INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC–2023–SRB023–00
Last Update: 25 August 2023

23rd Session of the IPHC Scientific Review Board (SRB023) – *Compendium of meeting documents*

25-27 September 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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INTERNATIONAL PACIFIC HALIBUT COMMISSION

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PROVISIONAL: AGENDA & SCHEDULE FOR THE 23rd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB023)

Date: 25-27 Sept 2023
Location: Seattle, WA, USA, & Electronic Meeting
Venue: IPHC HQ & Adobe Connect
Time: 09:00-17:00 (25-26th), 09:00-12:00 (27th) 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 22nd Session of the SRB (SRB022) (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 23rd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB023)

SCHEDULE FOR THE 22nd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB023)

Monday, 25 September 2023		
Time	**Agenda item**	**Lead**
09:00-09:30	*Meet and greet *Electronic meeting platform - Participants encouraged to call in and test connection	
09:30-09:35	1. OPENING OF THE SESSION 2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION	S. Cox & D. Wilson
09:35-10:00	3. IPHC PROCESS 3.1 SRB annual workflow (D. Wilson) 3.2 Update on the actions arising from the 22nd Session of the SRB (SRB022) 3.3 Outcomes of the 99th Session of the IPHC Annual Meeting (AM099) 3.4 Observer updates (e.g. Science Advisors)	D. Wilson
10:00-10:30	4. INTERNATIONAL PACIFIC HALIBUT COMMISSION 5-YEAR PROGRAM OF INTEGRATED RESEARCH AND MONITORING (2022-26)	D. Wilson
10:30-12:30	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
12:30-13:30	**Lunch**	
13:30-16:00	4.1 continued.	
16:00-17:00	SRB drafting session	SRB members

Tuesday, 26 September 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	4.2 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)	B. Hutniczak R. Webster
12:30-13:30	Lunch	
13:30-15:30	OPEN WORKING SESSION ON ANY TOPIC	
15:30-16:00	5. MANAGEMENT SUPPORTING INFORMATION	As needed
16:00-17:00	SRB drafting session	SRB members
Wednesday, 27 September 2023		
Time	**Agenda item**	**Lead**
09:00-09:30	Review of Day 2 and discussion of SRB Recommendations from Day 2	Chairperson
09:30-10:30	SRB drafting session	SRB members
10:30-12:00	6. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 23rd SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB023)	S. Cox

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

Document	Title	Availability
IPHC-2023-SRB023-01	Agenda & Schedule for the 23rd Session of the Scientific Review Board (SRB023)	✓ 26 Jun 2023
IPHC-2023-SRB023-02	List of Documents for the 23rd Session of the Scientific Review Board (SRB023)	✓ 26 Jun 2023
IPHC-2023-SRB023-03	Update on the actions arising from the 22nd Session of the SRB (SRB022) (IPHC Secretariat)	✓ 22 Aug 2023
IPHC-2023-SRB023-04	Outcomes of the 99th Session of the IPHC Annual Meeting (AM099) (D. Wilson)	✓ 26 Jun 2023
IPHC-2023-SRB023-05	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)	✓ 23 Aug 2023
IPHC-2023-SRB023-06	Development of the 2023 Pacific halibut (*Hippoglossus stenolepis*) stock assessment (I. Stewart & A. Hicks)	✓ 22 Aug 2023
IPHC-2023-SRB023-07	IPHC Secretariat MSE Program of Work (2023) and an update on progress (A. Hicks & I. Stewart)	✓ 23 Aug 2023
IPHC-2023-SRB023-08	Report on current and future biological and ecosystem science research activities (J. Planas)	✓ 25 Aug 2023
IPHC-2023-SRB023-09	2024-26 FISS design evaluation (R. Webster, I. Stewart, K. Ualesi, & D. Wilson)	✓ 25 Aug 2023
Information papers		
IPHC-2023-SRB023-INF01	Research projects (IPHC Secretariat)	✓ 23 Aug 2023

UPDATE ON THE ACTIONS ARISING FROM THE 22ND SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB022)

PREPARED BY: IPHC SECRETARIAT (22 AUGUST 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 SRB022.

BACKGROUND

At the SRB022, the members recommended/requested a series of actions to be taken by the IPHC Secretariat, as detailed in the SRB022 meeting report (IPHC-2023-SRB022-R) available from the IPHC website, and as provided in Appendix A.

DISCUSSION

During the 23rd Session of the SRB (SRB023), 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-SRB023-03, 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 (SRB022).
2) **AGREE** to consider and revise the actions as necessary, and to combine them with any new actions arising from SRB023.

APPENDICES

Appendix A: Update on actions arising from the 22nd Session of the IPHC Scientific Review Board (SRB022)

APPENDIX A
Update on actions arising from the 22nd Session of the IPHC Scientific Review Board (SRB022)

RECOMMENDATIONS

Action No.	Description	Update
SRB022–Rec.01 (para. 15)	***International Pacific Halibut Commission 5-year program of integrated research and monitoring (2022-26)*** The SRB **NOTED** the reporting table draft provided by the Contracting Parties (Appendix A of paper IPHC-2023-SRB022-05) and **RECOMMENDED** further modification by adding the following and as shown in Table 1 below: a) New Column: Brief description of the project and how it relates to the core mandate of the Commission; b) Description of the problem being addressed; c) Objective: List of concise objectives (research and how the results will be incorporated); d) Impact scale and timing; e) Interim performance/evaluation metrics.	***Ongoing*** **Update**: See paper **IPHC-2023-SRB022-05**
SRB022–Rec.02 (para. 19)	***Pacific halibut stock assessment*** **NOTING** that the scale of impact from different model weighting approaches presented here is small relative to the impact of other factors in the MSE (e.g. two- vs. three-year assessment intervals and TCEY), the SRB **RECOMMENDED** that the Secretariat continue using the equal weighting approach for model averaging.	***In Progress*** **Update**: Equal weighting will be applied to all four models in the final 2023 stock assessment ensemble.
SRB022–Rec.03 (para. 25)	***Management strategy evaluation*** To improve comparability of MPs in performance achieving TCEY objectives, the SRB **RECOMMENDED** equalizing MP performance on one of the conservation objectives.	***In Progress*** **Update**: This topic is presented and discussed in **IPHC-2023-SRB023-07.**

Action No.	Description	Update
SRB022–Rec.04 (para. 26)	The SRB **RECOMMENDED** that reconditioning the operating model should be limited to situations where the stock assessment has changed significantly. This likely means a three-year schedule for reconditioning the operating model in the year following each full stock assessment.	***Completed*** **Update**: The operating model has been updated following the 2023 stock assessment and is presented in **IPHC-2023-SRB023-07.**
SRB022–Rec.05 (para. 27)	The SRB **RECOMMENDED** that the Secretariat consider using explicit informative priors for conditioning the operating model to make fitting constraints more explicit.	***In Progress*** **Update**: A description of some of the conditioning process is described in **IPHC-2023-SRB023-07**. Additional details will be in the technical document available on the MSE Research webpage.
SRB022–Rec.06 (para. 28)	The SRB **RECOMMENDED** that exceptional circumstance (i) be evaluated annually based on comparisons between the simulation distribution (e.g. a 95% interval) of FISS values from MSE simulations to the realized FISS estimates; and (ii) be clearly distinguished from "unusual conditions". For example, exceptional circumstances should have a high threshold for persistent (i.e. more than a single year) deviation from MSE simulations.	***In Progress*** **Update**: Proposals for defining exceptional circumstances are provided in IPHC-2023-SRB023-07.
SRB022–Rec.07 (para. 29)	The SRB **RECOMMENDED** that an initial response to a suspected "exceptional circumstance" should include presentation at the next SRB meeting to establish whether the situation meets the definition of an "exceptional circumstance" and to formulate a response.	***In Progress*** **Update**: Proposals for defining exceptional circumstances are provided in **IPHC-2023-SRB023-07**.

Action No.	Description	Update
SRB022–Rec.08 (para. 32)	***Biology and ecology*** The SRB **NOTED** that the current maturity sampling design does not determine whether the high rate of individuals at the cortical alveoli stage in the southeastern portion of the study area is a function of differences in seasonal reproductive timing or in size/age at maturity. The SRB **RECOMMENDED** additional investigations on the region-specific seasonal reproductive cycles and evaluating the extent to which differences among regions can be explained by size or age of the sampled individuals.	***In Progress*** **Update**: The IPHC Secretariat is currently conducting a coastwide study on maturity with a significantly higher number of ovarian samples collected during the 2022 FISS and is expanding further the number of collected ovarian samples in the referenced study area during the current 2023 FISS.
SRB022–Rec.09 (para. 35)	The SRB **NOTED** the presentation on whale depredation avoidance devices and **RECOMMENDED** that the Secretariat pursue external funding opportunities for expanding this research and testing one or more devices in the presence of whales.	***Completed*** **Update**: The IPHC Secretariat submitted a grant proposal to test catch protection devices in the presence of killer whales that has been awarded.
SRB022–Rec.10 (para. 36)	**NOTING** that in terms of bioinformatic quality filtering to exclude loci, filtering based on sequencing depth alone may not be sufficient to exclude mitochondrial sequences, the SRB **RECOMMENDED** that loci be mapped to the published Pacific halibut mitochondrial genome to ensure that non-autosomal loci are included in analyses. Filtering based on sequencing depth alone is likely not sufficient to exclude regions of the genome that represent repetitive elements. Suggest sites be checked for repetitive elements.	***Completed*** **Update**: The IPHC Secretariat has addressed this recommendation in **IPHC-2023-SRB023-08.**

Action No.	Description	Update
SRB022–Rec.11 (para. 37)	The SRB **RECOMMENDED** that the Secretariat include other genome-wide summary measures of diversity. Measures could include (a) measures of genome size, (b) percentages of genome as singleton and duplicated loci, (c) other summary measures of diversity including (i) number of loci with minor allele frequency (MAF)>0.01, (ii) number of loci with MAF>0.05, (iii) a measure of deviation of observed and expected heterozygosity (Fis), (iv) observed heterozygosity (Ho) and expected heterozygosity (He).	***In Progress*** **Update**: The IPHC Secretariat has addressed part of this recommendation in **IPHC-2023-SRB023-08** and work is currently in progress.
SRB022–Rec.12 (para. 38)	The SRB **RECOMMENDED** that the Secretariat evaluate multiple 'windows' and inter-window 'spacing' to summarize diversity and differentiation. The SRB is unsure why a 15 Kb 'window was used with 7.5 Kb space for producing Manhattan plots. The size of the window will affect estimates of significance based on a measures of Fst significance. Specifically, the larger the 'window' likely the larger the standard deviation across a greater number of sites. Window size is also likely to affect levels of linkage disequilibrium and down-stream analyses based on it.	***Completed*** **Update**: The IPHC Secretariat has addressed this recommendation in **IPHC-2023-SRB023-08.**
SRB022–Rec.13 (para. 39)	**NOTING** that different outlier tests are based on different assumptions and statistical approaches, the SRB **RECOMMENDED** that the Secretariat implement more than one method. Selection of specific markers would appropriately be based on concordant designation of highly population discriminatory loci identify across methods. The Secretariat is likely to have greater confidence in assignment of 'outliers' based on principles of concordance using multiple and semi-independent software packages and statistical approaches.	***Completed*** **Update**: The IPHC Secretariat has addressed this recommendation in **IPHC-2023-SRB023-08.**

Action No.	Description	Update
SRB022–Rec.14 (para. 40)	The SRB **RECOMMENDED** that after statistical significance of SNP loci has been established, the Secretariat use gene set enrichment analyses to establish functional annotations for genes associated with SNPs.	***Completed*** **Update**: The IPHC Secretariat has addressed this recommendation in **IPHC-2023-SRB023-08.**
SRB022–Rec.15 (para. 41)	The SRB **APPRECIATED** that the Secretariat estimated Tajima's D as recommended (IPHC-2022-SRB021-R), and **RECOMMENDED** that: a) the Secretariat be cautious with filtering SNP loci based on minor allele frequency (MAF) at levels as low as 0.01 as employed in results described in IPHC-2023-SRB022-09, as this may affect values of Tajima's D; and b) a range of values be explored.	***Completed*** **Update**: The IPHC Secretariat has addressed this recommendation in **IPHC-2023-SRB023-08.**
SRB022–Rec.16 (para. 43)	The SRB **RECOMMENDED** looking for genome regions (more than 2 or more co-located 'significant' SNPS) with high divergence as indication of regions containing structural variants. Measures of linkage disequilibrium can also be profitably used to identify structural variants.	***In Progress*** **Update**: The IPHC Secretariat is currently working to address this recommendation.
SRB022–Rec.17 (para. 44)	The SRB **RECOMMENDED** plotting levels of heterozygosity as Manhattan plots across chromosomal regions.	***In Progress*** **Update**: The IPHC Secretariat has begun estimating additional genetic diversity measures and has updated the proposed workflow to reflect this. This would include visualizing heterozygosity levels across chromosomal regions.

Action No.	Description	Update
SRB022–Rec.18 (para. 45)	**NOTING** that use of high-throughput low-coverage DNA sequencing data can lead to biased estimates of the site frequency spectrum (SFS) due to high levels of uncertainty in genotyping, the SRB **RECOMMENDED** exploring other derivations from Secretariat proposed work described in IPHC-2023-SRB022-09 including visualisations of SFS in multi-dimensional space.	***Completed*** **Update**: The IPHC Secretariat has addressed this recommendation in **IPHC-2023-SRB023-08**.
SRB022–Rec.19 (para. 46)	**NOTING** that one of the primary objectives of the Pacific halibut genome project is to provide spatial discrimination of 'populations' (IPHC reporting regions) and to assign individuals to these groups, and that the Secretariat described genetic relationships among individuals from different IPHC reporting region and years of collection based on multivariate ordination using principle component analyses (PCA), and that levels of variability explained associated with PCA axes projects is low, the SRB **RECOMMNEDED**: a) conducting additional analyses to evaluate statistical significance of measures of inter-population differentiation (Fst); and b) re-analysis using only outlier loci.	***In Progress*** **Update**: The IPHC Secretariat is currently working to address this recommendation.
SRB022–Rec.20 (para. 47)	The SRB **RECOMMENDED**: a) that the Secretariat move forward to stock discrimination to satisfy the Secretariat objective of using genetic data to define spatial structuring including unsupervised clustering methods (e.g. K-means, Structure, etc.) as well as PCA-based clustering (e.g. Discriminant Analysis of Principle Component) clustering; b) using assignment testing and mixture analyses such as leave-one-out cross-validation simulations to assess the potential accuracy of mixed stock analysis (MSA).	***In Progress*** **Update**: The IPHC Secretariat is currently working to address this recommendation.

Action No.	Description	Update
SRB022–Rec.21 (para. 52)	***Management Supporting Information*** The SRB **NOTED** the presentation demonstrating how secondary FISS objectives influence choices for future FISS designs that may have already been endorsed by the SRB based only on primary objectives. The SRB **RECOMMENDED** that the MSE include some scenarios in which the FISS is skipped (as also requested above in para. 30) because of occasional (or persistent) economic constraints on executing full FISS designs. Such simulation scenarios would provide some indication of the potential scale of impacts on MP performance of maintaining long-term revenue neutrality of the FISS.	***Completed*** **Update**: Three scenarios for FISS data collection were simulated in the MSE and are presented in **IPHC-2023-SRB023-07.**
SRB022–Rec.22 (para. 55)	***Other business*** The SRB **NOTED** the continuing gap within the Secretariat of research scientist expertise in both population genomics and life history modelling. In terms of prioritizing future hires, e.g. re-opening previous hiring attempts for a research scientist life history modeller, the SRB **RECOMMENDED** prioritizing a research scientist position in population genomics given the investments and future potential contribution of this research to the overall goals of the Commission.	***Pending*** **Update:** Insufficient funding at this time.

REQUESTS

Action No.	Description	Update
SRB022–Req.01 (para. 16)	***International Pacific Halibut Commission 5-year program of integrated research and monitoring (2022-26)*** The SRB **REQUESTED** that during the next update of the Plan, consider specifying the role and timing of input from the SRB in developing and reviewing project methods, performance metrics.	***Ongoing*** **Update**: See paper **IPHC-2023-SRB022-05.**

Action No.	Description	Update
SRB022–Req.02 (para. 18)	***Pacific halibut stock assessment*** **NOTING** that analysis of whale depredation has clarified that the potential scale of removals from depredation is relatively small, except in IPHC Regulatory Area 4A, the SRB **REQUESTED** that updated analysis using USA observer data be presented at SRB023 to evaluate whether incorporation of whale depredation in the stock assessment is warranted.	***Completed*** **Update**: Results included in **IPHC-2023-SRB023-06.**
SRB022–Req.03 (para. 30)	***Management strategy evaluation*** The SRB **NOTED** that situations in which critical data streams (e.g. FISS index or age data) are unavailable for one or more years does not constitute an "exceptional circumstance" and **REQUESTED** that the MSE include evaluation of such missing FISS data scenarios for the SRB023.	***Completed*** **Update**: Three scenarios for FISS data collection were simulated in the MSE and are presented in **IPHC-2023-SRB023-07.**
SRB022–Req.04 (para. 50)	***FISS design evaluation*** The SRB **NOTED** that IPHC Regulatory Area 4B will not be sampled in 2023 and **REQUESTED** that the Secretariat present an analysis of the predicted CV for unsampled and partially sampled IPHC Regulatory Areas in 2024.	***Completed*** **Update**: see paper **IPHC-2023-SRB023-09.**

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

PREPARED BY: IPHC SECRETARIAT (D. WILSON, 26 JUNE 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-SRB023-04 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): UPDATES

PREPARED BY: IPHC SECRETARIAT (D. WILSON, J. PLANAS, I. STEWART, A. HICKS, B. HUTNICZAK, AND R. WEBSTER; 23 AUGUST 2023)

PURPOSE

To provide the SRB with an annual opportunity to comment and propose amendments to the IPHC's 5-year Program of Integrated Research and Monitoring (2022-26) (the Plan).

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.

The 1st iteration of the Plan was formally presented to the Commission at IM097 in November 2021 (IPHC-2021-IM097-12) for general awareness of the documents ongoing development. At the 98th Session of the IPHC Annual Meeting (AM098) in January 2022, the Commission requested a number of amendments which were subsequently incorporated.

The Plan had already been through two cycles of review and improvement with the Scientific Review Board (SRB).

In 2022, the plan went through two further cycles of review and improvement with the SRB, with amendments being suggested and incorporated accordingly. The current version will move to an annual comment and amendment process at each years' Interim and then Annual Meetings.

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.

At the 22nd Session of the Scientific Review Board (SRB022) in June 2023, the SRB provided the following recommendation to the Commission.

International Pacific Halibut Commission 5-year program of integrated research and monitoring (2022-26)

*SRB022–Rec.01 (para. 15) The SRB **NOTED** the reporting table draft provided by the Contracting Parties (Appendix A of paper IPHC-2023-SRB022-05) and **RECOMMENDED** further modification by adding the following and as shown in Table 1 below:*

a) New Column: Brief description of the project and how it relates to the core mandate of the Commission;

b) Description of the problem being addressed;

c) Objective: List of concise objectives (research and how the results will be incorporated);

d) Impact scale and timing;

e) Interim performance/evaluation metrics.

The template (provided at Appendix A) will be populated fully as we prepare for the Interim and Annual meetings. We have also commenced populating the table as provided in paper **IPHC-2023-SRB023-INF01**.

RECOMMENDATION

That the SRB:

1) **NOTE** paper IPHC-2023-SRB023-05 which provides the IPHC 5-year program of Integrated Research and Monitoring (2022-26) with potential updates.

APPENDICES

Appendix A: Overview of research activities within the 5-YPIRM – Contents provided as an excel file on the WM2023 page.

Appendix A
Overview of research activities within the 5-YPIRM

Project start/end year	General area	Topic	Problem	Relevance to General Area	Study objectives and rationale	Anticipated results/ application	Expected Impact	Impact timing	Funding details (amount required per year, funding source)	Commissioner decision	Status
E.g. 1, 2, 3	*Stock assessment or MSE*		*E.g. similar to typical science abstract to summarize project, with links to IPHC core mandate and decision-making*		*a list of concise project objectives including main research objectives and rationale for why the results are important to the General Area*	*Results and application in SA or MSE*	*High-Med-Low*	*expected timeframe in which the Impact will occur. These are labelled Short1 (within 1 year), Med2-4 (2-4 years), and Long6+ (more than 6 years)*	*E.g. 2023: $XX,XX; 2024:…; funded internally or externally for XX reason*	*E.g.* *Adopted* *Not adopted* *Supported by CAN only* *USA 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)											
…											

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

PREPARED BY: IPHC SECRETARIAT (I. STEWART & A. HICKS; 22 AUGUST 2023)

PURPOSE

To provide the IPHC's Scientific Review Board (SRB) with a response to recommendations and requests made during SRB022 (IPHC-2023-SRB022-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). 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. Preliminary development for the 2023 stock assessment was presented for SRB022 (IPHC-2023-SRB022-08). Topics for that review included routine software updates, exploration of alternative weighting methods for the ensemble of four models, evaluation of the frequency of directed commercial Pacific halibut fishery sex-ratio-at-age data, estimation of natural mortality, marine mammal depredation rates from logbook records and potential structural revision to the stock assessment to accommodate spatial stock structure should it be identified within the Convention area.

SRB REQUESTS AND RESULTS

The SRB made the following stock assessment requests and recommendations during SRB022:

1) SRB022–Req.02 (para. 18):

   *"**NOTING** that analysis of whale depredation has clarified that the potential scale of removals from depredation is relatively small, except in IPHC Regulatory Area 4A, the SRB **REQUESTED** that updated analysis using USA observer data be presented at SRB023 to evaluate whether incorporation of whale depredation in the stock assessment is warranted."*

2) SRB022-Rec.02 (para. 19):

   *"**NOTING** that the scale of impact from different model weighting approaches presented here is small relative to the impact of other factors in the MSE (e.g. two- vs. three-year assessment intervals and TCEY), the SRB **RECOMMENDED** that the Secretariat continue using the equal weighting approach for model averaging."*

Request – whale depredation analysis

The Secretariat established an agreement with the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries) for access to detailed at-sea observer data from vessels fishing for Pacific halibut in Alaskan waters. Although it was not possible to link the individual records with IPHC logbook data, observer information contained sufficient information for further comparisons. Observer records were first filtered to include only vessels fishing under Individual Fishing Quota (IFQ). The next step was to exclude all fishing that did not catch any Pacific halibut; this was necessary to remove any fishing targeting only sablefish (*Anoplopoma fimbria*) in deep water. IPHC Regulatory Areas were assigned based on NOAA Fisheries statistical areas, which provide a reasonable approximation in most locations and was sufficient for this preliminary investigation. There were two types of records that could represent marine mammal depredation, those that specifically observed depredation or damaged fish/gear and those that observed the marine mammal (either orca, *Orcinus orca*, or sperm, *Physeter macrocephalus* whales) but could not confirm depredation; both of these types of observation were classified here as depredation. A small number of records with obvious data errors or incomplete information were removed from the data set. Observers in Alaskan fisheries record the percent of the total fishing time they estimated that marine mammal monitoring was taking place. These values ranged from zero to 100%; however most were >50%, and a sensitivity analysis showed little difference in the percent of sets in which whales were observed when sub-setting to only those records with 25, 50, 75 or even 95% monitoring, therefore 25% monitoring was used for all subsequent analysis.

Direct comparison with logbook records indicated that observed fishing activity tended to interact less frequently (or the interaction was identified less frequently) than the rates reported by harvesters in their logbooks for both orca whales (Figure 1) and sperm whales (Figure 2). However, both data sets supported the conclusion that orca whale interactions occur at the highest frequency in Biological Regions 4 and 4B, while the rate of sperm whale interactions is highest in IPHC Regulatory Areas 2C and 3A. An important caveat to the observer data is that prior to 2013 there were no observers deployed specifically to vessels targeting only Pacific halibut. All records from this time period represent larger vessels (primarily over 60 feet or 18.3 m in length), and those fishing IFQ for at least one species other than Pacific halibut.

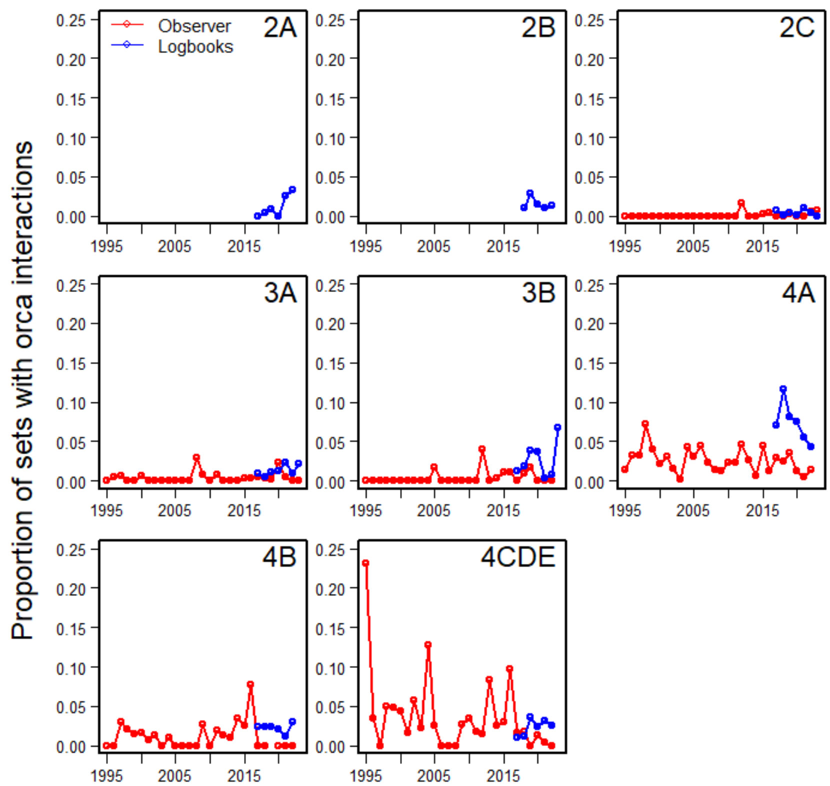

Figure 1. Proportion of observed and logbook-recorded sets with orca whale interactions by IPHC Regulatory Area.

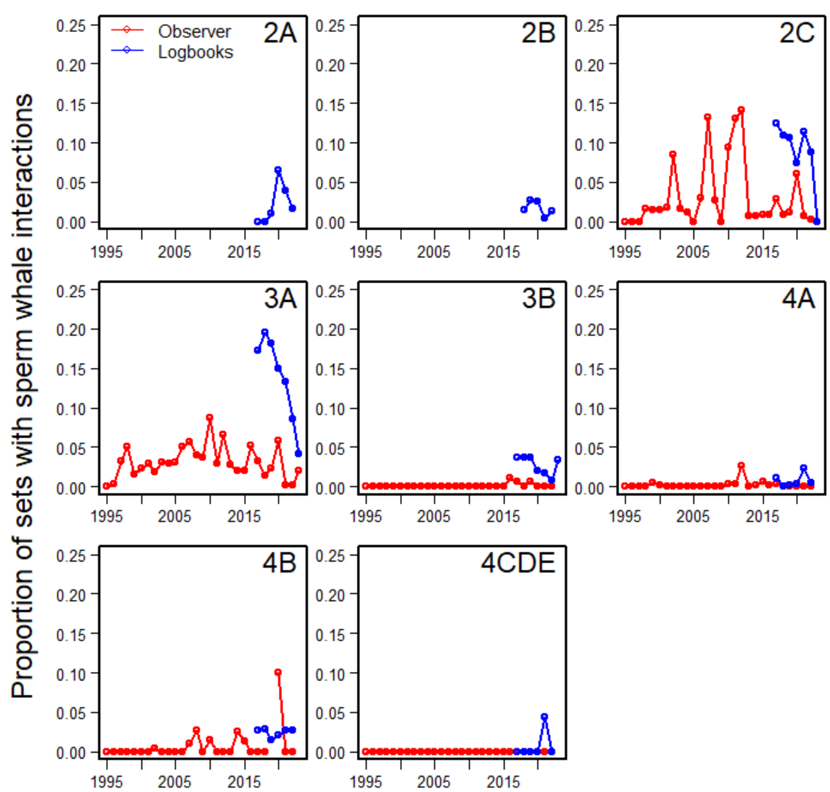

Figure 2. Proportion of observed and logbook-recorded sets with sperm whale interactions by IPHC Regulatory Area.

Based on this preliminary analysis and the generally lower rates reported by observers, further sensitivity was conducted using only logbook reported whale interactions. The subsequent analysis investigated how the formal inclusion of whale depredation might alter the stock assessment results and potentially affect management. In order to proceed with the relatively short time-series of logbook records the following simple assumptions were made:

1) the average rate at which the landed catch had been depredated (IPHC-2023-SRB022-08; $Dep_{rate} = {}^{depredation\ mortality}/_{landings}$) was calculated over the period 2017-2019, the earliest 3 years of data available;
2) This average rate was applied to the landings to estimate the depredation mortality for the time series from 1995-2016; and,
3) The same approach was taken for sublegal (Pacific halibut less than the current 32 inches or 81.3 cm minimum size limit), except that the mortality used in the stock assessment was first corrected for the discard mortality rate of 16% to represent total catch of sublegal Pacific halibut.

The additional mortality associated with whale depredation (both legal-sized and sublegal) was then added to the time-series used in each of the four stock assessment models. After re-estimating all parameters with the updated mortality time-series, each of the four models showed the expected response: the absolute level of spawning biomass was slightly larger than that estimated without whale depredation. This effect was present across the time-series, and in the range of 1-3%. The ensemble median 2023 spawning biomass estimate was 2% larger with whale depredation included.

In order to evaluate how this change would affect the mortality levels allocated to the directed fisheries, a projection of 2023 mortality due to whale depredation for both legal and sublegal Pacific halibut was needed. Similar to the approach taken in the sablefish stock assessment (Goethel et al. 2022), the three year recent average depredation mortality estimate (2020-2022) was added to the projected mortality for the directed commercial fishery for 2023. Projections were run using the adopted mortality limits for 2023 for the actual 2022 stock assessment (that did not include whale depredation) and the models including whale depredation. After adjusting the projected mortality to account for allocations among commercial, recreational, subsistence, and non-directed discards the net change to coastwide mortality was a 0.02 million pound increase over the actual adopted mortality limits set for 2023. As this is likely within the credible intervals of all the estimates of mortality included in the stock assessment the net effect should be considered negligible given the assumptions made for this analysis and at this time.

Recommendation – model weighting

All four models included in the stock assessment ensemble will be equally weighted for the final 2023 stock assessment. Further investigation of MASE and other weighting approaches will continue to be explored as the number of years for evaluation increases (since the sex-specific directed commercial fishery age composition starts in 2017) and new or existing methods for weighting multi-model stock assessments are developed.

PRELIMINARY DATA

For SRB022 sensitivity analyses to inclusion of sex-specific directed Pacific halibut commercial fishery age composition data were run. Results indicated only a small effect of adding these data each year (replacing the sexes-aggregated data available in-season) to each year's stock assessment. The genetic assays allowing for the processing of the 2022 sex-specific age composition information were completed in early August 2023. These data show the anticipated transition from a peak at older ages to the 2012 year-class in 2022 (Figure 3). When added to each of the four models in the stock assessment ensemble, the net effect was a 2.5% reduction in the estimated spawning biomass at the beginning of 2023. This suggests that the 2024 projections might be slightly more pessimistic with these data available than if they had not been processed and only the sexes-combined age composition data had been available. Although not a large effect on the results, during a period of continued stock decline it may be important to continue to provide as much detailed information for the annual stock assessment as possible. Preliminary evaluation of potential FISS designs for 2024 (IPHC-2023-SRB023-09) indicate that the FISS may have a very small geographical footprint in 2024 due to projected costs. Thus, the stock assessment may need to rely more heavily on commercial fishery trend and biological information in 2024 than in recent years with more comprehensive survey designs. For these reasons, the Secretariat recommends that the genetic analysis continue at least through 2024, pending a change in stock trend or other information.

Also of note in the recent commercial fishery age composition data is a small indication of systematic ageing bias of the 2005 year-class: the 2005 year-class has been aged at 15 years old in both 2021 and 2022 (when it should have been 16 and 17 years old) after tracking exactly from a peak at age 11 in 2016 through a peak at age 15 in 2020. This short-term anomaly, generally nonexistent in the age information for Pacific halibut, reflects the challenge of accurate age reading of older cohorts. However, the younger 2012 year class continues to track consistently from 2020-2022 and will be the most important driver of short-term stock trend and management advice.

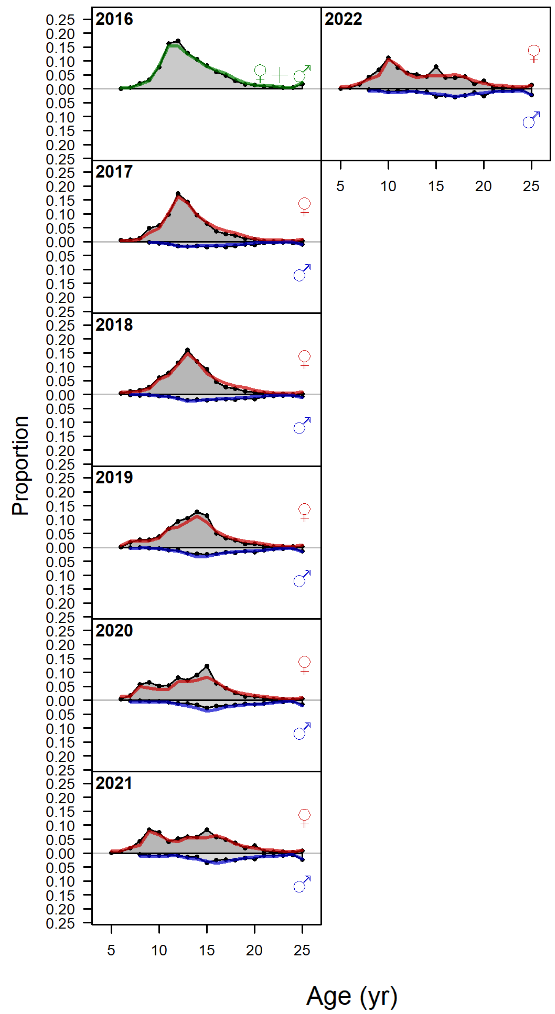

Figure 3. Fits to male (blue lines) and female (red lines) directed commercial Pacific halibut fishery age composition data (shaded polygons with black lines/points) from the short coastwide model updated from the final 2022 stock assessment with the 2022 sex-specific composition information. Sexes-aggregated data from 2016 (but not earlier years) is shown for comparison.

ADDITIONAL STEPS FOR THE FINAL 2023 STOCK ASSESSMENT

No structural changes to the stock assessment models or the ensemble weighting are anticipated for the final 2023 stock assessment beyond routine updating of time-series deviation parameters (e.g., recruitment) and iteration of the data weighting. Standard data sources that will be included in the final 2023 stock assessment include:

1) New modelled trend information from the 2023 FISS for all IPHC Regulatory Areas.
2) Age, length, individual weight, and average weight-at-age estimates from the 2023 FISS.
3) Directed commercial fishery logbook trend information from 2023 (and any earlier logs that were not available for the 2022 assessment) for all IPHC Regulatory Areas.
4) Directed commercial fishery biological sampling from 2023 (age, length, individual weight, and average weight-at-age) from all IPHC Regulatory Areas.
5) Biological information (lengths and/or ages) from non-directed discards (all IPHC Regulatory Areas) and the recreational fishery (IPHC Regulatory Area 3A only) from 2022. The availability of these data routinely lags one year.
6) Updated weight-at-age for younger Pacific halibut captured in NOAA Fisheries trawl surveys in the Aleutian Islands and Bering Sea in 2022. These data also routinely lag one year.
7) Updated mortality estimates from all sources for 2022 (where preliminary values were used) and estimates for all sources in 2023.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2023-SRB023-06 which provides a response to requests from SRB022, and an update on model development for 2023.
b) **RECOMMEND** any changes to be included in the final 2023 stock assessment to be completed for presentation at IM099.
c) **REQUEST** any further analyses to be provided at SRB024, June 2024.

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APPENDICES

Nil

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

PREPARED BY: IPHC SECRETARIAT (A. HICKS, I. STEWART; 23 AUGUST 2023)

PURPOSE

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

BACKGROUND

This document provides responses to past requests and recommendations from the SRB. It presents the updated 2023 operating model (OM), potential objectives for MSE evaluations, Fishery-Independent Setline Survey (FISS) data scenarios with differing levels of observation error, how the evaluation of management procedures (MPs) may be improved if equalized over a conservation objective, definitions of exceptional circumstances and actions to be taken if an exceptional circumstance is declared, and potential MPs to evaluate in 2023–2025.

OPERATING MODEL

The 2023 MSE OM was conditioned using assumptions, parameters, and outputs consistent with the 2022 full stock assessment, following SRB advice. Details are provided below.

> **IPHC-2023-SRB022-R (para. 26).** *The SRB **RECOMMENDED** that reconditioning the operating model should be limited to situations where the stock assessment has changed significantly. This likely means a three-year schedule for reconditioning the operating model in the year following each full stock assessment.*
>
> **IPHC-2023-SRB022-R (para. 27).** *The SRB **RECOMMENDED** that the Secretariat consider using explicit informative priors for conditioning the operating model to make fitting constraints more explicit.*

The MSE Operating Model (OM) was updated in 2023 based on assumptions and outputs of the 2022 full stock assessment (IPHC-2023-SA-01) and the data available at the end of 2022 (IPHC-2023-SA-02). The OM is an age-structured population dynamics model with movement between four Biological Regions. Multiple fishing sectors are modelled within IPHC Regulatory Areas along with landings and discard mortality. The OM incorporates four individual models (OM1–OM4) and integrates them into an ensemble to account for structural uncertainty and differing hypotheses about recruitment and distribution.

The OM was developed as a simulation model to explore alternate hypotheses of the population and is parameterized to allow for the specification of alternative hypotheses. However, this introduces the possibility of overparameterization and confounding between parameters. For example, movement between regions and the proportion of recruitment to each region are confounded and not easily separated with the inputs being conditioned to. Therefore, assumptions and priors are used to aid the conditioning process.

Assumptions and priors are described in the Technical Document on the IPHC MSE Research Website. In brief, movement assumptions include fixed movement between some regions (all but 4 to 3 and 3 to 2), age when Pacific halibut first move between regions, a maximum rate of movement-at-age, and a specific parametric function for each region-to-region movement. Assumptions related to distribution of age-0 recruits include that they can only recruit to one of the four regions and regions 3 and 4 receive the highest proportion of recruits.

The proportion of recruitment to each Biological Region and the movement-at-age from Biological Region 4 to 3 and from 3 to 2 were parameterized separately for low PDO years and high PDO years and also differed across OMs. The proportion of recruitment to Biological Region 4 was similar for low and high PDO years in OM1 but increased with high PDO for other OMs (Figure 1). The proportion increased for Biological Region 3 in OM1 but decreased with other OMs for high PDO years. A small amount of recruitment was distributed to Biological Regions 2 and 4B. OM2 had the highest proportion of recruitment to Biological Region 4.

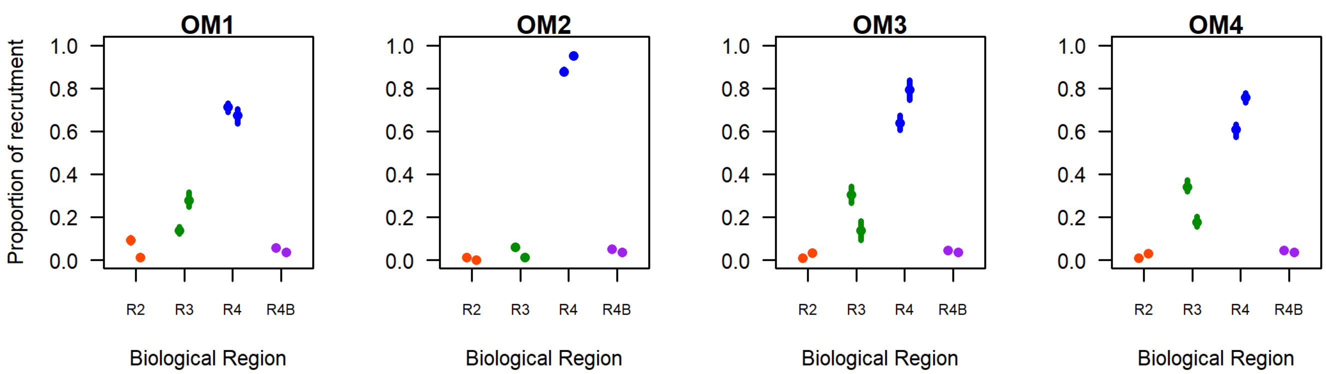

Figure 1. Proportions of recruitment distributed to each Biological Region for each OM. Low and high PDO years are shown as the two close points of the same color with low PDO on the left.

The probability of moving from one region to another over the lifetime of a Pacific halibut was used to summarize movement rates (Figure 2). This statistic was calculated as one minus the product of the age-specific probabilities of not moving to the other region. The lifetime movement rate was similar across OMs from Biological Region 4 to 3 but was slightly higher in low PDO years for OM1 and OM2. The movement from Biological Region 3 to 2 was lowest in OM1 and highest in OM2. Movement from 3 to 2 in OM3 and OM4 was similar to each other and intermediate to OM1 and OM2. Looking at movement and the distribution of recruits together, OM1 shows more widely distributed recruitment and less movement, OM2 shows most recruitment distributed to Biological Region 4 and high movement from west to east, and OM3 and OM4 are similar to each other and intermediate to OM1 and OM2. During the conditioning process, satisfactory outcomes were not found with distribution spread more evenly across IPHC Regulatory Areas. However, more research could be done to specifically investigate two hypotheses: 1) high proportions of recruitment occur in Biological Regions 3 and 4, and a high amount of movement occurs from west to east, or 2) recruitment is spread across IPHC

Regulatory Areas and movement is at lower rates. These four OMs traverse some of the range of these two hypotheses for recruitment distribution and movement.

Specific details of the OM will continue to be updated and published in a technical document available on the IPHC MSE Research Website.

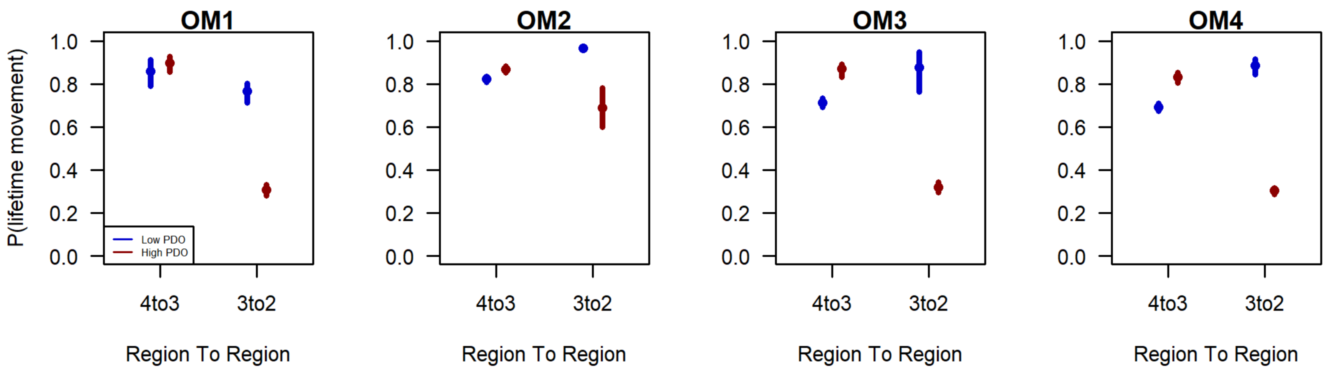

Figure 2. Probability of moving from Biological Region 4 to 3 over the lifetime of a Pacific halibut and the probability of moving from Biological Region 3 to 2 over the lifetime of a Pacific halibut for each OM. Low PDO years are shown in blue and high PDO years are shown in red.

The conditioned historical spawning biomass and projected spawning biomass integrated over the four OMs with no fishing mortality and with fishing intensity equal to a spawning potential ratio (SPR) of 43% are shown in Figure 3. Individual trajectories of spawning biomass are also shown in Figure 3, which show similar shapes with and without fishing. This is because weight-at-age and recruitment are large drivers of spawning biomass while fishing at a constant SPR has a large effect on the overall scale of spawning biomass. The median estimated spawning biomass from the ensemble stock assessment is similar to the median of the integrated OMs, and the integrated OM has a larger amount of uncertainty in recent years when compared to the ensemble stock assessment.

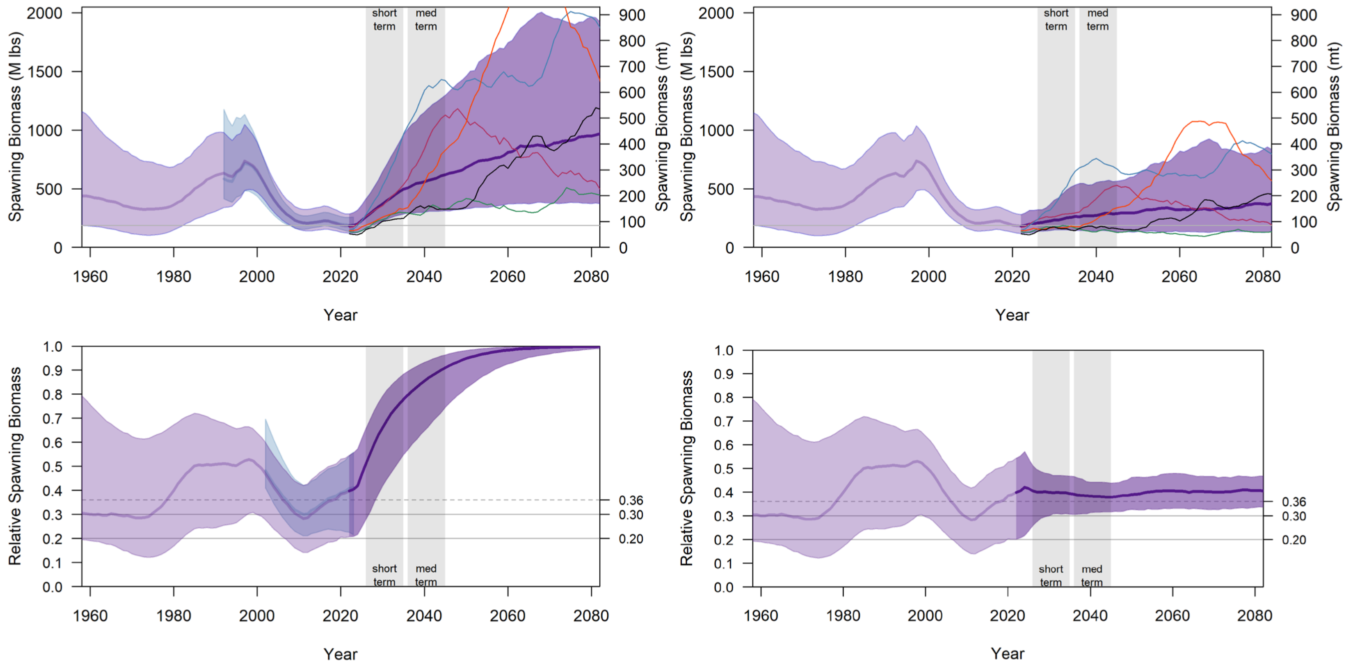

Figure 3. Simulated spawning biomass (top row) and relative spawning biomass (bottom row) assuming no fishing mortality (left column) and a fishing intensity equal to an SPR of 43% (right column). The median is shown by the thick dark line and the 5th and 95th percentiles are shown as the shaded polygon (the darker polygon indicates the projected time-period). Individual trajectories of spawning biomass are shown as small lines of different colors. Grey vertical panels indicate the short and medium time-periods used for calculating performance metrics. The grey horizontal line on the spawning biomass plots (top) indicate the median 2023 spawning biomass. The blue shaded area in the historical period shows the 5th and 95th percentiles from the ensemble stock assessment and the blue line is the median from the ensemble stock assessment for comparison.

OBJECTIVES

MSE objectives are constantly being improved and redefined to better meets the needs of the Commission. Four priority coastwide objectives are currently endorsed for the MSE.

> **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.*

A potential additional objective

The result 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 million pounds (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 ensemble, thus increasing the perceived productivity of the stock. In contrast to this optimistic result, 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 resulted in a 75% chance of a lower spawning biomass in 2024. The Commission departed from the current interim management procedure at AM099 and chose a TCEY of 36.97 Mlbs for 2023, 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 target relative spawning biomass of 36% and had a small chance (25%) of falling below 30% with any TCEY up to 60 Mlbs, the Commission decided to reduce the TCEY from the reference harvest level TCEY. This implies that there may be an additional objective: reducing the chance of the spawning biomass being less than the 2023 spawning biomass. Therefore, a potential new coastwide objective may be,

- Maintain the long-term coastwide female spawning biomass above the estimated 2023 female spawning biomass at least XX% of the time.

This potential objective would be a reasonable objective to meet concerns expressed at AM099 and would be a useful contrast to the dynamic reference points used in the current priority objectives because it sets an absolute limit to remain above. It also uses an observed reference (estimated 2023 female spawning biomass) that has concrete meaning to stakeholders and may be an indicator for a threshold level of efficiency and opportunity in the Pacific halibut fisheries. MSE simulations with an SPR of 43%, decision-making variability, estimation error, and observation error showed a probability of 20% that the long-term spawning biomass would be less than the 2023 spawning biomass. An initial test of this objective would be to receive input from stakeholders and Commissioners whether dropping below the 2023 spawning biomass estimate with a 1 in 5 chance is acceptable in the long term.

Improving the objective to conserve spatial population structure

The current primary objective to conserve spatial population structure compares proportions of female spawning biomass in each Biological Region to an *ad hoc* threshold determined from historical estimates of stock distribution (Appendix A). This has been problematic because it is difficult to determine the appropriate threshold in the absence of a long time-series of survey-based estimates and no MP evaluated in previous iterations of the MSE process has met this objective for Biological Region 4B. A different objective to conserve spatial population structure was noted recently by the SRB.

> **IPHC-2023-SRB022-R (para. 24).** *The SRB **NOTED** that the spatial structure objective could be better addressed through a criterion that compares biomass in each region to unfished biomass in the same region rather than using proportions of the total stock-wide biomass.*

The 2023 OM has updated population dynamics based on the recent 2022 full stock assessment and data through 2022. Those updated population dynamics include new estimates of movement and distribution of recruits. Simulations with an SPR of 43% indicate that the current primary objective to conserve spatial population structure is met for all Biological Regions (Figure 4). However, the threshold percentages remain *ad hoc*, and it is uncertain if these are appropriate percentages.

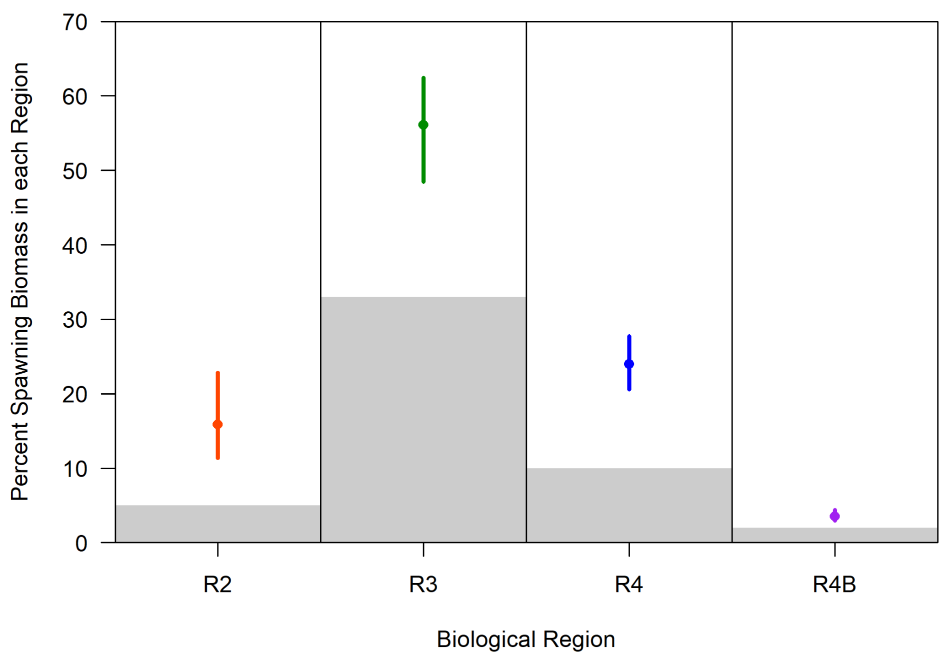

Figure 4. Percent spawning biomass in each Biological Region from 500 simulations based on an SPR of 43% with decision-making variability, estimation error, and observation error. The dot is the median and the vertical lines are the 5th and 95th percentiles. The grey indicates the area below the defined threshold. A vertical line extending into the grey area indicates that the objective is not met, which is not the case for any of these Biological Regions with these simulations.

A different objective may be to use the regional relative spawning biomass (see SRB paragraph 24 above) by comparing the regional biomass to the unfished regional biomass, where unfished regional biomass is calculated as the biomass that would have occurred if there was historically no fishing mortality. This objective would have specific meaning to the Biological Region and be independent of the amount of biomass in other regions. Additionally, relative spawning biomass is a commonly used statistic to measure conservation status. However, the threshold percentage, for which it is desired to remain above, and the tolerance are difficult to specify.

The historical conditioned regional RSB and projected regional RSB are shown in Figure 5. Biological Regions 2 and 3 were low at the beginning of the time-series and Biological Regions 4 and 4B were high. This is because there was little fishing mortality in Biological Regions 4 and 4B before 1958. As fishing mortality spread across the regions (and potentially changes in movement occurred), the historical RSB fluctuated near or below 36% in Biological Regions 2 and 3, remained above 36% in Biological Region 4, and decreased to near 36% in Biological Region 4B before increasing. Projections with decision-making variability, estimation error, and observation error, and using a MP similar to the harvest policy applied in recent years (SPR=43%) stabilized the RSB in each Biological Region, with Biological Region 2 remaining mostly below 30%.

Defining the appropriate threshold for each Biological Region is challenging because movement tends to occur from west to east, with Biological Regions 4 and 4B being source areas and Biological Regions 2 and 3 being sink areas. Therefore, Biological Regions 2 and 3 may be able to sustain lower relative spawning biomasses than Biological Regions 4 and 4B. In fact, the beginning of the time-series shows very low RSB for Biological Region 2, which had the majority of the fishing mortality in the early 1900s. The importance of each Biological Region is uncertain and likely varies across time, and perhaps a good starting point is the threshold for the coastwide spawning biomass (20%) but potentially with a higher tolerance than 5%. However, history has shown that the coastwide spawning stock was maintained even though the RSB in Biological Regions 2 and 3 were historically near or below 30%.

EXAMINING FISS DATA SCENARIOS

The FISS design has been rationalized in recent years and optimised designs are proposed to the Commission annually. However, logistical and funding constraints have sometimes resulted in designs smaller than the optimised designs, including the omission of samples from some survey charter regions and even entire IPHC Regulatory Areas. Even though the space-time model can make predictions for stations that were not sampled, the reduction in survey effort affects the precision of the FISS estimates. The SRB suggested that the effects of the reductions in FISS effort be examined using closed-loop simulations.

> **IPHC-2023-SRB022-R (para. 30).** *The SRB **NOTED** that situations in which critical data streams (e.g. FISS index or age data) are unavailable for one or more years does not constitute an "exceptional circumstance" and **REQUESTED** that the MSE include evaluation of such missing FISS data scenarios for the SRB023.*
>
> **IPHC-2023-SRB022-R (para. 52).** *The SRB **NOTED** the presentation demonstrating how secondary FISS objectives influence choices for future FISS designs that may have already been endorsed by the SRB based only on primary objectives. The SRB **RECOMMENDED** that the MSE include some scenarios in which the FISS is skipped (as also requested above in para. 30) because of occasional (or persistent) economic constraints on executing full FISS designs. Such simulation scenarios would provide some indication of the potential scale of impacts on MP performance of maintaining long-term revenue neutrality of the FISS.*

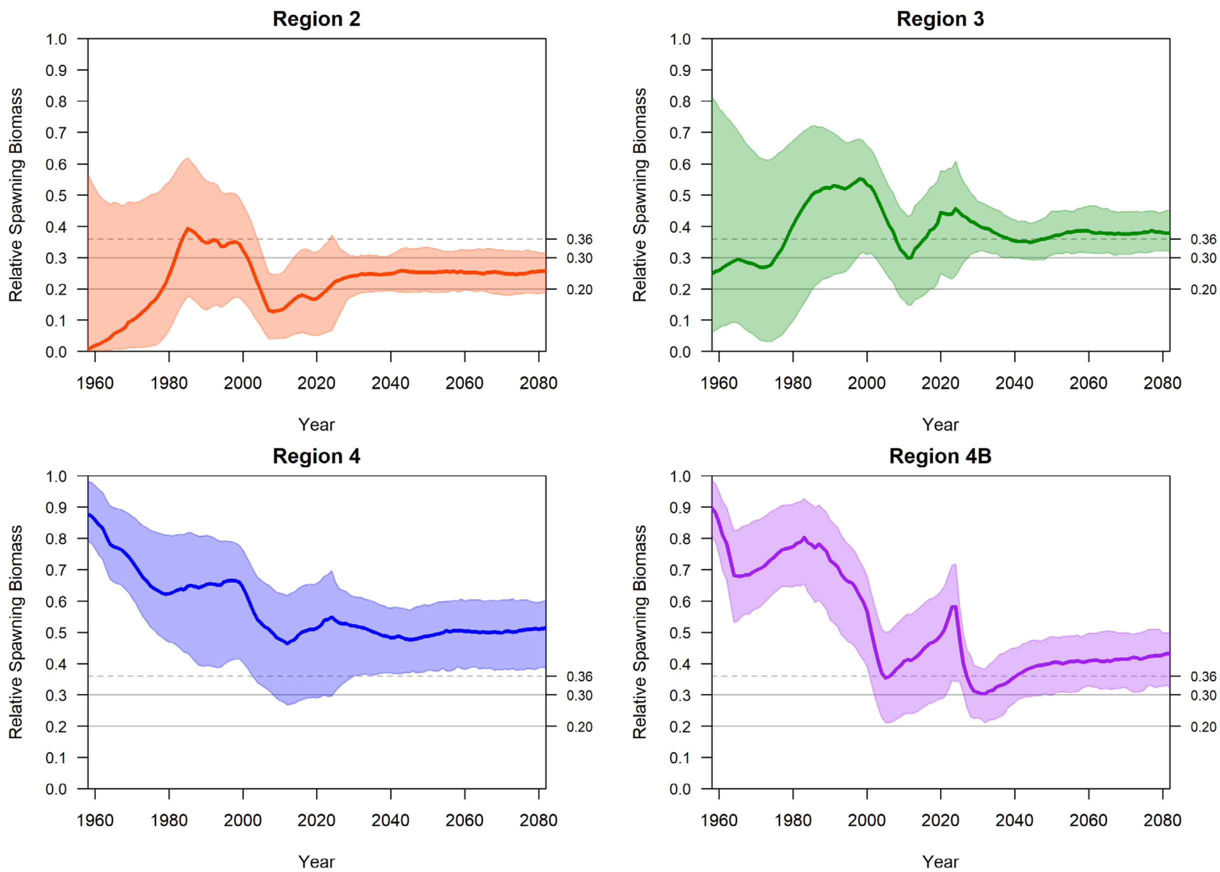

Figure 5. Relative spawning biomass in each Biological Region determined historically (pre-2023) and from projections using an SPR of 43%, a 30:20 control rule, decision-making variability, estimation error, and observation error. The horizontal solid lines are 30% and 20%, and the dashed horizontal line is the current coastwide target defined in objective 2.1 (Appendix A). The earliest years are a result of equilibrium assumptions and may not be representative of actual percentages before simulating through some years as a "burn-in".

Three FISS scenarios

As a preliminary investigation, three FISS design scenarios were developed related to the survey effort in each IPHC Regulatory Area. There are three types of designs for an individual IPHC Regulatory Area used to make a scenario, each affecting the coefficient of variation (CV) differently.

1) **Full:** sufficient stations are surveyed in an IPHC Regulatory Area to keep the CV near or below the target.
2) **Reduced:** Some stations are surveyed in an IPHC Regulatory Area but the CV is potentially higher than the target for a 'full' design.
3) **Missed:** no stations are surveyed in an IPHC Regulatory Area and the CV is in the highest range.

A minimum and a maximum CV for each IPHC Regulatory Area is defined using terminal year CVs since 2017 (Table 1). The minimum CV for the Full Design was determined as the average of the terminal year CVs for 2017 through 2019 for 2A, 4A, 4CDE, and 4B, 2018 through 2022 for 2B and 2C, 2019 through 2022 for 3A, and 2019 through 2022 for 3B. This accounted for years where the survey was nearly "full" and expansion stations had been surveyed. Minimum CVs for Reduced and Missed designs were increased compared to the Full design and the "slope" for the Reduced and Missed Designs is the slope of a linear or logistic function that determines how the CV increases from the min to the max (details explained below). The minimum CV for a reduced survey is the average of the min and max of the Full, and the minimum CV for a missed year is the maximum for a Full year.

Table 1. Assumed ranges of CVs for the three different FISS types of design for each IPHC Regulatory Area.

Design	CV	2A	2B	2C	3A	3B	4A	4CDE	4B
Full	Min	12.0%	6.0%	6.0%	5.0%	8.0%	15.0%	10.0%	13.0%
	Max	15.0%	10.0%	10.0%	10.0%	15.0%	18.0%	11.0%	16.0%
Reduced	Min	13.5%	7.0%	7.0%	7.5%	11.0%	16.5%	10.5%	14.5%
	Slope	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Max	20.0%	15.0%	15.0%	15.0%	15.0%	20.0%	15.0%	25.0%
Missed	Min	15.0%	8.0%	8.0%	10.0%	14.0%	18.0%	11.0%	16.0%
	Slope	1	1	1	1	1	1	1	1
	Max	30.0%	25.0%	25.0%	25.0%	25.0%	25.0%	20.0%	30.0%

The process to adjust the CV given the design in a specific year is described below. It follows a logistic increase/decrease or a linear increase/decrease depending on the design and what occurred previously. The effect of past designs on the CV is tracked by incrementing a counter up or down, with a minimum value of 0 which would result in the minimum CV for that design. The minimum CV is determined from the minimum of the previous year or the defined minimum to avoid sudden jumps in the CV when switching design types.

- If the design is Full in year *t* the CV linearly decreases and cannot exceed the max or be less than the minimum. It traverses the maximum to minimum in five years. Where it starts within this range depends on how many Missed or Reduced designs occurred in previous years.
- If the design is Reduced in year *t*
    - If the design in year *t*-1 was Full then the CV increases with a logistic function between the min and max.
    - If the design in year *t*-1 was Reduced then the CV is reduced slightly using a logistic function between the min and max.
    - If the design in year *t*-1 was Missed then the CV is reduced because it uses the Reduced parameters and a linear adjustment to the CV.

- If the design is Missed in year *t* a logistic function increases the CV using the Missed parameters.

The three FISS scenarios are a Full design for all IPHC Regulatory Areas, a Reduced design for some IPHC Regulatory Areas, and a design with Missed IPHC Regulatory Areas. The lettering (a, b, and e) are based on a larger set of scenarios, but there was not enough time to simulate all.

a. A Full design in every IPHC Regulatory Area and every year. This is the best-case scenario and is not cost-optimised. It is hypothetical and unlikely, but useful for comparison.

b. Reduced design for IPHC Regulatory Areas other than 2B and 2C. 2B and 2C are always a Full design. This is based on recent patterns of nearly Full designs in 2B and 2C when other IPHC Regulatory Areas are reduced. However, as stock distribution changes, other areas may be preferable for a Full design (which is not captured here).

e. Miss every other year for IPHC Regulatory Areas 2A, 3B, 4A, 4CDE, and 4B. Reduced otherwise. 2B and 2C always Full and 3A always Reduced. In other words, every other year is only a full survey of 2B and 2C and reduced for 3A.

Given the algorithm defined above, the time-series of CVs used in simulated projections for each scenario and IPHC Regulatory Area are shown in Figure 6. Each time-series starts with the historical CVs determined from this algorithm given the designs that were used. For scenario (a), the CVs quickly go to the minimum CV for the Full design type and remain there. For scenario (b), the CVs in IPHC Regulatory Areas other than 2B and 2C go to the minimum CV for the Reduced design type and remain there. For scenario (e), the CVs in IPHC Regulatory Areas other than 2B, 2C, and 3A increase to a maximum and then oscillate between the maximum for the Reduced design type and the maximum for the Missed design type. Many other scenarios can be created and simulated. In the future, scenarios that are density-dependent (the FISS targets Full designs in areas of high density to maximize revenue) may be considered.

The other consideration for reduced FISS sampling is the effect on the uncertainty in the stock assessment. Currently, the MSE simply simulates the total mortality and the relative spawning biomass from a bivariate normal distribution with a CV of 15% and an autocorrelation of 0.4 for each parameter. To keep the FISS scenarios simple, the estimation error CV is a function of the sum of the observation CVs. Thus, if the design results in a higher observation CV, the estimation CV also increases. The sum of the minimum observation CVs for the Full design is 0.75 and the sum of the maximum observations CVs for the Missed design is 2.05. With an ad hoc linear relationship using an intercept of 0.1125 and a slope of 0.05, the minimum estimation error CV is 15% and the maximum estimation error CV is 21.5%. Basically, the estimation error increases as the uncertainty in the FISS indices increases.

Simulation results examining FISS scenarios

Performance metrics for each FISS data scenario related to the priority objectives, along with some others, are shown in

Table 2. Conservation metrics are similar across the scenarios and the long-term and short-term TCEYs show little difference among scenarios. The variability in the TCEY is most affected by these scenarios with the short-term AAV increasing from 16.3% with the Full design (a) to 19.9% when some IPHC Regulatory Areas are not surveyed (Missed design, e).

The increase in FISS CVs for each IPHC Regulatory Area is expected to affect the yield variability more than any other performance metric. The CVs for each IPHC Regulatory Area result in a higher CV for the coastwide FISS index, which results in a higher estimation error (mimicking the stock assessment). The CV for estimation error is symmetric, although autocorrelated, and increases from 15% to 21.5% based on total FISS error. With symmetric assessment error, the use of a constant SPR will attempt to stabilize the long-term spawning potential at the expense of more variability in yield.

The TCEY and AAV for each IPHC Regulatory Area are shown in Figure 7. The TCEY is similar among FISS scenarios for each IPHC Regulatory Area, but the AAV increases considerably with scenario (e). IPHC Regulatory Area 2A has less variability because the distribution procedure assumes a fixed allocation unless the stock is low in that area. IPHC Regulatory Areas 3B and west have higher AAVs and are more affected by scenario (e).

These preliminary results should be considered as a pilot study to guide future decisions related to how to investigate changes to the FISS design. These results show that increased CVs for FISS coastwide index and stock distribution estimates result in increases to the inter-annual variability in yield and little change in realized yield and no conservation risk to the stock. Given that the variability in yield is above the maximum desired variability specified in some primary objectives for all FISS scenarios, a constraint or alternative approach may be necessary. Introducing an element to stabilize yield will likely result in bigger effects on conservation and yield performance metrics across the FISS scenarios. Recent years suggest that designs in the future could be sparser, resulting in higher CVs than simulated in any of these scenarios. The Full scenario is likely a bookend for the best the survey can do, but the Missed scenario (e) is unlikely a bookend to how uncertain the FISS can become in the future. Therefore, it is important to ensure that realistic observation error is simulated in future MSE work to reflect potential future FISS designs.

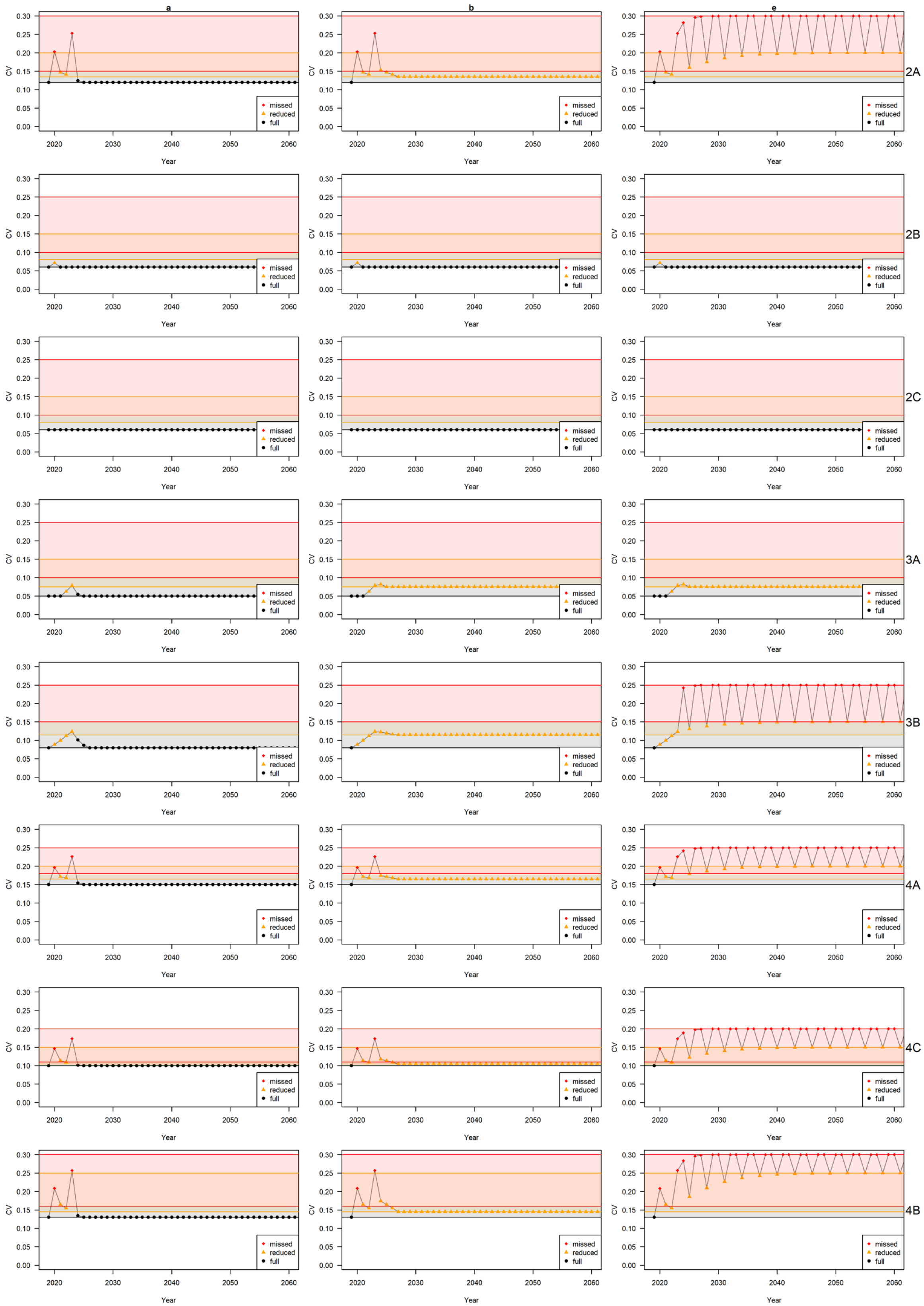

Figure 6. Three FISS scenarios (columns) for each IPHC Regulatory Area (row) with the range of CVs for each design type shaded in separate colors.

Table 2. Long-term and short-term performance metrics for three FISS data scenarios and 500 replicates. Metrics in italics are not specified as priority objectives but are useful to evaluate each scenario. The Full scenario is (a), the Reduced scenario is (b), and the Missed scenario is (e).

FISS data scenario	**a**	**b**	**e**
Long-Term Metrics			
Median RSB	*37.8%*	*37.8%*	*37.9%*
P(RSB_y<20%)	<0.002	<0.002	<0.002
P(RSB<36%)	0.580	0.586	0.576
Median TCEY	*65.7*	*65.6*	*65.9*
P(any3 change TCEY > 15%)	*0.834*	*0.862*	*0.920*
Median AAV TCEY	*17.5%*	*18.1%*	*22.2%*
Short-term Metrics (4-13 yrs)			
Median TCEY	59.2	59.2	59.1
P(any3 change TCEY > 15%)	*0.864*	*0.884*	*0.936*
Median AAV TCEY	16.3%	16.8%	19.9%

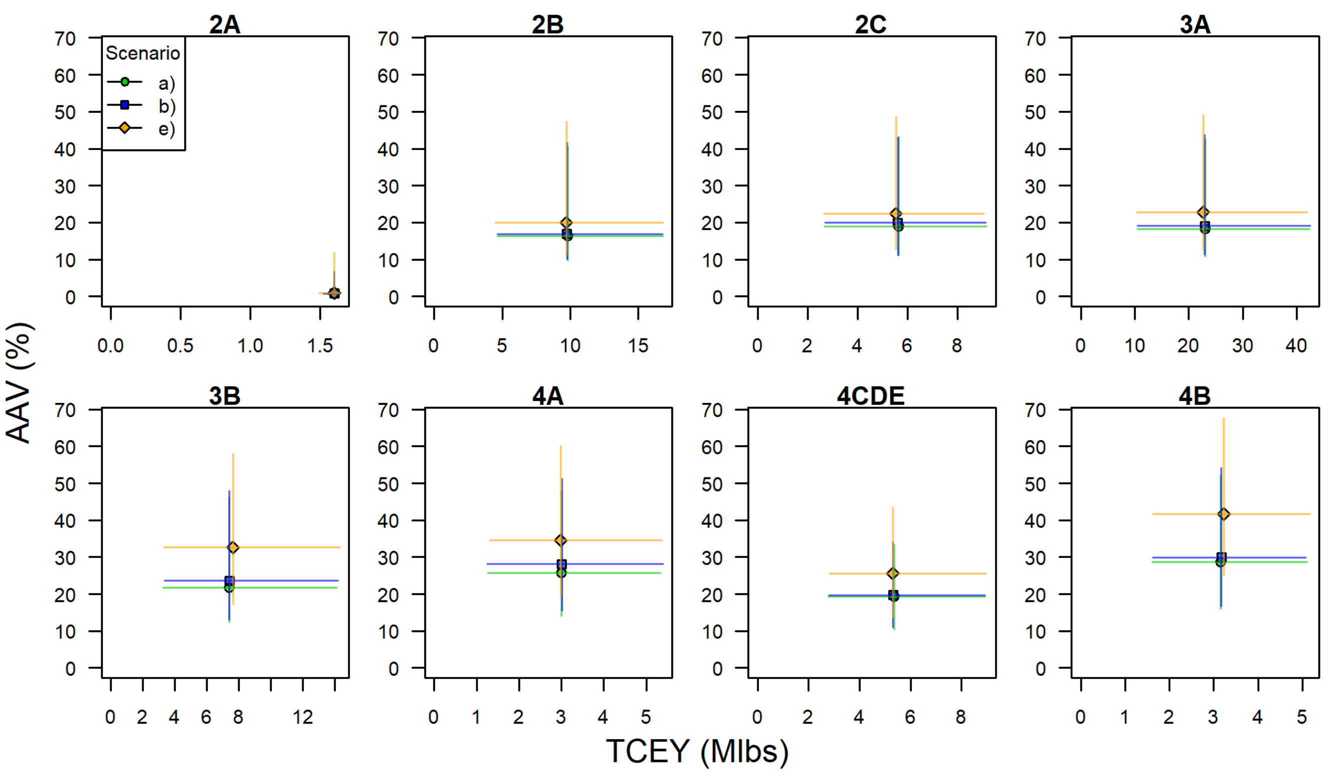

Figure 7. AAV (%) vs TCEY (Mlbs) for each IPHC Regulatory Area using an SPR of 43%, decision-making variability, estimation error, and three FISS data scenarios defining observation error. The lines show the 5th and 95th percentiles along each axis.

EQUALIZING MP PERFORMANCE ON CONSERVATION OBJECTIVES

There are two priority conservation objectives along with other objectives (Appendix A).

a. Maintain the long-term coastwide female spawning stock biomass above a biomass limit reference point ($B_{20\%}$) at least 95% of the time.

b. Maintain the long-term coastwide female spawning stock biomass above a biomass reference point ($B_{36\%}$) 50% or more of the time.

These priority conservation objectives are treated as thresholds rather than targets, meaning that for the objective to pass, they can not be exceeded, but the spawning biomass may be above the threshold with a larger probability than defined by the tolerance. For example, an MP that was above $B_{20\%}$ 99% of the time and above $B_{36\%}$ 70% of the time would pass, and the MP would be evaluated against other MPs based on fishery yield and variability, and potentially other objectives.

The SRB recommended equalizing the MPs based on one of the conservation targets to assist with evaluation. This means to specify the MPs such that they exactly meet a conservation objective, effectively removing that objective from the evaluation, and thus can be evaluated based only on other objectives.

> **IPHC-2023-SRB022-R (para. 25).** *To improve comparability of MPs in performance achieving TCEY objectives, the SRB* ***RECOMMENDED*** *equalizing MP performance on one of the conservation objectives.*

Equalizing the MPs being evaluated to one conservation objective would allow for a clear evaluation of the remaining objectives but may present MPs that are not desirable for adoption based on other criteria or result in the development of MPs that do not have desired properties related to yield. For example, meeting the criterion of the female spawning biomass being above $B_{20\%}$ 95% of the time cannot be done with the application of the 30:20 control rule (Figure 8). The female spawning biomass is unlikely to be below $B_{25\%}$ because the control rule reduces the fishing intensity such that the average applied fishing intensity is less than the reference fishing intensity. Using an SPR of 30% with a 30:20 control rule results in a median average long-term applied SPR of 38.6% and a median relative spawning biomass equal to 33%. Therefore, with the 30:20 control rule, the female spawning biomass is always above the biomass limit, but the SPR could be tuned to exactly meet the $B_{36\%}$ objective.

Removing the control rule and using a reference SPR of 30% resulted in a median average RSB equal to 29% and the biomass limit objective not being met (a 7% probability of RSB being 20% or more). The RSB was also less than $B_{36\%}$ in more than 50% of the simulations, and in fact more than 95% of the simulations (Figure 8). The median average long-term SPR was 33.6% and was greater than the reference SPR of 30% due to estimation error and decision-making variability when determining the final mortality limits. Evaluation of MPs could only be equalized on the biomass limit conservation objective if the control rule was eliminated and a high fishing intensity (i.e. low SPR) was used. Alternatively, the MPs could be equalized using the biomass target objective with a control rule. However, either of the options would likely limit the range of SPR values to examine and result in fishing intensities that may be higher than desired given other objectives. For these simulations, an SPR of 34% with a 30:20 control rule resulted in a relative spawning biomass of 35% (Figure 8). Other elements of an MP may be introduced, such as constraints, which would likely result in lower median realized fishing intensities (i.e. higher realized SPR) than the reference fishing intensity.

Furthermore, equalizing the MPs on the biomass limit objective, using SPR, would likely never meet the $B_{36\%}$ objective (given the scope of MPs that are under consideration). In Figure 8, the biomass limit objective is met when the lower end of the line is at or above the horizontal line at 0.20, and the $B_{36\%}$ objective is met when the dot is at or above the horizontal line at 0.36. To meet the biomass limit objective, the realized fishing intensity needs to increase, which results in a further departure from the $B_{36\%}$ objective. Alternatively, equalizing on the $B_{36\%}$ objective would likely meet the biomass limit objective. Alternatively, if the new potential objective, presented above, to maintain the long-term spawning biomass above the 2023 spawning was adopted, this may be a useful objective to equalize the MPs for evaluation.

It takes a considerable amount of time to run these MSE simulations, and searching for the SPR that equalizes MPs may take longer than running a pre-defined set of SPR values. Once a pre-defined set of SPR values is complete, MPs could be compared using the SPR values that approximately meet the biomass target conservation objective, as well as evaluated at different SPR values that pass both conservation objectives but may not meet them exactly.

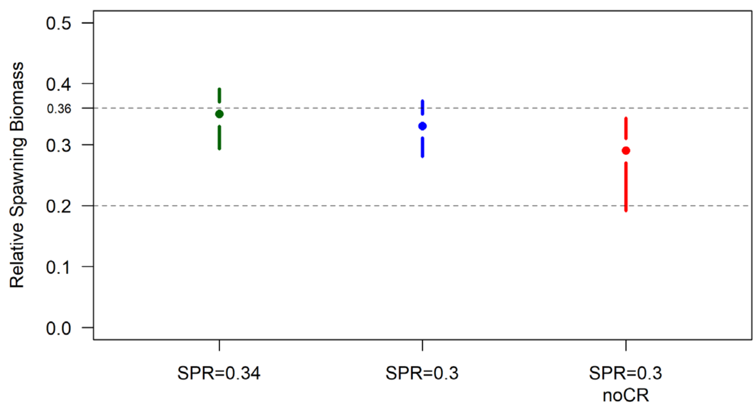

Figure 8. Relative spawning biomass for closed-loop simulations with decision-making variability, estimation error, and observation error. Reference SPR values of 30% and 34% with a 30:20 control rule (green and blue) and an SPR of 30% without a control rule (red) were simulated. The point is the median of 180 replicates, the bottom is the 5th percentile, and the top of the bar is the 95th percentile. The horizontal lines represent the biomass limit and biomass target of the priority conservation objectives. Additional simulations may be necessary to accurately determine the tail probabilities.

EXCEPTIONAL CIRCUMSTANCES

Two recommendations were made at SRB022 that guide the development of exceptional circumstances.

> **IPHC-2023-SRB022-R (para. 28).** The SRB **RECOMMENDED** that exceptional circumstance (i) be evaluated annually based on comparisons between the simulation distribution (e.g. a 95% interval) of FISS values from MSE simulations to the realized FISS estimates; and (ii) be clearly distinguished from "unusual conditions". For

> example, exceptional circumstances should have a high threshold for persistent (i.e. more than a single year) deviation from MSE simulations.
>
> IPHC-2023-SRB022-R **(para. 29).** The SRB **RECOMMENDED** that an initial response to a suspected "exceptional circumstance" should include presentation at the next SRB meeting to establish whether the situation meets the definition of an "exceptional circumstance" and to formulate a response.

An exceptional circumstance is defined as a process for deviating from an adopted MP (de Moor et al. 2022) and is useful to ensure that the adopted harvest strategy is retained unless it is absolutely necessary to deviate from the process. The IPHC interim harvest strategy policy has a decision-making step after the MP, thus the Commission may deviate from an adopted MP. This decision-making variability is included in the MSE simulations. The SRB provided clarity at SRB021 of what an exceptional circumstance is and how it may 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, and have been for more than one year, 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.

Definitions of exceptional circumstances

Suggested exceptional circumstances are as follows.

a) The coastwide all-sizes FISS WPUE or NPUE from the space-time model falls above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index for two or more consecutive years.

    i. This would be examined annually after the FISS WPUE and NPUE indices are available in November by comparing it to MSE simulations that are most similar to the recent catches. 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. If an exceptional circumstance is declared in a year without a stock assessment, it is unlikely that a stock assessment could be produced in time for the Interim Meeting, but an update on stock status may be available for the Annual Meeting.

b) The observed FISS all-sizes stock distribution for any Biological Region is above the 97.5th percentile or below the 2.5th percentile of the simulated FISS index over a period of 2 or more years.

i. These data were used to condition the OM, so are a reasonable choice for an exceptional circumstance. 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. This would be examined annually after the FISS stock distribution estimates are available in November by comparing it to MSE simulations that are most similar to the recent catches. If an exceptional circumstance is declared in a year without a stock assessment, it is unlikely that a stock assessment could be produced in time for the Interim Meeting, but an update on stock status may be available for the Annual Meeting.

c) Recruitment, weight-at-age, sex ratios, other biological observations, or new research indicating parameters that are outside the 2.5^{th} and 97.5^{th} percentiles of the range used or calculated in the MSE simulations.

i. Most likely, this would be identified during a full stock assessment, and a new OM would be conditioned. However, new understanding of the Pacific halibut population may warrant a reconsideration of MPs to evaluate. The details can be identified further.

Action after an exceptional circumstance is declared

Once an exceptional circumstance is declared a series of actions would occur.

1) A review of the MSE simulations to determine if the OM can be improved and MPs should be re-evaluated. At a minimum, the OM will be updated and reconditioned to the most recent observations, including those that resulted in the exceptional circumstance.
2) If a multi-year MP was implemented and an exceptional circumstance occurred in a year without a stock assessment, a stock assessment would be completed as soon as possible along with the re-examination of the MSE. However, it may not be possible to conduct a stock assessment in time for the Annual Meeting immediately following the declaration of an exceptional circumstance.
3) Consult with the SRB and MSAB to identify why the exceptional circumstance occurred, what can be done to resolve it, and determine a set of MPs to evaluate with an updated OM. Present these recommendations to the Commission.
4) Further consult with the SRB and MSAB after simulations are complete to identify if a new MP is appropriate. Present these recommendations to the Commission.

POTENTIAL MANAGEMENT PROCEDURES AND SCENARIOS TO EVALUATE

The SRB (**IPHC-2023-SRB022-R** paragraphs 30 and 52 listed above) and the MSAB have provided requests to investigate various MP elements.

> **IPHC-2023-MSAB018-R, para. 29:** *The MSAB **REQUESTED** that subsequent to an agreement on a distribution procedure by the Commission, the evaluation of annual and multi-year assessments include, but not limited to, the following concepts.*

a) Annual changes in the TCEY driven by FISS observations in non-assessment years of a multi-year MP;

b) A constraint on the coastwide TCEY to reduce inter-annual variability and the potential for large changes in assessment years of a multi-year. This may be a 10% or 15% constraint, a slow-up fast-down approach, or similar approach;

c) A smoothing element in the distribution procedure to account for uncertainty in the estimates of stock distribution and reduce the variability in area-specific TCEYs. For example, this may include a 3-year rolling average of stock distribution estimates;

d) SPR values ranging from 30% to 56% and alternate trigger reference points in the harvest control rule.

The following describes elements of MPs that could be evaluated as part of the current MSE Program of Work, categorized as priority elements, secondary elements, and additional elements. Priority elements would be done first, secondary elements would be examined with specific priority elements, and the additional element is optional.

PRIORITY

Annual stock assessment MPs: Management procedures with an annual stock assessment.

Multi-year stock assessment MPs: These are management procedures that conduct a stock assessment every 2nd or 3rd year and use an empirical MP based on the FISS survey trends to determine the TCEY in non-assessment years.

Fishing intensity: A range of SPR values (i.e. fishing intensity, currently 43%) and alternative trigger reference points (currently 30%) in the harvest control rule.

FISS reductions: Further investigate scenarios where the FISS effort is reduced or occasionally eliminated in various IPHC Regulatory Areas.

SECONDARY

Constraints: A constraint on the coastwide TCEY to reduce inter-annual variability. Details have not been determined, but past examples include a 15% constraint and a slow-up/fast-down approach.

Stock distribution: A method to reduce the inter-annual variability in the estimates of stock distribution for use in the MP. This may include using the average of the stock distribution estimates over the past 3 years, for example.

ADDITIONAL

TCEY distribution: If specific distribution management procedures are of interest to Commissioners to assist with coming to an agreement, these can be evaluated using the MSE process.

RECOMMENDATION/S

1) The SRB **NOTE** paper IPHC-2023-SRB023-07 presenting an updated operating model, potential new MSE objectives, evaluation of FISS data scenarios, an examination of how to equalize management procedure performance across conservation objectives, possible exceptional circumstances, and potential management procedures to evaluate in 2023–2025.
2) The SRB **ENDORSE** the 2023 operating model containing four individual models to represent structural uncertainty identified in the ensemble stock assessment.
3) The SRB **RECOMMEND** that an objective to maintain spatial population structure be (added or redefined) to maintaining the spawning biomass in a Biological Region above a defined percentage of the dynamic unfished equilibrium spawning biomass in that Biological Region with a defined tolerance. The percentage and tolerance may be defined based on historical patterns and appropriate risk levels.
4) The SRB **RECOMMEND** that an objective to maintain the long-term coastwide female spawning stock biomass above the estimated 2023 female spawning biomass at least some percentage of the time (to be defined by the Commission) be added to the priority objectives. This provides an absolute measure of biomass that has meaning to stakeholders and Commissioners and may relate to efficiency and opportunity (e.g. CPUE) in the fisheries.
5) The SRB **RECOMMEND** continued examination of FISS scenarios that are representative of future FISS designs.
6) The SRB **RECOMMEND** that an exceptional circumstance be declared if any of the following are met:
    a. The coastwide all-sizes FISS WPUE or NPUE from the space-time model falls above the 97.5^{th} percentile or below the 2.5^{th} percentile of the simulated FISS index for two or more consecutive years.
    b. The observed FISS all-sizes stock distribution for any Biological Region is above the 97.5^{th} percentile or below the 2.5^{th} percentile of the simulated FISS index over a period of 2 or more years.
    c. Recruitment, weight-at-age, sex ratios, other biological observations, or new research indicating parameters that are outside the 2.5^{th} and 97.5^{th} percentiles of the range used or calculated in the MSE simulations.
7) The SRB **RECOMMEND** that if an exceptional circumstance occurred the following actions would take place:
    a. A review of the MSE simulations to determine if the OM can be improved and MPs should be re-evaluated.
    b. If a multi-year MP was implemented and an exceptional circumstance occurred in a year without a stock assessment, a stock assessment would be completed as soon as possible along with the re-examination of the MSE.

c. Consult with the SRB and MSAB to identify why the exceptional circumstance occurred, what can be done to resolve it, and determine a set of MPs to evaluate with an updated OM.

d. Further consult with the SRB and MSAB after simulations are complete to identify if a new MP is appropriate.

8) The SRB **RECOMMEND** evaluating fishing intensity and frequency of the stock assessment elements of management procedures and FISS uncertainty scenarios using the MSE framework. MP elements related to constraints on the interannual change in the TCEY and calculation of stock distribution may be evaluated for a subset of the priority management procedures as time allows.

REFERENCES

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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 ($B_{20\%}$) at least 95% of the time	B < Spawning Biomass Limit (B_{Lim}) B_{Lim}=20% unfished spawning biomass	Long-term	0.05	$P(SB < SB_{Lim})$ Fail if greater than 0.05
	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 Reference (B_{Thresh}) B_{Thresh}=$B_{36\%}$ unfished spawning biomass	Long-term	0.50	$P(SB < SB_{Targ})$ Fail if greater than 0.5
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 IPHC MSE Research website contains additional documents with more detailed information.

https://www.iphc.int/management/science-and-research/management-strategy-evaluation

The MSE technical document (IPHC-2022-MSE-01) currently available on the IPHC MSE page will be updated with IPHC-2023-MSE-02 in the near future.

The MSE Explorer will be updated as additional results are produced. Links to the current MSE Explorer as well as archived results are available at

http://iphcapps.westus2.cloudapp.azure.com/

Report on Current and Future Biological and Ecosystem Science Research Activities

PREPARED BY: IPHC SECRETARIAT (J. PLANAS, 25 AUGUST 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 the 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 SA (Appendix II) and the MSE 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 SRB022 (IPHC-2023-SRB022-R):

SRB022–Rec.08 (para. 32) The SRB ***NOTED*** *that the current maturity sampling design does not determine whether the high rate of individuals at the cortical alveoli stage in the southeastern portion of the study area is a function of differences in seasonal reproductive timing or in size/age at maturity. The SRB* ***RECOMMENDED*** *additional investigations on the region-specific seasonal reproductive cycles and evaluating the extent to which differences among regions can be explained by size or age of the sampled individuals.*

The IPHC Secretariat is currently conducting a coastwide study on maturity with a significantly higher number of ovarian samples collected during the 2022 FISS and is expanding further the number of collected ovarian samples in the referenced study area during the current 2023 FISS (Section 2.2.1, this document).

*SRB022–Rec.09 (para. 35) The SRB **NOTED** the presentation on whale depredation avoidance devices and **RECOMMENDED** that the Secretariat pursue external funding opportunities for expanding this research and testing one or more devices in the presence of whales.*

The IPHC Secretariat submitted a grant proposal to test catch protection devices in the presence of killer whales that has been awarded for the period November 2023 – April 2025 (Appendix IV).

*SRB022–Rec.10 (para. 36) **NOTING** that in terms of bioinformatic quality filtering to exclude loci, filtering based on sequencing depth alone may not be sufficient to exclude mitochondrial sequences, the SRB **RECOMMENDED** that loci be mapped to the published Pacific halibut mitochondrial genome to ensure that non-autosomal loci are included in analyses. Filtering based on sequencing depth alone is likely not sufficient to exclude regions of the genome that represent repetitive elements. Suggest sites be checked for repetitive elements.*

The IPHC Secretariat used the following filtering criteria in addition to sequencing depth, as previously noted (p. 9, IPHC-2023-SRB022-09; slide 10, IPHC-2023-SRB022-09): a) Minor Allele Frequency (MAF): >= 0.01; b) missing data: a site must be covered in < 80% of individuals; and, c) SNP pval: remove sites with p-value < 1e-6 (i.e., probability of a site being variable). In addition, the RefSeq assembly used for read mapping (GCF_022539355.2) contains the published mitochondrial sequence. Since read mapping occurs prior to SNP detection, these reads can be filtered on the basis of genomic location. SNPs that were detected from reads mapping to non-autosomal regions, namely the mitochondrial genome and chromosome 9, which contains a large sex-associated region (Jasonowicz et al. 2022), were removed, and the number of SNPs (10,230,908) reported in SRB022 were referred to as autosomal, implying that mitochondrial SNPs and sex-linked SNPs are not included in the current summary of the dataset. We should note that the recommendation to ensure that non-autosomal loci are *included* in analyses is in contrast with the previous statement in this recommendation that filtering on sequencing depth alone may not be sufficient to exclude mitochondrial sequences. As stated above, non-autosomal loci would also include mitochondrial and sex-linked SNPs. We would argue that including non-autosomal SNPs in this dataset is not advisable since they have been shown to bias population genetic parameter estimates and analyses (Benestan et al. 2017) since mitochondrial and autosomal DNA are subject to different inheritance and evolutionary mechanisms. Finally, while filtering sites based on sequencing depth offers one means for excluding repetitive regions of the genome from downstream analyses, requiring sites to be covered in a minimum number of individuals can also be helpful for this purpose (Lou et al. 2021), as well as filtering sequencing reads based on mapping quality and their ability to map uniquely prior to SNP detection, as noted in IPHC-2023-SRB022-09. Part of the Pacific halibut genome annotation process conducted by NCBI includes the identification of repetitive regions so that we can also exclude these regions directly.

*SRB022–Rec.11 (para. 37) The SRB **RECOMMENDED** that the Secretariat include other genome-wide summary measures of diversity. Measures could include (a) measures of genome size, (b) percentages of genome as singleton and duplicated loci, (c) other summary measures of diversity including (i) number of loci with minor allele frequency (MAF)>0.01, (ii) number of loci with MAF>0.05, (iii) a measure of deviation of observed and expected heterozygosity (Fis), (iv) observed heterozygosity (Ho) and expected heterozygosity (He).*

The IPHC Secretariat has produced several of the suggested genome-wide summary measures of diversity. First, the complete Pacific halibut reference genome contains 52 scaffolds (602.1 Mbp), 24 of which represent fully assembled chromosomes (600.9 Mbp) (p.8, IPHC-2022-SRB020-08; Table 1, Jasonowicz et al. 2022). Second, genome assembly completeness, as estimated by BUSCO, indicates that 97.3% of the Pacific halibut reference sequence (GCF_022539355.2) is present in a single copy and 1.1% is duplicated (Table 1, Jasonowicz et al. 2022). Furthermore, as previously noted (p. 9, IPHC-2023-SRB022-09; slide 10, IPHC-2023-SRB022-09), the total number of SNPs identified in autosomal regions of the genome with a MAF ≥ 0.01 was 10,230,908, with 4,725,899 having a MAF ≥ 0.05. The estimation of additional diversity measures (Ho, He & Fis) is currently in progress and has been added to the updated proposed workflow (Figure 1).

*SRB022–Rec.12 (para. 38) The SRB **RECOMMENDED** that the Secretariat evaluate multiple 'windows' and inter-window 'spacing' to summarize diversity and differentiation. The SRB is unsure why a 15 Kb 'window was used with 7.5 Kb space for producing Manhattan plots. The size of the window will affect estimates of significance based on a measures of Fst significance. Specifically, the larger the 'window' likely the larger the standard deviation across a greater number of sites. Window size is also likely to affect levels of linkage disequilibrium and down-stream analyses based on it.*

The choice of window size is a starting point based on published literature using low-coverage whole- genome sequencing for studies of population structure of other commercially important groundfish species (Clucas et al. 2019). Given that the standard deviation will increase with the window size, we also estimated and plotted F_{ST} for single SNPs in order to visualize the dispersion of single SNP estimates of F_{ST} in relation to the estimate for the window, as previously provided in the supplemental documentation that was referenced in section 1.3.1.3. of document IPHC-2023-SRB022-09.

*SRB022–Rec.13 (para. 39) **NOTING** that different outlier tests are based on different assumptions and statistical approaches, the SRB **RECOMMENDED** that the Secretariat implement more than one method. Selection of specific markers would appropriately be based on concordant designation of highly population discriminatory loci identify across methods. The Secretariat is likely to have greater confidence in assignment of 'outliers' based on principles of concordance using multiple and semi-independent software packages and statistical approaches.*

The proposed workflow for the analysis of these data includes the identification of outlier loci using two approaches: 1) F_{ST} based outlier scans, and 2) PCA based selection scans, as previously noted (Fig. 1D; IPHC-2023-SRB022-09).

*SRB022–Rec.14 (para. 40) The SRB **RECOMMENDED** that after statistical significance of SNP loci has been established, the Secretariat use gene set enrichment analyses to establish functional annotations for genes associated with SNPs.*

Once statistical significance of SNPs has been established, we can proceed with this Recommendation. The IPHC Secretariat conducted enrichment analysis for genes identified in the large (12 Mb) sex-determining region in chromosome 9 of the Pacific halibut genome (Table S4, Jasonowicz et al. 2022). Therefore, the resources required for conducting enrichment analysis of genes associated with SNPs in the present study are readily available.

*SRB022–Rec.15 (para. 41) The SRB **APPRECIATED** that the Secretariat estimated Tajima's D as recommended (IPHC-2022-SRB021-R), and **RECOMMENDED** that:*

a) the Secretariat be cautious with filtering SNP loci based on minor allele frequency (MAF) at levels as low as 0.01 as employed in results described in IPHC-2023-SRB022-09, as this may affect values of Tajima's D; and

b) a range of values be explored.

The IPHC Secretariat used a minimal set of filters for any analyses requiring site frequency spectrum (SFS), as previously provided in the supplemental documentation referenced in section 1.3.1.3. of document IPHC-2023-SRB022-09. For such analyses, applying allele frequency-based filters will distort the SFS and the literature recommends that these types of filters should be avoided for analyses that rely on accurate estimation of the SFS (Matz 2018) and specifically when estimating Tajima's D from low coverage whole genome sequence data (See section 3.4.3 in Lou et al. 2021).

*SRB022–Rec.16 (para. 43) The SRB **RECOMMENDED** looking for genome regions (more than 2 or more co-located 'significant' SNPS) with high divergence as indication of regions containing structural variants. Measures of linkage disequilibrium can also be profitably used to identify structural variants.*

The IPHC Secretariat is currently working to follow up on this Recommendation. As previously shown (Fig. 1D, IPHC-2023-SRB022-09), the proposed bioinformatics workflow contemplates the use of the software ngsLD which estimates measures of linkage disequilibrium from genotype likelihoods (Fox et al. 2019).

*SRB022–Rec.17 (para. 44) The SRB **RECOMMENDED** plotting levels of heterozygosity as Manhattan plots across chromosomal regions.*

The IPHC Secretariat has begun estimating additional genetic diversity measures in response to SRB022–Rec.11 and has updated the proposed workflow to reflect this (Figure 1). This would include visualizing heterozygosity levels across chromosomal regions.

*SRB022–Rec.18 (para. 45) **NOTING** that use of high-throughput low-coverage DNA sequencing data can lead to biased estimates of the site frequency spectrum (SFS) due to high levels of uncertainty in genotyping, the SRB **RECOMMENDED** exploring other* *derivations from Secretariat proposed work described in IPHC-2023-SRB022-09 including visualisations of SFS in multi-dimensional space.*

The IPHC Secretariat recognizes the uncertainty inherent in low coverage DNA sequencing data and is using methods that account for this uncertainty which is critical when dealing with low coverage data (Korneliussen et al. 2014; Mas-Sandoval et al. 2022). With regards to the estimation of the SFS, the method that we are currently using is detailed in Rasmussen et al. (2022), and was specifically developed to accommodate uncertainty inherent to low coverage whole genome resequencing (lcWGR) data. We would like to note that we are not planning to use any analyses that require hard called genotypes as this is not appropriate for lcWGR data. All current and planned analyses (and software) utilize the raw sequence alignments or genotype likelihoods directly, taking into account uncertainty due to low sequencing depth.

*SRB022–Rec.19 (para. 46) **NOTING** that one of the primary objectives of the Pacific halibut genome project is to provide spatial discrimination of 'populations' (IPHC reporting regions) and to assign individuals to these groups, and that the Secretariat described genetic relationships among individuals from different IPHC reporting region and years of collection based on multivariate ordination using principle component analyses (PCA), and that levels of variability explained associated with PCA axes projects is low, the SRB **RECOMMNEDED**:*

a) *conducting additional analyses to evaluate statistical significance of measures of inter-population differentiation (Fst); and*

b) *re-analysis using only outlier loci.*

The IPHC Secretariat is currently working to address these two Recommendations.

*SRB022–Rec.20 (para. 47) The SRB **RECOMMENDED**:*

a) *that the Secretariat move forward to stock discrimination to satisfy the Secretariat objective of using genetic data to define spatial structuring including unsupervised clustering methods (e.g. K-means, Structure, etc.) as well as PCA-based clustering (e.g. Discriminant Analysis of Principle Component) clustering;*

b) *using assignment testing and mixture analyses such as leave-one-out cross-validation simulations to assess the potential accuracy of mixed stock analysis (MSA).*

The IPHC Secretariat proposed the use of unsupervised clustering methods, specifically K-means (Fig.1, IPHC-2023-SRB022-09; slide 10, IPHC-2023-SRB022-09), and they are being implemented. However, NGSadmix (Skotte et al. 2013) will be used rather than structure since it was developed for lcWGR data and can handle genotype likelihoods as input. The use of Discriminant Analysis of Principle Components (Jombart et al. 2010) may be problematic since the current implementation requires hard called genotypes and would not be appropriate for genotype likelihood data generated from lcWGR. Assignment testing using genotype likelihoods can be done with WGSassign (Desaix et al. 2023) and this has been added to the updated proposed workflow (Figure 1).

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 II). 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 III).

   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). 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), very little information is available on the geographic location and physical characteristics of these areas. The IPHC Secretariat 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, has resulted in catch locations for a total of 52,356 Pacific halibut aged 0-2 encountered from 1946 to 2022 (data sources provided in Table 1 of IPHC-2023-SRB022-09).

   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 was initiated in cooperation with Alaska Coastal Observations and Research (ACOR) and University of Alaska Fairbanks to mine data from unpublished sources that were recorded in the 1990s on juvenile Pacific halibut encounters in beach seines conducted off Kodiak Island, Afognak Island and Kachemak Bay, Alaska.

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 by using 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 (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, IPHC-2022-SRB021-09 and IPHC-2023-SRB022-09.

Additional components have been added to the proposed workflow for this project (Figure 1) to address SRB recommendations SRB022–Rec.11 and SRB022–Rec.20. The addition of estimating measures of genetic diversity from genotype likelihoods has been added to the workflow in Figure 1C and was carried out as follows. Genotype likelihoods estimated at 10,230,908 autosomal single nucleotide polymorphism (SNP) positions (methods on genotype likelihood estimation are detailed in IPHC-2023-SRB022-09) were used to estimate additional measures of genetic diversity (SRB022–Rec.11). ANGSD (v0.940) (Korneliussen et al. 2014) was used to test for departures from Hardy-Weinberg Equilibrium (-doHWE 1), estimate allele frequencies (-doMaf 1) and heterozygosity levels at each SNP for each sample collection and geographic area. A summary of these values is provided in Table 1. Population assignment testing has been added to the workflow in Figure 1C and will be carried out using WGSassign (https://github.com/mgdesaix/WGSassign), a software package for conducting population assignment testing using genotype likelihoods from lcWGR data (Desaix et al. 2023).

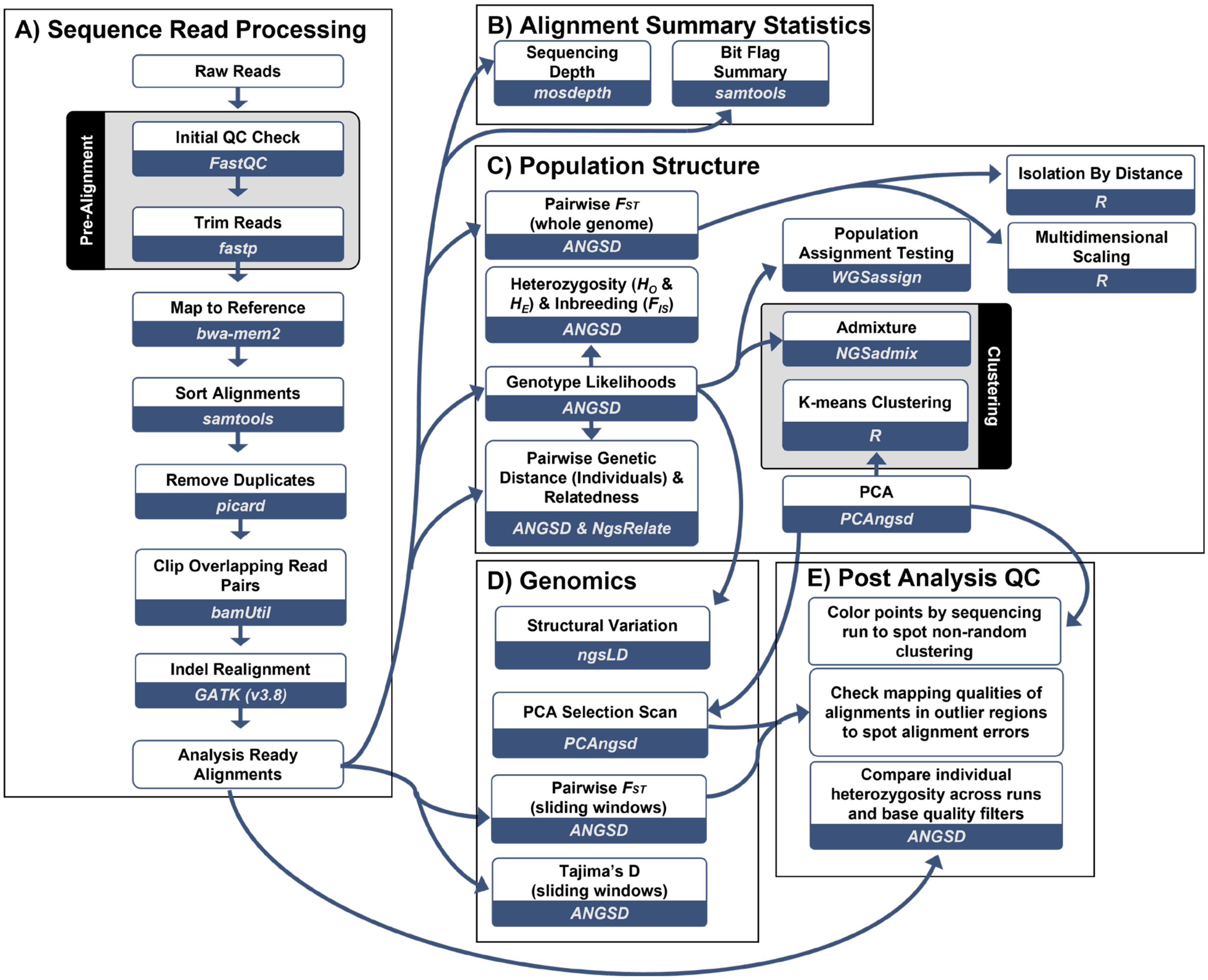


Figure 1. Proposed bioinformatic workflow for the interrogation of low-coverage whole genome sequence data. This diagram tracks the flow of data through the main stages of this project, (A) raw sequence read processing, (B) alignment summaries, (C) analysis of population structure, (D) genomic analyses,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

The IPHC Secretariat is currently conducting work to address components of SRB022–Rec.13, SRB022–Rec.14 and SRB022–Rec.20. Principal component analysis (PCA) was carried out using PCAngsd (v1.11) (Meisner and Albrechtsen 2018) to estimate a covariance matrix from the genotype likelihoods estimated from the lcWGR dataset (methods on genotype likelihood estimation are detailed in IPHC-2023-SRB022-09). A minor allele (MAF) threshold of 0.05 was applied, retaining 4,725,899 autosomal SNPs for covariance matrix estimation. and Eigendecomposition was performed using the *eigen* function in R (v4.2.2). To determine an appropriate number of principal components (PCs) to retain for downstream analyses, a scree plot of the first 20 eigenvalues was visually inspected and following Cattell's rule (Cattell 1966), we retained the first three PCs (Figure 2) for further analyses.

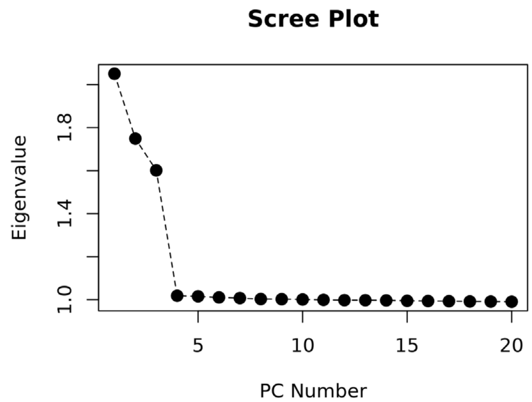


Figure 2. Scree plot of the eigenvalues for the first 20 principal components (PCs).

K-means clustering was performed on the retained PCs (SRB022–Rec.20) using the *kmeans* function in R. To determine the optimal number of clusters (*K*) present in the data we tested a range of *K* values (1 to 20) and used total within-cluster sum of squares (WSS) and Bayesian information criterion (BIC) to compare the *K* values tested (Figure 3). One method for choosing the optimal value of *K* is to look for an inflection point or "elbow" in the total WSS values and in the case of BIC, the lowest associated value (Jombart et al. 2010). In this data, a clear inflection point is not present in the WSS values (Figure 3A) and the lowest BIC value is associated with *K*=20, the maximal value of *K* tested. This could be taken as an indication that discrete clusters are not present in the dataset.

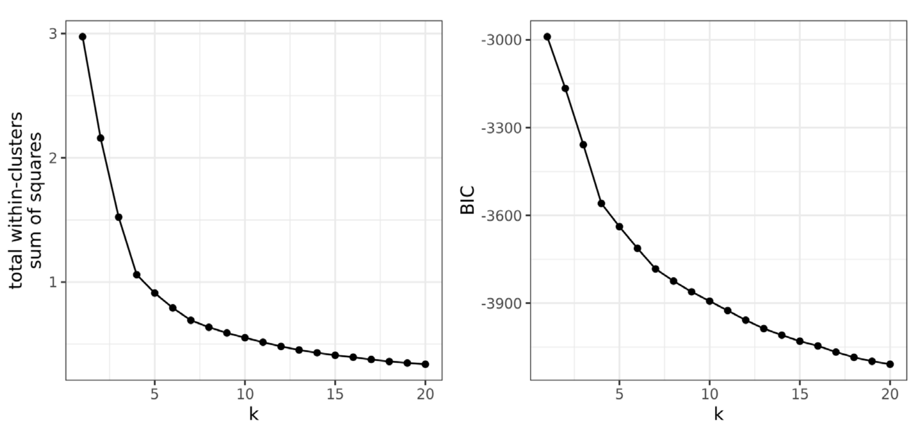


Figure 3. Plots of total within-clusters sum of squares (A) and Bayesian information criterion for each value of K tested (1-20).

Area	Collection Year	N	MAF > 0.01	MAF > 0.05	F_{IS}	H_O	H_E
British Columbia	1999	49	8,958,267	4,890,386	0.109	0.154	0.158
	2004	43	8,756,199	4,995,125	0.115	0.156	0.163
	2007	50	8,939,078	4,900,656	0.120	0.154	0.157
	all years	142	9,256,496	4,762,476	0.023	0.155	0.161
Central Gulf of Alaska	1999	50	9,131,547	4,993,279	0.049	0.158	0.171
	2004	50	9,065,567	5,163,204	0.029	0.162	0.189
	2007	50	9,052,210	5,052,609	0.058	0.159	0.176
	2018	49	8,627,118	4,893,881	0.172	0.153	0.153
	all years	199	9,561,613	4,862,986	-0.032	0.158	0.176
Bering Sea	2004	43	8,886,235	5,007,451	0.094	0.156	0.164
	2007	50	9,057,451	4,930,166	0.089	0.155	0.162
	all years	93	9,214,470	4,851,360	0.030	0.156	0.164
Central Aleutian Islands	2007	37	8,464,803	4,983,042	0.150	0.154	0.157
	2020	49	8,823,846	4,904,749	0.129	0.154	0.158
	all years	86	8,921,876	4,799,261	0.066	0.154	0.159
Western Aleutian Islands	2020	50	8,690,974	4,893,669	0.151	0.153	0.157
	all years	50	8,690,974	4,893,669	0.151	0.153	0.157

Table 1. Summary of diversity measures estimated from low coverage whole genome sequence data for sample collections of Pacific halibut. The table includes sample sizes (N), number of loci with minor allele frequency (MAF)>0.01, number of loci with MAF>0.05.

We also conducted PCA based selection scans along the top three PCs (Figure 2) to identify and establish statistical significance of outlier SNPs (SRB022–Rec.13, SRB022–Rec.14). An extended version of the pcadapt model (Luu et al. 2017) designed to accommodate genotype likelihoods implemented in PCansgd (Meisner et al. 2021) was used to identify SNPs that may be under selection. As with the covariance matrix estimation, a MAF threshold of 0.05 was applied, retaining 4,725,899 autosomal SNPs for the selection scan. The scores from PCAdapt were converted to p-values using the provided R script pcadapt.R (https://github.com/Rosemeis/pcangsd/blob/master/scripts/pcadapt.R). To correct for multiple testing and control the false discovery rate (FDR) p-values were adjusted using the Benjamini-Hochberg procedure (Benjamini and Hochberg 1995). Applying an FDR threshold of 0.001, we identified 16,272 candidate SNPs potentially under selection (Figure 4). We are currently exploring additional options of multiple testing corrections to determine optimal thresholds for outlier SNP detection (e.g. Storey and Tibshirani 2003).

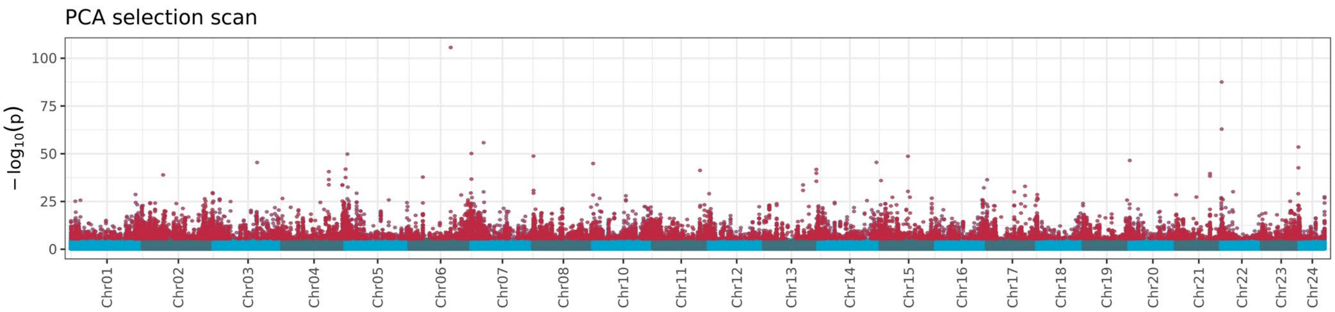


Figure 4. Manhattan plot of the -log10(p-values) obtained from the selection scan along the top three PCs carried out in PCangsd (using the pcadapt model). Points highlighted in read represent the 16,272 significant SNPs at an FDR threshold of 0.001.

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 has finalized 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 finalizing 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 is continuing 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, sampling efforts are only taking place 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 has 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 received training on this method by experts in the field (NOAA Fisheries, Northeast Fisheries Science Center, Wood Hole, MA) in May 2023. Ovarian samples for fecundity estimations are being collected during the 2023 FISS. Sampling is taking 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 experimentally-derived estimates of discard mortality rate in the directed longline fishery (Loher et al., 2022), 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. A manuscript describing this study has been submitted for publication in the peer-reviewed literature (Dykstra et al., submitted).

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. Current efforts are devoted to analyze collected data on capture conditions (e.g., bottom, ambient and fish temperatures; time on hook and on deck), blood stress parameters and injury and viability classifications.

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 (Appendix I). 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 provided for the SRB020 meeting: IPHC-2022-SRB020-08.

During the second phase of the project, the IPHC Secretariat 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 Solutions SA's catch protection device (i.e., shuttle) and one based on a modification of a slinky pot (i.e., shroud) deployed on branchline gear. Pilot testing was designed 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. Descriptions of the two different devices are as follows:

- Shuttle system. Manufactured in Norway by Sago Solutions AS, two shuttle devices were modeled after the Sago Extreme model but smaller at 80% size (Figure 5). 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 were deployed from the surface, during the haulback event, by threading them onto a blank skate of gear between the control and the treatment skates.

A) B)

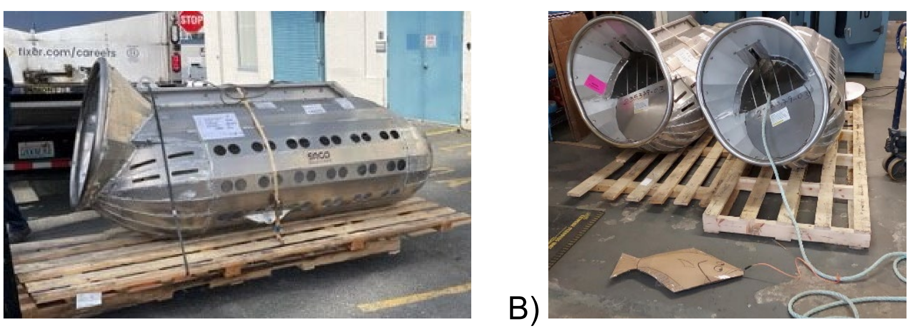
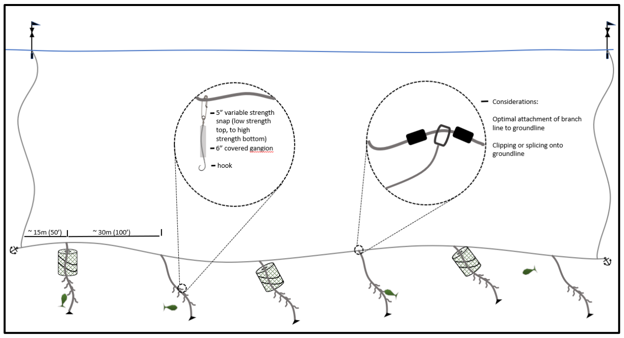


Figure 5. Images of the prototype shuttle devices used in this study in profile (A) and frontal view (B).

- Shroud system. Shrouds were constructed in house by modifying a slinky pot (opening one end and installing a rigid cap in the other end) and designed to slide down the branch line during haulback, clustering the snaps (and hooks) and covering any catch (Figure 6).

A) 

B) 

Figure 6. Schematic of shrouded branchline actively fishing on seabed (A) and a shroud made from a modified slinky pot (B).

Field work was conducted off Newport, OR, aboard the R/V Pacific Surveyor (56’ length) in late May 2023. Ten sets were made with each gear type, with an even number of treatments (controls or protection devices) per set. Shuttles had a standard fixed gear skate of 100 hooks on 18 foot spacing, a blank half skate (on which to thread and allow the shuttle to reach the bottom before entraining catch) followed by a second section with 100 fixed hooks. Shroud treatments initially consisted of six branchlines (each with 10 hooks snapped on at four-foot spacing), three with shrouds to cover the catch, and three controls with no protective shroud. This was reduced to two protected and two control branchlines, all with two-foot hook spacing to provide more handling time and to reduce risk to crew. The pilot nature of the study provided the flexibility to adjust and react to observations in real time. A moderate learning curve was required for shuttles to be able to efficiently thread onto the gear, shuttles had good entrapment of catch (similar catch rates to the control) (Figure 7), and smaller hooks and weaker gangions incurred lower levels of damage to the entrained fish. The devices are rugged, and safely operational on a small vessel.

A)  B)  C) 

Figure 7. Shuttle being retrieved A), catch entrained in shuttle B), and catch being emptied onto the vessel deck.

Branchline fishing with shrouds had a steep learning curve and presented some safety concerns. Upon working through these concerns, this type of catch protection device had a very small effective footprint, with minimal catch with which to make comparisons between shrouded branches and controls (Figure 8), despite the high hagfish activity. Many logistical issues would need to be worked out to scale this catch protection device up to real fishing conditions and would conceivably still provide opportunities for catch depredation to whales.

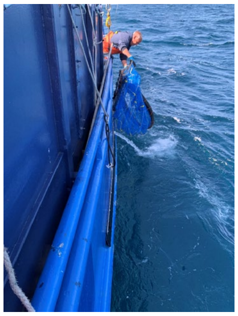
A)  B)  C) 

Figure 8. Shroud gear being retrieved A), skate covered by the shroud B), and a Pacific halibut and branchline hooks covered by the shroud C).

In a third phase of this project, the IPHC Secretariat has recently received another grant from the Bycatch Reduction Engineering Program-NOAA entitled “Full scale testing of devices to minimize whale depredation in longline fisheries” (NA23NMF4720414) to refine effective methods for protecting longline captured fish from depredation and to complete replicates in the presence of toothed whales in known depredation hotspots to demonstrate the efficacy and safety of the gear. Field work for this project is planned for mid-2024.

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2023-SRB023-08 which provides a response to Recommendations from SRB022, 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 (SA) and management strategy evaluation (MSE): rationale for biological research prioritization

Research areas	Research activities	Research outcomes	Relevance for stock assessment	Relevance for MSE	Specific analysis input	SA Rank	MSE Rank	Research priorization
Migration and population dynamics	Population structure	Population structure in the Convention Area	Altered structure of future stock assessments	Improve parametization of the Operating Model	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	2. Biological input	1. Biological parameterization and validation of movement estimates and recruitment distribution	2
	Distribution	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	3. Biological input		2
	Larval and juvenile connectivity studies	Improved understanding of larval and juvenile distribution	Improve estimates of productivity		Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	3. Biological input	1. Biological parameterization and validation of movement estimates	2
Reproduction	Histological maturity assessment	Updated maturity schedule	Scale biomass and reference point estimates	Improve simulation of spawning biomass in the Operating Model	Will be included in the stock assessment, replacing the current schedule last updated in 2006	1. Biological input		1
	Examination of potential skip spawning	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			1
	Fecundity assessment	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			1
	Examination of accuracy of current field macroscopic maturity classification	Revised field maturity classification			Revised time-series of historical (and future) maturity for input to the stock assessment			1
Growth	Evaluation of somatic growth variation as a driver for changes in size-at-age	Identification and application of markers for growth pattern evaluation	Scale stock productivity and reference point estimates	Improve simulation of variability and allow for scenarios investigating climate change	May inform yield-per-recruit and other spatial evaluations of productivity that support mortality limit-setting		3. Biological parameterization and validation for growth projections	5
		Environmental influences on growth patterns			May provide covariates for projecting short-term size-at-age. May help to delineate between effects due to fishing and those due to environment, thereby informing appropriate management response			5
		Dietary influences on growth patterns and physiological condition			May provide covariates for projecting short-term size-at-age. May help to deleineate between effects due to fishing and those due to environment, thereby informing appropriate management response			5
Mortality and survival assessment	Discard mortality rate estimate: longline fishery	Experimentally-derived DMR	Improve trends in unobserved mortality	Improve estimates of stock productivity	Will improve estimates of discard mortality, reducing potential bias in stock assessment results and management of mortality limits	1. Fishery yield	1. Fishery parameterization	4
	Discard mortality rate estimate: recreational fishery				Will improve estimates of discard mortality, reducing potential bias in stock assessment results and management of mortality limits			4
	Best handling and release practices	Guidelines for reducing discard mortality			May reduce discard mortality, thereby increasing available yield for directed fisheries	2. Fishery yield		4
Fishing technology	Whale depredation accounting and tools for avoidance	New tools for fishery avoidance/deterence; improved estimation of depredation mortality	Improve mortality accounting	Improve estimates of stock productivity	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	1. Assessment data collection and processing		3

APPENDIX II

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

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 links to biological research areas and research activities

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 awarded 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 (Juneau, Seattle)	$193,685	Stock structure	December 2021-January 2024
3	**Bycatch Reduction Engineering Program - NOAA**	Full scale testing of devices to minimize whale depredation in longline fisheries (NA23NMF4720414)	IPHC	NOAA Fisheries - Alaska Fisheries Science Center (Seattle)	$199,870	Mortality estimations due to whale depredation	November 2023 – April 2025
Total awarded ($)					**$493,255**		

2024-26 FISS design evaluation

PREPARED BY: IPHC SECRETARIAT (R. WEBSTER, I. STEWART, K. UALESI, & D. WILSON; 25 AUGUST 2023)

Part 1: 2024-26 FISS design evaluation

PURPOSE

To review the potential 2024-26 FISS designs presented previously at SRB022, along with 2024 design options accounting for the FISS objective of long-term revenue neutrality.

BACKGROUND

At SRB022, the Secretariat presented proposed FISS designs for 2024-26 together with a scientific evaluation of those designs (IPHC-2023-SRB022-06). Based on the evaluation, it is expected that the proposed designs would lead to estimated indices of density that would meet bias and precision criteria in the 2024-26 period.

The designs presented at SRB022 were evaluated only using criteria based on the primary FISS objective of sampling Pacific halibut for stock assessment and stock distribution estimation (Table 1). The IPHC Secretariat has developed a sequence of additional designs that account to varying degrees for the secondary FISS objective of long-term revenue neutrality. The estimate of net revenue for each design is based on preliminary information from the current FISS, which at the time of writing is not yet complete. Cost projections for 2024 designs are therefore subject to later revision.

For at least some of the design options below, projected coefficients of variation (CVs) will be calculated to help understand the impact of a reduced FISS footprint on data quality in 2024. It is our intention to present this information to the SRB in a Rev_1 version of this document and/or as part of the meeting presentation.

Table 1.1. 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

POTENTIAL DESIGNS FOR 2024-26

1) ***Options based on the primary objective (Table 1.1)**, to sample Pacific halibut for stock assessment and stock distribution estimation.*

Design options based on the Primary Objective for 2024-26 (Figures 1.1 to 1.3) use efficient subarea sampling in IPHC Regulatory Areas 2A, 4A and 4B, and incorporate a randomized subsampling of FISS stations in IPHC Regulatory Areas 2B, 2C, 3A and 3B (except for the near-zero catch rate inside waters around Vancouver Island), with a sampling rate chosen to keep the sample size close to 1000 stations in an average year, 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 included in the design for the 2024 FISS presented at SRB022. 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 1.1):

- 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 1.2):

- 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 design (Figure 1.3) 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. Further details were presented at SRB022 and can be found in IPHC-2023-SRB022-06.

The potential 2024 design in Figure 1.1 is designated as Design 1 of nine potential designs considered here. Each of the design options presented in this document was evaluated assuming that the average price in each charter region for Pacific halibut remains unchanged from 2023 to 2024 and that the landings in each charter region decrease by 5% on average across all stations.

DESIGN 1: Using preliminary information from the 2023 FISS, the potential 2024 design in Figure 1.1 based on primary objectives (Table 1.1) is projected to result in **a net loss of between 3.649 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

2) ***Options accounting for the secondary objective (Table 1.1),*** *long term revenue neutrality.*

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 is to provide a fiscally viable FISS design.

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 support costs (staffing, travel, training, gear transport etc.).

Balancing these factors results in modifications to designs such as increasing sampling effort in high-density regions and decreasing effort in low density regions. It had been anticipated that under most circumstances, cost considerations could be addressed by increasing effort (adding stations, increasing the number of skates set) in revenue-positive regions in the designs proposed in this report. However, with stocks near historic lows and extremely low prices for fish sales, the current funding model requires 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 FISS, 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 balanced the primary objective with the secondary objective by greatly reducing sampling outside of the core areas of the stock (IPHC-2022-IM098-R). The result will be increased uncertainty in estimates of WPUE and NPUE indices following the 2023 FISS, with projected 2023 CVs of 19-26% for IPHC Regulatory Areas 2A, 4A and 4B which received little or no sampling in 2023.

The 2023 FISS is expected to be completed at a substantial operating loss, due primarily to lower than expected catch rates and lower prices for Pacific halibut than projected. The Secretariat recognises that the FISS cannot continue in 2024 under similar pressures, and as such, we propose the following sequence of 2024 FISS design options that balance data collection and fiscal viability to varying degrees. The preliminary estimates of net cost for all 2024 design options are in Table 1.2.

Cost estimates are based on preliminary information from the 2023 FISS and it is important to note that data and accounting are not yet complete. Fish sales revenue and catch rates in some areas are still pending completion of work this summer (IPHC charter region Sanak and Sitka). Therefore, in preparing the 2024 projections, values for these regions were estimated factoring in the projected values as well as current patterns seen in surrounding regions. Final cost and accounting information will be available at the end of the fiscal year and will be used to refine these preliminary projections at that time.

Table 1.2. Comparison of preliminary design option costs for the 2024 FISS. Each design modifies the previous alternative as noted; see text for additional details.

Design	Description	Preliminary projected net revenue	Change in revenue from previous design
1	Pre-optimized design	-$3,649,000	--
2	Optimized design (adding stations and skates)	-$2,983,000	$666,000
3	Remove 4CDE	-$2,523,000	$460,000
4	Remove 4CDE and 2A	-$2,224,000	$299,000
5	Remove 4B, 4CDE and 2A	-$1,817,000	$407,000
6	Remove 4A, 4B, 4CDE and 2A	-$1,483,000	$334,000
7	Remove 3B, 4A, 4B, 4CDE and 4A	-$1,096,000	$387,000
8	Remove parts of 2B and all of 3A, 3B, 4A, 4B, 4CDE and 2A	-$384,000	$712,000
9	Design 8 with added efficiencies	$8,000	$392,000

DESIGN 2: This option adds stations and uses sets of 8 skates in revenue-positive charter regions in IPHC Regulatory Areas 2B and 2C (Figure 1.4). The station design in other IPHC Regulatory Areas is the same as Design 1 above. Design 2 is projected to result in **a net loss of 2.983 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

DESIGN 3: Removes IPHC Regulatory Area 4CDE from Design 2 (Figure 1.5). Design 3 is projected to result in **a net loss of 2.523 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

DESIGN 4: Removes IPHC Regulatory Area 2A from Design 3 (Figure 1.6). Design 4 is projected to result in **a net loss of 2.224 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

DESIGN 5: Removes IPHC Regulatory Area 4B from Design 4 (Figure 1.7). Design 5 is projected to result in **a net loss of 1.817 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

DESIGN 6: Removes IPHC Regulatory Area 4A from Design 5 (Figure 1.8). Design 6 is projected to result in **a net loss of 1.483 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

DESIGN 7: Removes IPHC Regulatory Area 3B from Design 6 (Figure 1.9). Design 7 is projected to result in **a net loss of 1.096 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

DESIGN 8: Removes IPHC Regulatory Area 3A and southern charter regions of IPHC Regulatory Area 2B from Design 7 (Figure 1.10). Design 8 is projected to result in **a net loss of 0.384 million dollars** (Table 1.2) and is therefore **not feasible**. **NOT RECOMMENDED**

As none of the above 2024 design options is preliminarily projected to be revenue neutral, an additional design was developed based on modifying Design 8 to further reduce costs and increase revenue.

DESIGN 9: The IPHC Secretariat has developed an alternative preliminary design for 2024 that is currently projected to be slightly revenue positive (Figure 1.11) by adding a series of cost-saving efficiencies to design 8. In order to achieve projected positive net revenue, sampling would only take place in the northern portion of IPHC Regulatory Areas 2B and in IPHC Regulatory Area 2C. Sampling in any other IPHC Regulatory Area is projected to lead to an overall operating loss for the 2024 FISS.

Several aspects of the standard FISS procedures were removed to achieve a revenue-positive design:

- No oceanographic monitoring will take place;
- NOAA Fisheries trawl surveys are not staffed by IPHC;
- All FISS training will be conducted virtually;
- Reduce field staff on each vessel from two to one in two charter regions; only basic biological information (length, weight and sex) would be collected.

Additional changes were required to the standard FISS design in sampled areas:

- Add a further 13 stations in high density regions to increase revenue.
- Allow for "Vessel captain stations", in which vessel captains can choose to fish up to one third of their sets at a location that is optimal in terms of catch rates or revenue. It is

assumed pending further evaluation these stations will achieve 120% of the average catch rate of the usual fixed-station design stations.

Further, the following assumptions regarding FISS bait were made:

- That there will be a decrease in price of chum salmon bait of approximately 25% from 2023;
- That data from the planned September bait comparison study is supportive of using pink salmon as bait, that pink salmon will comprise 25% of all FISS bait (used at 50% of the stations in 2C), and is 60% of the price of chum salmon.

With these modifications and assumptions, Design 9 (Figure 1.11) has **a preliminary projected net operating profit of $8,000** (Table 1.2). If the 2023 bait calibration study in IPHC Regulatory Area 2C is successful, it may be desirable to add a similar bait calibration in IPHC Regulatory Area 2B in 2024. Such an effort may further increase net revenue and generate sufficient information to proceed with the use of both pink and chum salmon in that area in 2025.

The lack of sampling in IPHC Regulatory Areas 2A, 4A and 4B will lead to further increases in uncertainty above those projected for 2023, and we anticipate CVs between 20 and 35% for these areas. With no sampling in IPHC Regulatory Areas 3A and 3B, uncertainty in estimates from these areas will also increase, and we expect a CV outside the target range of ≤15% for IPHC Regulatory Area 3B (given that with reduced sampling in 2022, the CV was 14%). With a NOAA Fisheries trawl survey expected to take place in the Bering Sea in 2024, the CV for IPHC Regulatory Area 4CDE is not expected to increase outside the target range. Increased uncertainty in most areas will carry through into coastwide estimates, although at present we anticipate the coastwide WPUE and NPUE indices to have CVs that remain in the target range of ≤10%. Estimates of stock distribution will also have higher levels of uncertainty, and the lack of data from most of the range of Pacific halibut also increases the potential for bias in estimates of overall stock trends from 2023 to 2024.

This very limited spatial design will result in much less information available for the annual stock assessment and management supporting calculations such as stock distribution. The increased uncertainty in the index of abundance is likely to cause the assessment model to rely much more heavily on the commercial fishery catch-per-unit-effort index. Given current variability and uncertainty in the magnitude of younger year classes (2012 and younger), missing biological information in the core of the stock distribution (Biological Region 3) makes it unlikely that the stock assessment will detect a major change in year class abundance, either up or down. Although the basic stock assessment methods can remain unchanged, a much greater portion of the actual uncertainty in stock trend and demographics will not be able to be quantified due to missing FISS data from such a large fraction of the Pacific halibut stock's geographic range.

This is the first time the Secretariat has attempted to evaluate FISS projections at this time of the year; therefore, these projections should be considered highly preliminary. With the 2023 FISS data still incomplete it is not currently possible to understand how the decline in catch rates observed in 2023 will interact with the estimated age structure of the population potentially leading to a larger or smaller projected decline in landings based on the pending stock assessment results. Further, budget estimates are incomplete and will not be fully reconciled until the end of the fiscal year; adjustments to 2023 costs will translate to changes in projected costs for 2024. Finally, the 2023 FISS still has vessels fishing and pending fish sales which may further adjust the basis for 2024 projections when completed.

RECOMMENDATION

That the Scientific Review Board:

1) **NOTE** paper IPHC-2023-SRB023-09, which reviewed the 2024-26 FISS designs presented at SRB022 and presented an evaluation of design options for 2024 accounting the secondary FISS objective of long-term revenue neutrality;

References

IPHC 2022. Report of the 98th Session of the IPHC Interim Meeting (IM098) IPHC-2022-IM098-R. 30 p.

Webster, R. A. 2022. 2023-25 FISS design evaluation. IPHC-2022-SRB020-05.

Webster, R. A. 2023. 2024-26 FISS design evaluation. IPHC-2023-SRB022-06.

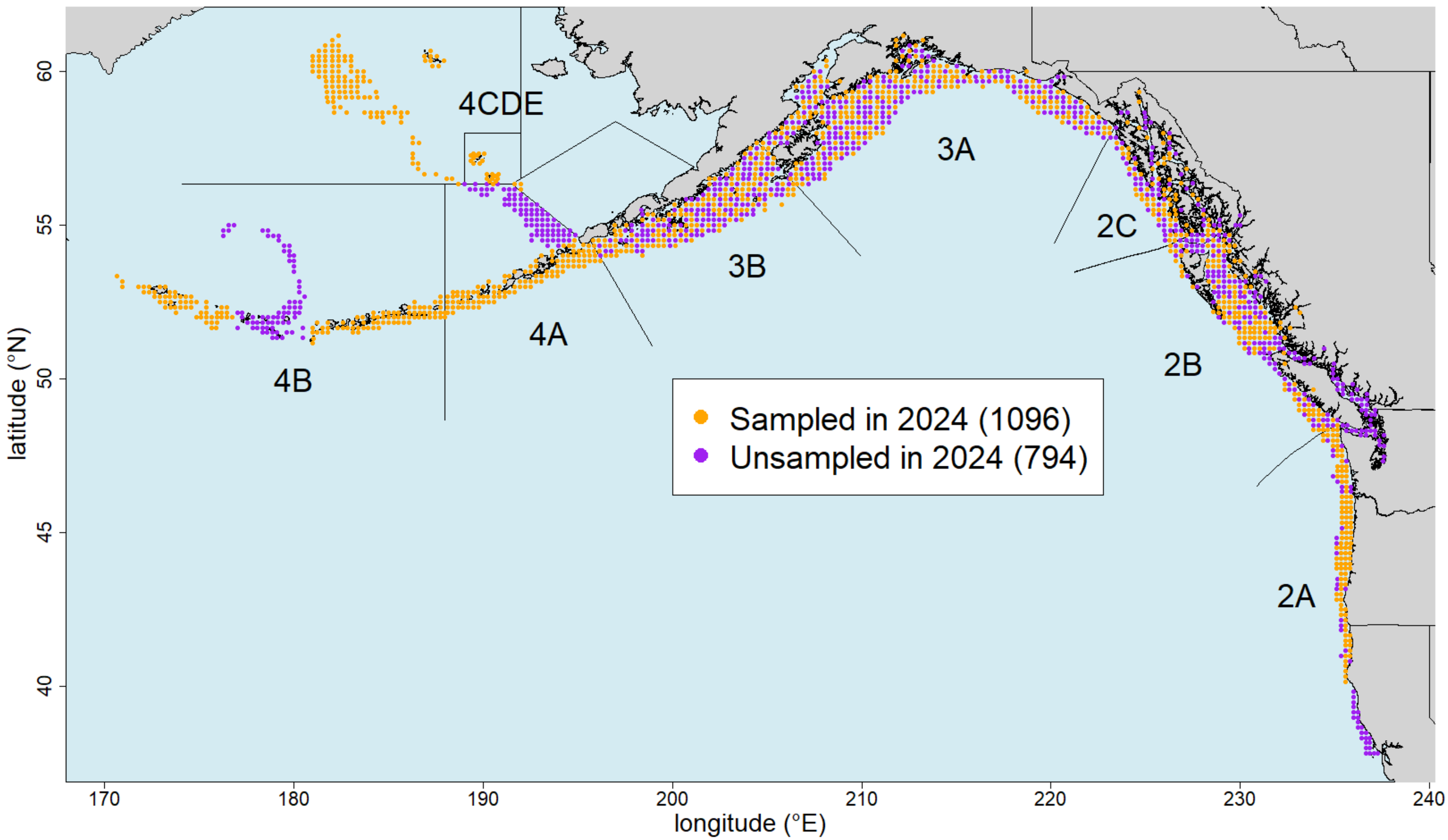

Figure 1.1. Potential FISS Design 1 in 2024 (orange circles) based on prioritization of the Primary Objective in Table 1.1. The design relies on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

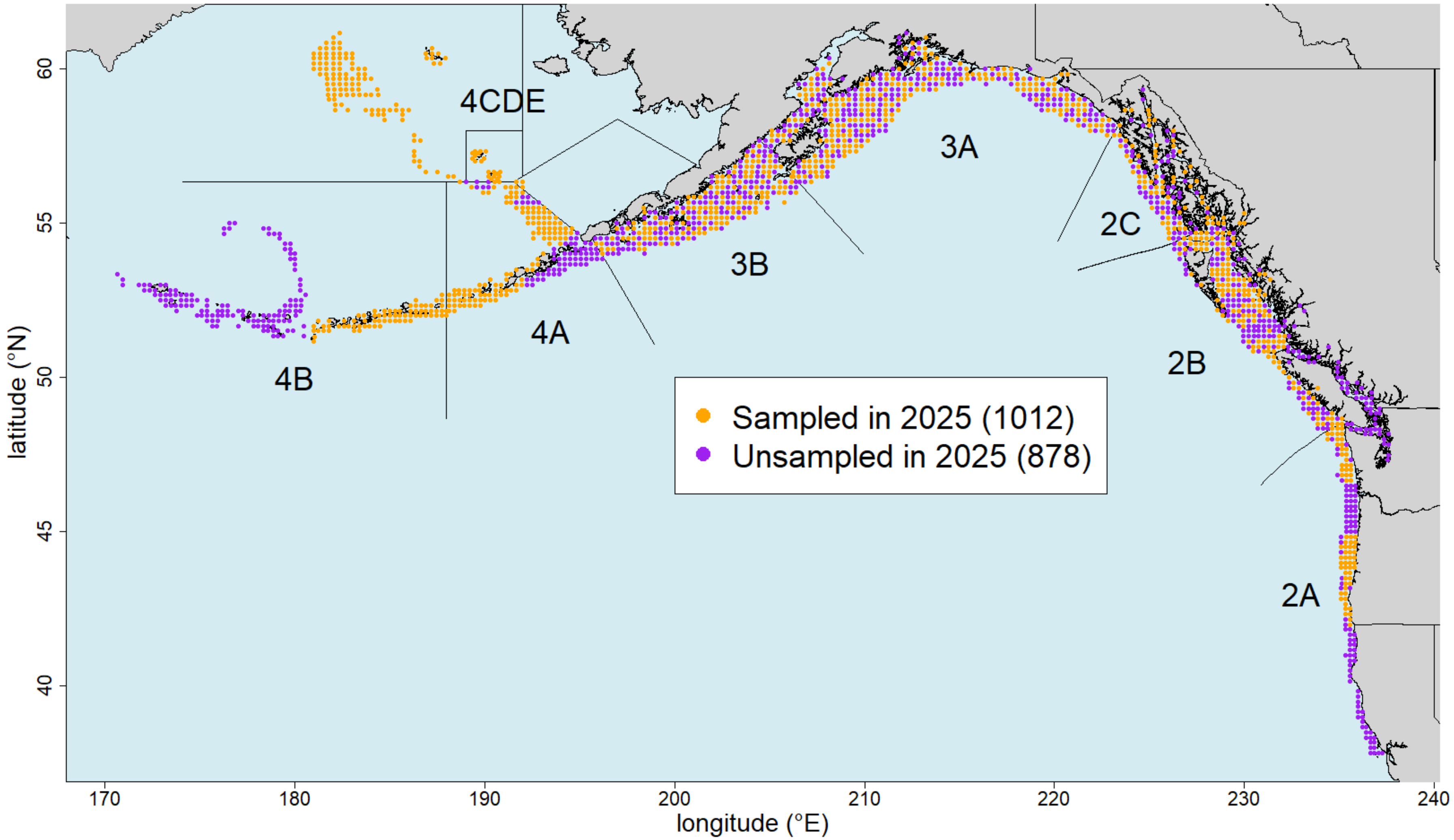

Figure 1.2. Potential FISS design in 2025 (orange circles) based on prioritization of the Primary Objective in Table 1.1. The design relies on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

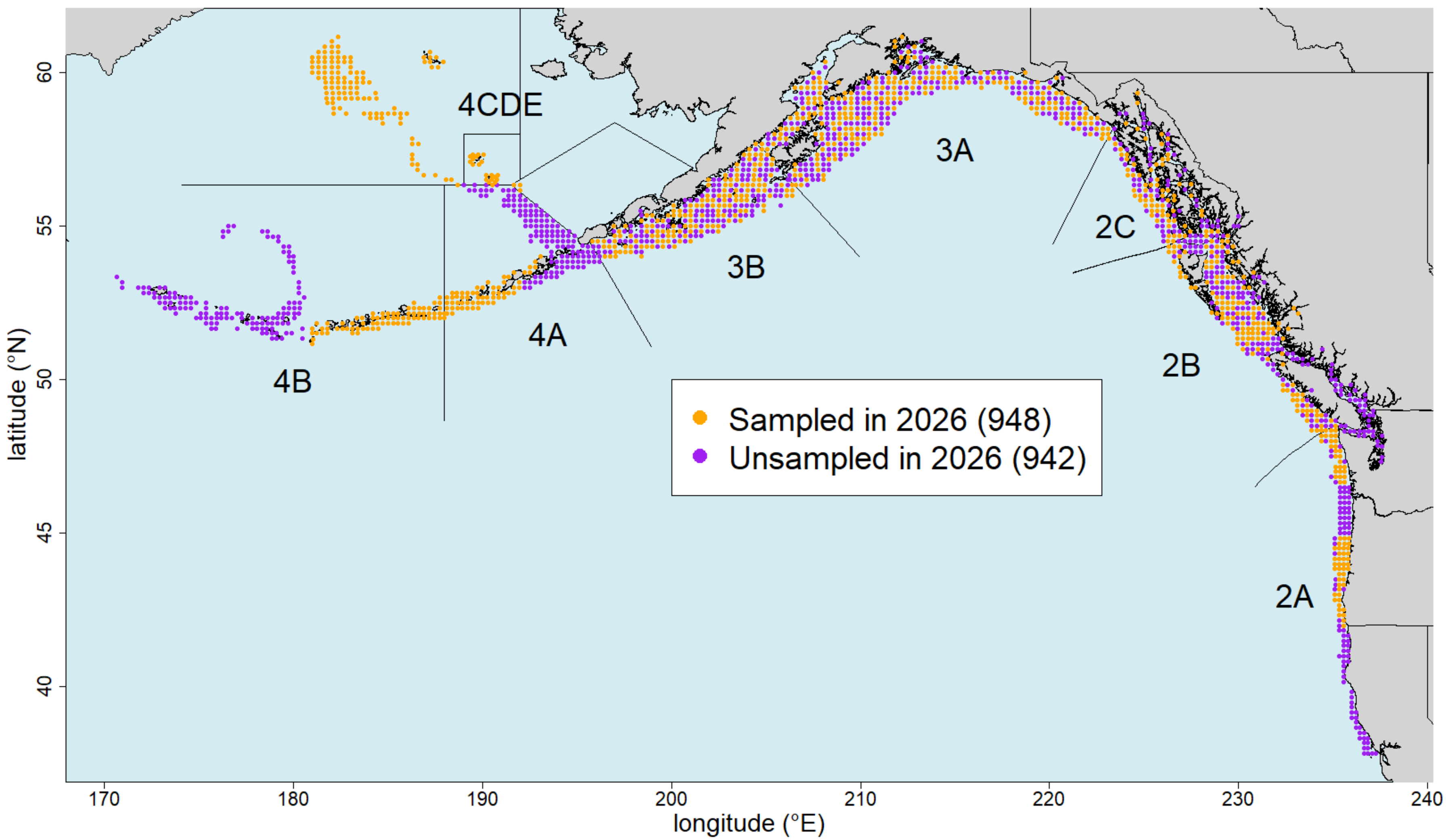

Figure 1.3. Potential FISS design in 2026 (orange circles) based on prioritization of the Primary Objective in Table 1.1. The design relies on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

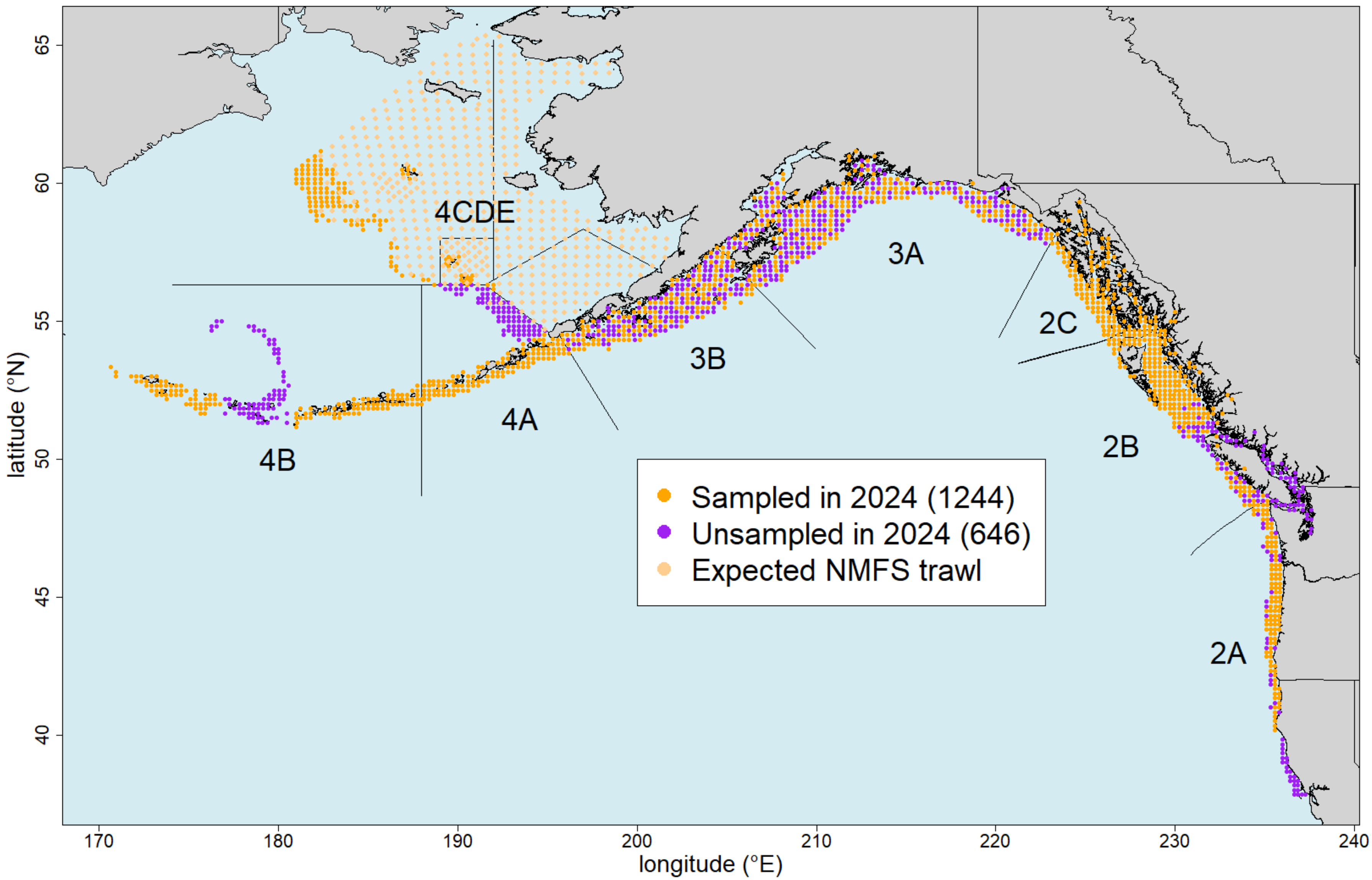

Figure 1.4. Potential FISS **Design 2** in 2024 (orange circles). See text and Table 1.2 for more information.

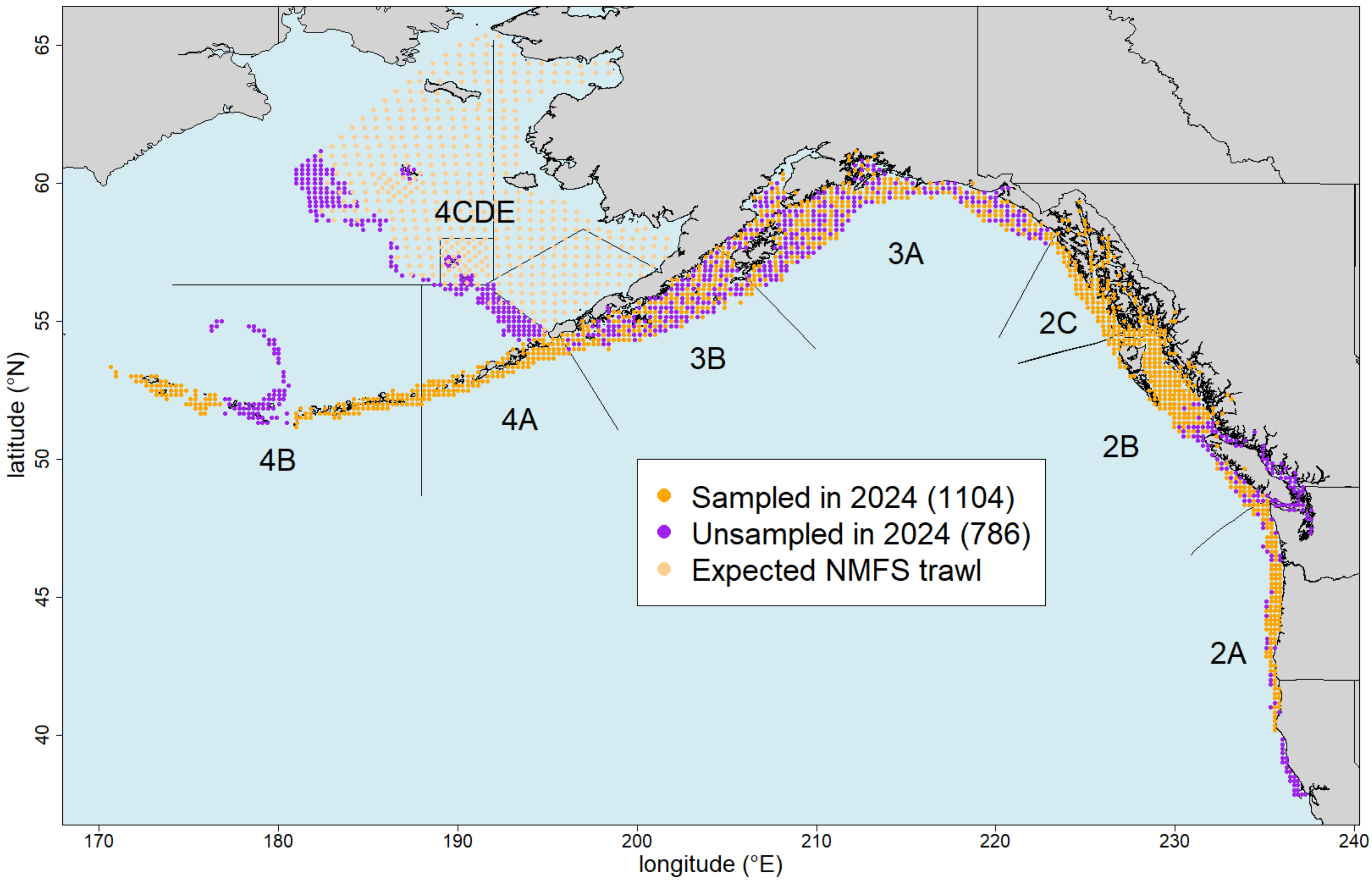

Figure 1.5. Potential FISS **Design 3** in 2024 (orange circles). See text and Table 1.2 for more information.

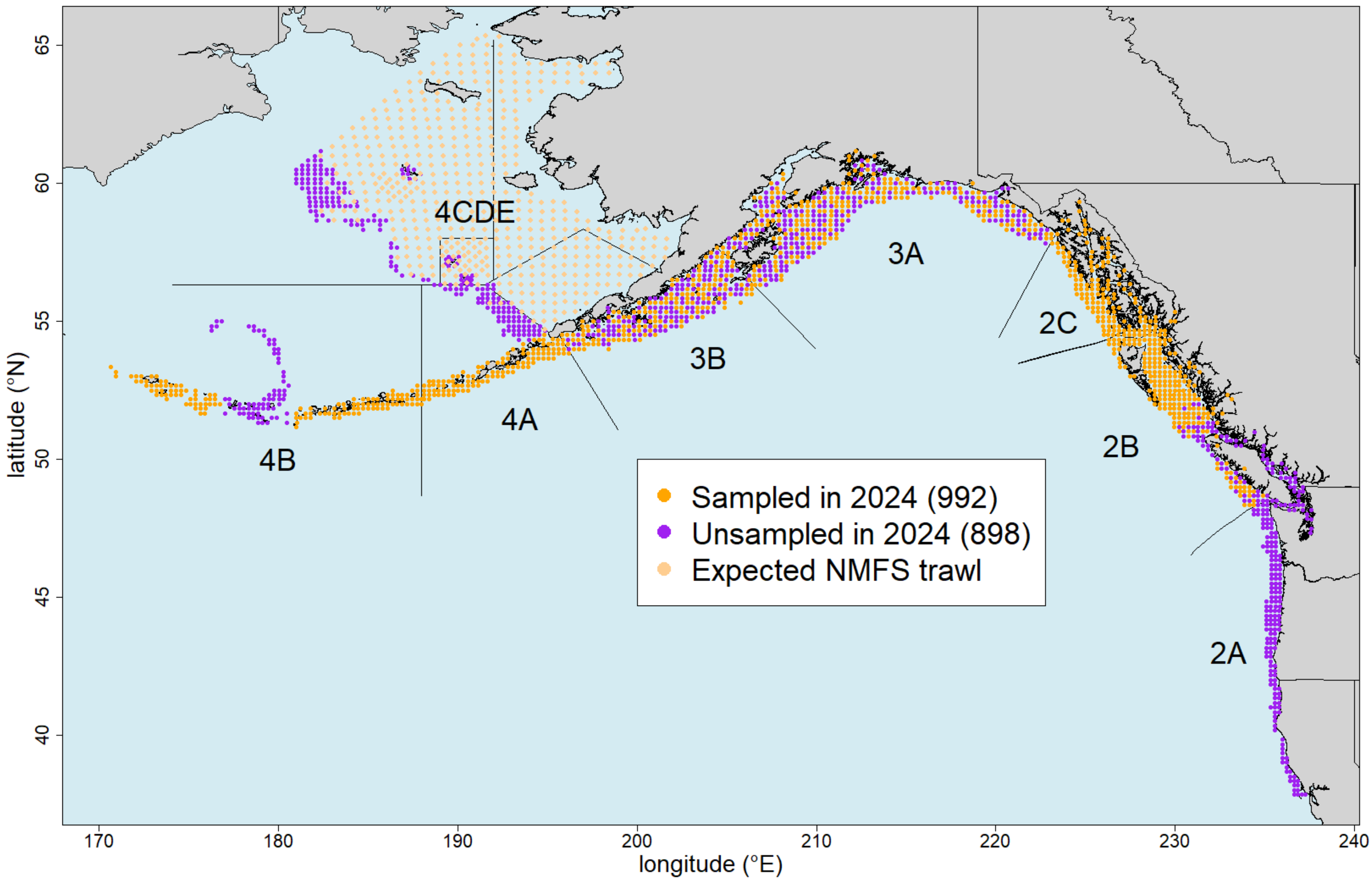

Figure 1.6. Potential FISS **Design 4** in 2024 (orange circles). See text and Table 1.2 for more information.

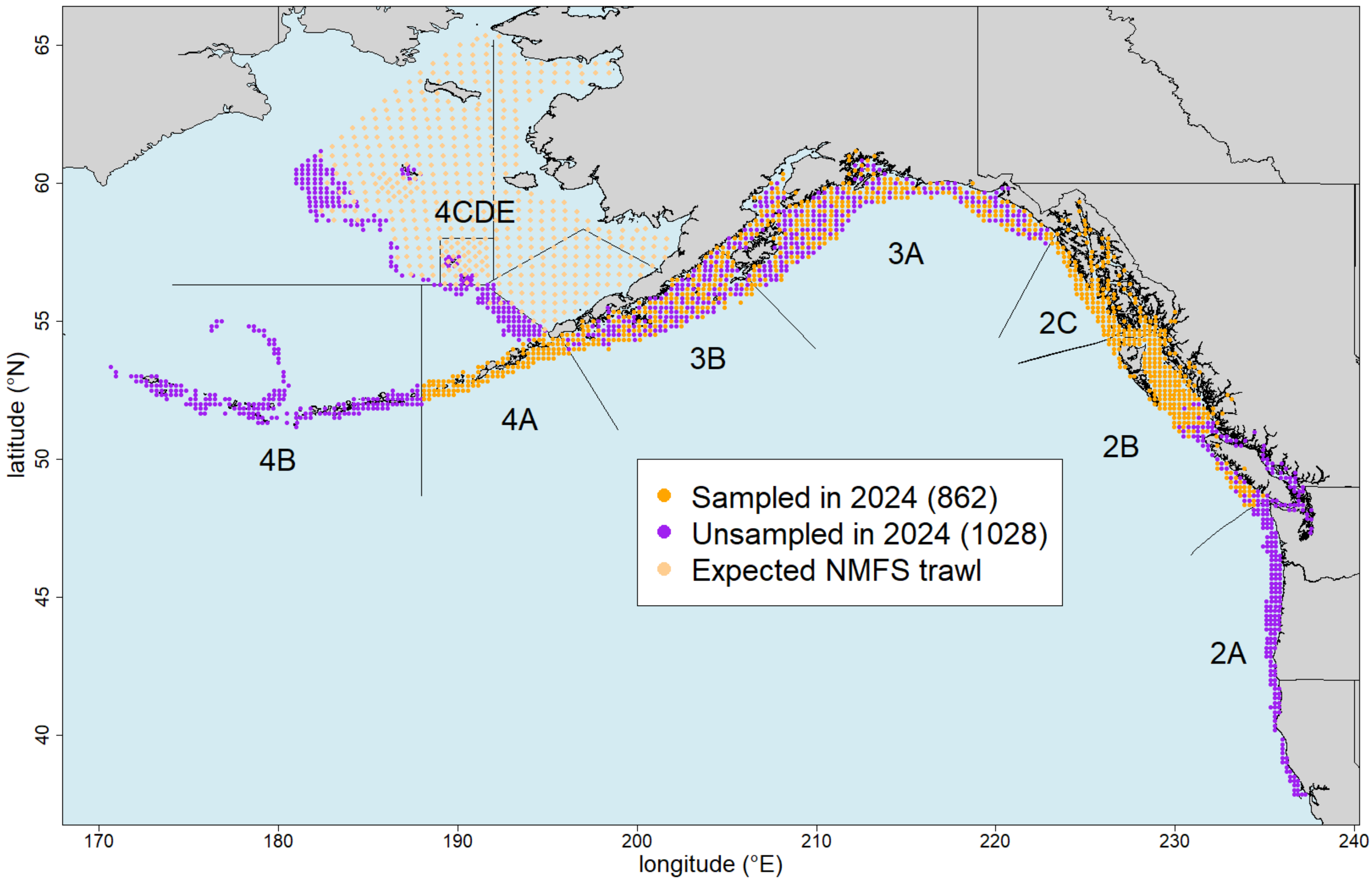

Figure 1.7. Potential FISS **Design 5** in 2024 (orange circles). See text and Table 1.2 for more information.

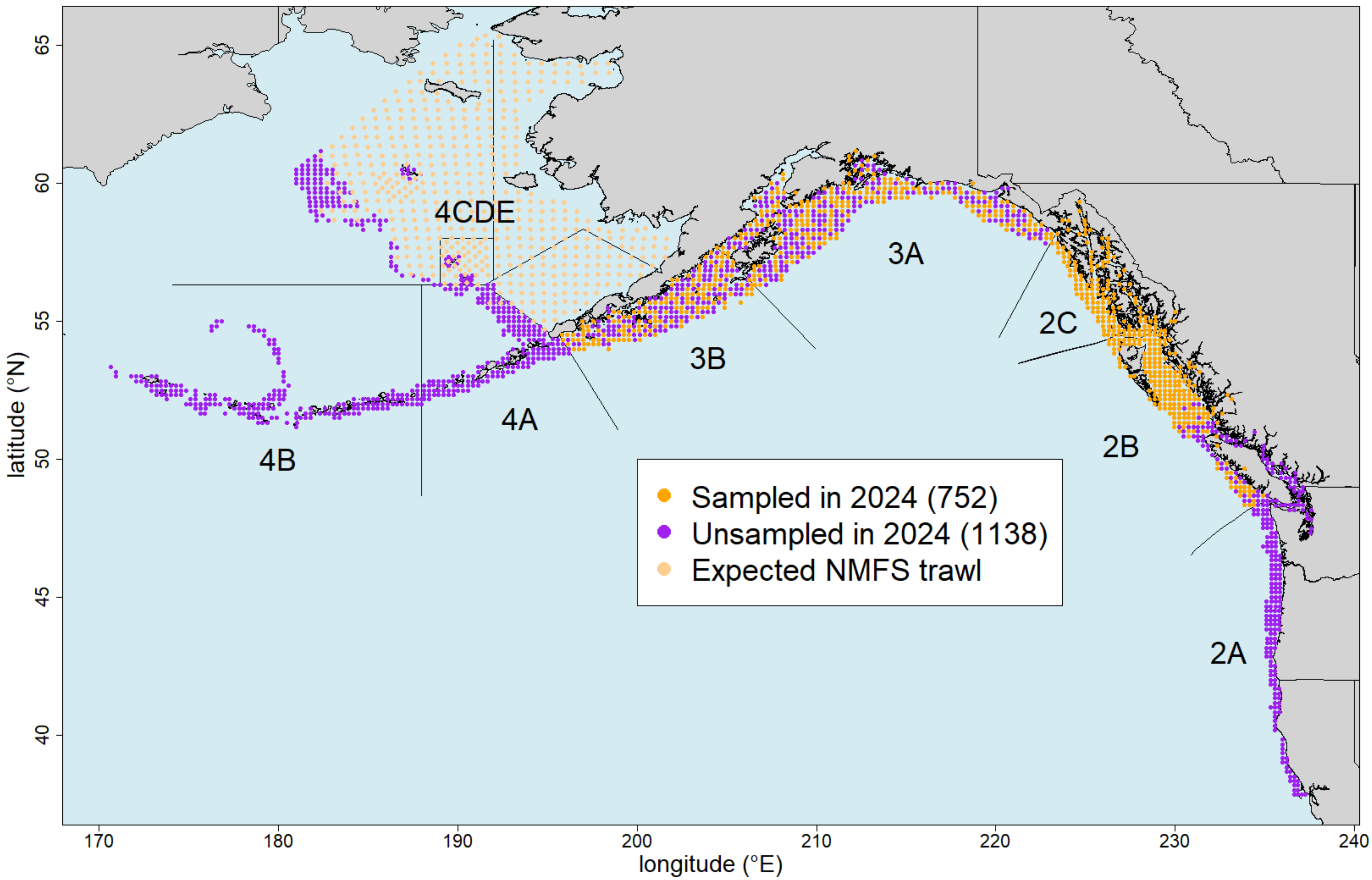

Figure 1.8. Potential FISS **Design 6** in 2024 (orange circles). See text and Table 1.2 for more information.

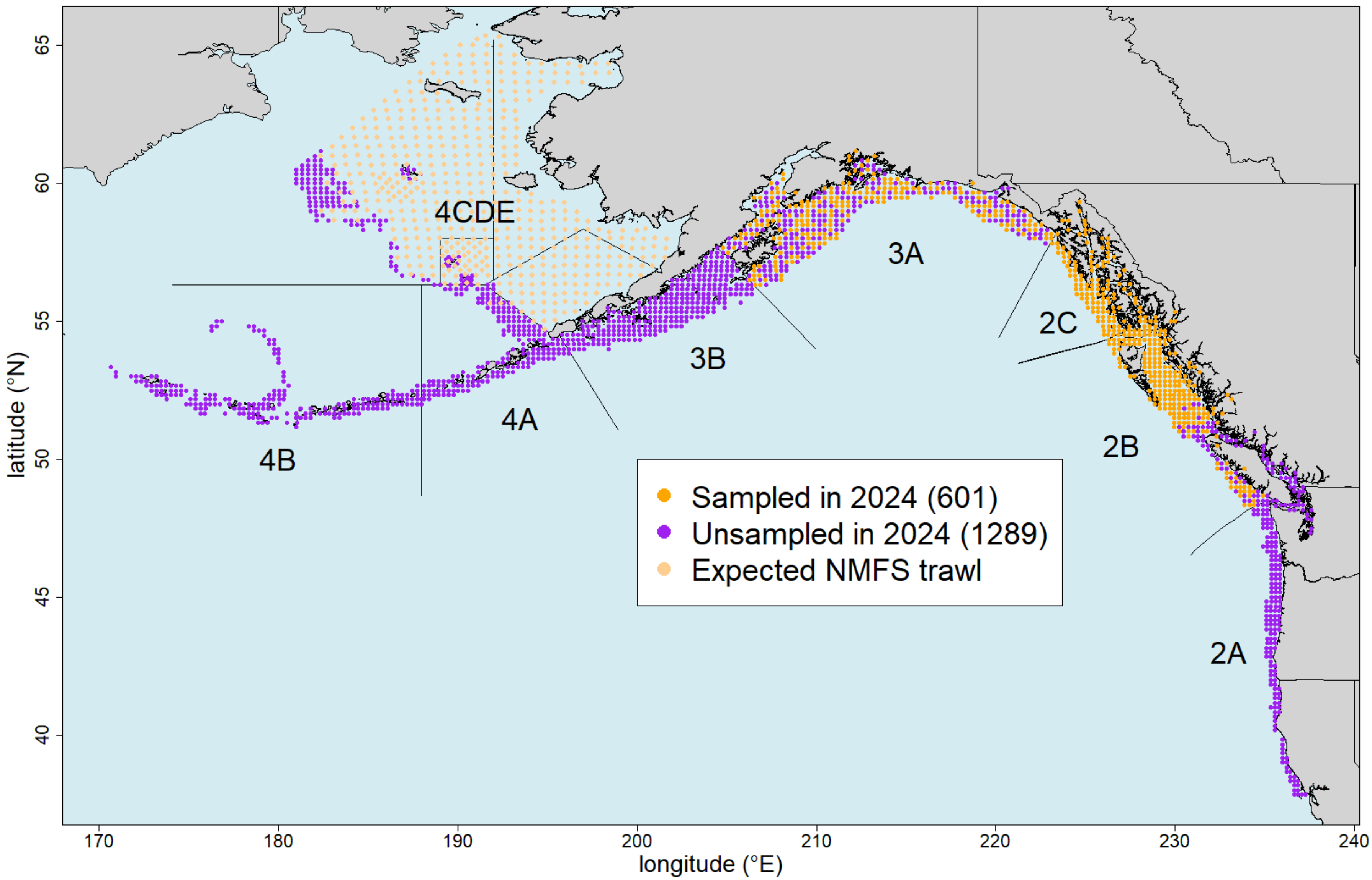

Figure 1.9. Potential FISS **Design 7** in 2024 (orange circles). See text and Table 1.2 for more information.

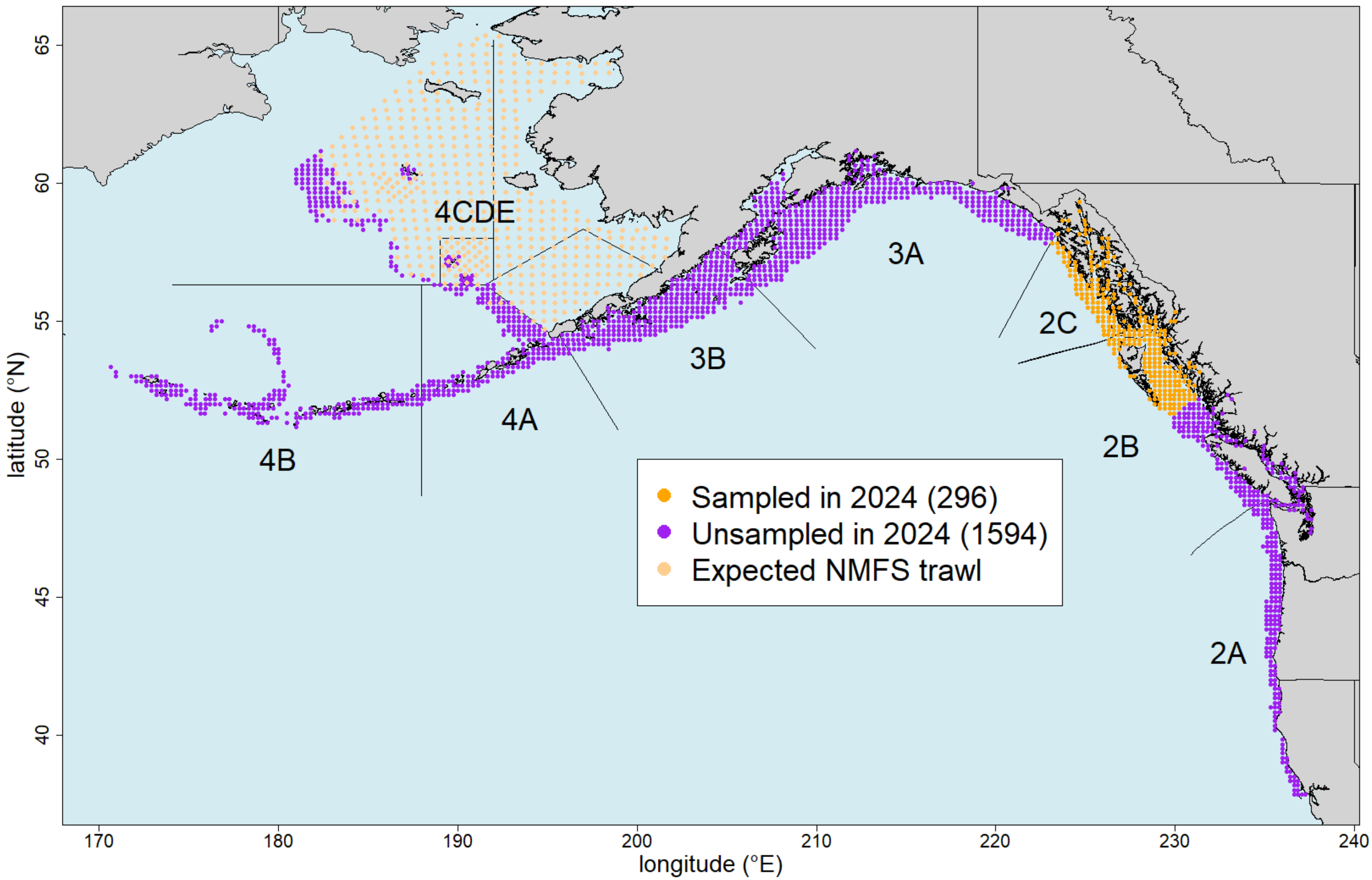

Figure 1.10. Potential FISS **Design 8** in 2024 (orange circles). See text and Table 1.2 for more information.

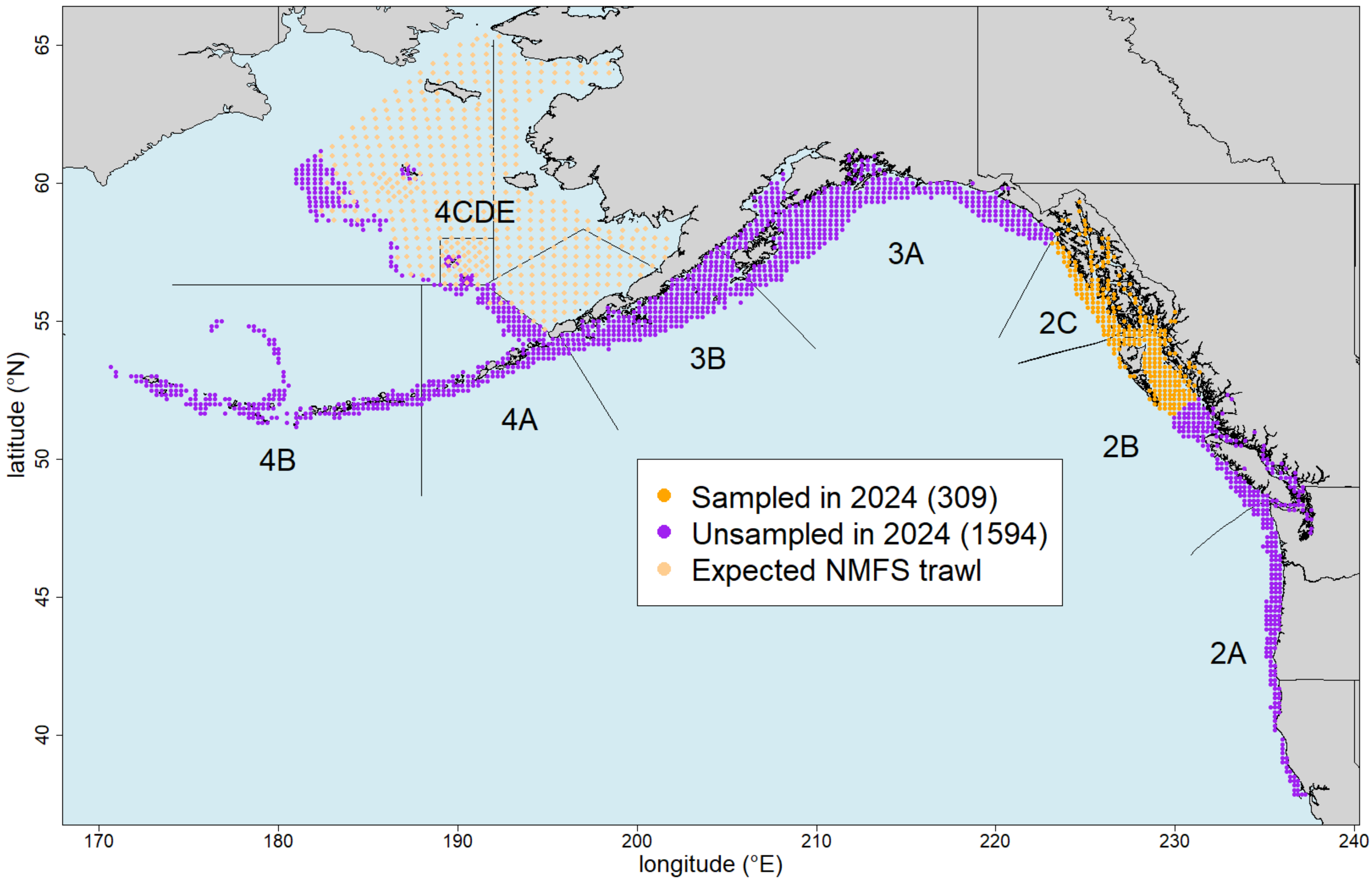

Figure 1.11. Preliminary FISS **Design 9** in 2024 (orange circles) based on prioritization of the Secondary Objective in [Table 1.1](#). An additional 13 revenue-positive stations are not shown on the map, while the location of proposed "skipper stations" are represented by stations on the standard grid. See text for more information.

Part 2: Modelling updates

PURPOSE

To present a potential revision to the space-time model for Pacific halibut survey data in response to an SRB request.

BACKGROUND/INTRODUCTION

At SRB021, the Scientific Review Board recommended that the Secretariat explore other parameterizations of the space-time model used for modelling Pacific halibut survey catch rates. From paragraph 20 in IPHC-2022-SRB021-R:

> *"**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."*

The 'hurdle' (or semi-parametric or delta) model structure is described in Webster et al. (2020), and involves specifying separate model components for the probability of a catch rate (weight or numbers per unit effort) of zero (a Bernoulli process) and for the non-zero observations (a gamma process). For this document, we refer to this as the "delta-gamma" model. While the two components share a common spatio-temporally correlated error structure, model covariates are generally included in both model components (zeros and non-zeros), increasing model complexity and likely leading to longer times for model fitting than simpler models.

The Tweedie model as implemented in R-INLA (the R package currently used for space-time modelling of FISS data) is a compound Poisson-gamma model (see https://inla.r-inla-download.org/r-inla.org/doc/likelihood/tweedie.pdf). The model has two hyperparameters, p and φ ("dispersion") compared to one hyperparameter for the delta-gamma model currently in use (the gamma variance or precision parameter) but as noted requires fewer covariate parameters. Both models have the same two parameters specifying spatial dependence and a single temporal correlation parameter. However, the current model has two hyperparameters for the random walk models of depth (one for each model component) and a scalar parameter linking the space-time model errors between the model components. Thus, the Tweedie model has one fewer hyperparameter, along with a reduction in the number of fixed effects parameters present in some models (e.g., distance from shelf edge in IPHC Regulatory Area 4CDE, gear effect in areas with recent snap/fixed gear comparisons).

We have fitted the Tweedie model to all-sizes WPUE data from several IPHC Regulatory Areas and compared model output in the form of posterior means and standard deviations of hyperparameters shared by both models, the deviance information criterion (DIC) as a measure of relative model fit, and the resulting model run time. Modelling of data from other IPHC Regulatory Areas is ongoing.

Results

Table 2.1 presents comparisons between the model output of the delta-gamma and Tweedie models for three IPHC Regulatory Areas. In all cases, the Tweedie models provides a better fit (lower DIC) and faster run time, while producing very similar estimates of parameters for temporal and spatial dependence.

Table 2.1. Comparison of DIC, model run time, and model parameter estimates (posterior means with standard deviations in parentheses) between the current delta-gamma model and the Tweedie model.

IPHC Regulatory Area	Parameter	Description	Delta-gamma	Tweedie	Difference
4A	DIC	Model fit	47 817.6	46 988.1	829.5
	Run time (s)		311	143	168
	ρ	Temporal correlation	0.952 (0.008)	0.950 (0.006)	
	θ_1	Spatial correlation	-6.84 (0.18)	-6.78 (0.11)	
	θ_2	Spatial correlation	5.07 (0.12)	5.41 (0.10)	
3B	DIC	Model fit	89 677.3	89 509.9	167.4
	Run time (s)		758	148	610
	ρ	Temporal correlation	0.928 (0.011)	0.933 (0.010)	
	θ_1	Spatial correlation	-6.17 (0.08)	-5.97 (0.07)	
	θ_2	Spatial correlation	4.82 (0.04)	4.88 (0.08)	
2C	DIC	Model fit	55 304.0	55 233.7	70.3
	Run time (s)		2145	223	1922
	ρ	Temporal correlation	0.963 (0.004)	0.962 (0.005)	
	θ_1	Spatial correlation	-8.97 (0.27)	-8.37 (0.36)	
	θ_2	Spatial correlation	6.69 (0.16)	6.78 (0.21)	

Figures 2.1, 2.2 and 2.3 compare the time series estimates for each area. The Tweedie time series for IPHC Regulatory Area 4A has more temporal variability but narrower 95% credible intervals than the delta-gamma time series (Figure 2.1). Time series for the other two areas are very similar between the two models.

Discussion

The initial results from fitting Tweedie models are very promising, with little to no effect on our understanding of trends or the strength of temporal or spatial dependence, but with much faster run times. It is worth noting that while delta-gamma models were fitted with good starting values (based on past model output) this wasn't the case with the Tweedie models. This implies we may expect further improvements in run times in the future. Not all Tweedie models converged with initial starting values: the model for IPHC Regulatory Area 2C had to be run twice after it failed to converge to a sensible solution the first time, and this appears to be an issue with the model for IPHC Regulatory Area 4B currently in progress. The model for IPHC Regulatory Area 3A is also in progress after crashing with an error regarding starting values. Similar issues arose the first year we used space-time modelling in 2016 and we expect them to be resolved without much difficulty. Work still needs to be done on creating the output MCMC values used for projection of coefficients of variation in FISS design evaluation, along with adapting the model to account for different probabilities of zeros between gear types (setline and trawl) in the Bering Sea (see IPHC-2022-SRB021-06, page 7).

While we looked at model run times for fitting the model, the greatest computing times occur when re-fitting the model for prediction and generating the posterior samples from the prediction model run. We will update the SRB with that information once it has been compiled. Our intention is to have a full coastwide comparison of the two models for the SRB to review at SRB024 based on the 1993-2023 data.

References

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Webster, R. A. 2022. 2023-25 FISS design evaluation. IPHC-2022-SRB021-06.

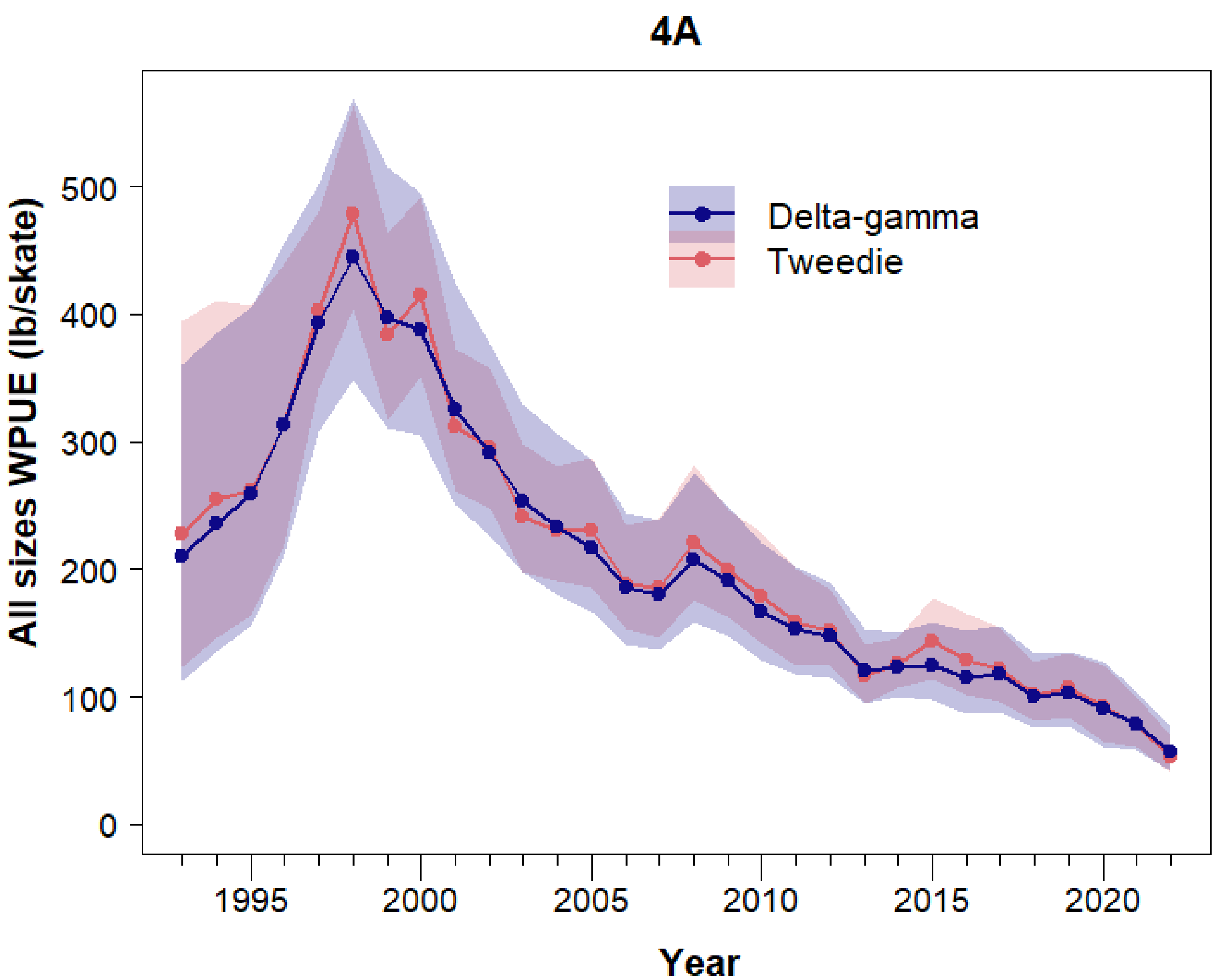

Figure 2.1. Comparison of estimated time series (posterior means by year) of all-sizes WPUE for the current delta-gamma model and the Tweedie model, for IPHC Regulatory Area 4A. Shaded regions represent 95% posterior credible intervals.

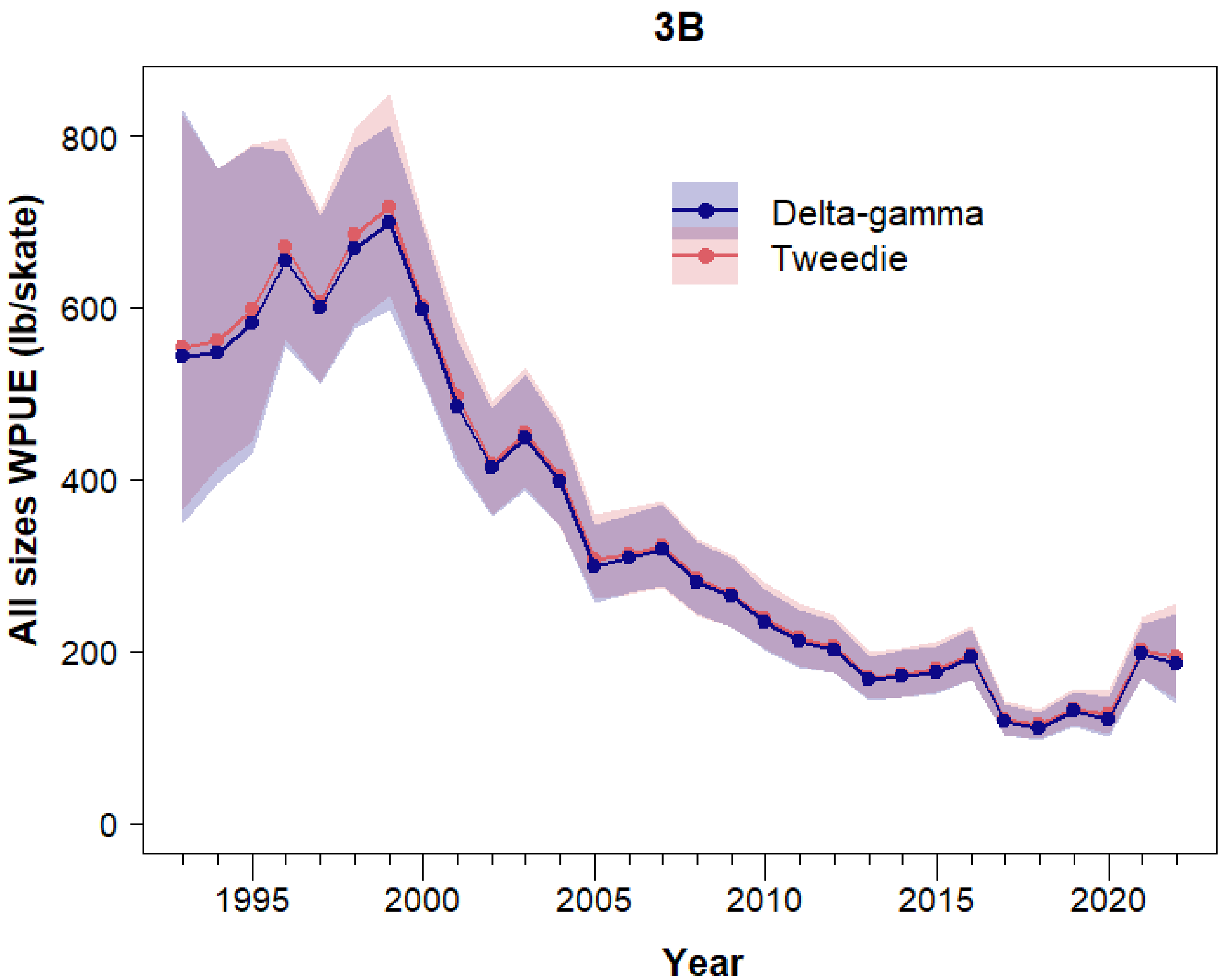

Figure 2.2. Comparison of estimated time series (posterior means by year) of all-sizes WPUE for the current delta-gamma model and the Tweedie model, for IPHC Regulatory Area 3B. Shaded regions represent 95% posterior credible intervals.

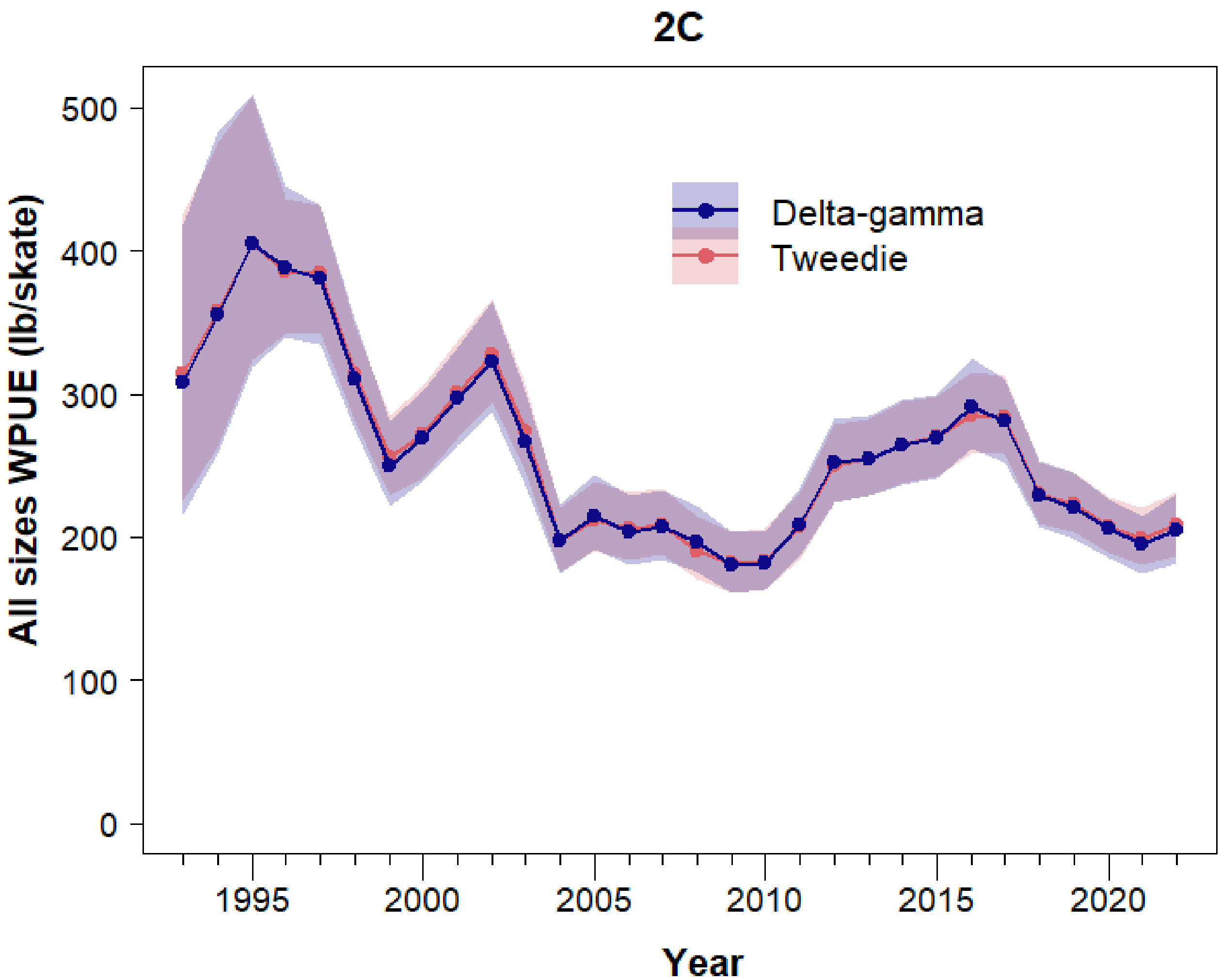

Figure 2.3. Comparison of estimated time series (posterior means by year) of all-sizes WPUE for the current delta-gamma model and the Tweedie model, for IPHC Regulatory Area 2C. Shaded regions represent 95% posterior credible intervals.

Biological Research Projects

Ongoing Research Projects

Research Project #	Project Title	Abstract	Objectives	Deliverables	Progress report	5YPRIM Research area	Management implications	Specific inputs into management	Period of Performance	PI	Funding source	Budget	Research prioritization for SA/MSE
1	Leveraging multiple genomic approaches to investigate population structure and dynamics of Pacific halibut	The Pacific halibut (Hippoglossus stenolepis) is a key flatfish species in the North Pacific Ocean ecosystem that supports important commercial, recreational and subsistence fisheries and that is managed as a single stock by the International Pacific Halibut Commission. The overarching goal of the present study is to advance our understanding of Pacific halibut population structure and dynamics in a changing climate through the use of genomic approaches to inform fishery management. In particular, we seek to improve our current understanding of stock structure among spawning groups of Pacific halibut in the northeast Pacific Ocean by conducting low coverage whole genome resequencing, a method that allows the characterization of genomic variation at the highest resolution possible and with which we will establish a baseline of Pacific halibut genetic diversity. Subsequently, we will leverage the obtained genomic data to identify markers that display high differentiation among the different genetic baseline datasets. The results from this study will inform on the delimitation of management units and provide preliminary information on stock composition in the Pacific halibut fishery, as well as provide a tool to monitor changes in distribution associated with climate change.	1. Investigate fine scale Pacific halibut population structure in the northeast Pacific Ocean using low coverage whole genome resequencing: characterization of neutral and adaptive variation at very high resolution among spawning groups leading to the identification of millions of genome-derived genetic markers. 2. Develop a high-throughput genetic marker panel consisting of a selection of genome-derived, high resolution markers	1.Establishment of a baseline of Pacific halibut genetic diversity. The genomic data produced will represent a detailed baseline of Pacific halibut genetic structure and diversity at neutral and adaptive markers over a large geographical scale (Gulf of Alaska, Aleutian Islands and Bering Sea) and over a broad temporal scale (last 30 years). 2.Delineation of fine-scale Pacific halibut stock structure. 3. Assignment of individuals to source populations and assessment of distribution changes.	IPHC-2023-SRB022-09/NPRB Interim Report July 2023/IPHC-2023-WM2023-12	Migration and Population Dynamics	1. Altered structure of future stock assessments. 2. Improve estimates of productivity	If IPHC Regulatory Area 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area. Research outcomes will be used to define management targets for minimum spawning biomass by Biological Region.	12/01/2021-1/31/2024	Josep Planas	External (North Pacific Research Board; Project No. 2110)	$193,685	Priority Rank #2
2	Mapping of Pacific halibut juvenile habitat	The IPHC Secretariat recently completed a study to investigate the 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, following the pelagic larval phase, begin their demersal stage as roughly 6-month-old juveniles, settling 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. In order to fill this knowledge gap, the IPHC Secretariat has initiated studies to identify potential settlement areas for juvenile Pacific halibut throughout IPHC Convention Waters.	1. Collect data sources on juvenile Pacific halibut presence. 2. Create a map of suitable settlement habitat by combining available bathymetry information (e.g. benthic sediment composition and shoreline morphological data) and information on recorded presence of age-0, age-1 and age-2 Pacific halibut juveniles as well as absence of young Pacific halibut noted by various nursery habitat projects focused on other flatfish species.	Map of juvenile Pacific halibut habitat.	IPHC-2023-SRB022-09/IPHC-2023-WM2023-12	Migration and Population Dynamics	Improve estimates of productivity	Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	1/1/2023-12/31/2025	Josep Planas	Internal	$0	Priority Rank #2
3	Female reproductive assessment	In fisheries, understanding the reproductive biology of a species is important for estimating the reproductive potential and spawning biomass of the stock and, consequently, for optimizing management of the species. Recent sensitivity analyses have shown the importance of changes in spawning output in female Pacific halibut due to changes in maturity schedules, in fecundity estimations and/or in skip spawning for stock assessment (Stewart and Hicks, 2020). These results highlight the need for a better understanding of factors influencing reproductive biology and spawning success in Pacific halibut. In order to fill existing knowledge gaps related to the reproductive biology of female Pacific halibut, research efforts are being conducted to characterize female reproductive capacity in this species. Improved knowledge on key aspects of the reproductive physiology of Pacific halibut (e.g., maturity schedules, fecundity, etc.) will provide an updated and more comprehensive description of reproductive capacity and success in this important species.	1.Produce an accurate description of oocyte developmental stages in female Pacific halibut that can be used to classify female maturity stages. 2.Describe changes in female and male maturity stages throughout an entire annual reproductive cycle based on histological assessment and physiological parameters that will be used to revise current estimates of female and male age-at-maturity. 3.Compare macroscopic (based on field observations) and microscopic (based on histological assessment) female and male maturity stages and revise maturity criteria used in FISS. 4.Update maturity schedules based on histological classification of female maturity. 5. Conduct investigations on fecundity and on the incidence of skip-spawning in female Pacific halibut. 6.Conduct investigations on possible temporal and spatial changes in reproductive performance (maturity, fecundity, skip-spawning) in female Pacific halibut.	1. Updated maturity schedule coastwide. 2. Fecundity-at-age and -size estimates. 3. Revised field maturity classification. 4. Information on skip-spawning.	IPHC-2023-SRB022-09/IPHC-2023-WM2023-12	Reproduction	Scale biomass and reference point estimates. Improve simulation of spawning biomass in the Operating Model.	Research outcomes will be included in the stock assessment, replacing the current maturity schedule last updated in 2006. Research outcomes 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. Research outcomes 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. Research outcomes will result in revised time-series of historical (and future) maturity for input to the stock assessment.	1/1/2017-12/31/2026	Josep Planas	Internal	$51,834 (FY2024)	Priority Rank #1
4	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries	In the north Pacific, both Killer (Orcinus orca) and Sperm (Physeter macrocephalus) whales are involved in depredation behavior in Pacific halibut (Hippoglossus stenolepis). In 2011 and 2012 fisheries observers estimated that 6.9% of Pacific halibut sets were affected by whale depredation in the Bering Sea. Reductions in catch per unit effort (CPUE) when whales were present ranged across geographic regions from 5 15-57% for Pacific halibut. These impacts also incur significant time, fuel, and personnel costs to fishing operations. From a fisheries management perspective, depredation creates an additional and highly uncertain source of mortality, loss of data (e.g. compromised survey activity), and reduces fishery efficiency. Stock assessments of both Pacific halibut (Stewart et al. 2020) and sablefish (Goethel et al. 2020) have adjusted their analysis of fishery independent data to account for the effects of whale depredation on catch rates. In the sablefish assessment, fishery limits are also adjusted downward to reflect expected depredation during the commercial fishery. Meanwhile, potential risks to the whales include physical injury due to being near vessels and gear, disruption of social structure , and developing an artificial reliance on food items that can be affected by fishery dynamics. Many efforts have been made over the years to mitigate this problem, with fishers generally limited to simple methods that can be constructed, deployed, or enacted without significantly disrupting normal fishing operations, or without violating gear regulations. Existing approaches include catch protection, physical and auditory deterrents, and spatial or temporal avoidance. These approaches have had variable degrees of success and ease of adoption in each fishery but none have provided a long-term solution. There are increasing data sources supporting the notion that technologies which reduce initial contact between gear and depredators will reduce the likelihood of foraging attempts around the gear, thereby sustaining levels of target catch while simultaneously reducing risk of depredator mortality and gear damage. Recent studies using physical catch protection methods include the development of underwater shuttles that unhook, and transport catch to the surface (Patagonian toothfish), light and expandable 'slinky' pots (sablefish), and flashers or mesh panels attached to the gear to obscure catch (tuna) (IPHC 2022). While slinky pots had quick uptake in the sablefish longline fishery, depredation occurring with this gear has been reported (Goethel et al. 2022), demonstrating the urgency of ongoing challenges to interrupting the	1. Identify potential methods for protecting hook captured fish from whale depredation. 2. Develop and field-test several simple low-cost catch-protection designs that can be deployed effectively using current longline fishing techniques.	1. Cost effective prospective terminal gear modifications designed to protect longline catch from whale depredation. 2. Demonstration of the functionality of these proof-of-concept catch protection devices in field tests and provide direction for further modifications and larger scale experimental testing.	IPHC-2023-SRB022-09/IPHC-2023-WM2023-12/BREP Interim Report May 2023	Fishing technology	Improve mortality accounting. Improve estimates of stock productivity.	Research outcomes 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.	11/1/2021-10/30/2023	Claude Dykstra/Ian Stewart	External (Bycatch Reduction Engineering Program - NOAA; Project NA21NMF4720534)	$99,700	Priority Rank #3

Proposed Research Projects

Research Project #	Project Title	Abstract	Objectives	Deliverables	Progress report	5YPRIM Research area	Management implications	Specific inputs into management	Requested period of performance	PI	Targeted funding source	Requested budget	Research prioritization for SA/MSE
1	Genomic analyses of Pacific halibut in Washington State waters to inform population structure and dynamics affecting coastal communities	Current studies at the IPHC, with funding from a grant from the North Pacific Research Board (Project #2110; 2022-2024), are devoted to the application of genome-based approaches (i.e. low coverage whole genome resequencing, lcWGR) to investigate stock structure among known spawning groups of Pacific halibut in the Gulf of Alaska (as far South as Haida Gwaii), Bering Sea and Aleutian Islands. By leveraging the recently sequenced and annotated reference Pacific halibut genome (Jasonowicz et al., 2022; GCF_022539355.2), the IPHC has conducted lcWGR for a total of 600 individual samples from the above-mentioned spawning groups at a coverage of 3X. This effort has so far resulted in the identification of 11.5 million autosomal single nucleotide polymorphisms (SNPs), of which 4 million SNPs have a minor allele frequency higher than 0.05. Considerable progress is currently being made towards using genome approaches to establish a genetic baseline for the available spawning groups, and towards the development of genomic tools aimed at addressing important ecological, environmental, and management-related issues with respect to Pacific halibut in the Gulf of Alaska, Bering Sea and Aleutian Islands. However, the lack of genetic samples from spawning groups off the WA coast limits the application of the above-mentioned genomic tools to advance our understanding of population structure, movement, connectivity, adaptive characteristics, and environmental responses of Pacific halibut in Convention waters. Although no major spawning ground has been mapped south of Cape St. James in the southern tip of Haida Gwaii (St. Pierre, 1984), archeological records along with traditional and ecological knowledge from Indian Tribes (e.g., Makah tribe, etc.) that fished Pacific halibut in the winter off the WA coast indicate that Pacific halibut, at least historically, spawned in what is now IPHC Regulatory Area 2A (Salmen-Hartley, 2018). Additionally, contemporary reports of spawning Pacific halibut south of Cape Flattery and the existence of suitable spawning habitat for Pacific halibut (i.e., deep areas off the continental slope, 200-600 m) are strongly indicative of the presence of spawning grounds for Pacific halibut off the WA coast. Therefore, the identification of potential winter spawning groups of Pacific halibut in WA waters and their biological (i.e., genetic and reproductive) characterization are important for addressing key issues related to Pacific halibut that impact coastal communities within Convention Waters. The overarching goal of this proposal is to characterize the genetic	1. To identify winter spawning groups of Pacific halibut off the WA coast with the use of traditional and ecological knowledge and collect biological samples. 2. To characterize the reproductive condition of female and male Pacific halibut off the WA coast during the winter spawning season. 3. To generate and incorporate genomic data from winter spawning groups off the WA coast to existing data from winter spawning groups in other geographic areas in the northeastern Pacific Ocean to establish an expanded baseline of Pacific halibut genetic diversity.	1. Information on Pacific halibut spawning groups off the WA coast: location information, spawning time and collection of biological (genetic and reproductive) samples. 2. Extended baseline of Pacific halibut genetic diversity and delineation of fine-scale Pacific halibut stock structure in WA waters and coastwide.	N/A	Migration and Population Dynamics	Altered structure of future stock assessments. Improved estimates of productivity coastwide.	Information of stock structure of the Pacific halibut population in Convention waters will inform management actions by validating management units. Research outcomes will be used to define management targets for minimum spawning biomass by Biological Region.	02/01/2024-1/31/2026	Josep Planas	External (Washington Sea Grant). Full proposal submitted in May 2023. Decision expected September 2023.	$288,652	Priority Rank #2
2	Full scale testing of devices to minimize whale depredation in longline fisheries	In the north Pacific, both Killer (Orcinus orca) and Sperm (Physeter macrocephalus) whales are involved in depredation behavior in Pacific halibut (Hippoglossus stenolepis). In 2011 and 2012 fisheries observers estimated that 6.9% of Pacific halibut sets were affected by whale depredation in the Bering Sea (Peterson et al. 2014). Reductions in catch per unit effort (CPUE) when whales were present ranged across geographic regions from 5 15-57% for Pacific halibut (Peterson et al. 2014). These impacts also incur significant time, fuel, and personnel costs to fishing operations. From a fisheries management perspective, depredation creates an additional and highly uncertain source of mortality, loss of data (e.g. compromised survey activity), and reduces fishery efficiency. Stock assessments of both Pacific halibut (Stewart et al. 2020) and sablefish (Goethel et al. 2020) have adjusted their analysis of fishery independent data to account for the effects of whale depredation on catch rates. In the sablefish assessment, fishery limits are also adjusted downward to reflect expected depredation during the commercial fishery. Meanwhile, potential risks to the whales include physical injury due to being near vessels and gear, disruption of social structure (e.g., Chilvers and Corkeron 2001), and developing an artificial reliance on food items that can be affected by fishery dynamics. Many efforts have been made over the years to mitigate this problem, with fishers generally limited to simple methods that can be constructed, deployed, or enacted without significantly disrupting normal fishing operations, or without violating gear regulations. Existing approaches include catch protection, physical and auditory deterrents, and spatial or temporal avoidance. These approaches have had variable degrees of success and ease of adoption in each fishery (Werner et al. 2015) but none have provided a long-term solution. There are increasing data sources supporting the notion that technologies which reduce initial contact between gear and depredators will reduce the likelihood of foraging attempts around the gear, thereby sustaining levels of target catch while simultaneously reducing risk of depredator mortality and gear damage. Recent studies using physical catch protection methods include the development of underwater shuttles that unhook, and transport catch to the surface (Patagonian toothfish), light and expandable 'slinky' pots (sablefish), and flashers or mesh panels attached to the gear to obscure catch (tuna) (IPHC 2022). While slinky pots had quick uptake in the sablefish longline	1. Assess the performance of catch protection devices to effectively reduce depredation of longline captured fish in the presence of toothed whales. 2. Assess the performance metrics of catch protection devices on the size, number, and condition of fish successfully entrained in the devices	1. Further define and develop previously identified high priority work that can break the reward cycle of depredation behavior and thereby suppress its prevalence. 2. Build on strategies to protect already captured fish in cost effective manners that are compatible with currently employed hook and line fishing practices in the North Pacific halibut fishery.	N/A	Fishing technology	Improved accuracy of mortality estimates. Improve estimates of productivity	Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	11/1/2023-04/30/2025	Claude Dykstra/Ian Stewart	External (Bycatch Reduction Engineering Program -NOAA). Full proposal submitted in March 2023. Decision expected August 2023.	$199,870	Priority Rank #3
3	Development of a non-lethal genetic-based method for aging Pacific halibut	Robust methods to estimate the ages of commercially exploited fish species are critical for stock assessment. Furthermore, when combined with data on other biological characteristics; such as length/weight, maturity, movement, and distribution; the age distribution or age structure of a fish population provides essential information on population dynamics related to age, predicted reproductive status, life history stage, etc. For Pacific halibut; an ecologically, economically and culturally important fish species in Alaska; age estimations are critical to our understanding of the composition of the stock for sustainable management, of historical changes in size-at-age, maturity-at-age, year class strength, mortality, etc., as well as of the response of the Pacific halibut stock to current and future climate variability. For many managed groundfish species, such as Pacific halibut, age has been traditionally estimated by manually counting the number of annuli or concentric lamellae present in sagittal otoliths (i.e. calcified structures located in the head that are used for balance and hearing) under a compound microscope. The International Pacific Halibut Commission (IPHC) has used sagittal otoliths for aging Pacific halibut since 1914, employing a method referred to as "surface aging" until 2002 and switching to a methodological variation known as "break-and-burn" thereafter (Forsberg, 2001). However, for various reasons, alternative methods to traditional otolith age estimations are being explored, developed and applied in fisheries. One of these is a genetic method for aging based on the known observation that the methylation patterns on genomic DNA change predictably with age. DNA methylation (DNAm) is an epigenetic modification of the DNA that consists in the covalent modification of cytosine, one of the four nucleobases found in DNA, and that regulates the expression of genes. Therefore, age-associated DNA methylation patterns can be modelled to generate molecular (i.e., epigenetic) age predictors capable of estimating chronological age with high accuracy. These are referred to as "epigenetic clocks" and can be developed from DNA isolated from any tissue, including non-lethal biological samples, such as a fin clip. Epigenetic clocks have been developed for many vertebrate species, including fish, with high accuracy (r between 0.84 and 0.99) and an average MAE of 0.87 years, that corresponds to 3.5% of the total lifespan of the species examined. Since DNA sequencing for measuring methylation levels is becoming cost effective and is a high throughput technique with little or no inherent human error or bias	1. To identify DNA methylation signals in Pacific halibut fin tissue. 2. To develop an age prediction model based on DNA methylation values: an epigenetic clock for Pacific halibut. 3. To develop a targeted DNA methylation assay for larger scale age estimations.	1. Reduced representation genome-wide map of DNA methylation at single base-pair resolution for Pacific halibut fin tissue. 2. Age predicting model for Pacific halibut using fin tissue.	N/A	Migration and Population Dynamics/Female Reproductive Assessment/Growth	Age is a critical input for stock assessment.	Age is a key biological input into stock assessment as it is used for estimating fish growth, fish mortality and fecundity-at-age, and mortality rates as well as population structure. Age distribution of Pacific halibut captured in the different fisheries and surveys is used in stock assessment.	02/01/2024-1/31/2026	Josep Planas	External (Alaska Sea Grant). Full proposal submitted in May 2023. Decision expected September 2023.	$60,374	Priority Rank #1