WA/OR) and 2017 (northern CA). Using the longest of these intervals (y=7 years) q_{s7} is shown in Figure 6. Values of $q_{2,7}$ (middle panel) are close to 50% in the most recent three years, meaning the risk of a change of at least 10% in biomass proportion is relatively high for this subarea over a seven-year period. We considered this risk when including this subarea in our proposal for 2024. Subarea 3 also has been largely unsampled since 2017, but the risk of large change over a seven-year period remains low (bottom panel).

Subarea 3 was last sampled in 2018 (Salish Sea in WA) and 2017 (southern CA stations), and is not proposed for sampling earlier than 2027. The values of $q_{3,9}$ (i.e., subarea 3 in 2026, nine years since 2017) are 20-25% for the most recent years, and we regard this as acceptable for this historically very low-density subarea.

IPHC REGULATORY AREA 4A:

Subarea 1 was last sampled in 2022, so the proposed sampling in 2024 represents a two-year period since previous sampling. Figure 7 shows very high risk that this area has changed by 10% or more in terms of biomass proportion over a two-year period in recent years, and is a high priority for sampling in 2024 (and indeed, we have been proposing it for annual sampling).

Subarea 2 also has increasing risk of large changes over two years, yet the proposed 2024 sampling represents five years since it was last sampled. If we consider the risk of at least a 10% change over five years, this value is almost 90% for 2022 (Figure 8). This very high risk of unmonitored change is the reason that sampling subarea 2 has been brought forward to 2024. Subarea 3, on the other hand, shows relatively low risk of such a change over a five-year period. Subarea 4 represents a small part of IPHC Regulatory Area 4A with annual coverage provided by the NMFS trawl survey and is not at present considered for future FISS sampling.

IPHC Regulatory Area 4B:

Subarea 3 (eastern Aleutians) has been the highest-density component of IPHC Regulatory Area 4B in recent years, and it was last sampled (albeit incompletely) in 2021. The risk for this subarea over a three-year period is 20-30% in the most recent years (Figure 9), but as this subarea is the core of the IPHC Regulatory Area 4B's stock, we continue proposing it for near-annual sampling to maintain precise estimates of density indices.

Subarea 2 was sampled in the 2022 and is not proposed for sampling in 2024-26. Figure 10 (middle panel) shows a low risk of at least a 10% change in biomass proportion for this area over a four-year period.

The western Aleutian Islands make up subarea 1 of IPHC Regulatory 4B, and these have not been sampled since 2019. Sampling in 2024 would mean five years since subarea 1 was last sampled. Due to increasing uncertainty in this subarea, Figure 11 (top panel) shows the most recent estimates of risk to be around 35% that this subarea's biomass proportion has changed by at least 10% over a five-year period.

Post-sampling evaluation for 2022

The evaluation of precision of proposed designs above is based on using simulated sample data generated under the fitted space-time model as data for future years. If observed data are more (or less) variable than those generated under the model, actual estimates of precision may differ from those projected from models making use of the generated data. Table 4 compares the estimates of the CV for mean O32 WPUE for the approved 2022 design based on using simulated data for 2022 and estimated from fitting the models including observed 2022 data. Only the three areas using subarea designs are included, as these are the only areas for which the design options under consideration have a strong influence on precision.

Table 4. Comparison of projected (in 2021) and estimated CVs (%) for O32 WPUE for 2022 by IPHC Regulatory Area.

Regulatory Area	2022 projected CV (%)	2022 estimated CV (%)
2A	14	16
4A	10	14
4B	14	19

Projected CVs in all three areas were lower than those estimated once the observed 2022 data were incorporated into the modelling. The projections for 2022 were made prior to the start of the 2021 FISS. As noted in IPHC-2022-SRB020-05, the 2021 FISS in IPHC Regulatory Areas 4A and 4B did not complete all planned stations due to logistical issues. In both areas, the unfished stations covered some of the most productive habitat in recent years. This affected both the projections for 2021 and 2022, which assumed a complete survey. Further, the western subregion of IPHC Regulatory Area 4B was planned to be sampled in 2022 but due to lack of viable charter bids, the FISS did not sample there.

The difference between projected and estimated CVs in IPHC Regulatory Area 2A was relatively small. Last year (IPHC-2022-SRB020-05) we noted an apparent increase in the underlying variability of Pacific halibut density in this area. The 2022 data did not show evidence for higher variability than other recent years, and the combined effect of 2021 and 2022 data was an estimated CV that was closer to the projection than last year.

Projected CVs were not calculated for other IPHC Regulatory Areas as they are not at present used to evaluate design proposals. Estimated CVs for O32 WPUE for the core IPHC Regulatory Areas of 2B, 2C, and 3A were all 6% in 2022, with a CV of 10% in IPHC Regulatory 4CDE. The CV for IPHC Regulatory Area 3B was 14%, but this was anomalous as it was due to unforeseen logistical issues leaving many stations unsampled. Typically, the CV is around 7% in this area.

CONSIDERATION OF COST

Ideally, the FISS design would be based only on scientific needs. However, some Regulatory Areas are consistently more expensive to sample than others, so for these the efficient subarea designs were developed. The purpose of factoring in cost was to provide a statistically efficient and logistically feasible design for consideration by the Commission. During the Interim and Annual Meetings and subsequent discussions, cost, logistics and tertiary considerations (Table

1) are also factored in developing the final design for implementation in the current year. It was anticipated that under most circumstances, cost considerations can be addressed by adding stations to the minimum design proposed in this report. In particular, the FISS is funded by sales of captured fish and is intended to have long-term revenue neutrality, meaning that any design must also be evaluated in terms of the following factors:

- Expected catch of Pacific halibut
- Expected Pacific halibut sale price
- Charter vessel costs, including relative costs per skate and per station
- Bait costs
- IPHC Secretariat administrative costs

Balancing these factors may result in modifications to the design such as increasing sampling effort in high-density regions and decreasing effort in low density regions. At present, with stocks near historic lows and extremely low prices for fish sales, the current funding model may require that some low-density habitat be omitted from the design entirely (as occurred in 2020 and 2023). This has implications for data quality, particularly if such reductions in effort relative to proposed designs continue over multiple years. In the 2021 and 2022 surveys, it was sufficient to include additional stations in core IPHC Regulatory Areas to generate a revenue-neutral coastwide design and so there were no planned reductions in coverage. The 2023 FISS balances the primary science objective with the secondary objective of long-term revenue neutrality by greatly reducing sampling outside of the core areas of the stock (IPHC-2022-IM098-R).

RECOMMENDATIONS

That the SRB:

1) **NOTE** paper IPHC-2023-SRB022-06 that provides background on and a discussion of the IPHC fishery-independent setline survey design proposals for the 2024-26 period;
2) **ENDORSE** the 2024 FISS design as presented in Figure 2, and
3) Provisionally **ENDORSE** the 2025-26 designs (Figures 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.

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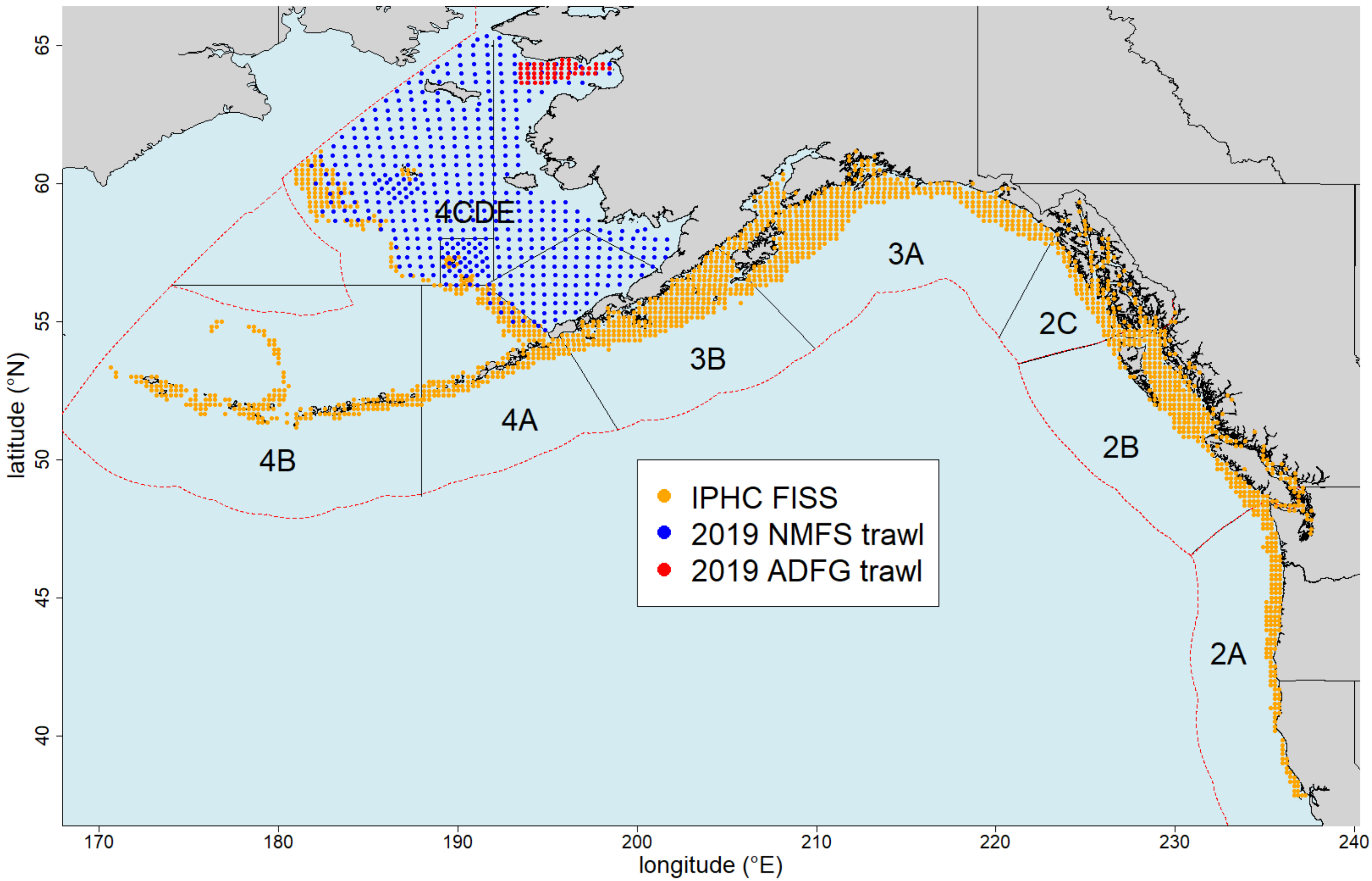

Figure 1. Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs, and other colours representing trawl stations from 2019 NMFS and ADFG surveys used to provide complementary data for Bering Sea modelling.

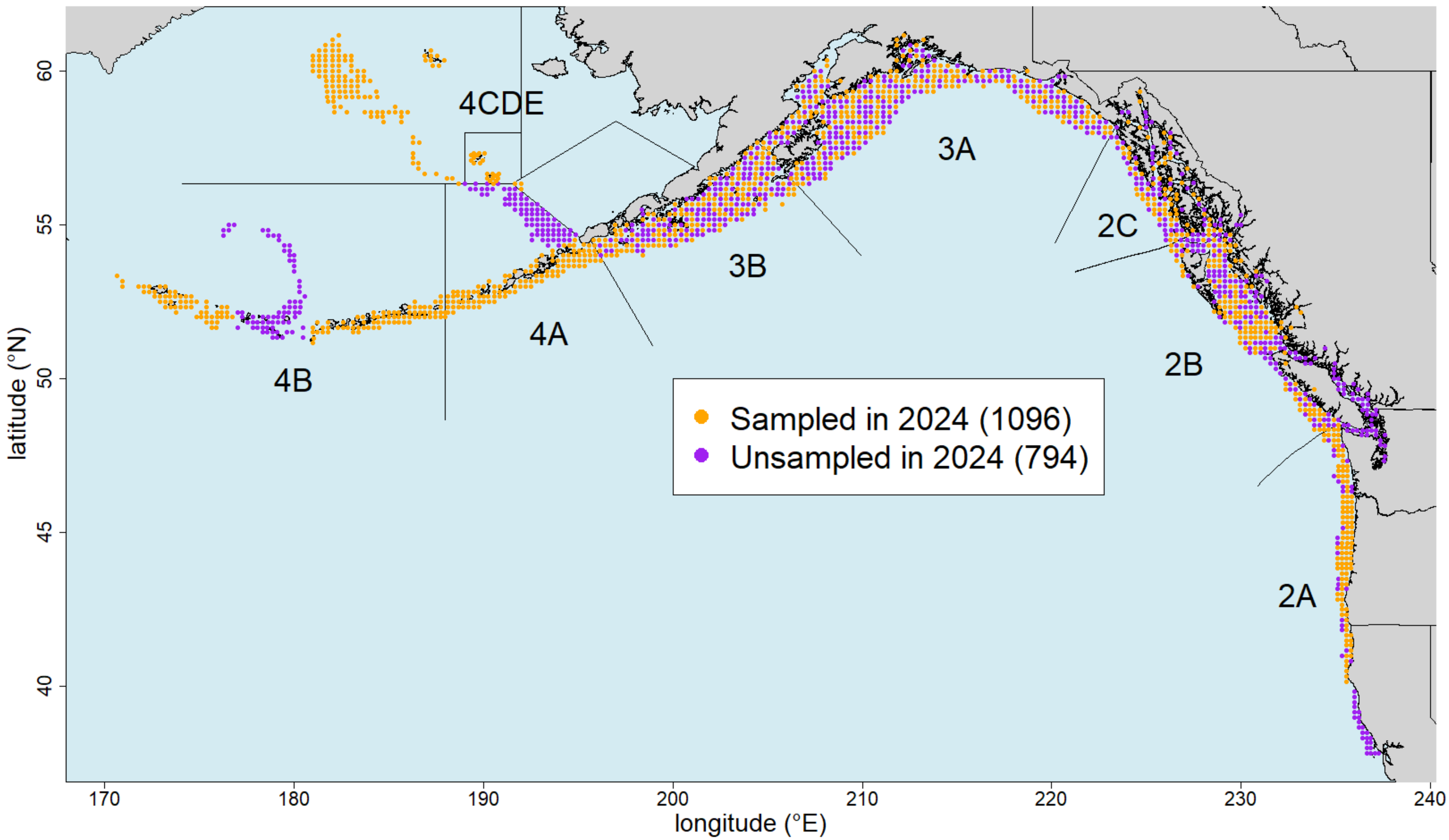

Figure 2. Proposed minimum FISS design in 2024 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

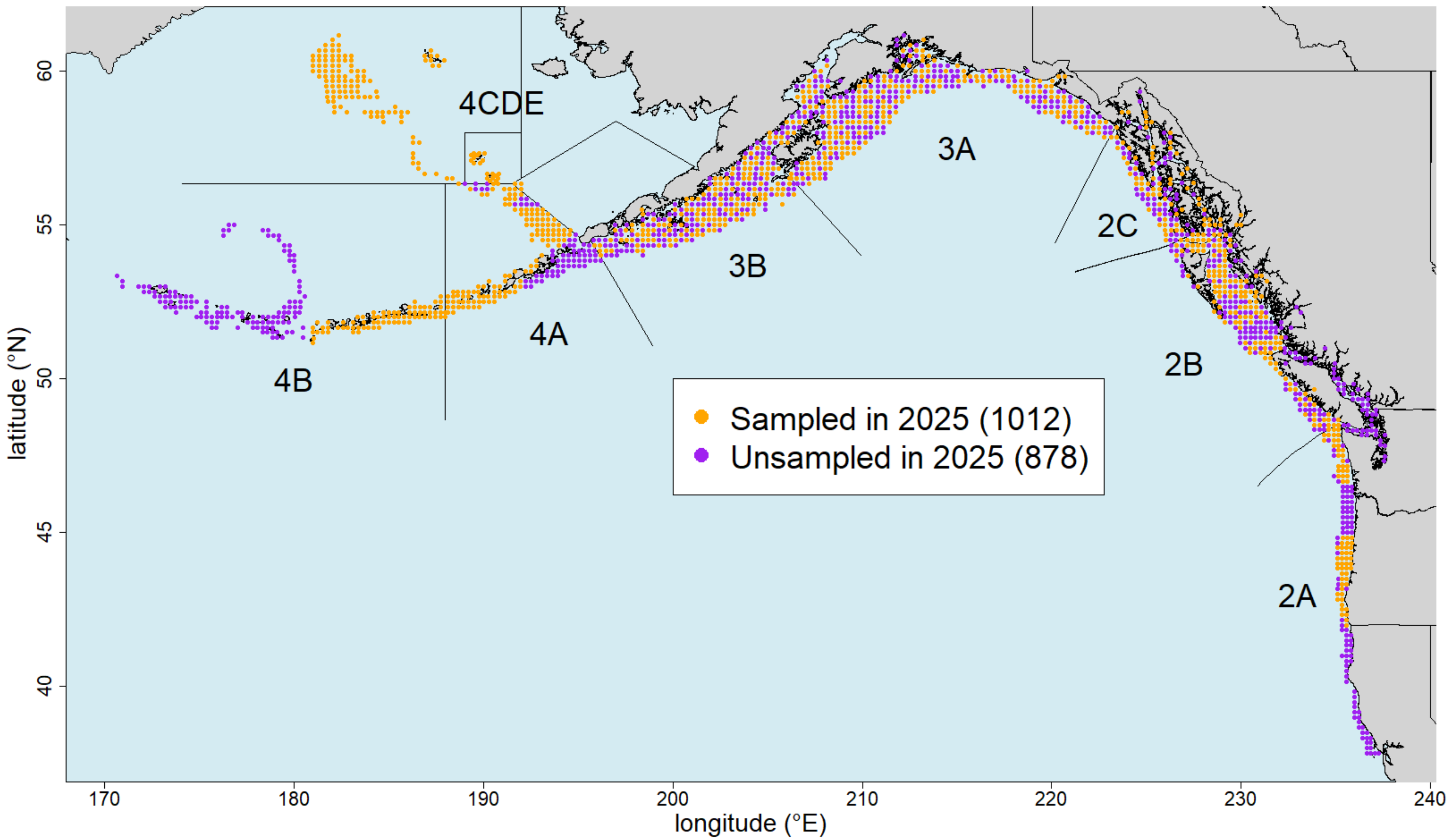

Figure 3. Proposed minimum FISS design in 2025 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

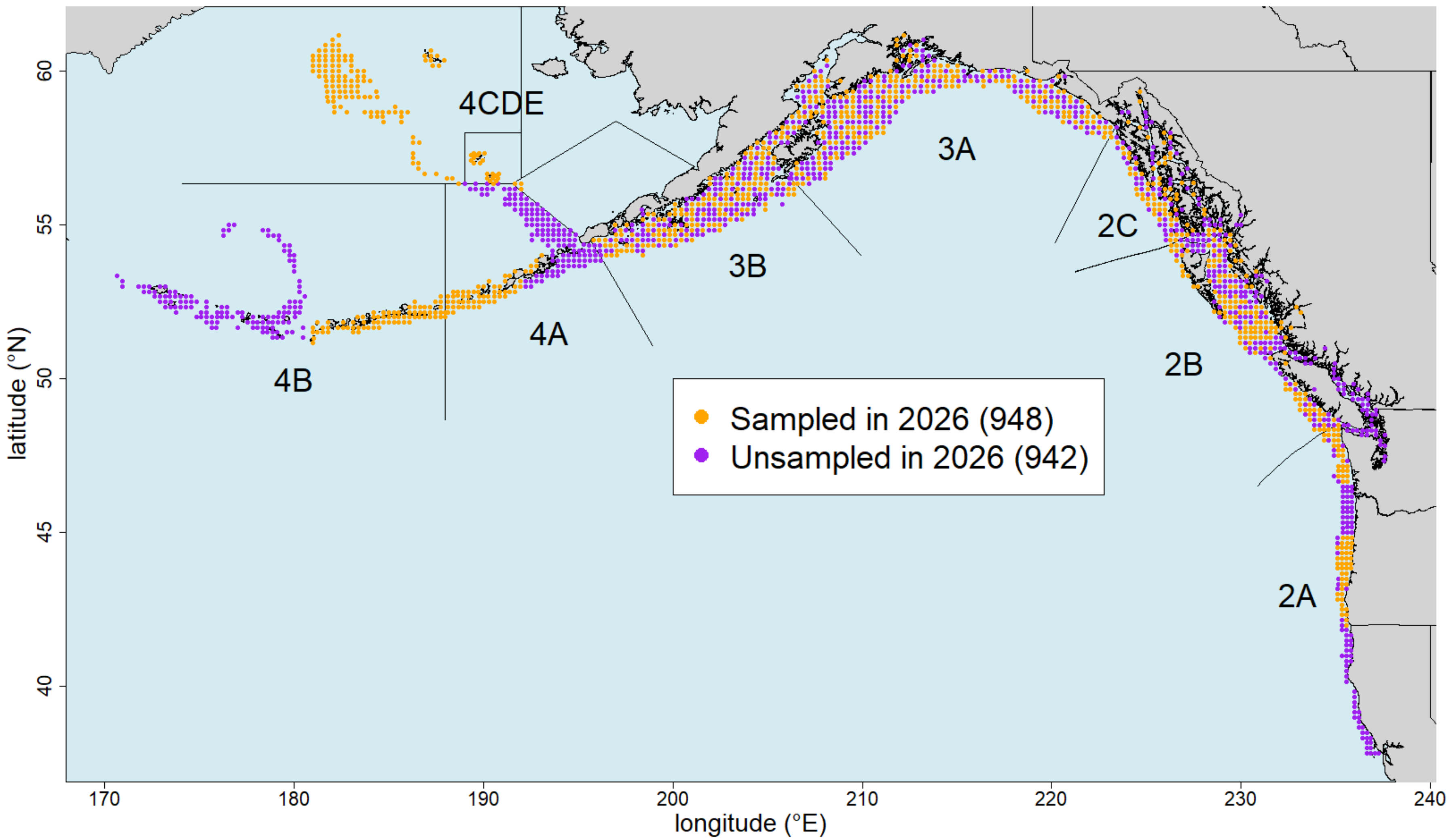

Figure 4. Proposed minimum FISS design in 2026 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

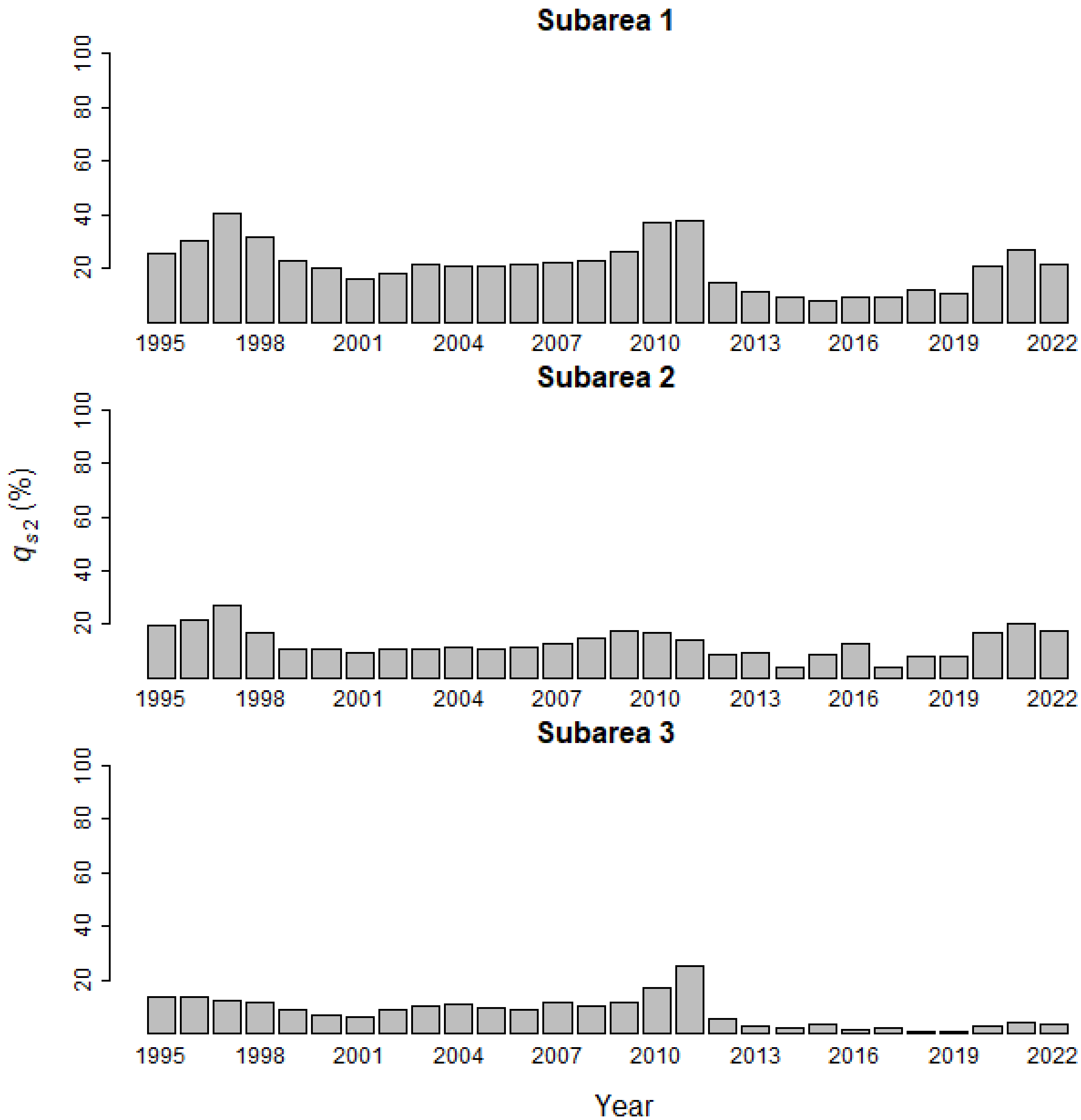

Figure 5. Risk (q_{s2}, %) of at least a 10% change in biomass proportion over the last 2 years for IPHC Regulatory 2A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

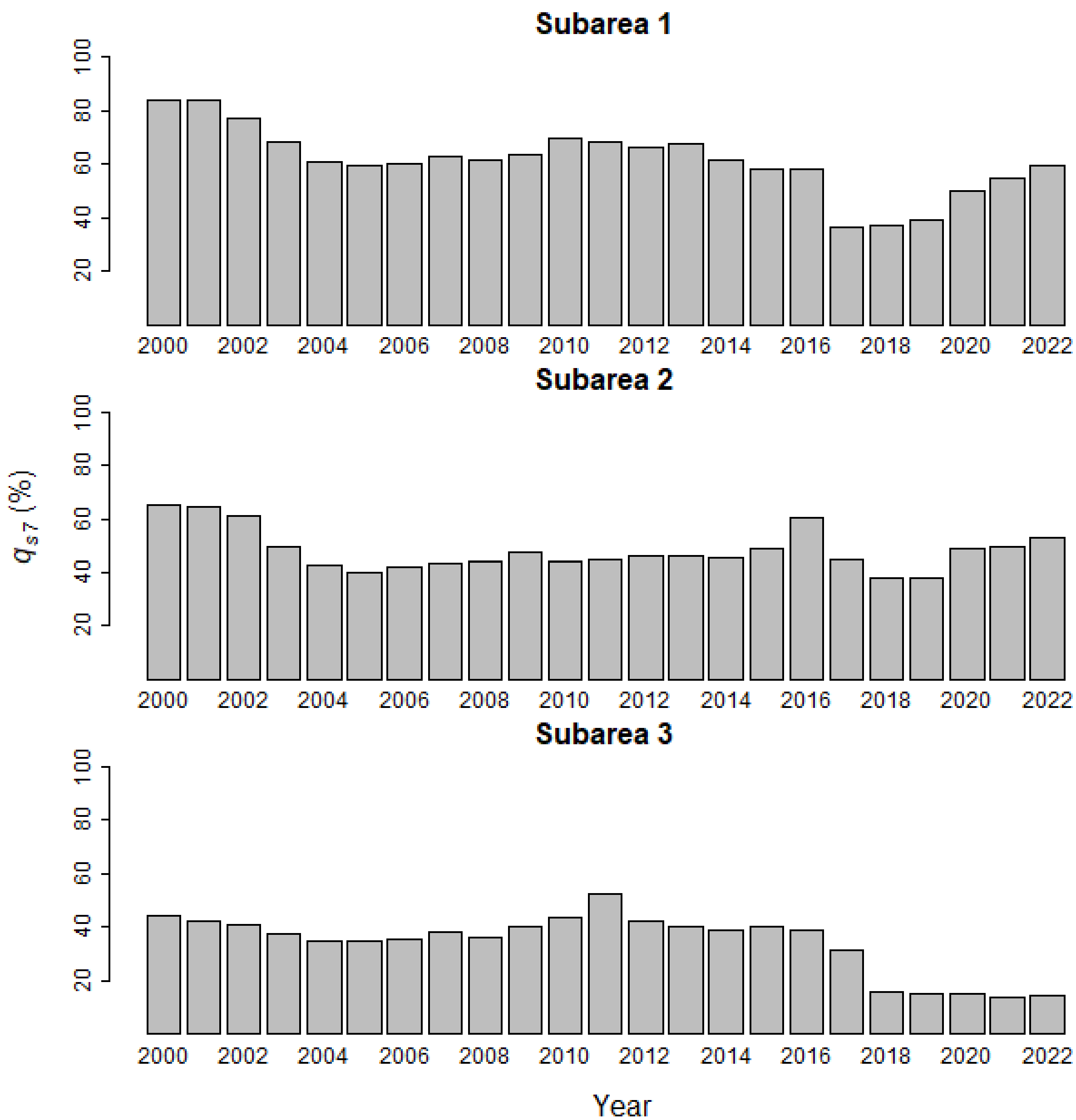

Figure 6. Risk (q_{s7}, %) of at least a 10% change in biomass proportion over the last 7 years for IPHC Regulatory 2A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

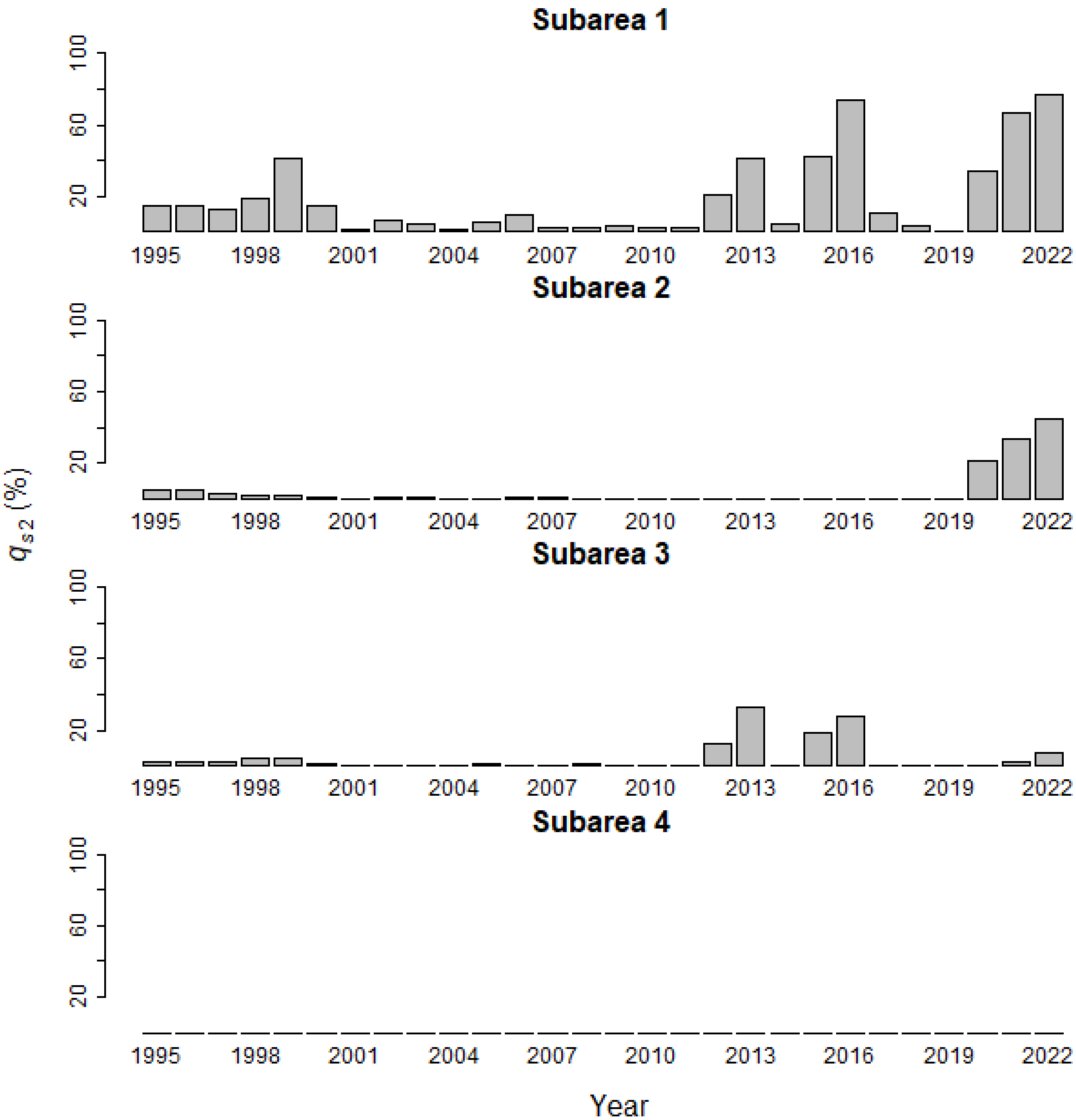

Figure 7. Risk (q_{s2}, %) of at least a 10% change in biomass proportion over the last 2 years for IPHC Regulatory 4A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

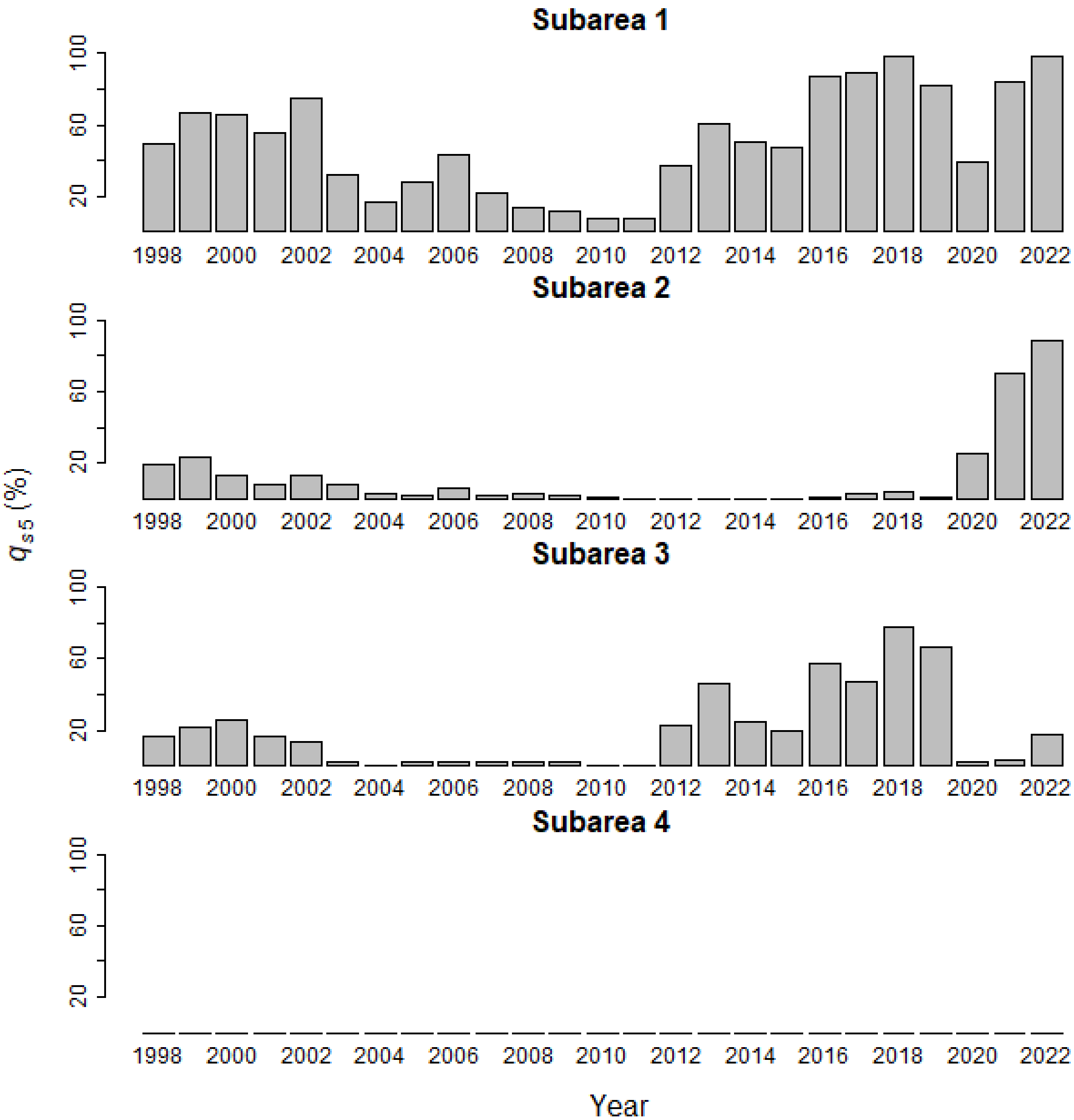

Figure 8. Risk (q_{s5}, %) of at least a 10% change in biomass proportion over the last 5 years for IPHC Regulatory 4A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

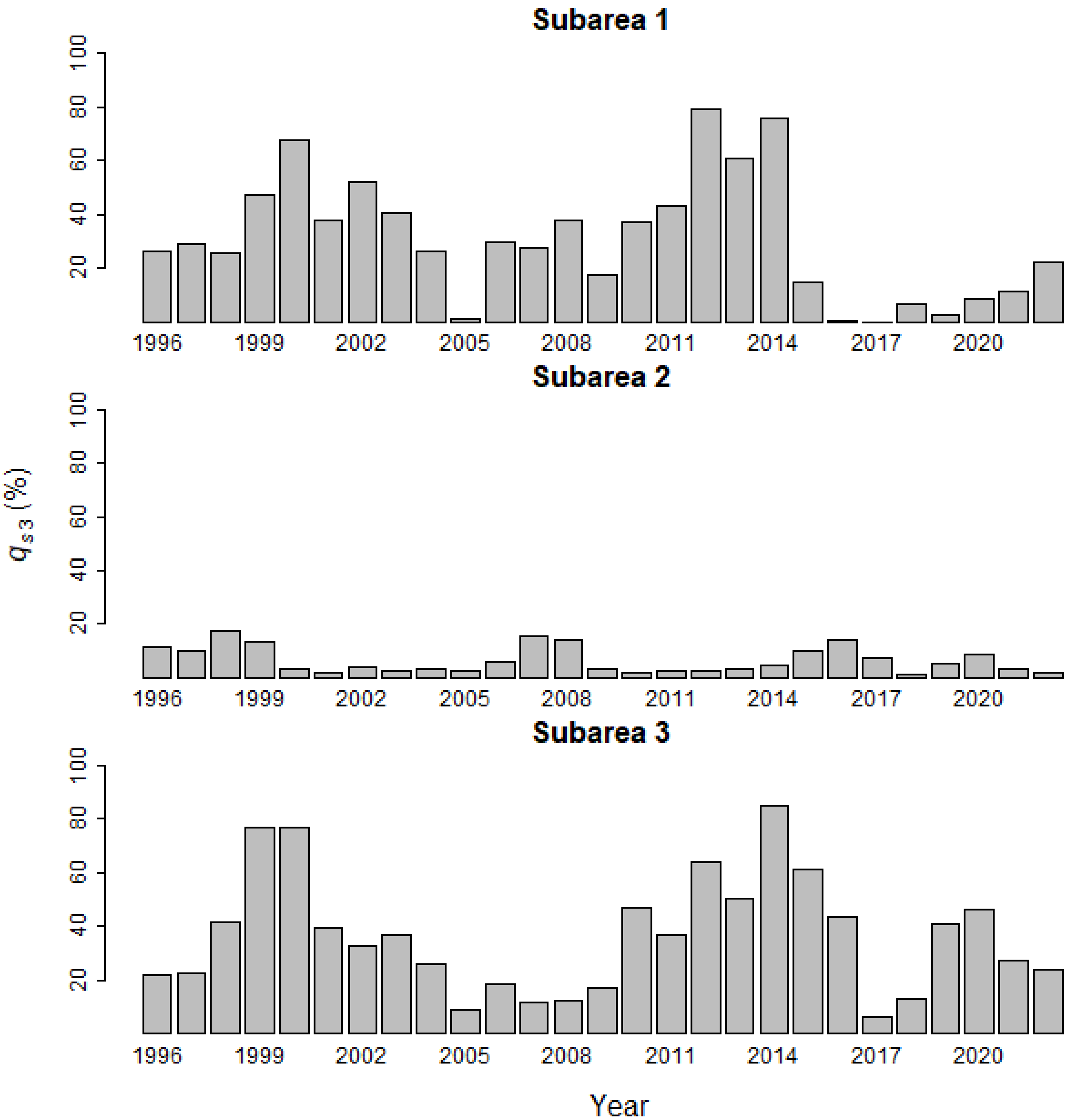

Figure 9. Risk (q_{s3}, %) of at least a 10% change in biomass proportion over the last 3 years for IPHC Regulatory 4B, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

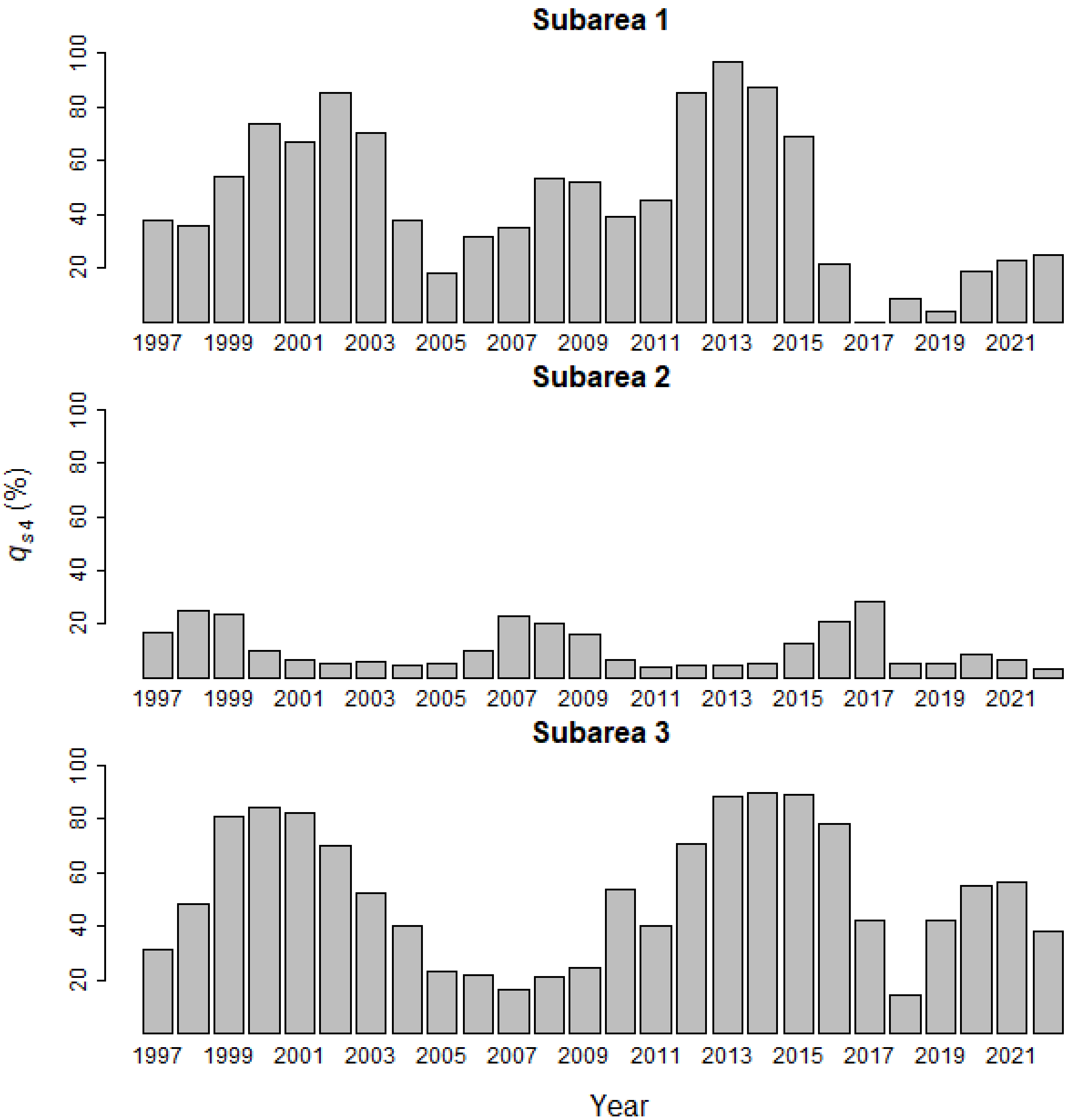

Figure 10. Risk (q_{s4}, %) of at least a 10% change in biomass proportion over the last 4 years for IPHC Regulatory 4B, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

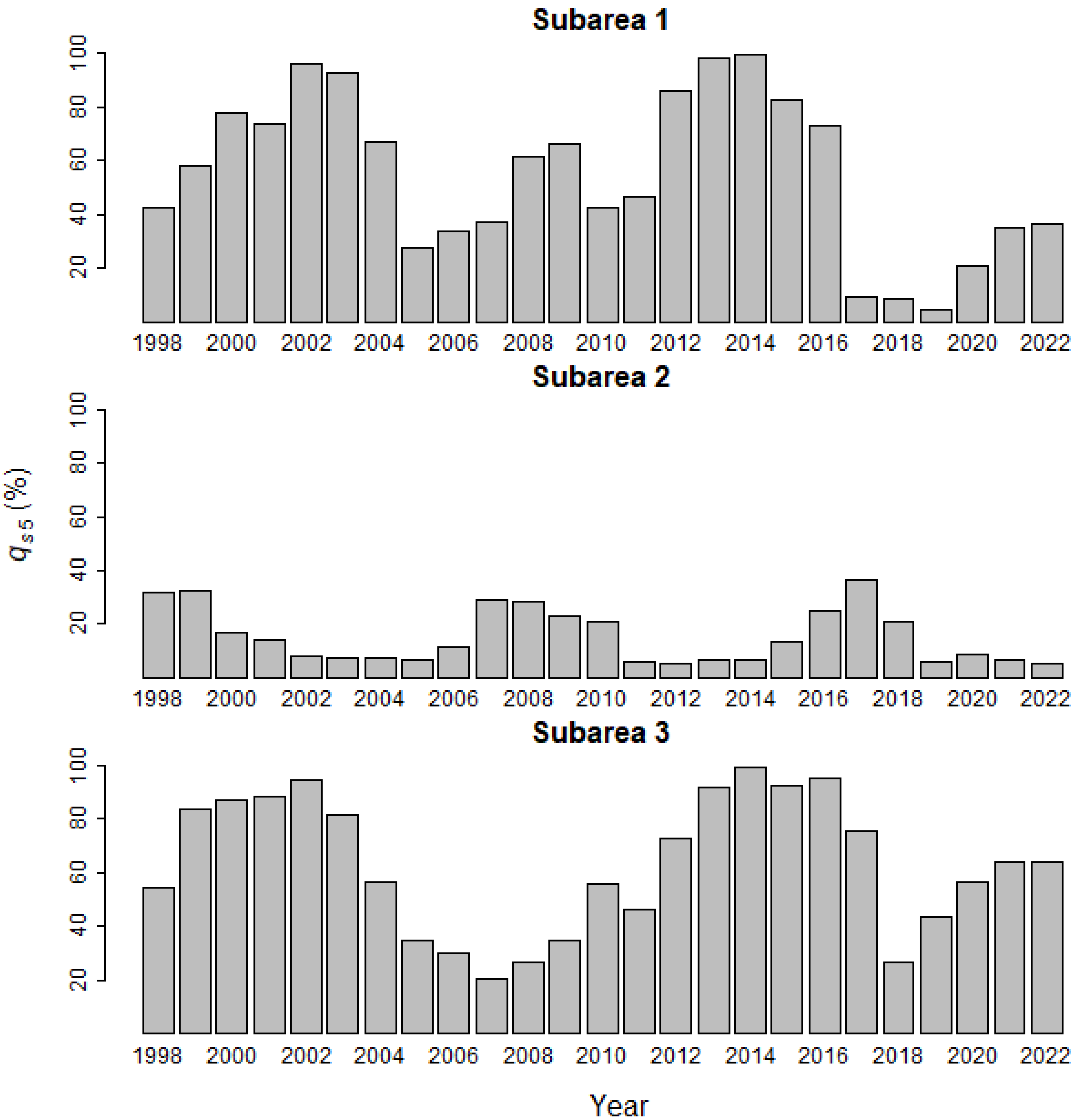

Figure 11. Risk (q_{s5}, %) of at least a 10% change in biomass proportion over the last 5 years for IPHC Regulatory 4B, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

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

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PURPOSE

To provide the Scientific Review Board (SRB) with an update on MSE progress in 2023 and potential tasks for 2023–2025.

BACKGROUND

Evaluations of size limits and multi-year assessments were completed in 2022 and provided at the 99th Session of the IPHC Annual Meeting (AM099) in document IPHC-2023-AM099-13. Some additional simulations for a small set of management procedures (MPs) were performed between MSAB017 (October 2022) and AM099 (January 2023) to reduce Monte Carlo error (e.g, increase the precision of the performance metrics). Specific scenarios have also been simulated that assumed the PDO was always high or always low.

This document describes the results from the additional simulations and outcomes of AM099. Additionally, potential MSE-related tasks for 2023–2025 are presented including further updating the operating model (OM), MPs to investigate, and defining exceptional circumstances.

ADDITIONAL SIMULATIONS FOR AM099

The simulations for MSAB017 and AM099 integrated four individual models in the OM and five distribution procedures. For each model and each distribution procedure, the same set of randomly generated values are used (e.g. future recruitments, weight-at-age, PDO, etc.) This allows for the most direct comparison across management procedures with the smallest number of simulations. However, it does require monitoring of Monte-Carlo error and associated precision of the results, creating a trade-off between the number of MPs and scenarios that can be investigated and the number of replicates for each.

For MSAB017, 500 replicates were performed for a large number of management procedures (see http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-MSAB017/). Therefore, there were 25 replicates for each OM model and distribution procedure combination. This provided an initial comparison of the performance of many MPs, but may be imprecise for some metrics, especially those occurring with low probability.

Therefore, the number of replicates was increased to 1100 (55 for each combination) for a small set of focal MPs to present at AM099 (see http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-AM099/). This small set included three (3) size limits (none, 26-inches, and 32-inches that are labelled MP-A0, MP-A26, and MP-A32, respectively), three biennial assessment options (Table 1) with a 32-inch size limit (labeled MP-Ba32, MP-Bb32, and MP-Bc32), and one option with a triennial assessment (option b in Table 1) and a 32-inch size limit (labelled MP-Tb32). These seven (7) MPs were all projected with an SPR equal to 43% and simulated decision-making variability (only on the distribution of the TCEY). Five of the MPs

(MP-A0, MP-A26, MP-A32, MP-Bb32, and MP-Tb32) were also simulated with no decision-making variability. All results can be viewed on the MSE Explorer for AM099, and some results are presented in IPHC-2023-AM099-13. Some insights are provided here.

Table 1. Three options for setting the TCEY in non-assessment years for the multi-year management procedures.

a. The same TCEY from the previous year for each IPHC Regulatory Area.
b. Updating the coastwide TCEY proportionally to the change in the coastwide FISS O32 WPUE and updating the distribution of the TCEY using FISS results and the applied distribution procedure.
c. Maintaining the same coastwide TCEY as the previous year but updating the distribution of the TCEY using FISS results and the applied distribution procedure.

Focusing on the five MPs and four objectives shown in Table 2, the differences due to increased precision are minor. However, greater differences were observed in long-term performance metrics related to the TCEY (not shown). For example, the long-term median average TCEY for MP-A32 was 72.1 Mlbs with 500 replicates, but was 62.2 Mlbs with 1100 replicates. Overall, the interpretations and comparisons from MSAB017 are valid and consistent with the updated results presented at AM099.

Table 2. Results of five MPs with 500 replicates (MSAB017) and 1100 replicates (AM099). The first two performance metrics (probabilities) are long-term statistics and the second two (TCEY) are short-term (4-14 years).

MP name	**MP-A0**	**MP-A26**	**MP-A32**	**MP-Bb32**	**MP-Tb32**
Assessment Frequency	**Annual**	**Annual**	**Annual**	**Biennial**	**Triennial**
Size Limit	**0**	**26**	**32**	**32**	**32**
Empirical Rule	**–**	**–**	**–**	**b**	**b**
500 replicates					
P(RSB<20%)	PASS	PASS	PASS	PASS	PASS
P(RSB<36%)	0.143	0.143	0.148	0.156	0.225
Median TCEY	60.1	59.8	58.2	58.5	58.4
Median AAV TCEY	18.0%	18.2%	18.5%	19.0%	14.2%
1100 replicates					
P(RSB<20%)	PASS	PASS	PASS	PASS	PASS
P(RSB<36%)	0.174	0.174	0.180	0.164	0.197
Median TCEY	60.5	59.9	58.3	58.5	58.3
Median AAV TCEY	17.2%	17.5%	17.8%	17.0%	14.1%

EFFECTS OF THE PDO ON REFERENCE POINTS AND DISTRIBUTION

Document IPHC-2019-SRB015-11 showed that, for Pacific halibut, biomass-based reference points, such as MSY and B_0, are strongly affected by a change in environmental regime, but relative reference points, such as relative spawning biomass (RSB) and SPR_{MSY}, are similar across regimes. This indicates that a consistent SPR-based management approach is likely robust across different environmental regimes. Analyses presented in this document looking at high and low PDO regimes show similar results, and also allow for the calculation of performance metrics specific to the IPHC MSE.

The median relative spawning biomass (RSB) when fishing at an SPR equal to 43% was similar for the high and low PDO scenarios (Table 3 and Figure 1). However, even though the median was near 36%, there was a higher probability that the RSB was less than 36% for the low PDO scenario. The long-term median TCEY was 18% less for the low PDO scenario and 18% more for the high PDO scenario when compared to the median TCEY for the base simulations that integrated across PDO regime shifts. Short-term median TCEYs were less affected by the PDO. Inter-annual variability in the TCEY was similar across the PDO scenarios.

Table 3. Performance metrics related to primary objectives for scenarios integrating over cycles of PDO (both), always low PDO (Low), and always high PDO (High) with an annual assessment, estimation error, and decision-making variability (MP-A32) and an SPR of 43%. Long-term results are shown for all performance metrics and short-term (4–13 years) results are also shown for fishery-related (TCEY) metrics.

PDO	Both	Low	High
Replicates	1100	1100	1100
Long-Term Metrics			
Median RSB	38.8%	38.3%	39.4%
P(RSB_y<20%)	<0.001	<0.001	<0.001
P(RSB<36%)	0.180	0.231	0.114
Median TCEY	62.21	50.88	73.35
P(any3 change TCEY > 15%)	0.852	0.844	0.832
Median AAV TCEY	16.3%	16.9%	16.4%
Short-term Metrics (4-13 yrs)			
Median TCEY	58.3	56.0	61.7
P(any3 change TCEY > 15%)	0.906	0.895	0.896
Median AAV TCEY	17.8%	17.6%	17.6%

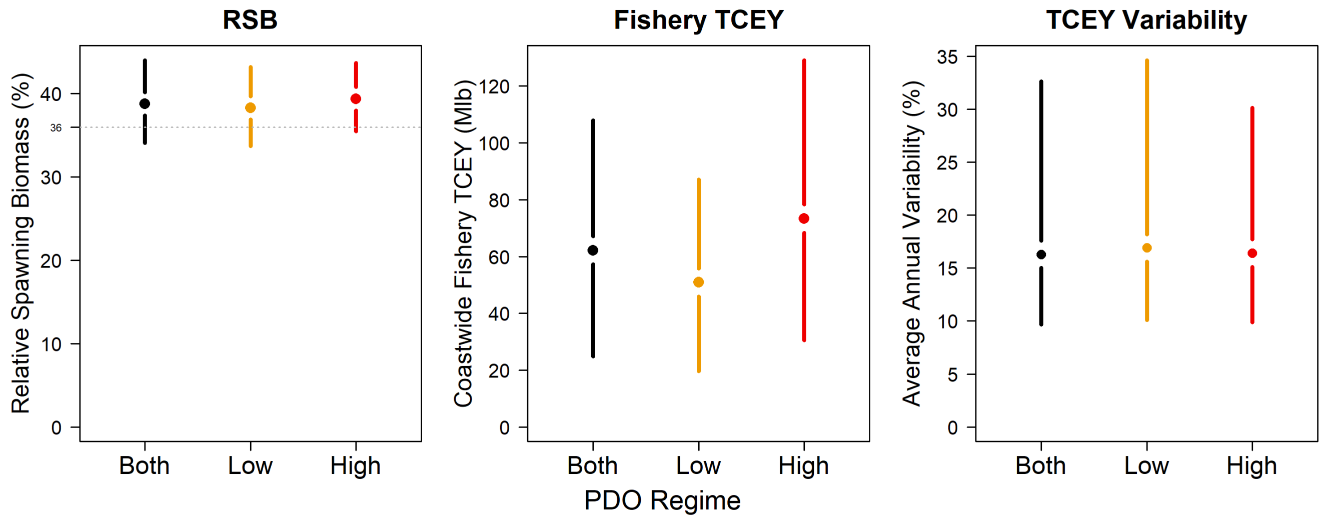

Figure 1. Long-term Relative Spawning Biomass (RSB), TCEY, and AAV for the base simulations integrating over PDO regime shifts (both) and using only low or high PDO scenarios. The reference RSB of 36% is shown as a horizontal dashed line.

The percentage of spawning biomass in each Biological Region is affected by fishing under an SPR-based management procedure integrated over five distribution procedures (Figure 2). The distribution of spawning biomass across the Biological Regions is also affected by the PDO regime because movement, recruitment distribution, and average recruitment are dependent on the PDO regime. Region 2 shows a reduction in the percentage of spawning biomass with fishing, and the low PDO results in a higher percentage. Region 3 shows a slight reduction in the percentage of spawning biomass with fishing and a higher percentage of spawning biomass with a high PDO. Region 4 shows a higher percentage of spawning biomass with fishing and is largely unaffected by the PDO regime. Region 4B has variable results with fishing and across PDO regimes.

Even though we cannot “manage” the PDO regime, it is useful to understand the effects of the PDO regime on the results, allowing for the separation of the effects of fishing from the effects of the environment. For Pacific halibut, the environment may sometimes have a larger effect on the distribution of spawning biomass than fishing does (at an SPR of 43% using the five distribution procedures defined earlier).

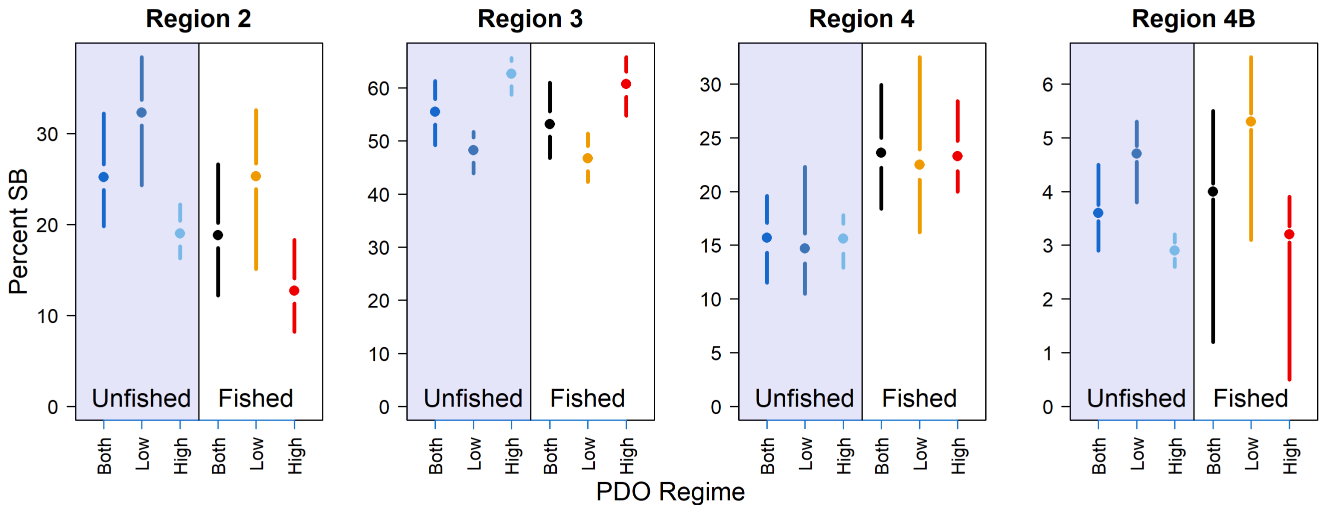

Figure 2. Percentage of spawning biomass in each Biological Region when fished with an SPR of 43% and when not fished. The PDO is modelled with low and high periods in "Both", is persistently low in "Low", and is persistently high in "High".

Outcomes of AM099

The MSE Program of Work for 2021–2023 was completed and delivered at the 99th Session of the IPHC Annual Meeting (AM099; see IPHC-2023-AM099-13). The MSE framework was improved and results investigating size limits and multi-year assessments were presented and evaluated using priority objectives with associated performance metrics.

> **IPHC-2023-AM099-R, para. 76.** The Commission **RECOMMENDED** that for the purpose of a comprehensive and intelligible Harvest Strategy Policy (HSP), four coastwide objectives should be documented within the HSP, in priority order:
>
> a) Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point (B20%) at least 95% of the time.
>
> b) Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point (B36%) 50% or more of the time.
>
> c) Optimise average coastwide TCEY.
>
> d) Limit annual changes in the coastwide TCEY.
>
> **IPHC-2023-AM099-R, para. 77**. The Commission AGREED that the performance metrics associated with the objectives in Paragraph 76 are:
>
> a) P(RSB): Probability that the long-term Relative Spawning Biomass (RSB) is less than the Relative Spawning Biomass Limit, failing if the value is greater than 0.05.
>
> b) P(RSB<36%): Probability that the long-term RSB is less than the Relative Spawning Biomass Reference Point, failing if the value is greater than 0.50.

c) Median TCEY: the median of the short-term average TCEY over a ten-year period, where the short-term is 4-14 years in the future.

d) Median AAV TCEY: the average annual variability of the short-term TCEY determined as the average difference in the TCEY over a ten-year period.

These priority objectives and performance metrics (also presented in Table 4) come from a larger list of objectives which includes objectives specific to Biological Regions and IPHC Regulatory Areas (Appendix A). Objective 2.1 has changed slightly, indicating to maintain the spawning biomass at or above a reference level. This was done to allow for the evaluation of trade-offs between the priority objectives, rather than tuning to a specific target that may have less than optimal yield-related outcomes.

Pertinent to size limits and multi-year assessment MPs, the Commission agreed to the following.

> **IPHC-2023-AM099-R, para. 84:** The Commission **AGREED** sufficient analysis has been completed and **RECOMMENDED** not to change the current 32 inch size limit.

> **IPHC-2023-AM099-R, para. 85**: The Commission **AGREED** that there is utility in continuing to explore multi-year stock assessment management procedures, in a manner consistent with the advice from SRB and MSAB.

Without an agreed upon distribution procedure, the recent MSE simulations integrated over five potential distribution procedures (see IPHC-2022-SS012-R, para 11). The Commission acknowledged that a distribution procedure has not been agreed upon at this time and provided the following.

> **IPHC-2023-AM099-R, para. 87:** The Commission **AGREED** that following agreement about a distribution procedure, the IPHC Secretariat and MSAB should reassess multi-year stock assessment management procedures, as well as coastwide elements of a management procedure such as the SPR value.

The advice from the 2022 full stock assessment (IPHC-2023-SA-01) using the current interim management procedure with an SPR of 43% was a TCEY of 52.0 Mlbs. This TCEY was higher than expected from previous assessments largely because natural mortality (*M*) was estimated higher than a previously fixed value in one of four models in the stock assessment ensemble, thus increasing the perceived productivity of the stock. In contrast to this optimistic advice, the coastwide FISS index of O32 WPUE was at its lowest value observed in the time-series (declining by 8% from the previous year) and a TCEY of 52.0 Mlbs in 2023 would have a 75% chance of a lower spawning biomass in 2024 (IPHC-2023-SA-01). The Commission departed from the current interim management procedure and chose a TCEY of 36.97 Mlbs, noting

> **IPHC-2023-AM099-R, para. 94.** The Commission **NOTED** that the adopted mortality limits for 2023 correspond to a 38% probability of stock decline through 2024, and a 36% probability of stock decline through 2026.

Although the status of the stock was above the reference relative spawning biomass of 36% and had a small chance (25%) of falling below 30% at any TCEY up to 60 Mlbs, the Commission decided to reduce the TCEY from the TCEY determined using the reference harvest level. This decision illustrated an additional Commission objective not currently included in those used by the MSE, perhaps relating to fishery performance and/or survey catch rates relative to recent historical experience. Further exploration of this potential objective may be important to future work and will be explored during MSAB018.

The Commission also requested the investigation of exceptional circumstances, especially with respect to multi-year assessments.

> **IPHC-2023-AM099-R, para. 88**: **NOTING** paragraph 60 from the 21st Session of the SRB (SRB021), the Commission **REQUESTED** the Secretariat develop a description of options to responding to exceptional circumstances that would trigger a stock assessment in non-assessment years and additional MSE analyses.
>
> > IPHC-2022-SRB021-R, para 60: *The SRB RECOMMENDED that Exceptional Circumstances be defined to determine whether monitoring information has potentially departed from their expected distributions generated by the MSE. Declaration of Exceptional Circumstances may warrant re-opening and revising the operating models and testing procedures used to justify a particular management procedure*

As noted above by the SRB, an exceptional circumstance is a defined event that would result in re-examination of the MSE process to determine if an update to the framework and evaluation of management procedures is necessary. An exceptional circumstance, in an MSE context, is not usually defined to trigger an action within the management procedure, but a trigger can be defined in a management procedure such that action does take place. An example is the 30:20 control rule which defines a reduction in the fishing intensity when stock status is less than 30%. A similar trigger could be defined that indicates an assessment should be done in a year when one was normally not scheduled.

POTENTIAL MSE-RELATED TASKS FOR 2023–2025

Based on outcomes from AM099, there are a number of useful tasks for the MSE. These include updating the OM to be consistent with the recent full stock assessment, defining a set of MPs for evaluation, and defining exceptional circumstances.

Updating the Operating Model

The evaluations presented at AM099 and in this document were based on an operating model consisting of four multi-region models that were conditioned using data, results, and assumptions from the 2021 stock assessment (IPHC-2022-SA-01). Two of these OM models used high values of natural mortality (*M;* 0.195 for females and 0.174 for males) based on the two stock assessments that estimated *M*, and two models used low values of natural mortality (0.15 for females and 0.146 estimated for males) based on the two stock assessments that assumed a fixed value for female *M*. MSE projections were integrated over these four models.

Table 4. Priority coastwide objectives.

General Objective	Measurable Objective	Measurable Outcome	Time-frame	Tolerance	Performance Metric
1.1. Keep female spawning biomass above a limit to avoid critical stock sizes and conserve spatial population structure	Maintain a female spawning stock biomass above a biomass limit reference point at least 95% of the time	SB < Spawning Biomass Limit (SB_{Lim}) SB_{Lim}=20% unfished spawning biomass	Long-term	0.05	$P(SB < SB_{Lim})$ PASS/FAIL
2.1 Maintain spawning biomass at or above a level that optimizes fishing activities	Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point (B36%) 50% or more of the time	SB<Spawning Biomass Target (SB_{Targ}) SB_{Targ}=36% unfished spawning biomass	Long-term	0.50	$P(SB < SB_{Targ})$
2.3. Provide Directed Fishing Yield	Optimize average coastwide TCEY	Median coastwide TCEY	Short-term		Median $\overline{TCEY}$
2.2. Limit Variability in Mortality Limits	Limit annual changes in the coastwide TCEY	Median coastwide Average Annual Variability (AAV)	Short-term		Median AAV

At AM099, a full stock assessment was presented that estimated natural mortality in three out of four of the models in the ensemble (IPHC-2023-SA-01), as opposed to only two models in previous years. The new estimate of female *M* in the model that previously fixed female *M* was greater than the previous fixed value of 0.15. A comparison of 2022 ensemble stock assessment results with previous stock assessments indicates that the estimates of spawning biomass from the 2022 ensemble were consistent with those from the 2012-2021 assessments. However, projections were more optimistic due in part to the increase in estimated productivity of the stock resulting from 3 out of 4, rather than 2 out of 4 models, with higher natural mortality.

Updating the model in the previous OM (medAAF_lowM) that corresponded to the previous assessment model with a fixed *M* (but was subsequently estimated at a higher value) would result in different outcomes, but the comparison of relative performance across MPs is likely to be similar since all MP evaluations would contain the update. Furthermore, the MSE simulations included variability in natural mortality, thus even with a change in the median value of *M* there will still be some overlap with past simulations.

Given that the 2022 stock assessment was a full assessment, and there was a significant paradigm shift, it would be prudent to develop a newly conditioned OM using this full assessment as a guide. Furthermore, reconditioning the OM immediately following an accepted full stock assessment (which occurs every three years) would maintain some congruency between the stock assessment and the MSE.

The process of developing an updated OM involves the following. First, four models are being conditioned based on each of the four stock assessment models.

OM1_longAAF: Starts in 1958. Parameters taken from the long AAF stock assessment model.

OM2_shortAAF: Starts in 1992. Parameters taken from the short AAF stock assessment model.

OM3_longCW: Starts in 1958. Coastwide parameters taken from the long coastwide stock assessment model. Region- and fishery-specific parameters taken from the long AAF stock assessment model.

OM2_shortCW: Starts in 1992. Coastwide parameters taken from the short coastwide stock assessment model. Region- and fishery-specific parameters taken from the short AAF stock assessment model. However, given the large difference in natural mortality between the short coastwide (*M* fixed at 0.15 for females) and the short AAF assessment models, parameters from the long AAF assessment model, or some other values, may be used or estimated.

The values used for age 3+ females and males in the OM are shown in Table 5.

Table 5. Values of natural mortality for age 3+ females and males used in the individual models of the MSE operating model.

	OM1_longAAF	OM2_shortAAF	OM3_longCW	OM4_shortCW
Female	0.184	0.213	0.215	0.150
Male	0.164	0.178	0.203	0.147

Each model was conditioned to the following four sources of information.

1. The estimated stock distribution from the modelled FISS data across the four Biological Regions.
2. The estimated spawning biomass from the corresponding stock assessment model.
3. The estimated all sizes index of abundance from the modelled FISS data for each Biological Region.
4. The estimated proportions-at-age from the FISS data for each Biological Region.

The goal of the conditioning was to create a multi-region OM that was representative of each of the four models in the stock assessment ensemble. Each source of information was weighted independently, with higher weights put on the stock distribution and spawning biomass. The conditioning is currently in progress, but preliminary results for OM1_longAAF are shown in Figure 3. Parameter uncertainty will be added at the end of the conditioning process.

Objectives and performance metrics

The Commission priority objectives are shown in Table 4, which is a subset of the Commission's primary objectives in Appendix A, which includes some area-specific objectives as well. These primary objectives have been used in past evaluations. Furthermore, the MSE Explorer has options to select many performance metrics beyond those defined by the primary objectives.

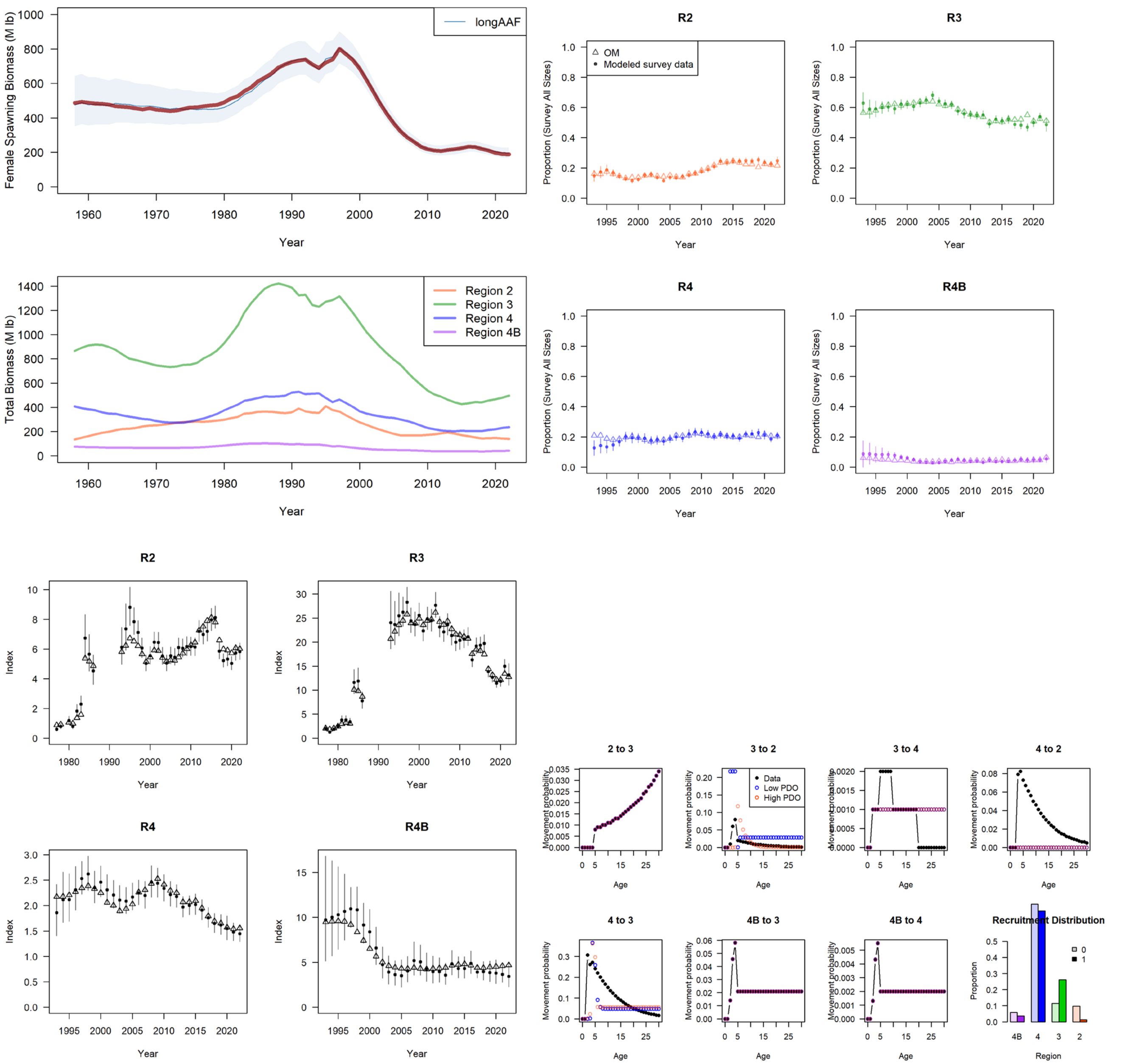

Figure 3. Outputs from conditioning OM1_longAAF. The top left is OM coastwide spawning biomass (red) with the blue polygon showing the 5th and 95th quantiles from the long AAF stock assessment model, and the OM total biomass in each Biological Region. The top right is the OM predicted proportion of all sizes fish caught in the FISS for each Biological Region (triangles) with space-time model estimates shown as filled circles and 2.5th and 97.5th quantiles. The bottom left is the OM predicted FISS all sizes index for each Biological Region (triangles) with space-time model estimates shown as filled circles and 2.5th and 97.5th quantiles. The bottom right shows the movement probabilities at age from and to each Biological Region with estimated movement probabilities in blue or red for low or high periods of the PDO, respectively. The recruitment distribution shows the proportion of coastwide recruitment in each Biological Region for low (0) or high (1) periods of the PDO.

One measurable objective that can use refinement is the Biological Region-specific objective "maintain a defined minimum proportion of female spawning biomass in each Biological Region." The purpose of this objective is to conserve geographical diversity within the spawning biomass because it is not known how each Biological Region contributes to the sustainability of the coastwide stock or individual Biological Regions. Minimum proportions, intended to be exceeded with no more than a 5% probability, were defined *ad hoc* for each Biological Region (Appendix A) based on historical estimates of distribution (Figure 4), but no recent MPs evaluated were able to meet the objective for Biological Region 4B (e.g. the "Both" for the "Fished" run in Figure 2). Further investigation of the percentage of spawning biomass in Biological Region 4B under scenarios of persistent low PDO and persistent high PDO (Figure 2) show that the percentage of spawning biomass in Biological Region 4B is much more variable when fished than when not fished, and the "high" PDO results in lower percentages of spawning biomass in that region, sometimes less than 1%.

There are several solutions to alleviate this issue and find MPs that meet the objective of maintaining coastwide spawning biomass in Biological Region 4B.

a) Determine a new value for the minimum percentage in Biological Region 4B (currently 2%).
b) Adjust the tolerance to a value great than 5%.
c) Find a management procedure that will meet the current objective. This would likely be achieved by lowering the relative harvest rate in IPHC Regulatory Area 4B. For example, a yield-per-recruit analysis suggested a relative harvest rate of 0.5 for Biological Region 4B (Table 6).

Table 6. Estimated harvest rates from a yield-per-recruit analysis in each Biological Region relative to Biological Region 3 for different years. Reproduced from Table 2 in IPHC-2020-AM096-12.

		Biological Region			
Weight-at-age	**Selectivity**	**2**	**3**	**4**	**4B**
1985	1985	1.0	1.0	0.7	0.5
1999	1999	1.0	1.0	0.8	0.5
2018	2018	1.0	1.0	1.0	0.5

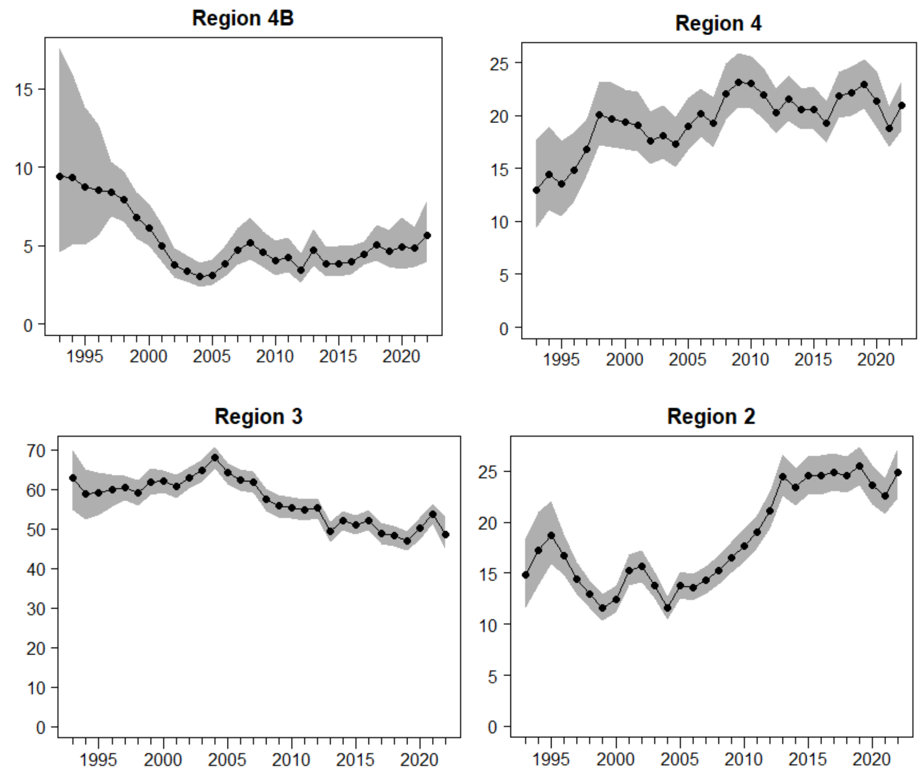

Figure 4. Estimated percent of coastwide stock biomass in each Biological Region, with 95% credible intervals, from the FISS space-time model.

Management procedures

The current interim management procedure consists of a scale component to determine the coastwide TCEY which is then passed through a distribution procedure to distribute the TCEY to each IPHC Regulatory Area (Figure 5). A decision process occurs at the end of the harvest strategy policy where the final TCEYs for each IPHC Regulatory Area may deviate from those determined by the management procedure, which occurred at AM099.

The Commission decided to depart from the reference SPR at AM099 and choose a lower TCEY. Paragraph 94 of IPHC-2023-AM099-R (see above) suggests that the Commission was not willing to accept a high chance of further declines in the spawning biomass. If that was the case, the 30:20 control rule could be revised to avoid going to low levels, although the decision was probably a combination of many factors which may include low catch rates, continually declining indices, a recent series of poor recruitment, mostly relying on one year class, and low weight-at-age.

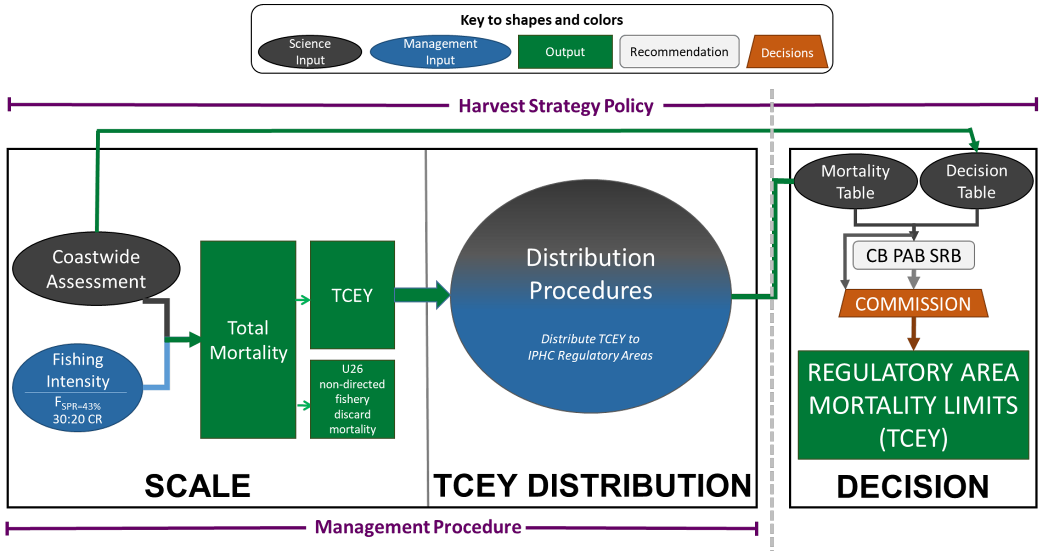

Figure 5. Illustration of the Commission interim IPHC harvest strategy policy (reflecting paragraph ID002 in IPHC-2020-CR-007) showing the coastwide scale and TCEY distribution components that comprise the management procedure. The distribution procedure is currently undefined. The decision component is the Commission decision-making process, which considers inputs from many sources.

Multi-year MPs use a simple procedure in years without an assessment to determine the TCEY. This simple procedure can be based on the FISS WPUE and adjust the TCEY up or down in proportion to the change in the FISS WPUE, thus reflecting the trend in abundance. If there is an additional concern of being at low catch-rates or below a specific FISS WPUE, a trigger could be added to reduce the TCEY even further or to trigger an assessment in a year when one normally would not occur. There would be little time to trigger an assessment after the survey results were finalized and used in the space-time modelling, however.

In paragraph 88 of the Report from AM099 (IPHC-2023-AM099-R; see above), "exceptional circumstances that would trigger a stock assessment in non-assessment years" was mentioned. It may be preferable to define this trigger as part of the management procedure because an exceptional circumstance, in the classic MSE sense, is when an observation is made outside of what was simulated in the closed-loop simulations of the MSE, requiring the MSE simulations to be reconsidered. Putting a trigger to conduct an assessment in the management procedure allows it to be evaluated as part of the MSE process.

An element can be added to the management procedure that would account for any of these factors. If low catch-rates and declining indices was an important factor in the decision to reduce the TCEY, the management procedure may incorporate an additional control rule based on the FISS O32 WPUE. For example, the fishing intensity (or TCEY) could be linearly reduced when the FISS O32 WPUE is below some value. Various values could be tested to produce the desired performance. However, the evaluation of that performance would depend on a new objective related to catch-rates or FISS WPUE.

In summary, potential elements of MPs to evaluate with the MSE include:

- Annual assessment with additional reduction in the TCEY if the FISS WPUE is below some value in an attempt to mimic decisions made at AM099. The probability of further decline in spawning biomass may also be included.
- Re-evaluate the multi-year assessment MPs evaluated previously, but with the updated OM. This includes biennial and triennial options with empirical rules to determine the TCEY for each IPHC Regulatory Area.
- Multi-year assessment with the TCEY in non-assessment years determined empirically and an assessment is triggered when the FISS WPUE is below some value, the FISS WPUE or NPUE changes by a considerable amount, or some other trigger.
- Various SPR values trigger values in the control rule, and constraints on the annual change in TCEY given a newly updated OM, and possibly an agreement on distribution of the TCEY.

EXCEPTIONAL CIRCUMSTANCES

An exceptional circumstance is defined as a process for deviating from an adopted MP (de Moor et al. 2022). The IPHC interim harvest strategy policy has a decision-making step after the MP (Figure 5), thus the Commission may deviate from an adopted MP. The SRB provided clarity at SRB021 of what an exceptional circumstance is to fit within the IPHC process.

> **IPHC-2022-SRB021-R**, para 60: The SRB **RECOMMENDED** that Exceptional Circumstances be defined to determine whether monitoring information has potentially departed from their expected distributions generated by the MSE. Declaration of Exceptional Circumstances may warrant re-opening and revising the operating models and testing procedures used to justify a particular management procedure.

This statement indicates that exceptional circumstances should be defined using observations rather than model outputs and should be compared to the distribution generated by the MSE simulations. If the observation(s) are outside of that range, revising the MSE framework and conducting additional simulations should be considered. It is important to have clear definitions for when the agreed upon MP should be re-evaluated.

The Commission may have interpreted the continued decline in abundance indices and projected spawning biomass seen at AM099 as an exceptional circumstance, but this is within the distribution of simulations from the MSE. Figure 6 shows that in the near-term, the spawning biomass has a chance of continuing to decline (21% and 16% of the simulations show a decline in the spawning biomass from 2023 to 2024 and from 2024 to 2025, respectively). However, after a few years of projections, the spawning biomass is likely to increase. In the long-term, it is not unlikely that the spawning biomass would be at levels seen recently, according to these simulations with an SPR of 43%. The stock assessment estimated the 2023 spawning biomass at 192 Mlbs in 2023 and the median simulated 2023 spawning biomass from the MSE OM was 188 Mlbs. The simulated spawning biomass in 2081 was less than the 2023 assessment spawning biomass in 19% of the simulations.

Potential exceptional circumstances could be as follows.

a) The coastwide all-sizes FISS WPUE or NPUE falls above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index in a specific timeframe.

b) The observed percentage of FISS all-sizes WPUE is above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index for each Biological Region in a specific timeframe. These data were used to condition the OM, so may be a reasonable choice.

c) The proportions-at-age in the coastwide or region-specific FISS observations are above the 97.5th percentile or below the 2.5th percentile of the simulated FISS proportions-at-age in a specific timeframe. Exactly how to make this comparison over all ages would have to be determined.

The all-sizes index would be a better option because to calculate O32, the OM makes an assumption of how to split the observations into U32 and O32.

An exceptional circumstance would trigger a review of the MSE simulations to determine if the OM can be improved and MPs should be re-evaluated. If a multi-year MP was implemented and an exceptional circumstance occurred in a year without a stock assessment, it may be useful to specify that a stock assessment would be completed as soon as possible along with the re-examination of the MSE.

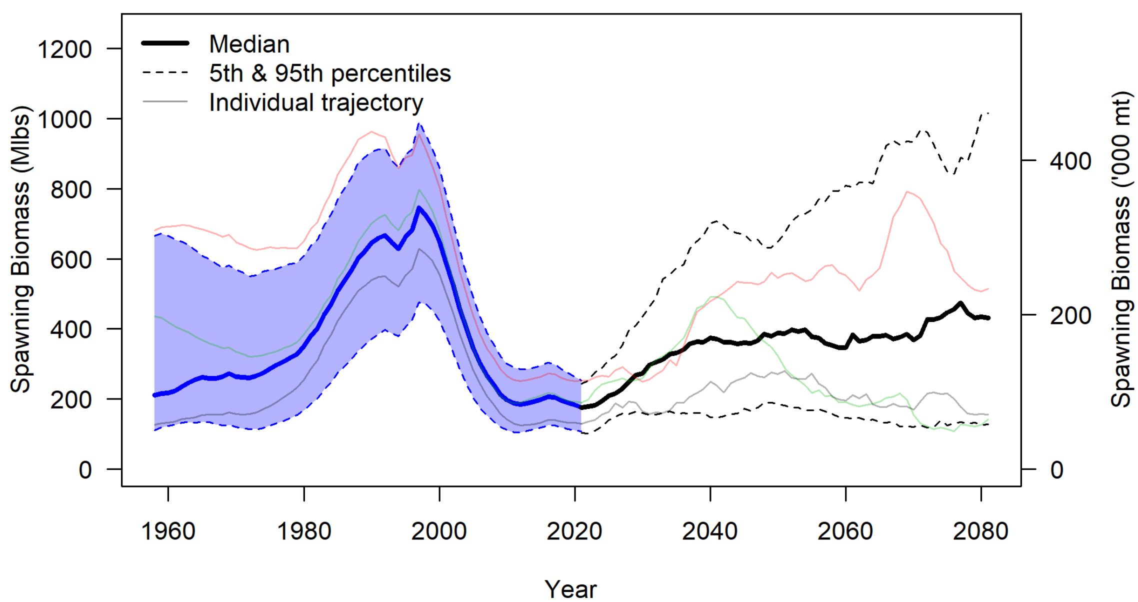

Figure 6. Median, 5th percentile, and 95th percentile of projected spawning biomass when using an SPR of 43%. Three individual trajectories (chosen *ad hoc*) are shown as thin lines to provide an idea of the variability in one trajectory over the entire period.

TWO-YEAR PROCESS FOR SRB REVIEW OF THE MSE

An MSE process may take one (1) to four (4) years, but because the MSE process at IPHC has matured and an MSE framework is in place, the timeframe for presenting results to the Commission on these topics is likely to take two years. How the SRB may engage in the MSE process over the next two years is described next.

Scientific Review Board

The SRB reviews the technical aspects of the MSE, trusting that the MSE developers are correctly implementing those details. The SRB also plays an important role in reviewing objectives and making sure that performance metrics are appropriate and correct. The Secretariat also works with the SRB to determine effective and succinct ways to present results to the Commission.

Two SRB meetings each year works well with the MSE process. SRB engagement in 2023 and 2024 may occur as follows.

Spring 2023 SRB meeting:

- Review outcomes of the Spring MSAB meeting.
- Review any technical aspects of the MSE framework that have not been reviewed before.
- Review the set of primary objectives and performance metrics to be used for evaluation.
- Review proposed MPs for evaluation and identify a set for preliminary evaluation.

Fall 2023 SRB meeting:

- Review preliminary simulation results including those related to questions of scientific interest and of interest to decision-makers.
- Assist in narrowing down the MPs to a succinct set to present to the Commission.
- Provide guidance on communicating progress.

Spring 2024 SRB meeting:

- Review outcomes of the Spring MSAB meeting.
- Review any technical aspects of the MSE framework that have not been reviewed before.
- Review the set of primary objectives and performance metrics to be used for evaluation.
- Review proposed MPs for evaluation and identify a set for evaluation.
- Provide guidance on methods for communicating results.

Fall 2024 SRB meeting:

- Review the simulation results including those related to questions of scientific interest and of interest to decision-makers.
- Assist in narrowing down the MPs to a succinct set to present to the Commission.
- Provide further guidance on communicating results.

One task of the SRB is to consider outcomes of MSAB meetings. The MSAB may best serve the Commission by considering inputs for the MSE process. One MSAB meeting per year, in May, would be sufficient, although adding in an information session when appropriate may be useful to keep MSAB members informed as they prepare for the Interim and Annual Meetings.

REFERENCES

de Moor CL, Butterworth DS, Johnston S. 2022. Learning from three decades of Management Strategy Evaluation in South Africa. ICES Journal of Marine Science. 79. 1843-1852.

RECOMMENDATION/S

1) The SRB **NOTE** paper IPHC-2023-SRB022-07 presenting simulations performed since MSAB017, outcomes of AM099, and potential MSE-related tasks for 2023–2025.
2) The SRB **NOTE** that additional simulations beyond those presented at MSAB017 resulted in more precise values of the performance metrics, but the relative comparisons between management procedures remained the same.
3) The SRB **NOTE** that different PDO regimes (i.e. always high or always low)
    a. had little effect on the priority conservation objective, but low PDO resulted in low TCEYs and high PDO resulted in high TCEYs;
    b. affected the long-term distribution of spawning biomass differently in each Biological Region and;
    c. may have as much or a larger effect on the long-term distribution of spawning biomass in each Biological Region than fishing with the current interim harvest strategy policy does.
4) The SRB **ENDORSE** the process for developing and conditioning the 2023 OM, and that conditioning should occur following each full stock assessment.
5) The SRB **REQUEST** management procedures to develop and simulate using the MSE framework.
6) The SRB **REQUEST** that exceptional circumstances be based on comparing the MSE simulations to the uncertainty of modelled FISS estimates (e.g. a 95% credible interval) and if an exceptional circumstance occurred the MSE framework would be reviewed by the SRB, re-developed where necessary, and MPs would be re-evaluated as appropriate.

APPENDICES

Appendix A: Primary objectives defined by the Commission for the MSE

Appendix B: Supplementary material

APPENDIX A
PRIMARY OBJECTIVES DEFINED BY THE COMMISSION FOR THE MSE

Table A.1. Primary objectives, evaluated over a simulated ten-year period, accepted by the Commission at the 7th Special Session of the Commission (SS07). Objective 1.1 is a biological sustainability (conservation) objective and objectives 2.1, 2.2, and 2.3 are fishery objectives. Priority objectives are shown in green text.

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	MEASURABLE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRIC
1.1. KEEP FEMALE SPAWNING BIOMASS ABOVE A LIMIT TO AVOID CRITICAL STOCK SIZES AND CONSERVE SPATIAL POPULATION STRUCTURE	Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point at least 95% of the time	*B* < Spawning Biomass Limit (B_{Lim}) B_{Lim}=20% unfished spawning biomass	Long-term	0.05	$P(SB < SB_{Lim})$
	Maintain a defined minimum proportion of female spawning biomass in each Biological Region	$p_{SB,2} > 5\%$ $p_{SB,3} > 33\%$ $p_{SB,4} > 10\%$ $p_{SB,4B} > 2\%$	Long-term	0.05	$P(p_{SB,R} < p_{SB,R,min})$
2.1 MAINTAIN SPAWNING BIOMASS AT OR ABOVE A LEVEL THAT OPTIMIZES FISHING ACTIVITIES	Maintain the long-term coastwide female spawning stock biomass at or above a biomass reference point ($B_{36\%}$) 50% or more of the time	*B*<Spawning Biomass Target (B_{Targ}) B_{Targ}=$B_{36\%}$ unfished spawning biomass	Long-term	0.50	$P(SB < SB_{Targ})$
2.2. PROVIDE DIRECTED FISHING YIELD	Optimize average coastwide TCEY	Median coastwide TCEY	Short-term		*Median* $\overline{TCEY}$
	Optimize TCEY among Regulatory Areas	Median $TCEY_A$	Short-term		*Median* $\overline{TCEY_A}$
	Optimize the percentage of the coastwide TCEY among Regulatory Areas	Median $\%TCEY_A$	Short-term		*Median* $\overline{\left(\frac{TCEY_A}{TCEY}\right)}$
	Maintain a minimum TCEY for each Regulatory Area	Minimum $TCEY_A$	Short-term		*Median Min(TCEY)*
	Maintain a percentage of the coastwide TCEY for each Regulatory Area	Minimum $\%TCEY_A$	Short-term		*Median Min(%TCEY)*
2.3. LIMIT VARIABILITY IN MORTALITY LIMITS	Limit annual changes in the coastwide TCEY	Annual Change (*AC*) > 15% in any 3 years	Short-term		$P(AC_3 > 15\%)$
		Median coastwide Average Annual Variability (AAV)	Short-term		*Median AAV*
	Limit annual changes in the Regulatory Area TCEY	Annual Change (*AC*) > 15% in any 3 years	Short-term		$P(AC_3 > 15\%)$
		Average AAV by Regulatory Area (AAV_A)	Short-term		*Median* AAV_A

APPENDIX B
SUPPLEMENTARY MATERIAL

The MSE technical document (IPHC-2022-MSE-01) and is available on the IPHC MSE page (https://www.iphc.int/management/science-and-research/management-strategy-evaluation).

An archived MSE Explorer contains results presented at AM099.

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-AM099/

Results for the Low/High PDO scenarios are available in a different MSE Explorer.

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-HighLowPDO/

Results presented at MSAB017 are available in an archived MSE Explorer

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-MSAB017/

Development of the 2023 Pacific halibut (*Hippoglossus stenolepis*) stock assessment

PREPARED BY: IPHC SECRETARIAT (I. STEWART & A. HICKS; 18 MAY 2023)

PURPOSE

To provide the IPHC's Scientific Review Board (SRB) with a response to recommendations and requests made during SRB021 (IPHC-2022-SRB021-R) and to provide the Commission with an update of the 2023 stock assessment development.

INTRODUCTION

In 2022 the International Pacific Halibut Commission (IPHC) undertook its annual coastwide stock assessment of Pacific halibut (*Hippoglossus stenolepis*). That assessment represented a full analysis, following the previous full assessment conducted in 2019, updated in 2020 and again in 2021. Changes from the 2021 assessment were developed and reviewed by the IPHC's SRB, in June (SRB020; IPHC-2022-SRB020-07, IPHC-2022-SRB020-R) and September 2022 (SRB021; IPHC-2022-SRB021-08, IPHC-2022-SRB021-R). Changes that were included in the 2022 stock assessment and new data included:

1. Updating the version of the stock synthesis software used for the analysis (3.30.19).
2. Expanding the treatment of natural mortality (*M*) to include an informative prior based on longevity and assign increased values at the youngest ages based on meta-analysis of other flatfish species.
3. Improving the basis for data weighting via use of bootstrapped effective sample sizes as model inputs based on the FISS and fishery sampling programs, rather than the raw number of sets/trips used in previous assessments.
4. Estimating *M* in the short time-series Areas-As-Fleets (AAF) model.
5. Including standard updates to mortality estimates from all fisheries, directed commercial fishery and FISS (fishery-independent setline survey) biological and trend information, and other sources including data collected in 2022.

A summary of stock assessment results (IPHC-2023-AM099-11) was provided for the IPHC's Annual Meeting (AM099). In addition, the input data files are archived each year on the stock assessment page of the IPHC's website, along with the full assessment (IPHC-2023-SA-01) and data overview (IPHC-2023-SA-02) documents. All previous stock assessments dating back to 1978 are also available at that location.

For 2023, the Secretariat plans to conduct an updated stock assessment, consistent with the schedule for conducting a full assessment and review approximately every three (3) years. Standard data sources are expected to remain unchanged.

TIME-SERIES AND SOFTWARE UPDATES

In order to provide comparability between preliminary results and all subsequent steps working toward the final 2023 stock assessment (the annual bridging analysis), this evaluation began with the final 2022 models. First, each of the four assessment models was extended by one year, including projected 2023 mortality from all sources based on the mortality limits set during AM099 (IPHC-2023-AM099-R). Extending the time-series without adding any new data does not affect the historical time-series' estimates, but allows for a simple stepwise evaluation of the effects of adding data and other making any other changes to the models prior to the final version used for management.

Next, the Stock Synthesis (SS) software was updated from the version used for the 2022 stock assessment (3.30.19) to the most recent release (10 February 2023), 3.30.21. The changes to the software between these two versions were unimportant to the Pacific halibut stock assessment (the results were identical to the final 2022 assessment). However, maintaining a current version (when possible and efficient) reduces the likelihood of compatibility issues with plotting and other auxiliary software and reduces the cumulative transitional burden when future changes are added. Encouragingly, model run-times were similar or slightly faster than those for final 2022 models. Further, memory allocation appeared to have improved, removing the need to allocate more temporary memory to model runs to avoid writing to disk and dramatically slowing computational speed; AD Model Builder (ADMB), the computational engine for SS, was also updated between these versions, and it is unclear whether improvements in SS or ADMB were responsible for the improved performance. Although there are some new features being added to SS, none of these has been specifically explored in the preliminary analyses reported here.

The IPHC has relied on a variety of model platforms for implementing its stock assessment, many of which have been developed specifically for Pacific halibut (e.g., Clark and Hare 2006; Deriso et al. 1985; Quinn et al. 1990). From 2012 to 2014, the IPHC transitioned from a single stock assessment model to an ensemble of models including alternative structural assumptions. At the same time, the software platform was also transitioned from the previous halibut-specific model implemented directly in ADMB to models using SS. This transition was made in order to speed the evaluation of a wide range of alternative models, facilitate quantitative summary of multiple models, reduce the potential for undiagnosed coding errors, and provide for more tranparent review. The benefits of using a generalized platform for the Pacific halibut stock assessment come with costs, which include lack of some parameterizations that might be desirable, delayed development of new approaches, and in some cases run times that are inflated due to unused model features. These pros and cons have been discussed previously by the SRB and were noted in the 2019 external review (Stokes 2019). Although stock synthesis currently meets the assessment modelling needs for the IPHC, several features would be useful for further development of our assessment models. These include implementation of random effects for time-varying processes (e.g., recruitment and selectivity), more flexible movement and tagging parameterizations for spatially-explicit models, and alternative likelihoods such as the logistic-normal. Similar to other institutions, the IPHC will continue to monitor development of and seek involvement in alternative modelling platforms and whether they provide a sufficient suite of options to support the Pacific halibut stock assessment.

The independently-programmed MSE operating model (generally based on the structure of the current stock assesment) has and will continue to refine the Secretariat’s understanding of key biological processes and technical modelling needs. There is an important feedback loop between the assessment modelling and the MSE development fostering increased data and structural testing, as well as exploration and prioritization of hypotheses and research priorities.

Ultimately, the choice of a medium- to long-term assessment platform may depend on the type of MP selected by the Commission. The current compressed stock assesment analysis conducted each fall in order to provide annual management information is based on the current year’s data and must be stable and simple enough to be completed in less than two weeks. If a management procedure based on modelled survey trends, or a multi-year procedure is adopted, it may be uneccesary to conduct annual stock assessments. That type of procedure and timeline could allow for the development of more complex stock assessment ensembles/models (including fully Bayesian analyses), given extended development time between assessments. Therefore, the MSE, adoption of a management procedure by the IPHC and strategic planning for the stock assessment modelling platform should be considered together and the long-term focus should be on selecting the most efficient tools to meet management needs as they continue to evolve.

COMMISSION AND SRB REQUESTS AND RESULTS

During 2022 there were a number of management-supporting analyses requested by the Commission. However, there were no requests made at AM099 specifically relating to the 2023 stock assessment. In 2022, the SRB made the following assessment recommendations and requests during SRB021:

1) SRB021-Rec.07 (para. 34):

   *"The SRB **RECOMMENDED** not implementing MASE weighting for the 2022 stock assessment advice and, instead, continuing to use the equal weighting approach to the ensemble components."*

2) SRB021-Rec.08 (para. 35):

   *"**NOTING** the integration between the stock assessment and biological research in evaluating the impact of genetic sex composition data (and the one-year lag in providing these data) on assessment results along with the resourcing implications, the SRB **RECOMMENDED** continued evaluation of the impact on stock assessment output of analyzing this genetic sex composition data on 1, 2, or 3 year intervals."*

3) SRB021-Req.03 (para. 32):

   *"The SRB **RECALLED** SRB020–Rec.02 (para. 23) and SRB020-Rec.04 (para. 25) (shown below), and **REQUESTED** an update at SRB022:*

   *SRB020–Rec.02 (para. 23) "The SRB **NOTED** that most models within the ensemble produced reasonable and well-constrained estimates of natural mortality (M) and **RECOMMENDED** that estimation of M should be adopted in the short AAF assessment model with consideration in other models as part of the stock assessment research program."*

   *SRB020–Rec.04 (para. 25) "The SRB **NOTED** apparent discrepancies in marine mammal prevalence among anecdotal reports, FISS observations, and preliminary evaluation of logbook data, and therefore **RECOMMENDED** further investigation of methods to better estimate marine mammal prevalence and impacts on the fishery."*

4) SRB021-Req.04 (para. 33):

   *"**NOTING** the substantial interannual variation in MASE weightings of the four assessment models, the SRB **AGREED** that one-step-ahead predictive skill is a potentially promising basis for model weighting, and **REQUESTED** continued research into MASE weightings*

averaged over longer time periods as well as comparing these to alternative weighting metrics, for example, via cross-validation."

5) SRB021-Req.09 (para. 45):

   *"**NOTING** the Secretariat's interest in identification of evidence for spatial population structure, and given the IPHC manages stocks on the basis of biological reporting regions, the SRB **REQUESTED** clarification on how the Secretariat may alter assessments if 'functionally isolated components of the population are found'."*

Recommendation – Use of MASE in 2022

Equal model weights for all four stock assessment models were retained for the final 2022 stock assessment. Additional exploration of updated MASE statistics using the final 2022 stock assessment models and potential model weighting is described below.

Recommendation – Evaluation of the frequency of sex-specific fishery data

In order to explore the relative effect of adding sex-specific directed commercial fishery age composition data to the assessment models a series of sensitivity analyses were run starting from the final 2022 stock assessment. That assessment included sex-specific age data from the commercial fishery for the years 2017 through 2021; 2022 data were unavailable due to the standard one-year lag in processing. Three alternative assessments were run, each incrementally replacing the sex-specific age compositions available for the 2022 stock assessment (data from 2017 through 2021) with the sex-aggregated data that would have been available without the genetic assays. For each of these, the beginning of year (2023) spawning biomass (SB) and terminal year (2022) SPR were calculated, along with the 95% credible interval range of each. Each of the estimates and credible ranges was then compared with the actual estimate and interval range to evaluate the relative importance of this additional information and the effect on management-informing quantities.

The results of this analysis showed that removing one, two, or three years of sex-specific information had little effect on the terminal (beginning of the year 2023) estimates of spawning biomass and SPR (2022), and generally caused a small (<7%) underestimate in the credible interval range (Figure 1). This indicates that model predictions are quite robust to missing sex-specific information and/or that changes in sex-ratio-at-age have been relatively small over the last three years.

The commercial fishery age data collected in 2022 showed a shift in the mode from older year classes to the emerging 2012 year class (IPHC-2023-SA-01). This shift is expected to be accompanied by an increased proportion of females in the aggregate landings as dimorphic growth interacts more strongly with younger year-classes, from which fewer males are above the current 32" (82 cm) minimum size limit. As such, the 2022 sex-specific commercial fishery age data may have a larger relative influence on the stock assessment than recent years where the tracking of the aging 2005 cohort has occurred consistent with model predictions.

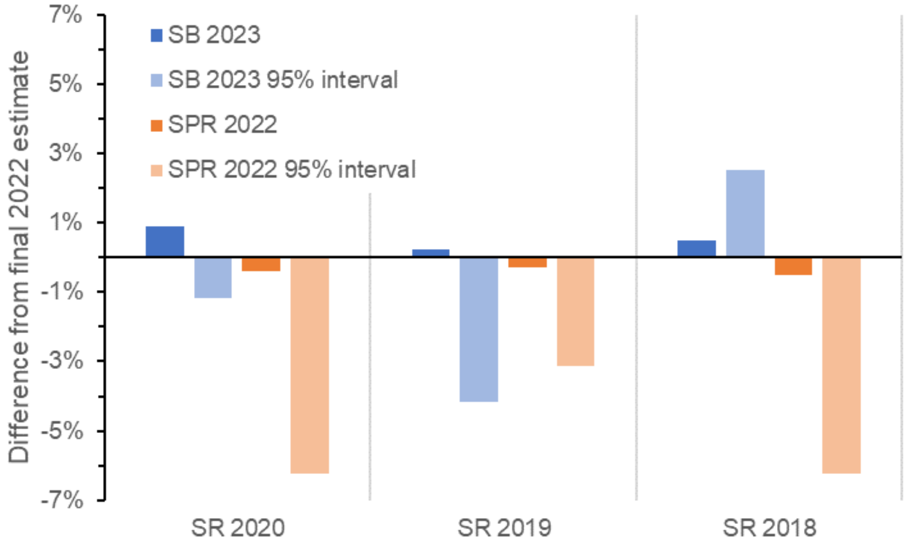

Figure 1. Change in key management quantities as a function of removing 1 year (SR 2020), 2 years (SR 2019) or 3 years (SR 2018) of sex-specific commercial fishery age composition data from the 2022 stock assessment. Percentages represent the difference from the final 2022 stock assessment results.

Commercial fishery sex-ratio-at-age data via genetic analysis from the 2022 fishery are currently being processed and are anticipated to be available and included in preliminary models presented at SRB023, 19-21 September 2023. Based on the results of the analysis presented here, it appears that the Commission could in the near future, consider could pausing the processing of commercial fishery sex-ratio data for a period of 1-3 years with little effect on the assessment results and subsequent management decisions. It would make sense to continue to collect the genetic samples from the fishery, as these fish are already being handled for collection of length, weight and otoliths, and the tissue samples could be retrospectively analyzed if needed and also used for other genetic analyses. Potential reduction in processing specific to the sex-ratio analysis may provide the opportunity to focus additional resources on other high-priority Commission research.

Request – Estimation of natural mortality and continued investigation of marine mammal

The 2022 full stock assessment relied on the same four stock assessment models used in recent years. The most important change made occurred in the short time-series Areas-As-Fleets (AAF) model, where the natural mortality rate for female Pacific halibut was estimated using the available data and a prior based on longevity rather than fixed at an arbitrary value (IPHC-2022-SRB020-07). As part of that decision, likelihood profiles were evaluated to determine the strength of information on natural mortality in the available data (and prior), convergence of the model was assessed and general plausibility of the estimate was considered. All of these indicated that it was reasonable to estimate natural mortality for female Pacific halibut (males were already estimated) in that preliminary model.

As a further evaluation of this modeling choice, the estimates of natural mortality from the AAF short time-series model were compared among the preliminary stock assessment presented at SRB020, the final 2022 stock assessment including data through 2022, as well as over a 5-year retrospective analysis sequentially removing the terminal year of data from the final 2022 stock assessment for 1 through 5 years. Comparison of these results indicated that the estimates of both female and male natural mortality were robust to recent data added to the model, and that there were no strong trends observed in those estimates (Figure 2). The estimate of female natural mortality from the final 2022 assessment was 0.213, the preliminary assessment 0.211 and the one-year retrospective 0.213. Similarly for males the estimates were 0.177, 0.177 and 0.178. Retrospective results removing years 2-5 were slightly lower (0.209 to 0.200 for females and 0.178 to 0.173 for males); however, these comparisons represented removal of up to all but a single year (2017) of sex-specific commercial fishery age data. In aggregate, this analysis supports the conclusion that the current estimate of natural mortality for both female and male Pacific halibut is robust and not being substantially updated with each new year of information.

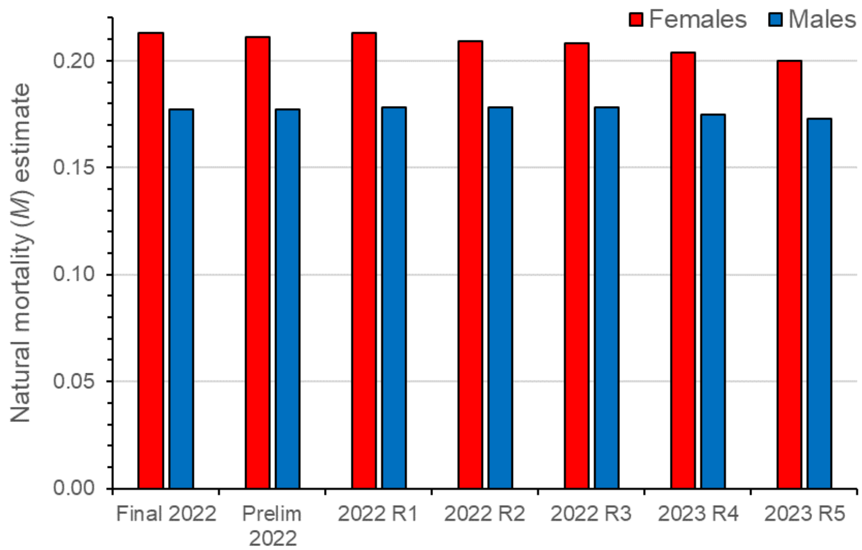

Figure 2. Estimates of female and male natural mortality in the AAF short model conducted during 2022. “Prelim 2022” represents the model presented during SRB020, R1 to R5 the retrospective analyses sequentially excluding 1 to 5 years of terminal data.

The second part of this request from SRB021 recommended further work on marine mammal depredation, following the very preliminary analysis presented at SRB020 (IPHC-2022-SRB020-07). That analysis identified a number of inconsistencies among anecdotal reports and verified logbook information but represented the first attempt to filter and evaluate the logbook information available from the commercial fishery. Subsequent to that analysis, the Commission has undertaken an assessment of data collection efforts by field staff, including a clarification of how to record missing information vs. unclear information (e.g., no information recalled/provided by the vessel compared to reporting that whales were present but the species and/or number was unknown). In tandem, a number of codes were reconciled in the Commission database tables leading to a much large number of records (a record in this case is a single longline ‘set’ that resulted in at least one halibut retained, including a reported target of that set: either Pacific halibut or ‘mixed’ targeting of Pacific halibut and sablefish, *Anoplopoma fimbria*) that were determined to be ambiguous in the preliminary 2022 analysis now able to be assigned accurately to either an encounter that could have included depredation or one that did not. This resulted in a relatively large proportion of the total fishing effort available for analysis in most IPHC Regulatory Areas (Figure 3) for the period 2018-2022 (with few records available at this time for 2023).

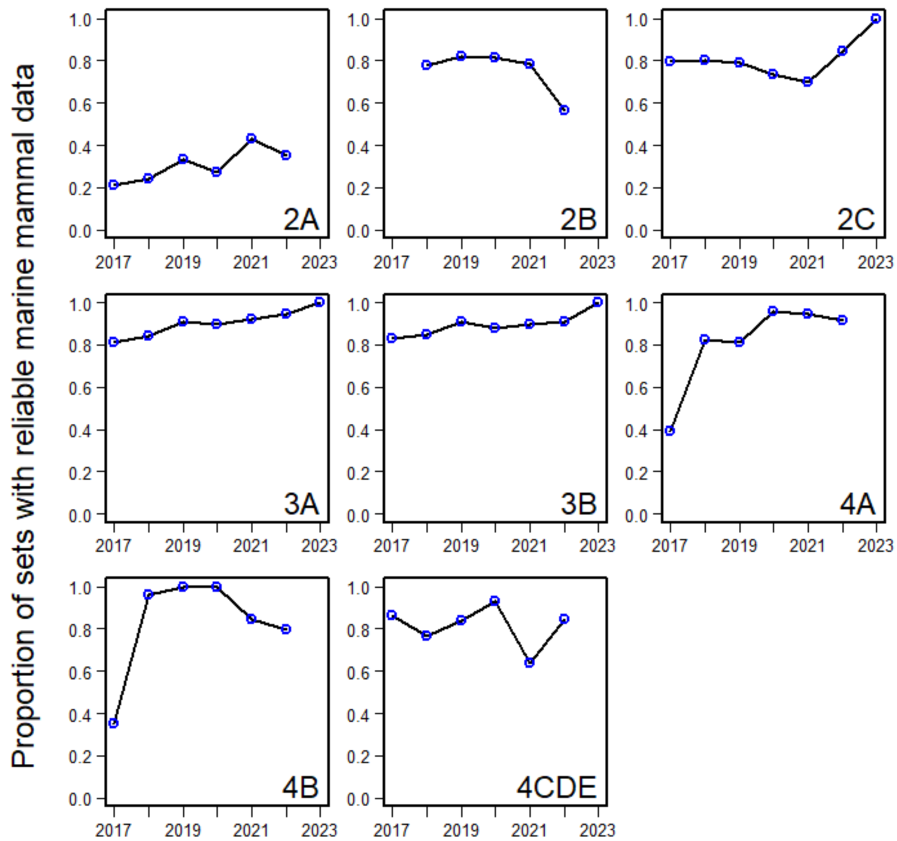

Figure 3. Proportion of logbook sets with complete information on species target and whale interactions. Note that during 2017 not all logbooks or field interviews included marine mammal interactions and that data for 2023 are still very sparse.

We used an approach intended to represent the 'worst case' estimate of potential marine mammal depredation, identifying sets where the presence of the two most common depredating species (Orca whales, *Orcinus orca*, and sperm whales, *Physeter macrocephalus*) was positively confirmed during hauling of the gear. We did not require any reported damage to the gear or catch, as field staff reported that this information was often omitted and evaluation of IPHC's Fishery Independent Setline Survey (FISS) has suggested increases in damaged gear (bent, broken or missing hooks and gangions) may be small enough to be unobserved during normal fishing operations (unpublished analysis). Once these complete records were identified each was assigned to a target species (halibut or mixed) and a marine mammal interaction (orca whales present, sperm whales present, or no whales present during hauling of the gear). Orca whale interactions were generally more common on mixed target sets than halibut target sets, consistent with the anecdotally reported preference for sablefish over Pacific halibut and the highest rate of interaction occurred in IPHC Regulatory Area 4A (Figure 4). This pattern was even more pronounced for sperm whale interactions, likely reflecting the preferential use of deeper water areas where mixed target fishing is more likely to occur (Figure 5). Although the rate of depredation was higher for mixed target sets, the majority of commercial halibut landings came from sets targeting only halibut (Figure 6).

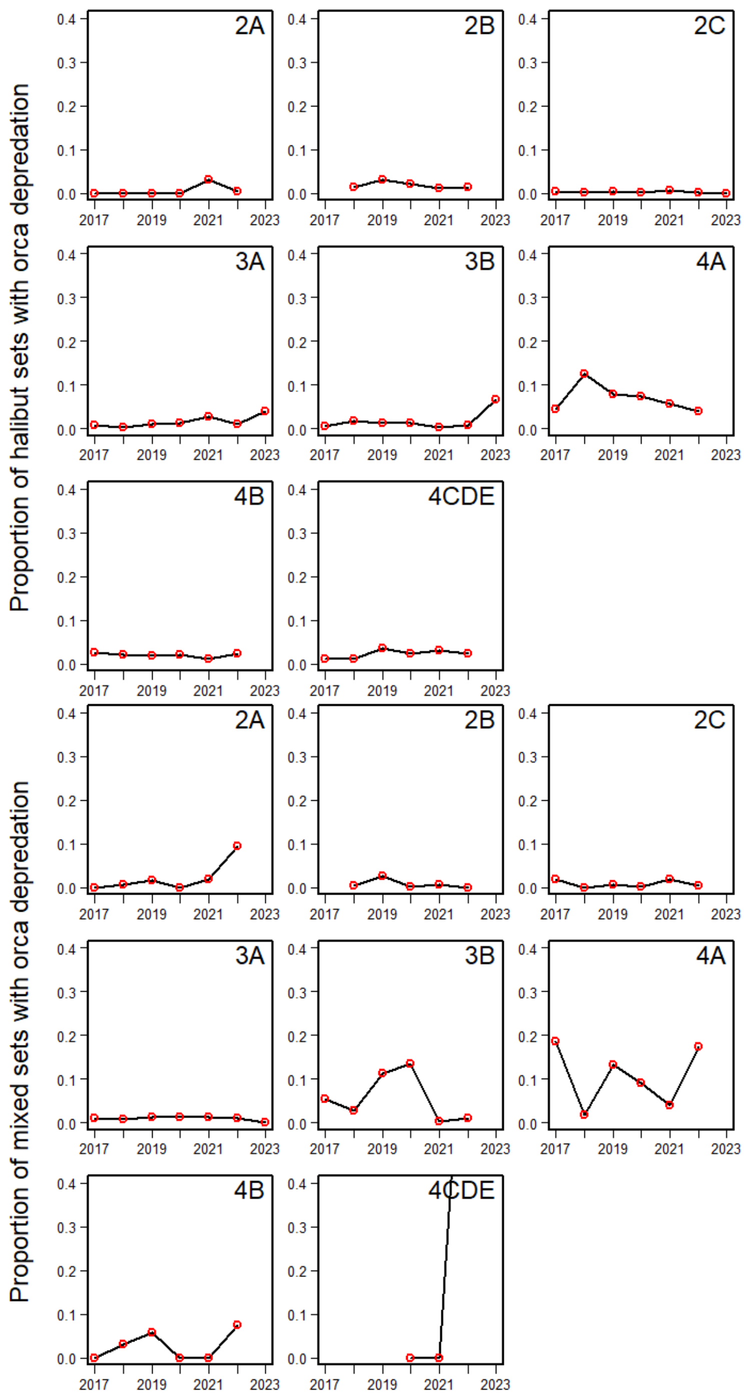

Figure 4. Proportion of commercial fishing sets reported to have orca whale interactions by IPHC Regulatory Area and set target. Upper panels represent halibut target sets and lower panels mixed halibut and sablefish target sets.

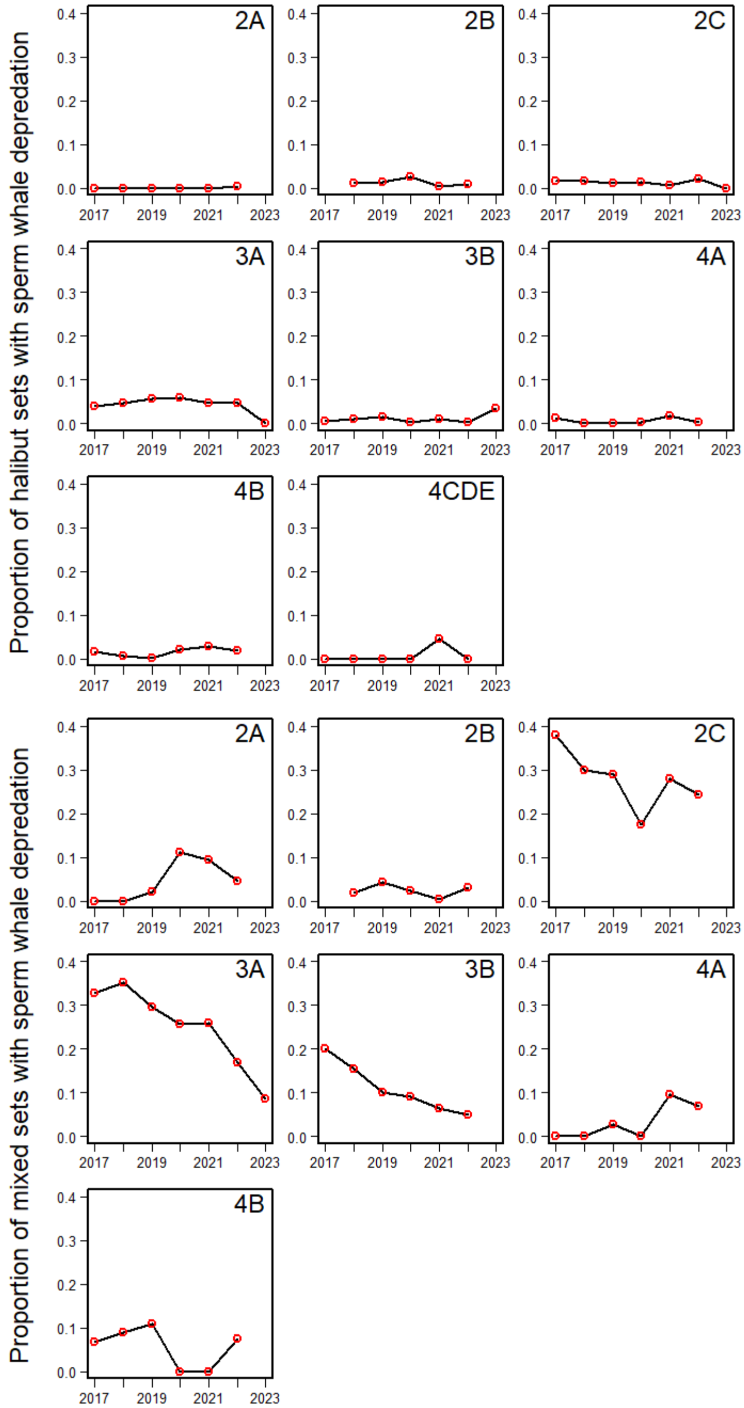

Figure 5. Proportion of commercial fishing sets reported to have sperm whale interactions by IPHC Regulatory Area and set target. Upper panels represent halibut target sets and lower panels mixed halibut and sablefish target sets.

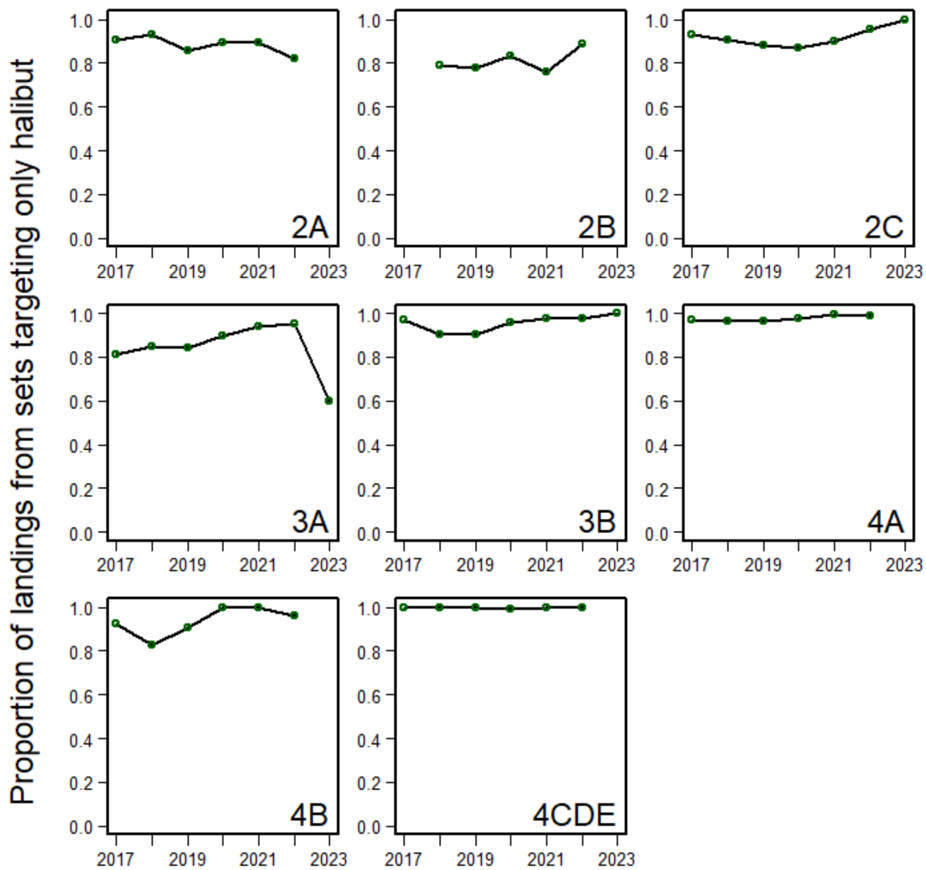

Figure 6. Proportion of commercial landings from halibut target sets. Note that few data were available for 2023 at the time of this analysis.

In order to approximate the effect on catch-rate of whale depredation we relied on estimates from the Commission's spatiotemporal model based on the FISS catches in the presence and absence of observed marine mammal depredation. The coefficients for relative catch when depredation occurred were: 84% (68-104% credible interval) for orca whales estimated in IPHC Regulatory Area 3A, 51% (43-60%) for orca whales in IPHC Regulatory Area 4A and 86% (75-99%) for sperm whales in IPHC Regulatory Area 3A (IPHC-2021-SRB019-05). These values were extrapolated as follows: all sperm whale depredation was assumed to occur at the 3A rate regardless of IPHC Regulatory Area, the orca whale depredation rate for 3A was applied to IPHC Regulatory Areas 2A-3B, and the rate estimated for IPHC Regulatory Area 4A was applied to 4A-4CDE. These coefficients were applied to the proportion of sets for each target type, the target-specific proportion of sets depredated and the landings for each target type by IPHC Regulatory area.

Recent estimates of depredation produced by this analysis ranged from very low values in IPHC Regulatory Area 2A to much higher values in IPHC Regulatory Area 3A, up to a high of 123 thousand net pounds in 2019 (Figure 7). Because the landings in each IPHC Regulatory Area differ, the highest average depredation as a percentage of area-specific landings occurred in IPHC Regulatory Area 4A, peaking at 5.9% in 2018 (Figure 7).

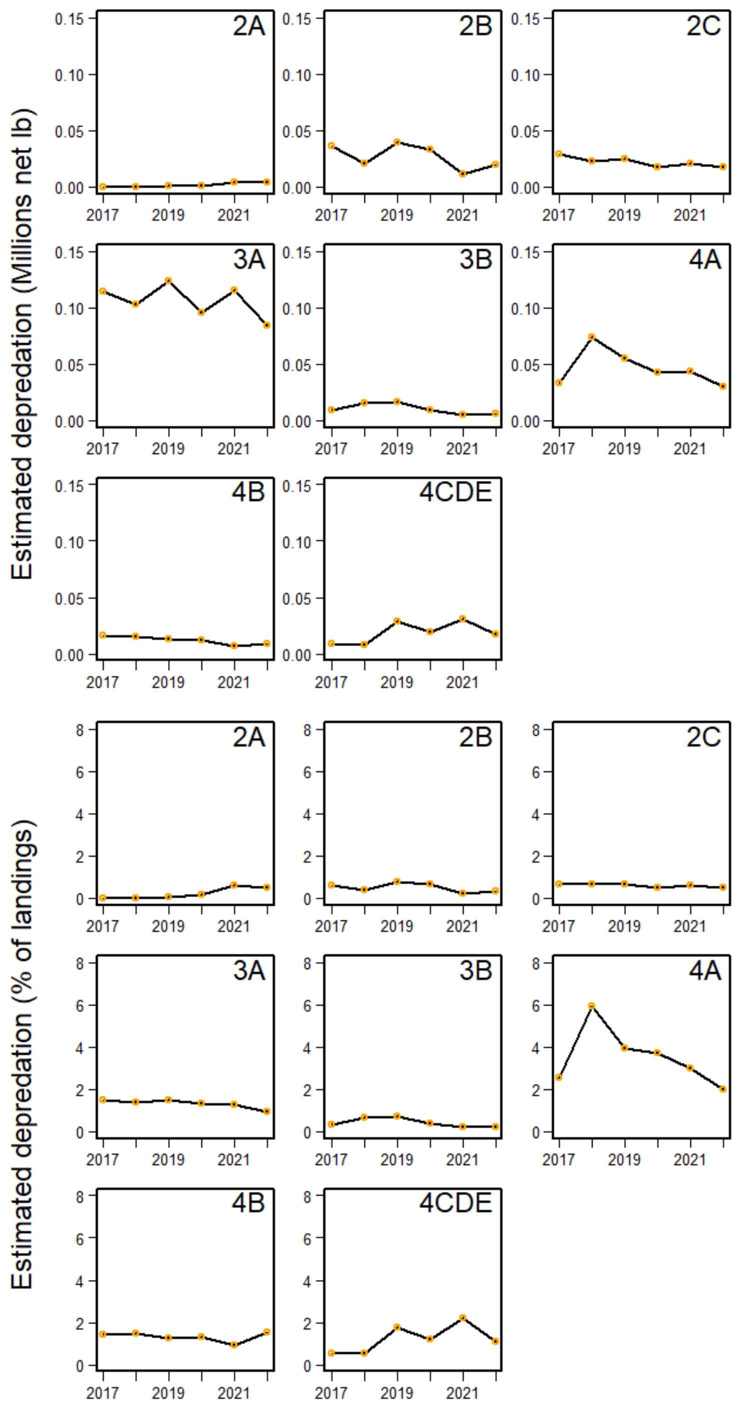

Figure 7. Estimated whale depredation by IPHC Regulatory Area (upper panels) and as a percentage of the annual landings (lower panels).

Several extensions to this analysis are possible, ranging from additional reporting of results to potential direct inclusion in the stock assessment and management process. It would be possible to quantify some of the uncertainty in the estimates by reporting the range of potential depredation based on the credible interval for coefficients estimated from the FISS instead of only the point estimates. However, it is likely that the greatest sources of uncertainty are related to observation/reporting by the fleet and the definition of which sets to include as 'depredated', both of which are currently impossible to quantify.

The stock assessment for sablefish explicitly includes marine mammal depredation in the fishery mortality, both for the historical period as well as projected for setting of mortality limits (Goethel et al. 2022). A similar approach could be taken for Pacific halibut, with the benefit of making the effect of marine mammal depredation more transparent, and potentially accounting for the differential affects among IPHC Regulatory Areas. The cost of this approach would be an increase in complexity associated with an additional ‘fleet’ in each stock assessment model, and the need to include another step in projected mortality limits. Based on previous sensitivity analyses (IPHC-2022-SA-01), increasing the fishery mortality by a small amount of whale depredation will increase the estimated scale of the population which would result in slightly larger mortality limits that are then decremented by the projection of whale depredation. This is the same general result that occurred in the sablefish stock assessment, which uses an average of the depredation rate estimated for the most recent three years for yield projections (Goethel et al. 2022). Due to the relatively small magnitude of whale depredation currently estimated for Pacific halibut and the substantial uncertainties associated with the estimates it may make sense to explore fisheries observer and other information and consider how to extrapolate farther back in time before adding this source of mortality to the stock assessment. Whale depredation is hypothesized to have begun increasing into a larger problem after the fisheries in Alaska and Canada moved from ‘derby’ style management to a quota system in 1995 and 1991, allowing fishing throughout most of the calendar year and the development of this marine mammal behavior. At present it is unclear how recent estimates would be extrapolated prior to 2017 when the quota fisheries were operating but marine mammal interactions were not reliably reported in IPHC logbooks. The IPHC Secretariat has initiated the process to obtain recent self-reported depredation information from Fisheries and Oceans Canada and detailed at-sea fisheries observer data for fisheries in Alaska, the latter would include information at least as far back as 2013.

Request – Model weighting

The primary focus on model weighting has been ‘hindcast’ predictive performance. This approach removes data from the assessment models and evaluates their skill in predicting subsequent observations. An increasingly common measure of model skill is the Mean Absolute Standardized Error (MASE; Hyndman and Koehler 2006). Because of the correlated time-series nature of observations used in stock assessment models, the hindcasting method is more appropriate than standard statistical cross-validation.

The MASE statistic has been used as a diagnostic tool for stock assessment models (Carvalho et al. 2021; Kell et al. 2021), but it’s use has ignored the heterogeneous variance associate with each year’s observations. Therefore, as presented at SRB020 and SRB021, we employed a ‘standardized’ MASE, calculated as

$$MASE = \frac{\frac{1}{n}\sum_{t=1}^{n} \left| \frac{O_t - E_t}{\sigma_t} \right|}{\frac{1}{n}\sum_{t=1}^{n} \left| \frac{O_t - O_{t-1}}{\sigma_t} \right|}$$

Where *O* indicates the observation at time *t*, *E* the prediction (or expected value) and σ_t is the standard deviation of the observation. The calculation can be averaged over any number of years (lags) relevant to the predictive problem. As defined, MASE estimates must be positive, and the range of values is interpreted as:

>1: model predictive skill is worse than the naïve prediction (last year’s index)

1: model predictive skill is exactly equal to the naïve prediction

<1: model predictive skill exceeds that of the naïve prediction

0: model predictions perfectly match subsequent observations

In order to turn the MASE statistic into a model weight we need to specify the scale of the weighting and the behavior at the end-points. In this case, for model (*m*) within the set of models (*M*; limited to those models with MASE values <1):

$$MASE\ weight_m = \frac{1 - MASE_m}{\sum_{m=1}^{M} 1 - MASE_m}$$

Models that do not outperform the naïve prediction (MASE >= 1) over the set of years included get assigned zero weight. At the other extreme, a set of models all perfectly predicting the subsequent observations (MASE = 0) will receive equal weights.

The current set of four stock assessment models all fit the index of abundance generated from the FISS very well (Figure 8, upper panel). Further, despite large differences in the structure of these models and the parameter estimates on which they are based (e.g., differences in estimated natural mortality), all four predicted the decline in the index observed in 2022 nearly as well as the fit when those data were included in the likelihood (Figure 8, lower panel).

Because the sex-ratio of the commercial fishery landings is unavailable prior to 2017, hindcasting skill cannot be explored prior to 2018 without making major changes to the current model structure which would make reasonable comparison with more recent model performance skill impossible. However, over the period from 2018 through 2022, change in the index has included both negative and positive trends, as well as one year (2020) when the index remained virtually identical from the previous year (Figure 8). Prior to computing the MASE weights, it is useful to compare the deviations between the observed index, the naïve prediction (the previous year's index) and each of the four models for each year of hindcast prediction (Table 1). Notably, the 2020 observation was predicted better by the previous year's observation than by any of the four models. The increase in 2021 and the subsequent decrease in 2022 were both predicted well by all four models, with the short coastwide model performing most poorly in all but 2018 and 2022.

It is unclear how long a period is optimal for averaging model performance. On one end of the spectrum, as was noted in the 2022 analysis, using only 1- or 2-year periods likely reflects the most current model skill, but leads to highly volatile weighting. At the other extreme, longer term averages would generate more stable weights, at the cost of a slower response to real changes in model skill as data and population dynamics change over time. Simulation analysis seems like a promising approach for investigating this trade-off. The Secretariat has begun collaboration with University of Washington researchers on exactly this topic. For the current analysis, weights were calculated based on 2- to 5-year averages, with 5 years being the longest period possible for evaluation. Results generally show lower weight assigned to the coastwide short model, and similar weights assigned to the other three (Figure 9).

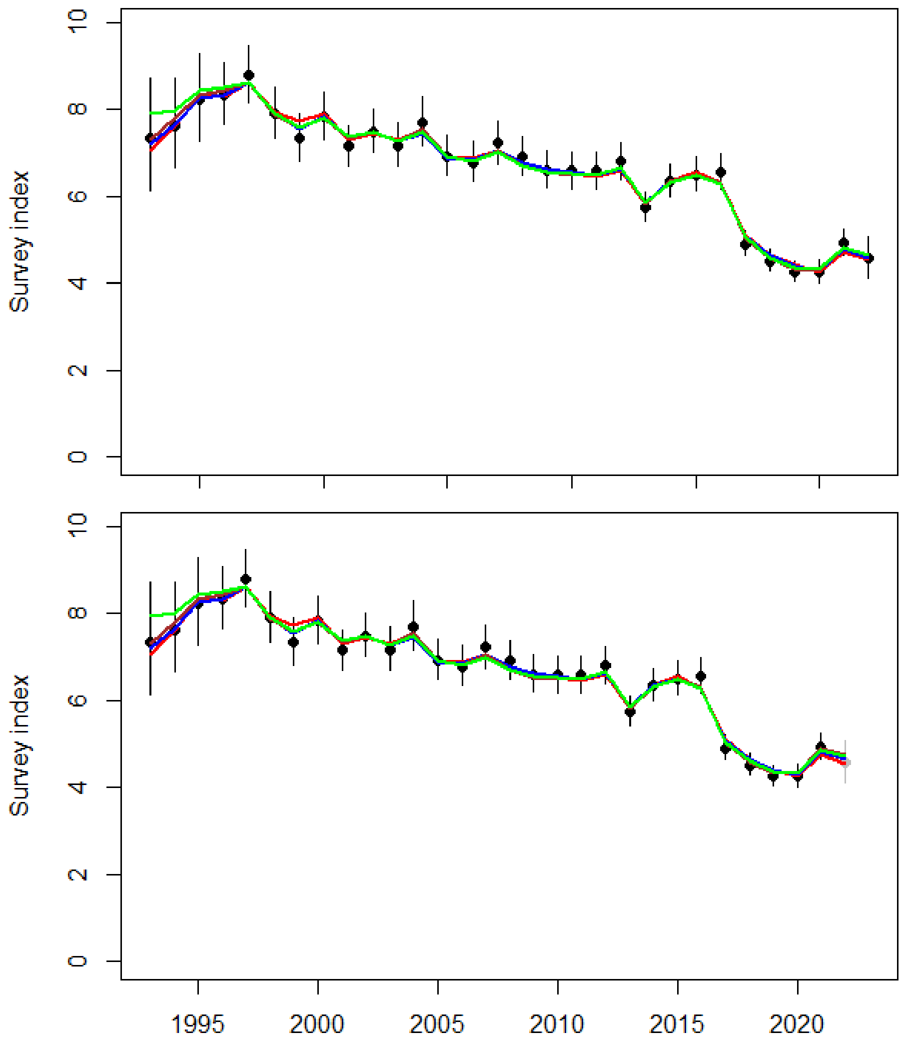

Figure 8. Fit to FISS index from the final models used for 2022 (upper panel) and hindcast projection based only on data through 2021 (lower panel).

Table 1. Scaled deviations ($\frac{O-E}{\sigma}$) between survey predictions and subsequent observations used in calculating MASE weights. Note that none of the four models had a smaller deviation than the naïve prediction (the previous year's observation) in 2020.

	Model				
Year	Naive	CW short	CW long	AAF short	AAF long
2018	3.08	0.52	0.39	1.10	1.00
2019	2.02	1.17	0.16	0.80	0.80
2020	0.07	2.19	0.45	0.14	0.15
2021	4.25	3.86	1.12	1.76	0.72
2022	1.53	0.06	0.33	0.60	0.76

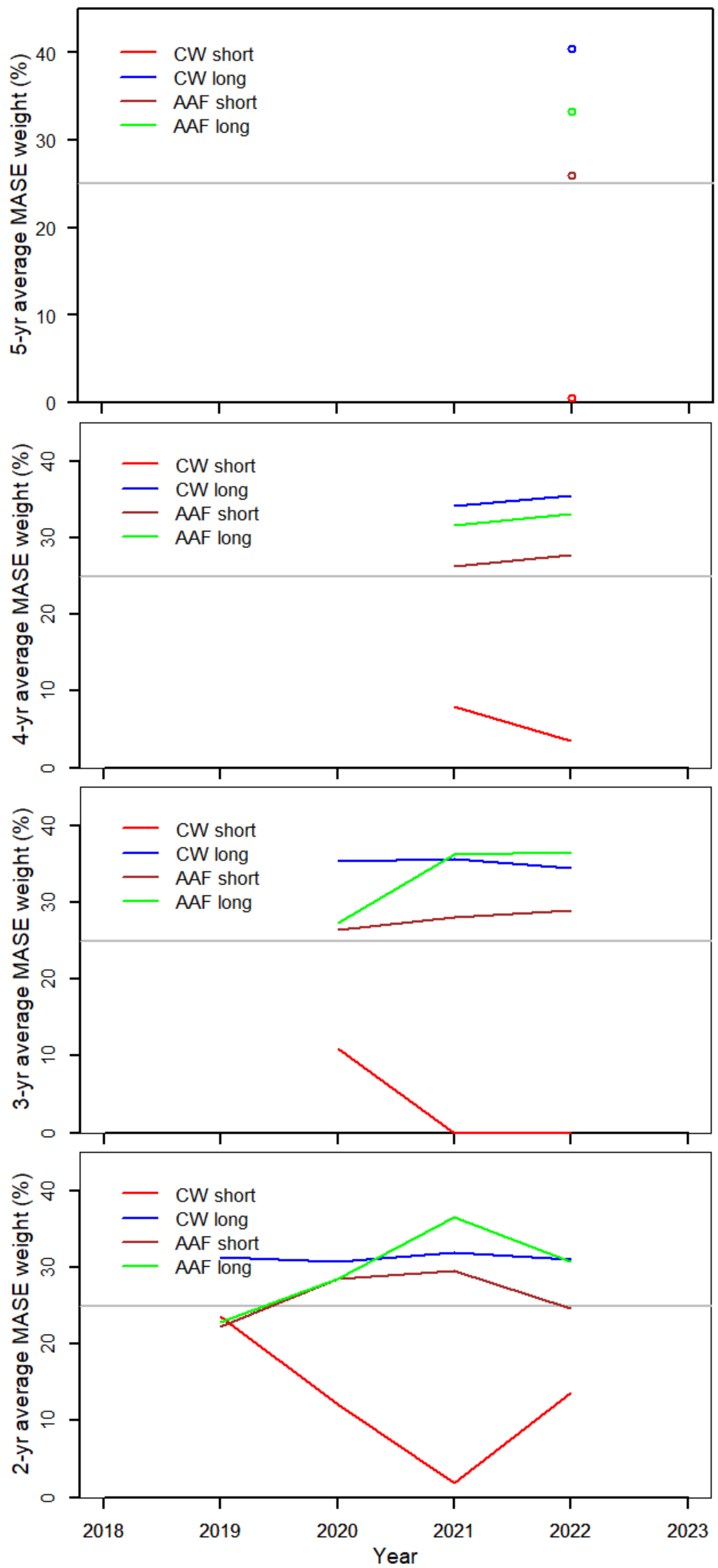

Figure 9. MASE weights for each year calculated based on the most recent 5, 4, 3, or 2-year period (panels from top to bottom).

As the modelling progresses toward the next full stock assessment scheduled for 2025, there will be 2 additional FISS observations to extend these results (2023 and 2024), and to provide a better perspective on the stability/performance trade-off in the number of years to include in the MASE weighting approach. Further, there may be simulation results relevant to this and other stock assessments. In the interim, the Secretariat plans to continue to investigate estimation of natural mortality in the coastwide short assessment model (a potential contributor to poorer performance than other models in the current set) and to annually update these MASE calculations.

Request – Potential assessment revision to accommodate stock structure

Until 2006, demographically separate stock assessments were conducted for each IPHC Regulatory Area (Clark and Hare 2006). This approach was based on the hypothesis that there was little movement of adult Pacific halibut among IPHC Regulatory areas, and therefore the population dynamics could be approximated acceptably with separate assessments regardless of the potential for recruitment and/or juvenile exchange among areas. However, the IPHC's PIT-tagging experiment in the early 2000s indicated appreciable exchange of adult Pacific halibut among IPHC Regulatory areas (Webster et al. 2013), meaning that closed-area assessments would be biased to larger population estimates due to the immigration of older and larger fish. Since 2006, the annual stock assessment has included the entire geographical range of Pacific halibut within the convention waters. This approach makes the implicit assumption that the Russian border comprises a boundary with only a small rate of demographic exchange; this appears reasonable given relatively low densities observed in recent years in the most northern convention waters. Exploration of that boundary may be increasingly important under future climate change, but recent world events have reduced the potential for collaboration and data exchange with Russian scientists.

There are two primary considerations with regard to potential stock structure within the greater Pacific halibut population in the IPHC convention waters: conservation of biological/genetic diversity and optimization of fishery yield. The IPHC has adopted the objective of maintain the spawning biomass in each Biological Region at or above the minimum proportion of the coastwide stock observed in the FISS since 1993. Evidence of unique genetic components of the stock within existing Biological Regions would warrant consideration of refining the management objective to maintain all such components in a similar manner. Genetic isolation would also imply little to no exchange of adults or recruits which would suggest conducting a separate stock assessment for a smaller stock component. Current research priorities for IPHC Regulatory Area 4B have been developed to specifically address whether there is evidence that Area 4B is genetically separated from the rest of the convention waters and therefore warrants development of a separate stock assessment with self-contained dynamics. A separate assessment for IPHC Regulatory Area 4B would allow the Commission to evaluate fishing intensity and spawning biomass reference points specific to that area in both tactical results from the stock assessment and strategic performance of management approaches as part of the MSE.

OTHER TOPICS

Other assessment development topics are ongoing; updates on progress will be provided if available in time for SRB022.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2023-SRB022-08 which provides a response to requests from SRB021, and an update on model development for 2023.

b) **REQUEST** any further analyses to be provided at SRB023, 19-21 September 2023.

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Report on Current and Future Biological and Ecosystem Science Research Activities

PREPARED BY: IPHC SECRETARIAT (J. PLANAS, 17 MAY 2023)

PURPOSE

To provide the Scientific Review Board with a description of progress towards research activities described in the IPHC's five-year Program of Integrated Research and Monitoring (2022-2026).

BACKGROUND

The primary biological and ecological research activities at IPHC that follow Commission objectives are identified and described in the IPHC Five-Year Program of Integrated Research and Monitoring (2022-2026). These activities are integrated with stock assessment (SA) and the management strategy evaluation (MSE) processes (Appendix I) and are summarized in five main areas, as follows:

1) Migration and Population Dynamics. Studies are 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.
2) Reproduction. Studies are aimed at providing information on the sex ratio of the commercial catch and to improve current estimates of maturity and fecundity.
3) Growth. Studies are 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.
4) Mortality and Survival Assessment. Studies are aimed at providing updated estimates of discard mortality rates in the guided recreational fisheries and at evaluating methods for reducing mortality of Pacific halibut.
5) Fishing Technology. Studies are aimed at developing methods that involve modifications of fishing gear with the purpose of reducing Pacific halibut mortality due to depredation and bycatch.

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

The SRB issued the following recommendations in their report of SRB021 (IPHC-2022-SRB021-R):

*SRB021–Rec.09 (para. 41) **NOTING** the information on recent wire tagging of Pacific halibut as part of the recreational DMR study and intent to characterize movements of Pacific halibut* *among IPHC Regulatory Areas, the SRB **RECOMMENDED** that the data available be summarized to map and analyze existing trends in the data.*

A summary of Pacific halibut movement from available data generated during the recreational DMR study will be provided for SRB022.

*SRB021–Rec.10 (para. 44) **NOTING** the Secretariat's interest in applications of molecular markers for somatic growth and evaluation of growth patterns, the SRB **RECOMMENDED** that the Secretariat devote attention to annotation of sequence data that may be relevant to understanding spatial, temporal, and demographic (size/age) variation growth and maturation.*

The Secretariat is discussing avenues to address the SRB recommendation.

*SRB021–Rec.11 (para. 47) **NOTING** the flow chart presented in Figure 1 of paper IPHC-2022-SRB021-09, the SRB **RECOMMENDED** that (i) additional analyses be conducted in areas of unsupervised clustering for individuals, and (ii) estimate measures of genetic variation among individuals within and among sampling groups to characterize inter-individual relationships, which could provide further indication of admixture. The coefficients of relationship among individuals within sampling location and levels of pair-wise variance in SNP allele frequency between sampling locations can be used to identify 'source' and 'sink' regions.*

The IPHC plans to conduct K-means clustering using individuals principal component scores and perform analyses, a range of vales for K will be tested and model selection criteria (eg. Bayesian information criterion) will be used to select the best fit model. Admixture proportions will also be estimated, and used to infer the true number of genetic groups present in the data. The use of inter-individual measures of relatedness will be explored. Figure 1 in document IPHC-2023-SRB022-09 has been updated to reflect this.

*SRB021–Rec.12 (para. 48) The SRB **NOTED** that in the sub-area of Population Genetics and Structure, the Secretariat intends to use Site Frequency Spectral (SFS) analyses. Both selection and population growth can produce similar SFS patterns in data. As such, the SRB **RECOMMENDED** testing using a 'Tajima D' analysis and estimate levels of excess of low frequency SNP alleles within sampling areas (or reporting units).*

The IPHC Secretariat has begun incorporating the estimation of Tajima's D for each collection in their analysis of low-coverage whole genome resequencing data. Figure 1 IPHC-2023-SRB022-09 has been updated to reflect this.

*SRB021–Rec.13 (para. 49) **NOTING** that Secretariat's intention to use Multiple Dimensional Scaling to visualise inter-individual and inter-location genetic similarity, the SRB **RECOMMENDED** that the Secretariat develop a data baseline of background information at the individual level to better develop hypotheses to explain visual patterns in data.*

The biological data and sample attributes for the individuals used for low-coverage whole genome resequencing will be used for this. Relationships between these attributes and the results obtained from the ordination methods (eg. PCA & MDS) planned for this analysis will be examined, aiding in the interpretation of the resulting visual patterns produced by these methods.

*SRB021–Rec.14 (para. 50) **NOTING** the Secretariat's interest in describing linkage relationships, and that descriptions of linkage disequilibrium can be fraught with difficulty in situations of admixture and due to vagaries in breeding structure, the SRB **RECOMMENDED** that the Secretariat explore other literature not cited in IPHC-2022-SRB021-09 in this area.*

The IPHC Secretariat acknowledges this and will explore additional literature that pertains to this issue to ensure that these analyses are consistent with current literature.

*SRB021–Rec.15 (para. 51) The SRB **RECOMMENDED** that the Secretariat (i) develop a rapid screening panel of SNP markers (e.g. GTseq, RADcapture) for future use in Close-Kin Mark recapture (CKMR), population assignment, or other applications (CKMR applications may necessitate the development of microhaplotypes to achieve adequate accuracy in multi-generational pedigree analyses), and (ii) begin developing potential SNP panels and evaluate accuracy of population-based or pedigree-based assignment under scenarios likely to be encountered in future IPHC applications.*

The low-coverage whole genome resequencing dataset that the IPHC Secretariat has recently generated could be leveraged to develop application specific marker panels in the future.

SRB REQUESTS

The SRB issued the following requests in their report of SRB021 (IPHC-2022-SRB021-R):

*SRB021–Req.05 (para. 37) The SRB **REQUESTED** that the Secretariat amend the priorities under bullet "2. Reproduction" (IPHC-2022-SRB021-09) to include other avenues of investigations such as size/age specific fecundity and spatial variation in same.*

Fecundity estimations by size/age and spatial variation are now incorporated as priorities for the research area of Reproduction.

*SRB021–Req.06 (para. 39) The SRB **NOTED** and **APPRECIATED** details provided concerning ongoing or anticipated statistical analyses of data that enhanced the SRB's ability to understand and critique methods to expected research outcomes and **REQUESTED** continued consistency in the presentation in these areas.*

The Secretariat will continue efforts to provide details of data analysis approaches used and planned.

*SRB021–Req.07 (para. 40) **NOTING** the progress update on Migration and Distribution and the specific research goal of creating a map of suitable juvenile Pacific halibut settlement habitat, the SRB **REQUESTED** (i) a clearer statement of the relevance of this research to management, MSE, and/or the stock assessment and (ii) clarification regarding the types of* *data to be collected and used to determine occupancy (and preference), and by what data sources.*

The Secretariat will clarify the relevance and data sources and types used for mapping suitable juvenile habitat in SRB022.

*SRB021–Req.08 (para. 43) **NOTING** the Secretariat's interest in growth and size-at-age relationships, the SRB **REQUESTED** clarification of narrative regarding collection of environmental covariate data for projecting future short-term size-at-age trends.*

The Secretariat is working towards better defining future work on the influence of environmental covariate data on size-at-age trends.

*SRB021–Req.09 (para. 45) **NOTING** the Secretariat's interest in identification of evidence for spatial population structure, and given the IPHC manages stocks on the basis of biological reporting regions, the SRB **REQUESTED** clarification on how the Secretariat may alter assessments if 'functionally isolated components of the population are found'.*

A summary of this topic is included in IPHC-2022-SRB022-08.

UPDATE ON PROGRESS ON THE MAIN RESEARCH ACTIVITIES

1. Migration and Population Dynamics.

   The IPHC Secretariat is currently conducting studies on Pacific halibut juvenile habitat and movement through conventional wire tagging, as well as studies that incorporate genomics approaches in order to produce useful information on population structure, 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 I). Furthermore, the relevance of these research outcomes for the MSE process is in biological parameterization and validation of movement estimates, on one hand, and of recruitment distribution, on the other hand (Appendix II).

   1.1. Identification of Pacific halibut juvenile habitat. The IPHC Secretariat recently investigated the level of connectivity between spawning grounds and possible settlement areas based on a biophysical larval transport model (Sadorus et al. (2021): https://doi.org/10.1111/fog.12512). Although it is known that Pacific halibut initiate their demersal stage as roughly 6-month-old juveniles following the pelagic larval phase and settle in shallow nursery (settlement) areas, near or outside the mouths of bays (Carpi et al. (2021): https://doi.org/10.1007/s11160-021-09672-w), very little information is available on the geographic location and physical characteristics of these areas. Currently, the IPHC Secretariat has initiated studies to identify potential settlement areas for juvenile Pacific halibut throughout IPHC Convention waters and to identify suitable habitat characteristics for settlement grounds. Data mining of multiple sources ranging from IPHC's own historical databases to other public and private agencies who have collected data relevant to this project (Table 1), has resulted in catch locations for a total of 52,356 Pacific halibut aged 0-2 encountered from 1946 to 2022.

Data source	Number of records				Sites where absent#
	Age-0*	Age-1	Age-2	Total	
IPHC historical projects (prior to 1961)	288	1,494	1,234	3,016	
IPHC/NOAA joint trawl projects (1961-1996)	40	368	1,032	1,440	
Other IPHC projects	1	6	91	98	
NMFS trawl surveys	76	2,897	16,427	19,400	
DFO commercial	1	113	836	950	
DFO research	1	145	398	544	
NMFS observer program	42	456	23,948	24,446	
ADFG beam trawl surveys	34	677	1,463	2,174	
ACOR research projects (2018-2022)	69			69	393
NOAA Nearshore Fish Atlas	128	76	2	206	1,037
Literature	13			13	
Total	**693**	**6,232**	**45,431**	**52,356**	**1,430**

Table 1. The number of age-0, age-1, and age-2 Pacific halibut recorded by data source. * Ages were determined through either direct otolith reading or estimated using fork length (i.e. 0-9 cm = age-0; 10-19 cm = age-1; 20-29 = age-2). # Absence indicates those geographical sites located in what was determined as plausible nursery habitat areas for flatfish in Alaska, based on bottom depth (< 50 m depth), and that were sampled with fishing gear that was appropriate for capturing small flatfish (e.g. beach seines and beam trawls) but that did not capture any Pacific halibut.

Estimated ages are based on either direct age determination through otolith reading or fork length if otolith-based ages are not available. An additional 1,430 locations that were study sites located in what was determined as plausible nursery habitat areas for flatfish in Alaska based on bottom depth information (< 50 m depth), and that were sampled with fishing gear that was appropriate for capturing small flatfish (e.g., beach seines and beam trawls) but that did not capture any Pacific halibut, have been noted as stations where Pacific halibut were absent. The IPHC Secretariat is also actively collecting substrate data, some of which has been recorded alongside species capture data (e.g. select records within NOAA's Nearshore Fish Atlas database: https://www.fisheries.noaa.gov/alaska/habitat-conservation/nearshore-fish-atlas-alaska), as well as overlays generated using the United States Geological Survey usSEABED sediment database (https://doi.org/10.5066/P9H3LGWM). The IPHC Secretariat is continuing to locate other sources of sediment and bottom-type data throughout the Convention Area.

In the summer of 2023, additional work will commence in cooperation with Alaska Coastal Observations and Research (ACOR) and University of Alaska Fairbanks to mine data from unpublished sources that was recorded in the 1990s on juvenile Pacific halibut encounters in beach seines. Also in cooperation with ACOR, juvenile Pacific halibut data and genetic samples will be collected from juveniles encountered during non-targeted research taking place around Kodiak Island and the Alaska Peninsula..

1.2. Wire tagging of U32 Pacific halibut. The patterns of movement of Pacific halibut among IPHC Regulatory Areas have important implications for management of the Pacific halibut fishery. The IPHC Secretariat has undertaken a long-term study of the migratory behavior of Pacific halibut through the use of externally visible tags (wire tags) on captured and released fish that must be retrieved and returned by workers in the fishing industry. In 2015, with the goal of gaining additional insight into movement and growth of young Pacific halibut (less than 32 inches [82 cm]; U32), the IPHC began wire-tagging small Pacific halibut encountered on the National Marine Fisheries Service (NMFS) groundfish trawl survey and, beginning in 2016, on the IPHC fishery-independent setline survey (FISS). A total of 1,499 Pacific halibut were tagged and released on the 2022 IPHC FISS but no tagging was conducted in the NMFS groundfish trawl surveys in 2022. Therefore, a total of 8,931 U32 Pacific halibut have been wire tagged and released on the IPHC FISS and 205 of those have been recovered to date date (these totals include a subset of U32 releases that were part of a tail pattern project). In the NMFS groundfish trawl surveys through 2019, a total of 6,421 tags have been released and, to date, 78 tags have been recovered.

1.3. Population genomics. 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

1.3.1. Studies to resolve the genetic structure of the Pacific halibut population in the Convention Area. Details on sample collection, sequencing, bioinformatic processing and proposed analyses utilizing low-coverage whole genome sequencing (lcWGR) to investigate Pacific halibut population structure were provided in documents IPHC-2021-SRB018-08 and IPHC-2022-SRB021-09.

1.3.1.1. Bioinformatic Processing of Sequence Data and Read Alignment. To ensure consistent quality across the three completed sequencing runs and to identify samples that may not be suitable for further analysis, an initial quality check of the raw sequence reads were conducted using FastQC (Andrews et al. 2015) (Figure 1A). The raw sequence reads for each sample were processed as follows. First, reads were trimmed using multiple filters implemented in fastp (v0.23.2) (Chen et al. 2018). To remove low quality bases at the end of the sequence reads, a sliding window approach was used. If average base quality was less than 20 in a 4 bp window, the remainder of the read was trimmed. Poly-G trimming was also performed to remove poly-G tails that can occur when platforms such as the Illumina NovaSeq that utilize a two-channel sequencing chemistry. Sequencing adapters were trimmed from the raw reads using two approaches implemented in fastp, automatic adapter detection, and by supplying the Illumina Nextera transpose adapter sequences directly.

Genomic Sequencing	Sequencing Run # 1	Sequencing Run # 2	Sequencing Run # 3
Number of samples*	250 (247)	250 (249)	110 (108)
Sequencing Platform	Illumina NovaSeq S4	Illumina NovaSeq S4	Illumina NovaSeq S4
Raw Reads Per Sample (Millions)**	24.8 (11.5-47.2)	24.9 (13.0-51.6)	27.7 (14.1-85.8)
Reads Retained (%)**	71 (62-77)	71 (57-77)	70 (59-75)
Coverage Per Sample (x)**	3.7 (1.8-5.9)	3.7 (1.8-7)	4.2 (1.8-11.6)

Table 2. Summary of raw sequence data and genome alignments for three Pacific halibut lcWGR sequencing runs. Summary statistics are only calculated for samples retained for further analyses (>1.5x coverage) *numbers in parenthesis indicate number of samples with > 1.5x coverage. **expressed as mean (min – max).

Trimmed sequence reads were aligned to the Pacific halibut reference genome (Ref Seq: GCF_022539355.2; Jasonowicz et al., 2022) using bwa-mem2 (v2.2.1) (Vasimuddin et al. 2019) and the resulting alignments were coordinate sorted and converted to the binary alignment map format (BAM) using samtools (v1.16) (Li et al. 2009). Mate-pair information was verified and fixed if needed using Picard tools (v2.27.4) (broadinstitute.github.io/picard/). Next, PCR and optical duplicates were removed using Picard tools, supplying a maximum pixel distance of 2500 to detect optical duplicates. Overlapping read pairs were then clipped using bamUtil (v1.0.15) (Jun et al. 2015). Next, realignment around insertion/deletion elements was performed using GATK (v3.8) (Van der Auwera and O'Connor 2020). Metrics for the resulting alignments were obtained using samtools to summarize the bit values set in the FLAG field of each BAM file and mosdepth (v0.3.3) (Pedersen and Quinlan 2018) was used to calculate the sequencing depth for each individual (Figure 1B). Individuals were removed from the data set if sequencing depth was less than 1.5x in fully assembled autosomal regions of the genome, retaining 604 individuals for further analysis. Sequencing yield per sample was 25.4 million reads on average (range = 11.5 – 85.8 million reads), and an average coverage per sample of 3.43x (Table 2).

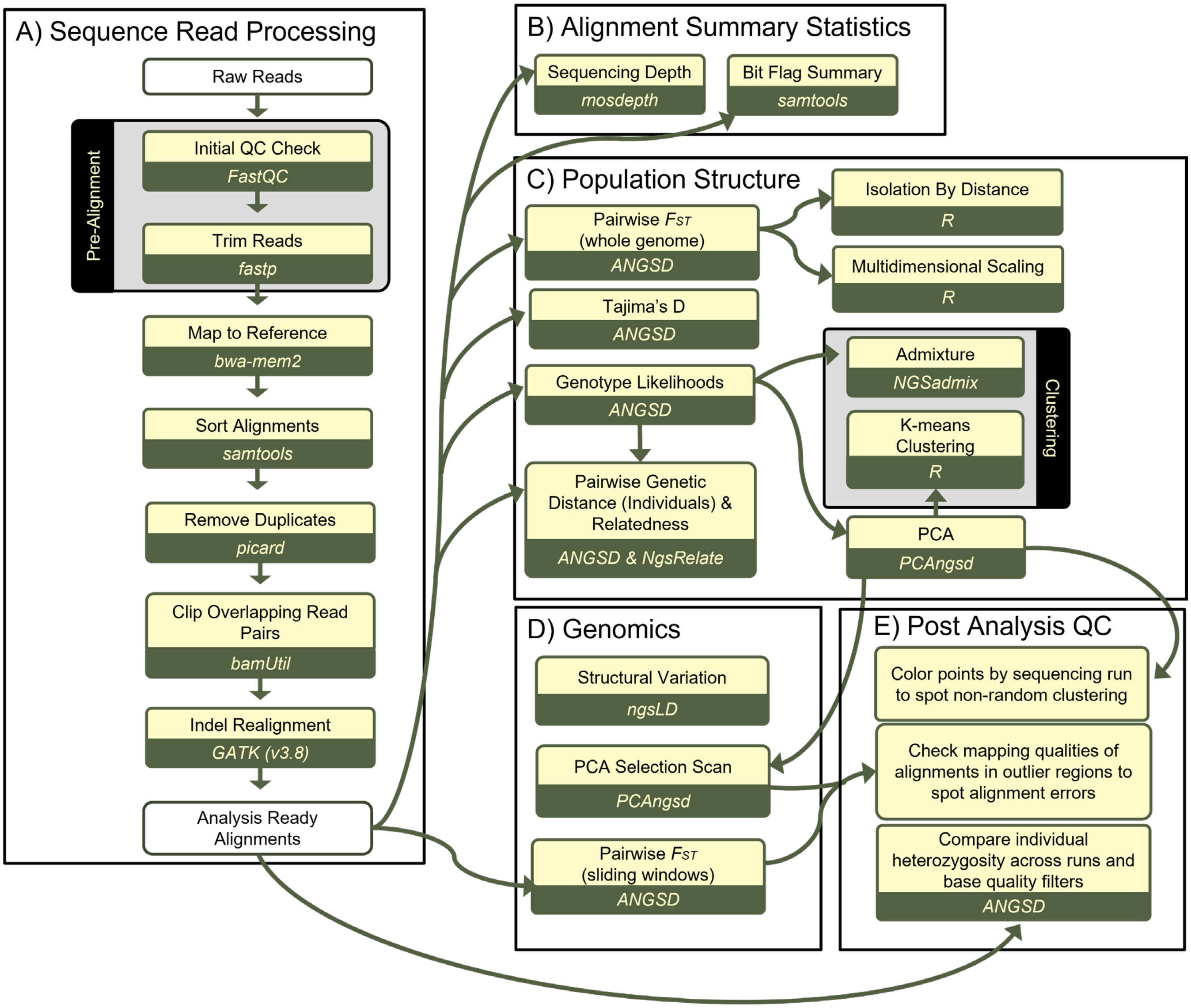


Figure 1. Proposed bioinformatic workflow for the interrogation of low-coverage whole genome sequence data. This diagram tracks the flow of data through the main stages of this project, (A) raw sequence read processing, (B) alignment summaries, (C) analysis of population structure, (D) genomic analyses, and (E) quality control steps to be taken.

1.3.1.2. Genotype Likelihood Estimation and SNP Detection. Genotype likelihoods were estimated using the GATK model in ANGSD (Figure 1C). This model assumes that sequencing errors are independent at a given site and the base quality scores accurately reflect the probability of sequencing error. This is in contrast to the other models implemented in ANGSD which may fail to correctly identify low frequency mutations and classify them as sequencing errors instead (Lou and Therkildsen 2021). Low quality base calls and reads with low mapping qualities were removed using ANGSD's input filters. A minimum base quality of 20 and mapping quality of 20. Quality scores are encoded as $-10log10(e)$ where e is the probability of an error, therefore a quality score of 20 corresponds to a base call or read alignment accuracy of 99%. Reads mapping to multiple genomic locations were also removed. A p-value threshold of 1e-6 for a site being variable was used and SNPs were only retained if they had a minor allele frequency (MAF) ≥ 0.01 and covered in at least 80% of the individuals. Minimum and maximum sequencing depth filters were imposed and sites were excluded if the total sequencing depth for all samples combined was not between 604 and 3624. This was to exclude regions of the genome that may be poorly covered or might represent repetitive regions. This resulted in 10,230,908 SNPs being identified in fully assembled autosomal regions of the genome, with 4,725,899 SNPs having a MAF ≥ 0.05.

1.3.1.3. Population Genomics Analyses. Initial results in this area are provided in the Supplementary Documentation. Furthermore, additional analyses are being conducted based on recommendations from the SRB. To accommodate *SRB021–Rec.12*, Tajima's D will be estimated by calculating 1 dimensional site frequency spectra (SFS) for each and sample collection and the realSFS tool included with ANGSD will be used to obtain estimates for Tajima's D in a sliding window fashion (15 Kb windows, 7.5 Kb step) across the genome (Figure 1C). Additionally, inter-individual genetic distances will be estimated (*SRB021–Rec.11*) using the single read sampling approach in ANGSD, and NgsRelate (Korneliussen and Moltke 2015) will also be used to obtain relatedness estimates using genotype likelihoods directly (Figure 1C).

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.

The IPHC Secretariat is currently processing genetic samples from the 2022 aged commercial landings.

2.2. Maturity assessment.

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) update of maturity schedules based on histological-based data; and, 2) fecundity determinations.

2.2.1. Update of maturity schedules based on histological-based data. The IPHC Secretariat is undertaking studies to revise maturity schedules in all four biological regions through histological (i.e. microscopic) characterization of maturity, as reported previously. The maturity schedule that is currently used in stock assessment was based on visual (i.e. macroscopic) maturity classification in the field (FISS). To accomplish this objective, the IPHC Secretariat collected ovarian samples for histology during the 2022 FISS. The FISS sampling resulted in a total of 1,016 ovarian samples collected coastwide for histological analysis, with 437 ovarian samples from Biological Region 2, 348 samples from Biological Region 3, 180 from Biological Regions 4, and 51 samples from Biological Region 4B. Ovarian samples have been processed for histology and IPHC Secretariat staff is currently scoring samples for maturity using histological maturity classifications as previously described in Fish et al. (2020, 2022). Following this maturity classification criteria, all sampled Pacific halibut females will be assigned to either the mature or immature categories.

The proportion of Pacific halibut females that are mature at a given length or age will be evaluated through the generation of maturity ogives. Maturity ogives will be represented using a logistic curve to which the maturity data (each female will be assigned as mature or immature according to histological classification) will be fit applying a generalized linear model with a binomial data distribution and a logit link function, as described by Dominguez-Petit et al. (2017) and with publicly available R code (MARVLS repository for reproductive analyses: https://github.com/MARVLS/Fish-Gonad-Staging/tree/main/analyses). The length and age at 50% maturity will be calculated from fitted models using the dose.p function and the proportion of mature individuals (p) set to 0.5. Variation in the proportion mature with length and age will be examined among all four IPHC biological regions based on data available.

IPHC Secretariat will continue to collect ovarian samples in 2023 on the FISS. This will allow us to investigate both spatial and temporal differences in female Pacific halibut maturity. Due to the reduction in FISS design for 2023, we will be sampling in IPHC Biological Regions 2 and 3. Targets are to collect 400 samples in Biological Region 2 and 1,000 in Biological Region 3.

2.2.2. Fecundity estimations. The IPHC Secretariat have initiated studies that are aimed at improving our understanding of Pacific halibut fecundity. This will allow us to estimate fecundity-at-size and -age and could be used to replace spawning biomass with egg output as the metric for reproductive capability in stock assessment and management reference points. Fecundity determinations will be conducted using the auto-diametric method (Thorsen and Kjesbu 2001; Witthames et al., 2009). IPHC Secretariat staff are currently receiving training on this method by experts in the field. The IPHC Secretariat will be collecting ovarian samples for fecundity estimations as part of the 2023 FISS. Sampling will take place in IPHC Biological Region 3, with a minimum target of 250-300 fecundity samples (from fish that will also have a maturity sample collected, as described in 2.2.1).

3. Growth.

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.

No updates to report.

4. Mortality 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 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 parametrization (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.

After having reported on our estimates of discard mortality rate in the directed longline fishery (Loher et al., 2022; https://doi.org/10.1002/nafm.10711), the second component of this study investigated the relationships among hook release techniques (e.g., gentle shake, gangion cutting, and hook stripping), injury levels, stress levels and physiological condition of released fish, as well as the environmental conditions that the fish experienced during capture. Gentle shake and gangion cutting resulted in the same injury and viability outcomes with 75% of sublegal fish in Excellent condition, while the hook stripper produced the poorest outcomes (only 9% in Excellent condition). Hook stripping also resulted in more severe injuries, particularly with respect to tearing injuries, whereas gentle shake and gangion cutting predominantly resulted in a torn cheek, effectively the injury incurred by the hooking event. Physiological stress indicators (plasma levels of glucose, lactate, and cortisol) did not significant change with viability outcomes, except for higher lactate plasma levels in fish categorized as Dead. Hematocrit was significantly lower in fish that were categorized as Dead. Furthermore, 89% of fish classified as Dead were infiltrated by sand fleas, present in several sets in deeper and colder waters. Our results indicated that avoiding the use of hook strippers and minimizing soak times in areas known to have high sand flea activity result in better survival outcomes.

4.2. Estimation of discard mortality rates in the charter recreational sector.

Results from the similar study conducted in fish captured using guided recreational fishery practices yielded an estimated discard mortality rate of 1.35% (95% CI 0.00-3.95%) for Pacific halibut released in Excellent viability category that were captured and released from circle hooks. This estimate is consistent with the supposition that fish discarded in the recreational fishery from circle hooks in excellent condition have a mortality rate that is arguably lower than 3.5%, as is currently used for Excellent viability fish released in the commercial fishery (Meyer, 2007). As this estimate does not factor in mortality rates on fish in less than Excellent condition, does not inform mortality rates on non-circle hooks (J-hooks, jigs, other), nor directly applies to fish captured and released from non charter practices, changes to the overall recreational discard mortality estimation are not currently contemplated. These results represent the first report of experimentally-derived estimates of mortality of Pacific halibut captured and discarded in the recreational fishery.

By the end of 2022, of the 281 fish that were tagged with opercular wire tags (243 fish in IPHC Regulatory Area 2C and 38 in IPHC Regulatory Area 3A) 32 tags have been recovered: 30 from IPHC Regulatory Area 2C and 2 from IPHC Regulatory Area 3A. Tags recovered by fisheries are summarized in Table 3 and shown in Figure 2. Ten tags were recovered within 5.5 km (3 nm) of their initial release (5 in year 1, and 5 one year later).

Tag Type	Release Area	Recovery Year	N	Distance Traveled (km)			Days at Large		
				Average	Min	Max	Average	Min	Max
Wire	2C	2021	14	99.2	0.9	571.3	56*	10	112
Wire	2C	2022	16	20.8	0.1	105	396	325	459
Wire	3A	2021	1	0.1	-	-	51	-	-
Wire	3A	2022	1	39.8	-	-	267	-	-
Satellite	3A	2021	7	0.5	0.1	2.4	59	38	70
Satellite Tether	3A	2022	1	23.9	-	-	438	-	-

* 3 with no recovery location information

Table 3. Summary of distances traveled (km) and days at large for fishery recoveries of recreationally captured and released Pacific halibut fitted with a wire opercular tag or a sPAT tag or tether.

For the 80 fish in excellent viability, 76 provided sufficient data for survival analysis. Of the 4 sPAT tags that did not provide data, 2 sPAT tags never reported and 2 tags did not have sufficient data for successful interpretation. Track plots of the spatial release to recovery for these tags can be found in Figure 3, and general recovery metrics can be found in Table 4. The one sPAT listed in Table 3 as being recovered in 2022 represents the recovery of a fish with the anchor tether still attached and whose satellite tag reported successfully after 96 days.

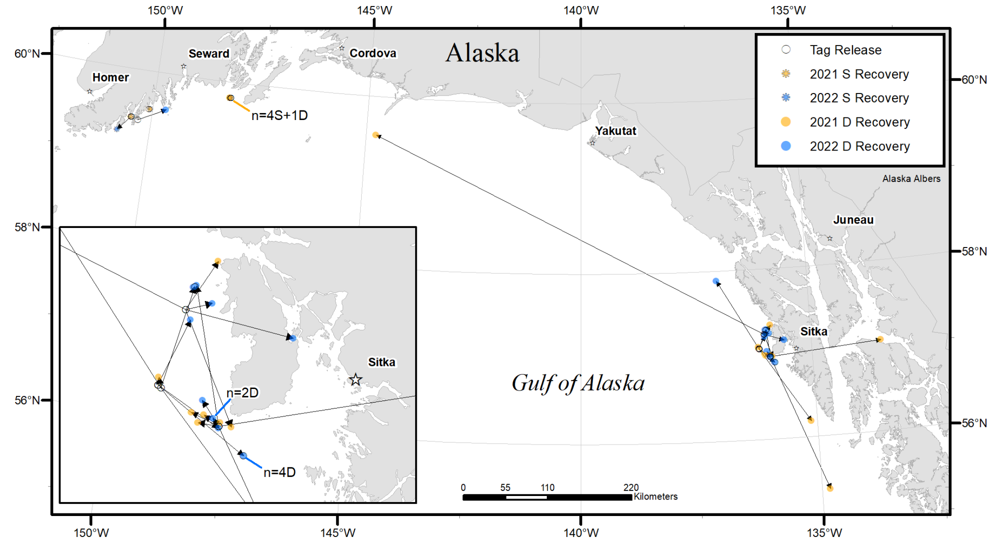


Figure 2. Release and fishery recovery locations of recreationally captured and released Pacific halibut fitted with a wire opercular tag (D) or a sPAT (S) by year of recovery.

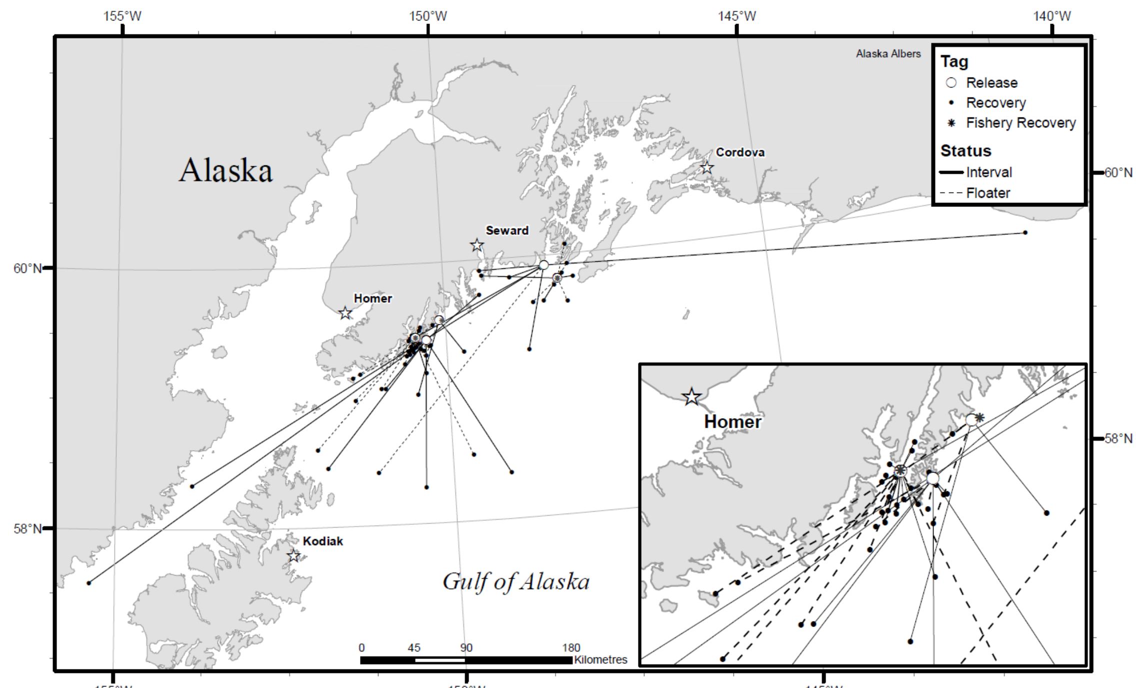


Figure 3. Release and recovery (satellite report or fishery removal) locations of recreationally captured and released Pacific halibut fitted with a sPAT. Status tracks indicate whether a tag reported prematurely (floater) or after the maximum 96-day retention period (interval). The majority of floaters were fully active at the time of tag loss.

Of the seven sPAT fishery recoveries in the first year (Table 4), one was recovered 2.4 km from its release location, and the remaining 6 tags were recovered less than 0.5 km from their release location, so effectively all were recaptured on or about their release location.

Tag Type	Release Ar	Recovery Year	Recovery Type	N	Distance Traveled (km)			Days at Large		
					Average	Min	Max	Average	Min	Max
Satellite	3A	2021	Broadcast	73*	43.0	0.45	415.6	78.07	3.6	96
Satellite	3A	2021	Fishery	7	0.5	0.1	2.4	59	38	70

* 2 tags failed to report, 2 tags didn't record sufficient information for survival analysis.

Table 4. Summary of distance traveled (km) and days at large for recreationally captured and released Pacific halibut fitted with a sPAT tag.

5. Fishing technology.

The IPHC Secretariat has determined that research to provide the Pacific halibut fishery with tools to reduce whale depredation is considered a high priority. This research is now contemplated as one of the research areas of high priority within the 5-year Program of Integrated Research and Monitoring (2022-2026). Towards this goal, the IPHC secretariat is investigating gear-based approaches to catch protection as a means for minimizing whale depredation in the Pacific halibut and other longline fisheries with funding from NOAA's Bycatch Research and Engineering Program (BREP) (NOAA Award NA21NMF4720534; Appendix IV). The objectives of this study are to: 1) work with fishermen and gear manufacturers, via direct communication and through an international workshop, to identify effective methods for protecting hook-captured flatfish from depredation; and 2) develop and pilot test 2 simple, low-cost catch-protection designs that can be deployed effectively using current longline fishing techniques and on vessels currently operating in the Northeast Pacific Ocean.

The results and outcome of the first phase of this project were reported in the documentation to the previous SRB meeting: IPHC-2022-SRB020-08.

During the second phase of the project, the IPHC Secretariat has worked with catch protection device manufacturers for the design of two different types of devices for field testing: one based on a modification of Sago's catch protection device (i.e., shuttle) and one based on a modification of a slinky pot (i.e., shroud) deployed on branchline gear. The two different devices will be tested on a chartered fishing vessel off Newport, OR in late May of 2023. The focus of the testing will be to investigate (1) the logistics of setting, fishing, and hauling of the two pilot catch protection designs, and (2) the basic performance of the gear on catch rates and fish size compared to non-protected gear. These two different devices are the following:

- Shuttle system. Manufactured in Norway by Sago, two shuttle devices were modeled after the Sago Extreme but smaller at 80% size (Figure 4). Their dimensions are 2.60 m (8.5 ft) long by 0.80 m (2.6 ft) in diameter, each weighing approximately 100 kg (220 lb.) when empty. Typically, these devices are set with the gear; however, for this study the units will be deployed from the surface, during the haulback event.

A) 

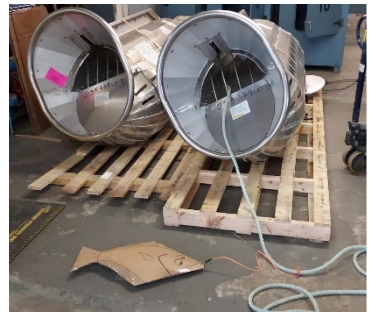
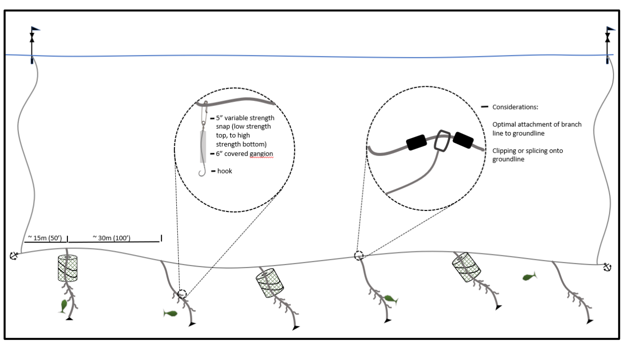
B) 

Figure 4. Images of the prototype shuttle devices to be used in this study in profile (A) and frontal view (B).

- Shroud system. Several shroud systems are currently under construction and will consist of a modified slinky pot designed to slide down the branch covering the catch during hauling (Figure 5).

A) 

B) 

Figure 5. Schematic of shrouded branchline actively fishing on seabed (A) and an unmodified slinky pot to be modified into a shroud (B).

Recommendation/s

That the SRB:

a) **NOTE** paper IPHC-2023-SRB022-09 which provides a response to requests from SRB021, and a report on current research activities contemplated within the IPHC's five-year Program of Integrated Research and Monitoring (2022-26).

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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
Summary of active research grants

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	**Bycatch Reduction Engineering Program - NOAA**	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries (NA21NMF4720534)	IPHC	Deep Sea Fishermen's Union, Alaska Fisheries Science Center-NOAA, industry representatives	$99,700	Mortality estimations due to whale depredation	November 2021 – October 2023
2	**North Pacific Research Board**	Pacific halibut population genomics (NPRB No. 2110)	IPHC	Alaska Fisheries Science Center-NOAA	$193,685	Stock structure	December 2021- January 2024
Total awarded ($)					**$293,385**		