# Report on Current and Future Biological and Ecosystem Science Research Activities

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***Outcome sought:*** *NOTE the report; provide guidance on research priorities.*

## PURPOSE

To provide the Commission with a description of progress towards research activities described in the current IPHC Integrated Research and Monitoring Plan.

## BACKGROUND

The primary biological and ecological research activities at the IPHC that follow Commission objectives are identified and described in the current IPHC Integrated Research and Monitoring Plan. 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 is provided.

## UPDATE ON PROGRESS ON THE MAIN RESEARCH ACTIVITIES

1. Migration and Population Dynamics.

   The IPHC Secretariat is currently focusing on 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 the 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 the 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. Population genomics. The primary objective of these studies is to investigate the genetic structure of the Pacific halibut population and to conduct genetic analyses to inform Pacific halibut population dynamics and distribution within Convention Waters.

1.1.1. Population genetic structure. Understanding population structure is imperative for sound management and conservation of natural resources. Pacific halibut in US and Canadian waters are managed as a single, panmictic population based on tagging studies and historical (pre-2010) analyses of genetic population structure that failed to demonstrate significant differentiation in the eastern Pacific Ocean. While genetic techniques previously employed in fisheries management have generally used a small number of markers (e.g. microsatellites, ~10-100), whole-genome scale approaches can now be conducted at lower cost and are able to provide orders of magnitude more data (millions of markers) that allow investigation of genetic variation in fish populations at an unprecedented resolution.

The main purpose of the present study was to conduct an analysis of Pacific halibut population structure in IPHC Convention Waters using state-of-the-art low-coverage whole-genome resequencing (lcWGR) methods. The final collection of genetic samples representing the complete baseline dataset to finalize our population genomic studies consisted of 731 separate individuals (Figure 1, Table 1).

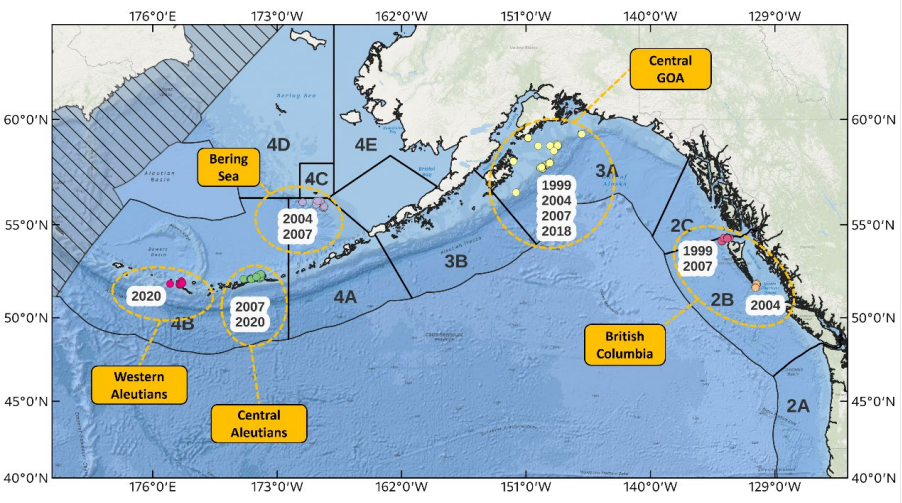



**Figure 1**. Map of sample collections made during the spawning season used for genomic analysis of population structure in Pacific halibut in the northeast Pacific Ocean.

| | Winter Collections (baseline samples) | | | | |
|---|---|---|---|---|---|
| | 1999 | 2004 | 2007 | 2018 | 2020 |
| British Columbia (winter) | 59 | 63 | 61 | | |
| GOA (winter) | 61 | 61 | 61 | 60 | |
| Bering Sea (winter) | | 61 | 61 | | |
| Central AI (winter) | | | 61 | | 61 |
| Western AI (winter) | | | | | 61 |

**Table 1.** Final sample sizes for each area in the baseline dataset by year of sample collection after a minimum sequencing depth threshold of 1x is applied.

Despite using very high-resolution genomic methods to characterize genomic variation in spawning groups of Pacific halibut collected over large spatial and temporal scales, our results do not provide evidence of genetic differentiation among the baseline samples and are strongly supportive of genetic panmixia. Genetic differentiation was estimated from lcWGR data using a new bioinformatics method specifically developed by the IPHC Secretariat that improves previous methods to estimate $F_{ST}$ values among several populations and at a lower computational cost. This new method has been described in a manuscript submitted for publication in a leading peer-reviewed journal in the field and is currently under review (Jasonowicz and Planas, in review). From a management perspective, these results support IPHC's current stock assessment practices that model the Pacific halibut stock as a single coastwide unit within IPHC Convention Waters (Stewart and Hicks, 2024). A manuscript describing our results on the lack of population structure in Pacific halibut is currently being written for publication in a leading peer-reviewed journal.

1.2. Genomics-based method for estimating age of Pacific halibut. The primary objective of this project (funded by Alaska Sea Grant; Appendix IV) is to develop a genetic method for aging Pacific halibut using fin tissue, a sample that can be easily collected from either live or dead individuals. This method is based on the identification of DNA methylation patterns in fin tissue that are associated with age through the development of an age estimation model (i.e. epigenetic clock) for Pacific halibut.

For developing an epigenetic clock, we selected genetic samples (fin clips) from 249 fish collected during IPHC's Fishery-Independent Setline Survey (FISS) from 2021 to 2024 throughout IPHC Convention Waters and covering most of IPHC's Regulatory Areas (Table 2). These genetic samples correspond to fish with known ages (read twice by the break-and-bake aging method) between 6 and 30 years and include 6-10 individual samples (aiming for an equal number of males and females) per year of age (Figure 2).

To date, all 249 genetic samples have been processed for DNA extraction and sequenced to identify methylated sites in the genome and quantify the percentage of methylation at each site. Current efforts are devoted to analyzing the methylation data from all individuals using a bioinformatic pipeline developed specifically for this project. Once finalized, we

will characterize the relationship between otolith-derived age and percent methylation across age-correlated genomic sites using established models.

| Year | 2A | 2B | 2C | 3A | 3B | 4A | 4B | 4D | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2021 | 1 | 12 | 12 | 3 | 0 | 3 | 1 | 0 | 32 |
| 2022 | 2 | 22 | 17 | 20 | 2 | 2 | 3 | 1 | 69 |
| 2023 | 16 | 32 | 25 | 14 | 10 | 0 | 0 | 0 | 97 |
| 2024 | 0 | 15 | 26 | 7 | 1 | 0 | 0 | 2 | 51 |
| **Total** | **19** | **81** | **80** | **44** | **13** | **5** | **4** | **3** | **249** |

**Table 2**. Number of genetic samples by year and by IPHC Regulatory Area.




**Figure 2**. Histograms showing the number of female (top) and male (bottom) genetic samples by year of age that are available for the development of the Pacific halibut epigenetic clock.

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 the 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 some of the most important biological inputs for the SA. The relevance of these research outcomes for the 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 2025 aged commercial landings, and the results have been incorporated into the 2026 stock assessment.

2.2. Reproductive assessment. Sensitivity analyses have shown the importance of changes in spawning output due to changes in maturity schedules and/or skip spawning and fecundity for the SA (Stewart and Hicks, 2018). Information on these key reproductive parameters provides direct input to the SA. For example, information on fecundity-at-age and -size could be used to replace spawning biomass with egg output as the metric for reproductive capability in the SA and management reference points. This information highlights the need for a better understanding of factors influencing reproductive biology and success of Pacific halibut. To fill existing knowledge gaps related to the reproductive biology of female Pacific halibut, research efforts are devoted to characterizing female reproduction in this species. Specific objectives of current studies include: 1) update of maturity schedules based on histology-based data, and 2) collection of samples for fecundity estimations.

2.2.1. Update of maturity schedules based on histology-based data. The IPHC Secretariat provided an update on spatial and temporal patterns in histology-derived maturity ogives by Biological Region from 2022 to 2024, and a revised coastwide maturity ogive using histology-based data in IPHC-2026-AM102-14. The results derived from this work have been described in a manuscript submitted for publication in a leading peer-reviewed journal in the field that is currently under review (Jones et al., in review).

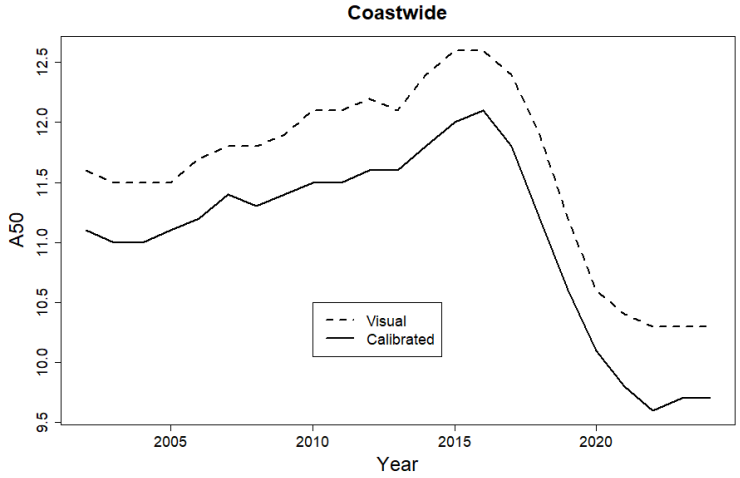



**Figure 3**. Coastwide $A_{50}$ calculated from visual (dashed line) and calibrated (solid line) maturity ogives from 2002 to 2024.

The IPHC Secretariat developed a calibration between histological and visual maturity ogives from the 2022-2024 data and produced calibrated maturity ogives based on FISS visual maturity data from 2002-2024. This time series started in 2002 when the IPHC Secretariat changed aging methods from surface reading to break and bake. From these data, a mean coastwide calibrated visual maturity ogive for the 2002-2024 time series was generated, yielding an $A_{50}$ value (age at 50% maturity) of 11.0 years.

This new coastwide maturity ogive yielded an $A_{50}$ value that is 0.6 years lower than that of the visual maturity ogive previously used in stock assessment. The revised coastwide maturity ogive was incorporated for the first time in the 2025 stock assessment and will also be incorporated in the 2026 stock assessment.

During the 23-year period between 2002 and 2024, we observed significant changes in the $A_{50}$ value based on the new calibrated maturity ogives (Figure 3; solid line). These results evidence two temporal shifts, one characterized by a gradual increase in the $A_{50}$ (i.e. females maturing at a later age) from 2004 to 2016, and a second one characterized by a sharp decrease in $A_{50}$ (i.e. females rapidly maturing at an earlier age) from 2017 to 2022. Studies are underway to identify possible drivers of these temporal shifts in maturity-at-age in female Pacific halibut.

To continue monitoring maturity over time, the IPHC Secretariat collected ovarian samples for maturity in the 2025 and 2026 FISS seasons. In 2025, FISS sampling resulted in the successful collection of 1,276 ovarian samples from all four Biological Regions: 275 samples in Biological Region 2, 380 samples in Biological Region 3, 355 samples in Biological Region 4, and 266 samples in Biological Region 4B. In 2026 (Figure 4), we collected 1,275 ovarian samples from Biological Regions 2, 3 and 4: 359 samples in Biological Region 2, 489 samples in Biological Region 3, and 427 samples in Biological Region 4. Unfortunately, no samples were collected in Biological Region 4B in 2026 due to the lack of FISS vessel bids. These samples will allow us to further investigate both spatial and temporal differences in histology-based female Pacific halibut maturity.

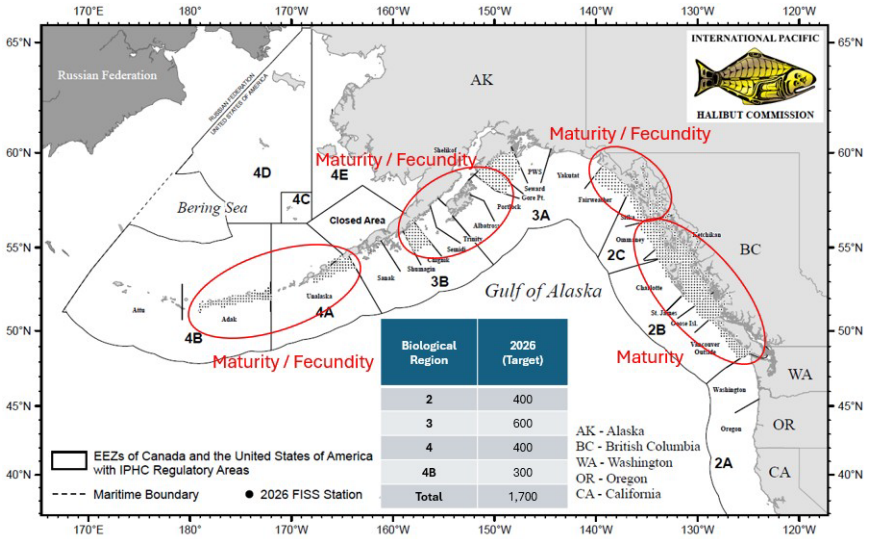



**Figure 4**. Coastwide map of sample areas and targets for maturity and fecundity collection in the 2026 FISS.

2.2.2. Collection of ovarian samples for fecundity estimations. The IPHC Secretariat has initiated studies that are aimed at improving our understanding of Pacific halibut fecundity. These studies will allow us to estimate fecundity-at-size and fecundity-at-age and could be used to replace spawning biomass with egg output as the metric for

reproductive capability in SA and management reference points. Fecundity determinations in female Pacific halibut will be conducted using the auto-diametric method (Thorsen and Kjesbu, 2001; Witthames et al., 2009) that has been developed for other fish species. IPHC Secretariat staff received training on this method by experts in the field (NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA) in May 2023. For the development and application of the auto-diametric method for estimating fecundity in female Pacific halibut, ovarian samples from maturing females of a wide range of sizes and ages are needed. For this reason, the IPHC Secretariat initiated efforts in 2023 to collect ovarian samples for fecundity estimations.

Ovarian samples from maturing female Pacific halibut have been collected for fecundity during the FISS in 2023, 2024, 2025 and 2026. In addition, special projects aimed at collecting ovarian samples at the end or after the FISS season to target large females (> 90 cm in fork length) at more advanced stages of ovarian development, were conducted in Biological Region 2 in 2024, 2025 and 2026, and in Biological Region 3 in 2026. In 2023, sampling during the FISS was conducted only in Biological Region 3, with a total of 231 fecundity samples collected. In 2024, sampling during the FISS was conducted in Biological Regions 2 and 4, with 33 and 54 fecundity samples collected, respectively. In the fall (October-November) of 2024, 219 additional fecundity samples from large females were collected in Biological Region 2 as part of the special project. In 2025, fecundity samples were collected in the FISS in all four Biological Regions (22, 109, 171 and 77 samples in Regions 2, 3, 4 and 4B, respectively) and 238 samples were collected in Biological Region 2 in the late summer as part of the special project. In 2026, fecundity samples were collected in the FISS, with 23, 30 and 38 samples collected in Biological Regions 2, 3 and 4, respectively. The IPHC Secretariat also collected fecundity samples as part of the special project from mid-September to October of 2026 in Biological Regions 2 and 3, with 199 and 200 samples from large females, respectively. The numbers of ovarian samples for fecundity collected by sampling platform (FISS or special project), by Biological Region and by year, are shown in Table 3.

| | | Collection Year | | | | |
|---|---|---|---|---|---|---|
| **Sampling platform** | **Biological Region** | **2023** | **2024** | **2025** | **2026** | **Total by Biological Region** |
| FISS | 2 | - | 33 | 22 | 23 | 78 |
| FISS | 3 | 231 | - | 109 | 30 | 370 |
| FISS | 4 | - | 54 | 171 | 38 | 263 |
| FISS | 4B | - | - | 77 | - | 77 |
| Special project | 2 | - | 219 | 238 | 199 | 656 |
| Special project | 3 | - | - | - | 200 | 200 |
| | **Total by year** | 231 | 306 | 617 | 490 | 1644 |

**Table 3**. Number of ovarian samples for fecundity method development and fecundity estimations collected by year and by Biological Region in each of the two sampling platforms.

The size and weight distributions of Pacific halibut females from which the fecundity samples were collected are shown in Figures 5 and 6, respectively.

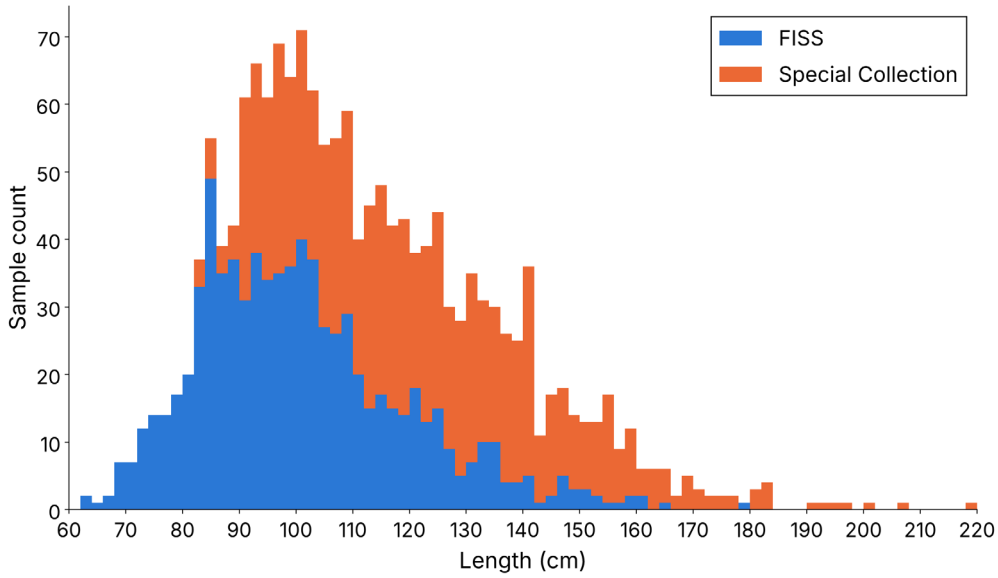



**Figure 5**. Size distribution of Pacific halibut females from which fecundity samples were collected for the development and application of the fecundity estimation method in the FISS (blue) and in the special projects (red).

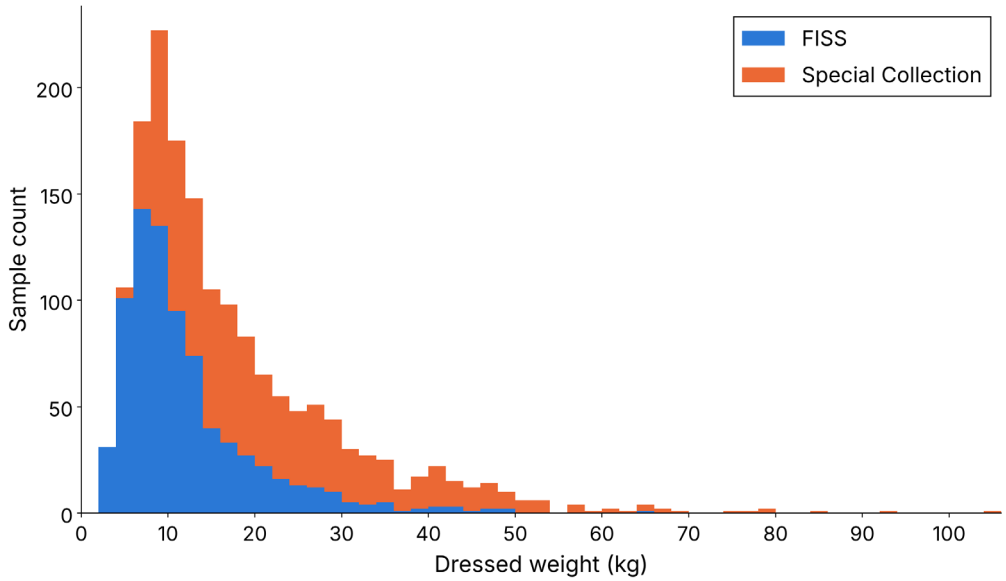



**Figure 6**. Weight distribution of Pacific halibut females from which fecundity samples were collected for the development and application of the fecundity estimation method in the FISS (blue) and in the special projects (red).

Overall, the collected ovarian samples will allow the IPHC Secretariat to develop the auto-diametric method and apply it to estimate fecundity-at-size and fecundity-at-age in female Pacific halibut, and to compare fecundity estimations across space (i.e. Biological Regions) and across time (i.e. years).

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 the 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 MSE process is in the improvement of the simulation of variability and in allowing 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 size-at-age by investigating the physiological mechanisms that contribute to growth changes in Pacific halibut. The two main objectives of these studies have been: 1) the identification and validation of molecular growth markers for somatic growth; and 2) the application of molecular growth markers for evaluating growth patterns in the Pacific halibut population. A manuscript describing the results of these studies has been published (Planas et al., 2025).

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 SA. 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 the SA, changes in the estimates of incidental mortality will influence the output of the SA 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 the SA resides in their ability to improve estimates of trends in unobserved mortality, thereby improving estimates of stock productivity, and these outcomes represent the most important inputs in fishery yield for the SA (Appendix II). The relevance of these research outcomes for the MSE process is in fishery parameterization (Appendix III).

4.1. Estimation of discard mortality rates in the guided recreational sector. Results from the completed study investigating discard mortality rates and characteristics of fish captured and released using guided recreational fishery practices are currently being prepared for publication in a peer-reviewed journal.

5. Fishing technology.

The IPHC Secretariat has determined that research to provide the Pacific halibut fishery with tools to reduce whale depredation is a high priority (Appendix I), as indicated in the current Integrated Research and Monitoring Plan. Important management implications of these studies reside in improving estimations of mortality of Pacific halibut in the directed commercial fishery that will lead to improved estimates of stock productivity (Appendix II). Depending on the estimated magnitude of whale depredation, this may be included as another explicit source of mortality in the SA and mortality limit-setting process.

The IPHC Secretariat has been 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 Reduction Engineering Program (BREP) (NOAA Awards NA21NMF4720534 and NA23NMF4720414). The testing phase of this project took place in May 2025 in the Unalaska region and involved (1) refining effective methods related to the deployment and use of an underwater shuttle as a catch protection device, and (2) conducting tests in the presence of killer whales to demonstrate the efficacy and safety of the device (Figure 7).

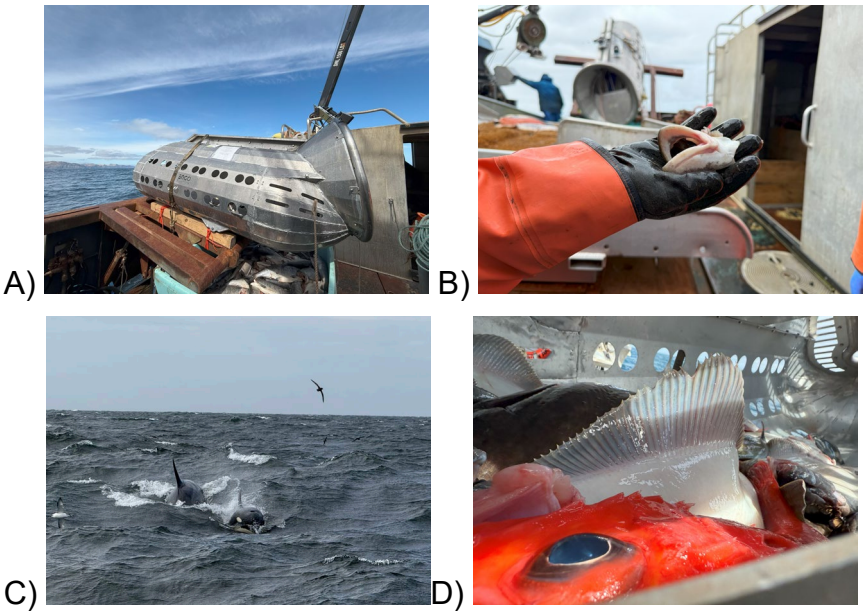



**Figure 7.** A) Shuttle device in transport. B) Typical evidence (lips only) of depredation. C) Killer whales rapidly approaching the hauling site. D) Catch retained within the shuttle.

Preliminary results from video footage suggest that the shuttle device had high retention rates of Pacific halibut when compared to other frequently encountered species (Table 4). In addition, preliminary results on catch rate comparisons between protected and unprotected skates did not show clear differences, likely due to high variability among catch rates within treatments. Overall, the shuttle device demonstrated good retention capacity (up to 835 kg/1,840 lb) in the trials, with capacity for higher weights. Incidentally, rare footage of killer whales around the groundline at depth was captured.

| Common Name | Encountered | Excluded | Entered and Escaped | Entered and Passed Through | Retained |
|---|---|---|---|---|---|
| **Pacific halibut** | **121** | **1 (0.8%)** | **0** | **9 (7.5%)** | **112 (93.3%)** |
| Sablefish | 186 | 2 (1.1%) | 54 (29.4%) | 34 (18.5%) | 96 (52.2%) |
| Pacific cod | 124 | 3 (2.4%) | 13 (10.7%) | 6 (5.0%) | 102 (84.3%) |
| Rockfish | 19 | 7 (43.8%) | 2 (16.7%) | 1 (8.3%) | 9 (75.0%) |
| Skate | 18 | 3 (16.7%) | 0 | 2 (13.3%) | 13 (86.7%) |

**Table 4.** Numbers of fish encountered by the shuttle device that were either excluded, entered and escaped, entered and passed through still on the hook, and/or finally retained on 11 of 15 sets with video footage analyzed to date.

Data analysis and video review are ongoing. These preliminary results suggest potential for this approach to interrupt the reward cycle underpinning toothed whale depredation.

## RECOMMENDATION/S

That the Commission:

1) **NOTE** paper IPHC-2026-IM102-13, that provides a report on current and planned biological and ecosystem science and research activities contemplated in the current IPHC Integrated Research and Monitoring Plan.

## REFERENCES

Jasonowicz, A.J. and Planas, J.V. 2026. fst-gl: Efficient and performance-oriented estimation of $F_{ST}$ from genotype likelihoods. Bioinformatics. In Review.

Jones, C.L., Webster, R.A., Stewart, I.J., Hicks, A.C., Planas, J.V. Spatial and temporal characterization of histology-based maturity-at-age for female Pacific halibut (*Hippoglossus stenolepis*). Canadian Journal of Fisheries and Aquatic Sciences. In Review.

Planas, J.V., Jasonowicz, A.J., Simeon, A., Simchick, C., Timmins-Schiffman, E., Nunn, B.L., Kroska, A.C., Wolf, N., Hurst, T.P. 2025. Molecular mechanisms underlying thermally induced growth plasticity in juvenile Pacific halibut. Journal of Experimental Biology. 228 (19):jeb251013. https://doi.org/10.1242/jeb.251013

Stewart, I., and Hicks, A. 2018. Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2017. Int. Pac. Halibut Comm. Annual Meeting Report: IPHC-2018-AM094-10.

Stewart, I., and Hicks, A. 2024. Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2023. Int. Pac. Halibut Comm. Annual Meeting Report: IPHC-2024-SA-01.

Thorsen, A., and Kjesbu, O.S. 2001. A rapid method for estimation of oocyte size and potential fecundity in Atlantic cod using a computer-aided particle analysis system. Journal of Sea Research. 46: 295-308. doi: https://doi.org/10.1016/S1385-1101(01)00090-9.

Witthames, P.R., Greenwood, L.N., Thorsen, A., Dominguez, R., Murua, H., Korta, M., Saborido-Rey, F., and Kjesbu, O.S., 2009. Advances in methods for determining fecundity: application of the new methods to some marine fishes. Fishery Bulletin. 107: 148–164. uri: http://hdl.handle.net/10261/25187.

# 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 current external research grants

| Project # | Grant agency | Project name | PI | Partners | IPHC Budget ($US) | Management implications | Grant period |
|---|---|---|---|---|---|---|---|
| **1** | **Alaska Sea Grant** | Development of a non-lethal genetic-based method for aging Pacific halibut (R/2024-05) | IPHC, Alaska Pacific University (APU) | Alaska Fisheries Science Center-NOAA (Juneau) | $60,374 | Stock structure | January 2025-February 2027 |
| **Total awarded ($)** | | | | | **$60,374** | | |