Report on Current and Future Biological and Ecosystem Science Research Activities

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PURPOSE

To provide the Commission with a description of the biological and ecosystem science research projects conducted and planned by the IPHC Secretariat and contemplated within the Five-year Program of Integrated Research and Monitoring (2022-2026).

BACKGROUND

The main objectives of the Biological and Ecosystem Science Research at the IPHC are to:

1) identify and assess critical knowledge gaps in the biology of the Pacific halibut;
2) understand the influence of environmental conditions; and
3) apply the resulting knowledge to reduce uncertainty in current stock assessment models.

The primary biological research activities at IPHC that follow Commission objectives are identified and described in the IPHC Five-Year Program of Integrated Research and Monitoring (2022-2026). These activities are summarized in five broad research areas designed to provide inputs into stock assessment and the management strategy evaluation processes (Appendix I), 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.
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.

DISCUSSION 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 stock assessment (SA) resides (1) in the introduction of possible changes in the structure of future stock assessments, as separate assessments may be constructed if functionally isolated components of the population are found (e.g. IPHC Regulatory Area 4B), and (2) in the improvement of productivity estimates, as this information may be used to define management targets for minimum spawning biomass by Biological Region. These research outcomes provide the second and third top ranked biological inputs into SA (Appendix II). Furthermore, the relevance of these research outcomes for the management strategy evaluation (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. 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 on the basis of 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 (i.e. microsatellites, ~10-100), whole-genome scale approaches can now be conducted with lower cost and are able to provide orders of magnitude more data (millions of markers) that allow investigating genetic variation in fish populations at an unprecedented resolution.

   The main purpose of the present study is 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. For this purpose, the IPHC Secretariat used genetic samples from male and female adult Pacific halibut collected during the spawning (winter) season from known spawning grounds in five geographic areas: Western and Central Aleutian Islands, Bering Sea, Central Gulf of Alaska and British Columbia (Figure 1). Furthermore, temporal replicates at many of these locations are available and have enabled the IPHC Secretariat to evaluate the stability of genetic structure over time, ensuring confidence in the results. As a requisite for the lcWGR approach used, the IPHC Secretariat first produced a high-quality reference genome (Jasonowicz et al., 2022) that has been used to generate genomic sequences from 570 individual Pacific halibut collected from the five above-mentioned geographic areas (Figure 1).

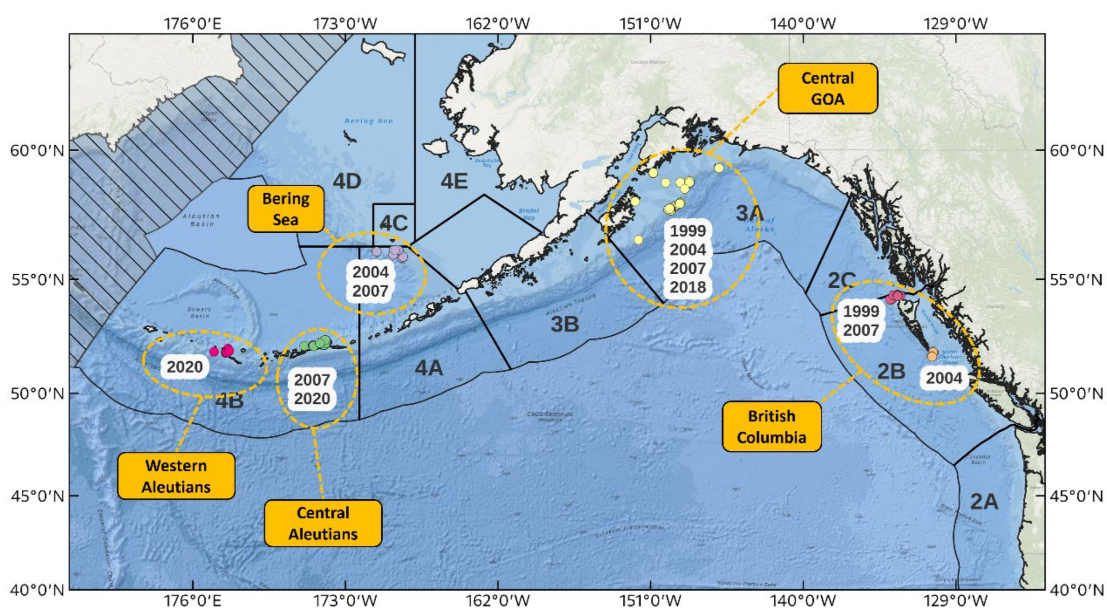


Figure 1. Map of sample collections made during the spawning season used for genomic analysis of population structure in Pacific halibut in the northeast Pacific Ocean.

Using the lcWGR approach, the IPHC Secretariat has identified approximately 10.2 million single nucleotide polymorphisms (SNPs) that have been used to evaluate population structure at the highest resolution possible. Despite the use of a very high-resolution genomic approach, preliminary analyses of population structure using a genome-wide subset of 4.7 million SNPs, indicated that distinct genetic groups were not apparent in the dataset. Multiple methods were used to characterize population structure: principal component analysis revealed a considerable degree of genetic similarity between samples collected in different geographic areas (Figure 2), and unsupervised clustering methods (K-means clustering and the estimation of admixture proportions) also failed to detect discrete genetic groups. These results suggest that there is very little spatial structure among the five spawning groups sampled in different geographic areas within IPHC Convention Waters. Furthermore, assignment testing was carried out to assess our ability to accurately assign samples back to their location in which they were collected. Cross-validation was used to evaluate assignment accuracy and indicated a limited ability (34.7%) to accurately assign samples back to the geographic location in which they were collected from. We hypothesize that the absence of distinct genetic groups among our sample collections is due to a considerable degree of geneflow among the geographic areas sampled in this study and, consequently, to the genetically panmictic nature of the Pacific halibut population sampled for this study.

The lack of structure observed aligns with our current knowledge and understanding of Pacific halibut biology. Annual migration rates estimated from tag recovery data suggest that there is ample opportunity for individuals to move among IPHC Regulatory Areas throughout their lives (Webster et al. 2013). Analysis of tag recovery data has shown that approximately 11% of Pacific halibut tags are recovered in a different IPHC

Regulatory Area than they are released (Carpi et al. 2021). This varies by Regulatory Area but for most IPHC Regulatory Areas, the percentage of migrants observed exceeds 10% (Carpi et al. 2021). Substantial rates of movement extend to very early life stages of Pacific halibut as well. Oceanographic connectivity between the Bering Sea and Gulf of Alaska has been linked to a considerable degree of larval exchange between these areas. It has been estimated that 47%-58% of larvae originating from spawning grounds in the Western Gulf of Alaska are transported to the Bering Sea (Sadorus et al. 2021). Furthermore, these rates can still be as high as 4.5%-8.6% for larvae originating from spawning grounds in the Eastern Gulf of Alaska (Sadorus et al. 2021).

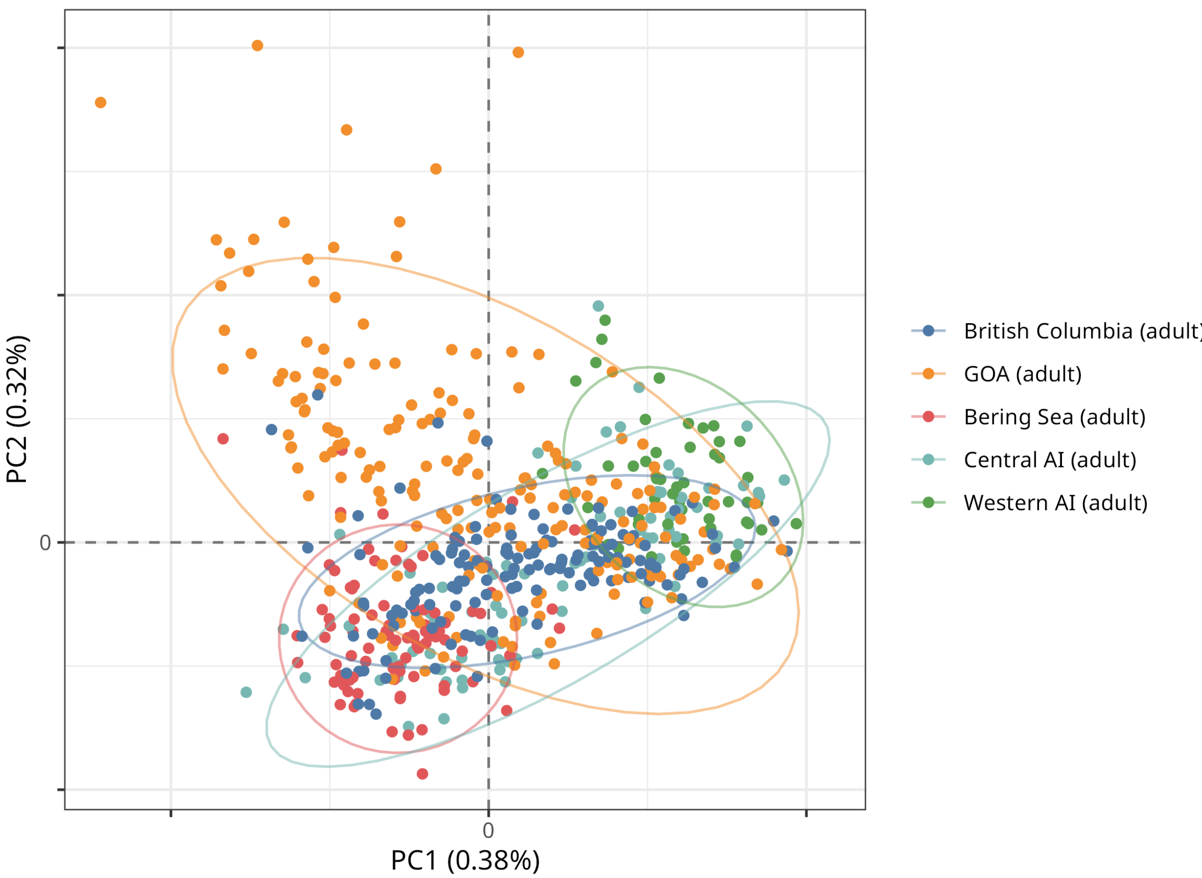


Figure 2. Principal Component Analysis (PCA) biplot of the first two PC axes for 570 Pacific halibut. Samples are colored by geographic area. Circles represent 95% confidence ellipses.

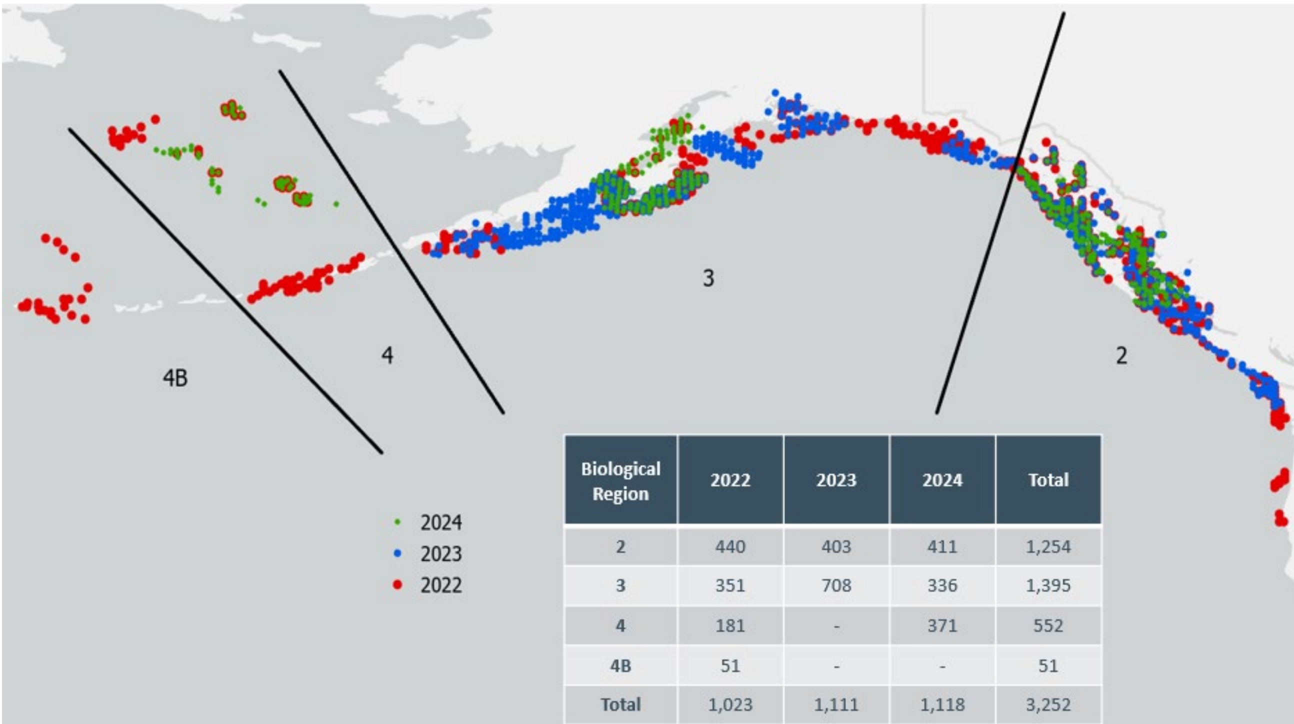
The concept of a stock and the ability to define management units is central to sound management of marine fishes (Begg et al. 1999; Cadrin 2020). Advances in genomic technology have led to the development of useful and powerful tools that can aid in the delineation of management units (Bernatchez et al. 2017). Despite using very high-resolution genomic methods to characterize genomic variation in spawning groups of Pacific halibut collected over large spatial and temporal scales, the results presented here are consistent with genetic panmixia. However, while it is important to note that we cannot simply prove that panmixia exists by failing to reject it, the results presented here are consistent with the current assessment practices of the IPHC which considers Pacific halibut in IPHC Convention Waters as a single coastwide stock (Stewart and Hicks 2024).

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) as they represent the most important biological inputs for SA. The relevance of these research outcomes for the management strategy evaluation process is in the improvement of the simulation of spawning biomass in the Operating Model (Appendix III).

Recent sensitivity analyses have shown the importance of changes in spawning output due to changes in maturity schedules and/or skip spawning and fecundity for 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 of 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. In order 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 histological-based data; and 2) fecundity estimations.

2.1. Update of maturity schedules based on histological-based data. The coastwide maturity schedule (i.e. the proportion of mature females by age) that is currently used in SA is based on visual (i.e. macroscopic) maturity data collected in IPHC's Fishery-Independent Setline Survey (FISS). However, the coastwide maturity schedule has not been revised in recent years and it may have an undetermined degree of uncertainty. For this reason, the IPHC Secretariat is undertaking studies to revise the female maturity schedule coastwide and in all four IPHC Biological Regions through histological (i.e. microscopic) characterization of maturity. To accomplish this objective, the IPHC Secretariat started collecting ovarian samples for histology during the 2022 and 2023 FISS seasons. The 2022 FISS sampling resulted in a total of 1,023 ovarian samples collected in Biological Regions 2, 3, 4 and 4B. Due to a reduced FISS design, in 2023 sampling only occurred in Biological Regions 2 and 3 and 1,111 ovarian samples were collected (Figure 3). Ovarian samples from 2022 and 2023 were processed for histology and scored 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 were assigned to either the mature or immature categories. Mature female Pacific halibut are deemed to have at least reached the early vitellogenic (Vtg1) female developmental stage (Fish et al., 2020).



Biological Region	2022	2023	2024	Total
2	440	403	411	1,254
3	351	708	336	1,395
4	181	-	371	552
4B	51	-	-	51
Total	1,023	1,111	1,118	3,252

Figure 3. Map of 2022, 2023 and 2024 maturity samples for histology collected on FISS. Red dots (2022), blue dots (2023) and green dots (2024) indicate a distinct FISS station in which a sample was collected.

Maturity ogives (i.e., the relationships between the probability of maturity determined by histological assessments and variables including IPHC Biological Region, age, and year) were estimated by fitting generalized additive models (GAM) with logit link (i.e., logistic regression) to the 2022 and 2023 data using year as a factor (Figure 4). When comparing Biological Regions 2 and 3 (the only two Biological Regions with two consecutive years of data) spatial and temporal differences in maturity ogives become apparent. First, the maturity ogive for Biological Region 2 shows lower steepness than that for Biological Region 3 in both years, indicating that Biological Region 2 has a lower proportion of mature females from ages 7 to 25 than Biological Region 3 over the period of ovarian sample collection during the FISS. Second, the maturity ogive in Biological Region 2 increased markedly in steepness between 2022 and 2023, indicating an increase in the proportion of mature females at younger ages, whereas the maturity ogive in Biological Region 3 was very similar across the two years. Future collection of ovarian samples in additional years will be required to establish any potential temporal and/or spatial differences in maturity ogives. For this reason, the IPHC Secretariat continued to collect ovarian samples in the 2024 FISS. A total of 1,118 ovarian samples were collected during 2024, with 411 samples in Biological Region 2, 336 samples in Biological Region 3, and 371 samples in Biological Region 4.

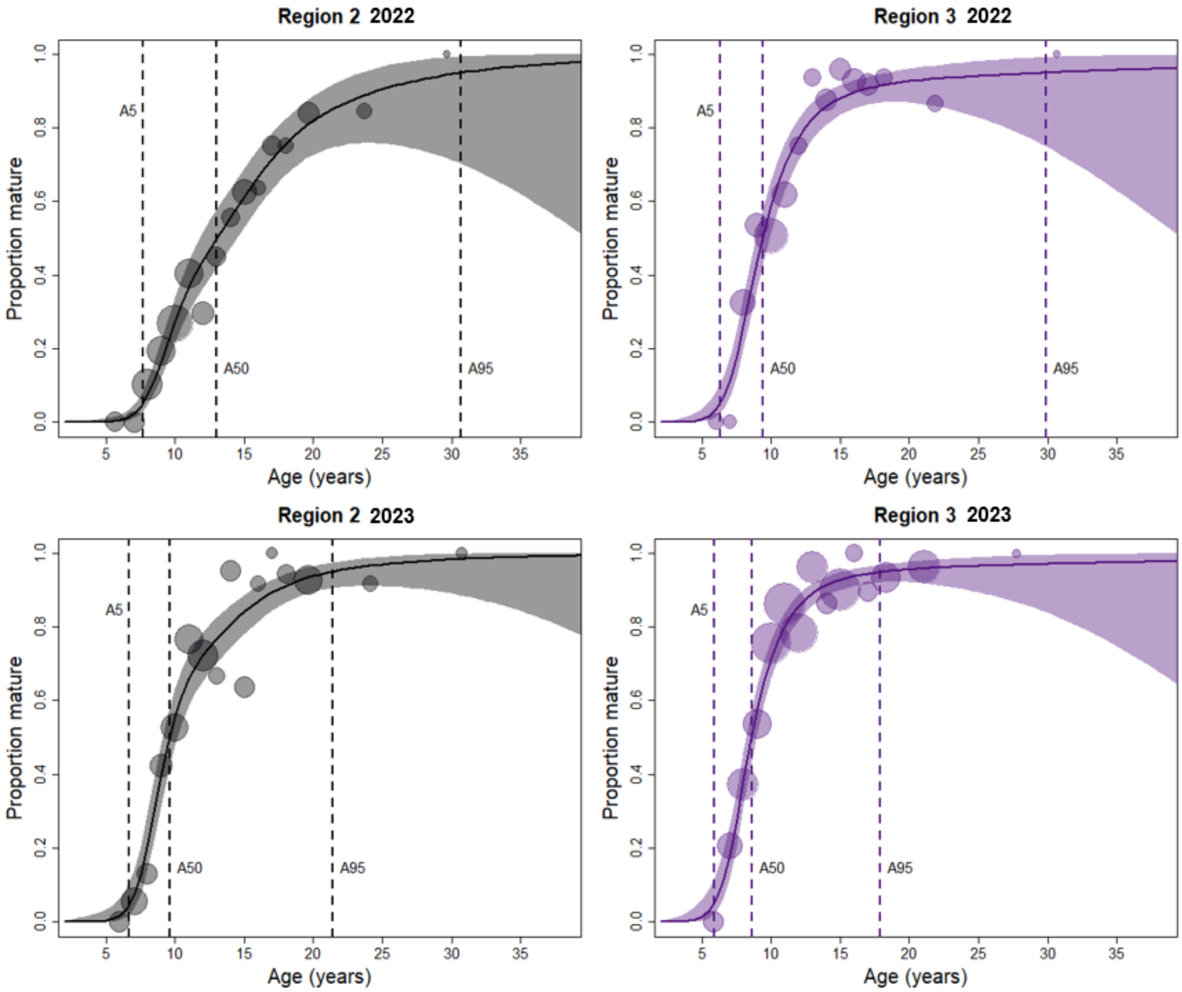


Figure 4. Female Pacific halibut age-at-maturity by IPHC Biological Region (BR2, left; BR3, right) and year (2022, top; 2023, bottom) using best-fit GAM. Color shading indicates 95% confidence intervals for each IPHC Biological Region. Vertical dash lines indicate age at 5% (A5), 50% (A50), and 95% (A95) maturity.

To generate a coastwide maturity ogive, the estimated regional abundance proportions from IPHC's most recent FISS space-time model were used as weights given that sample size was not proportional to population size for each Biological Region. The value of the coastwide ogive at each age was calculated as the abundance proportion at age multiplied by the proportion of mature females at age summed across the Biological Regions. The modeled coastwide ogive for maturity-at-age appears to fall between the maturity ogives for Biological Regions 2 and 3 (Figure 5). This result was expected because Biological Regions 2 and 3 currently have the highest estimated abundance. Using the histology-based coastwide maturity ogive, age at 50% maturity (A50; i.e., age at which half of the females are considered to be mature) was calculated to be at 10.3 years of age, a A50 value that is 1.3 years younger than that from currently used maturity estimates obtained from macroscopic (field) data (A50 at 11.6 years;

Clark and Hare, 2006). These results strongly suggest that a higher proportion of female Pacific halibut are maturing at a younger age than previously indicated, with potential implications for overall spawning stock biomass (SSB) estimates.

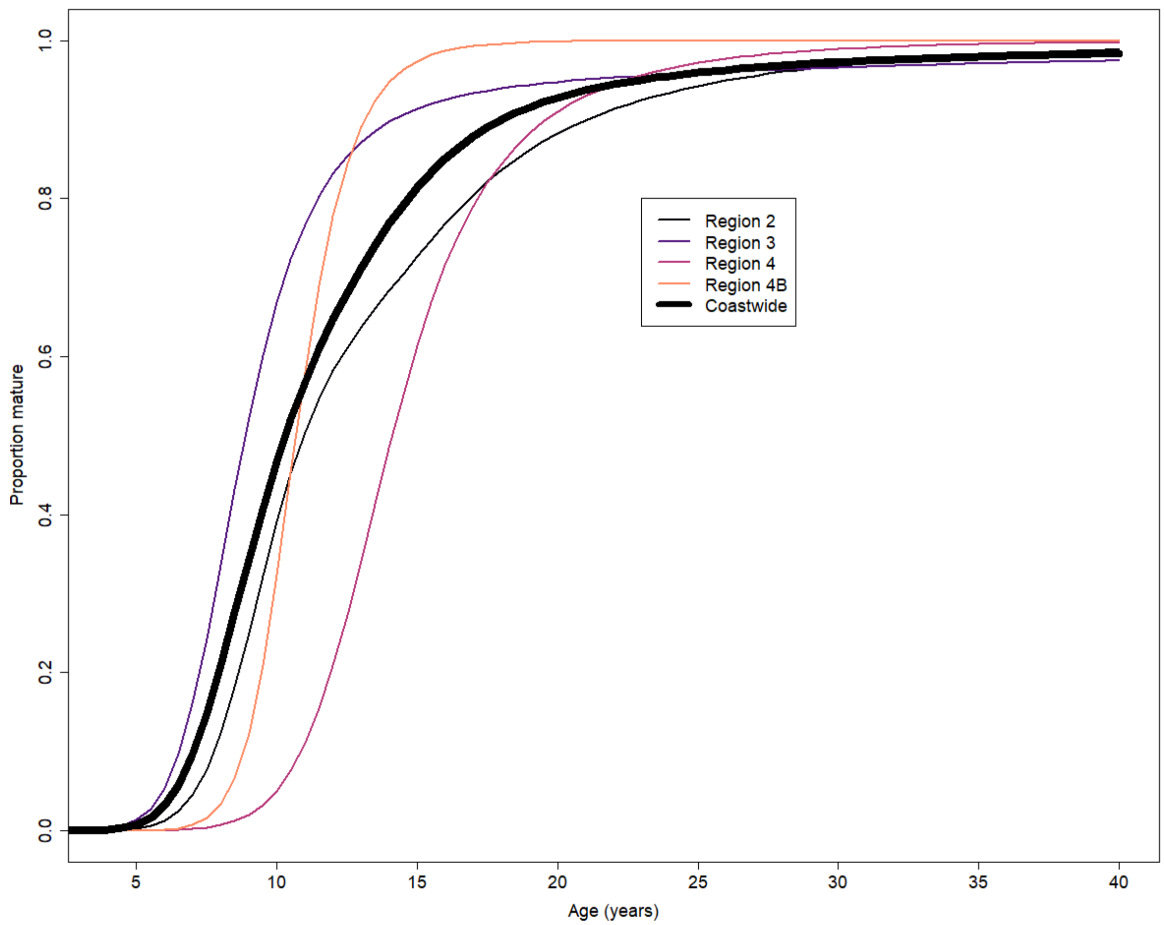


Figure 5. Coastwide maturity-at-age ogive (thick black line) generated from estimated regional abundance proportions. Shown without confidence intervals to better visualize differences between the coastwide and Biological Region ogives.

The IPHC Secretariat has also conducted preliminary analyses to examine maturity-at-length and maturity-at- weight. Using the same best-fit GAM model as for maturity-at-age, coastwide maturity ogives for length and net weight were estimated. Length at 50% maturity (L50) was calculated to be at 87.04 cm fork length. This preliminary L50 value is approximately 10 cm smaller than maturity estimates obtained from macroscopic (field) data (L50 of 85.8 cm; Clark and Hare, 2006). Preliminary results also showed that net weight at 50% maturity (W50) was calculated to be at 5.46 kg.

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) and 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 the development and application of the auto-diametric method to estimate fecundity in female Pacific halibut were collected during the IPHC's FISS in 2023 and 2024. In 2023, sampling was conducted only in Biological Region 3, with a total of 456 fecundity samples collected. In 2024, sampling was conducted in Biological Regions 2 and 4, with 149 and 359 fecundity samples collected, respectively. In the Fall of 2024, 273 additional fecundity samples targeting large females (85-200+ cm in fork length) were collected in Biological Region 2. This large collection of ovarian samples will be used initially for the development of the auto-diametric method, followed by actual fecundity estimations by age and by size (length and weight).

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 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 strategy evaluation process is in the improvement of the simulation of variability and to allow for scenarios investigating climate change (Appendix III).

The IPHC Secretariat completed a study funded by the North Pacific Research Board (NPRB Project No. 1704; 2017-2020) to identify relevant physiological markers for somatic growth. This study resulted in the identification of 23 markers in skeletal muscle that were indicative of temperature-induced growth suppression and 10 markers in skeletal muscle that were indicative of temperature-induced growth stimulation. These markers represented genes and proteins that changed both their mRNA expression levels and protein abundance levels in skeletal muscle, respectively, in parallel with changes in the growth rate of Pacific halibut. A manuscript describing the results of this study is currently in preparation (Planas et al., in preparation).

In addition to temperature-induced growth manipulations, the IPHC Secretariat has conducted similar studies as part of NPRB Project No. 1704 to identify physiological growth markers that respond to density- and stress-induced growth manipulations. The respective justifications for these studies are that (1) population dynamics of the Pacific halibut stock could be affected by fish density, and (2) stress responses associated with capture and release of discarded Pacific halibut may affect subsequent feeding behavior and growth. Investigations related to the effects of density and stress exposure are still underway.

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 (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 for regulatory reasons), respectively, represent important sources of mortality that can result in significant reductions in exploitable yield in the directed fishery. Given that the incidental mortality from the commercial Pacific halibut fisheries and bycatch fisheries is included as part of the total removals that are accounted for in 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 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 SA (Appendix II). The relevance of these research outcomes for the management strategy evaluation process is in fishery parameterization (Appendix III).

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

4.1. Discard mortality rates of Pacific halibut in the directed longline fishery. This project is completed and the results on survival estimates and their relationship to capture and release conditions have been published in the journals *North American Journal of Fisheries Management* (Loher et al. 2022) and *Ocean and Coastal Management* (Dykstra et al. 2024).

4.2. Discard mortality rates of Pacific halibut in the charter recreational fishery. Results from this study 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 and tagged with acceleration-logging pop-up archival transmitting tags (sPATs). These results represent the first experimentally-derived estimate of mortality of Pacific halibut recreational discards, and is consistent with the notion 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 fish released in Excellent viability by the commercial fishery (Meyer, 2007). Results on the relationship of injury types, viability categories and survival of discarded fish with capture (e.g., environmental parameters, time on deck, hooking time, etc.) and physiological (e.g., stress) conditions are currently being analyzed and subsequently a manuscript will be prepared for publication in the peer-reviewed literature.

5. Fishing Technology.
The IPHC Secretariat is conducting studies aimed at developing methods that involve modifications of fishing gear with the purpose of reducing Pacific halibut depredation and bycatch. Specific objectives in this area include 1) investigating new methods for whale avoidance and/or deterrence for the reduction of Pacific halibut depredation by whales (i.e., catch protection methods), and 2) investigating behavioral and physiological responses of

Pacific halibut to fishing gear in order to reduce bycatch. 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.

5.1. Gear-based approaches to catch protection to minimize whale depredation in longline fisheries. The IPHC Secretariat has conducted investigations on gear-based approaches to catch protection as a means for minimizing whale depredation in the Pacific halibut longline fisheries with funding from NOAA's Bycatch Research and Engineering Program (BREP) (NOAA Award NA21NMF4720534; 2021-2023). The objectives of this study were to 1) work with fishermen and gear manufacturers, via direct communication and through a virtual International Workshop (link), to identify effective methods for protecting hook-captured flatfish from depredation; and 2) develop and pilot test simple, low-cost catch-protection designs that can be deployed effectively using current longline fishing techniques and on vessels currently operating in IPHC Convention Waters.

From the outcomes of the first objective, two different types of catch protection devices were selected for further development and field testing: 1) an underwater shuttle based on a modification of a commercial catch protection device (Figure 6), and 2) a branch gear with a sliding shroud system based on a modification of a slinky pot deployed on branchline gear. The two different devices were tested off Newport, OR in May of 2023 on a 56' (17m) chartered fishing vessel with an open deck design and typical boom and winch capacity. The focus of the testing was to investigate (a) the logistics of setting, fishing, and hauling of the two pilot catch protection designs, and (b) the basic performance of the gear on catch rates and fish size compared to non-protected gear in the absence of whales.

A) B) C)

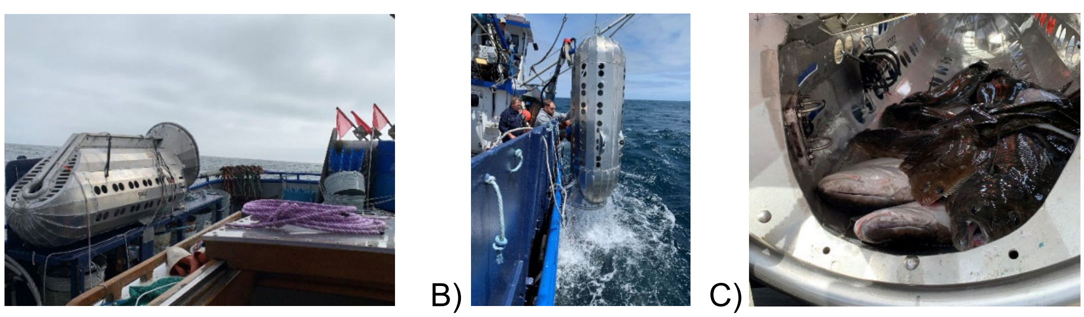


Figure 6. Shuttle unit stowed on vessel (A), shuttle being hoisted onto vessel during retrieval (B), and fish contained within the shuttle before emptying on deck (C).

The results from the field testing conducted in May 2023 indicated that the underwater shuttle was a safe and effective gear type which entrained comparable quantities, sizes, and types fish as the control gear (Figure 7), whereas the sliding shroud and branch gear had substantial logistical issues that require to be addressed before scaling up to a fishery level.

In a third phase of this project, the IPHC Secretariat has recently received an additional research grant from the Bycatch Reduction Engineering Program-NOAA program entitled "Full scale testing of devices to minimize whale depredation in longline fisheries" (NA23NMF4720414; Appendix IV) to refine effective methods for protecting longline captured fish from depredation using the shuttle device, and to complete replicates in the presence of toothed whales in known depredation hotspots to demonstrate the efficacy and safety of the gear. Requests for tenders to conduct the work during 2025 are being prepared for submission.

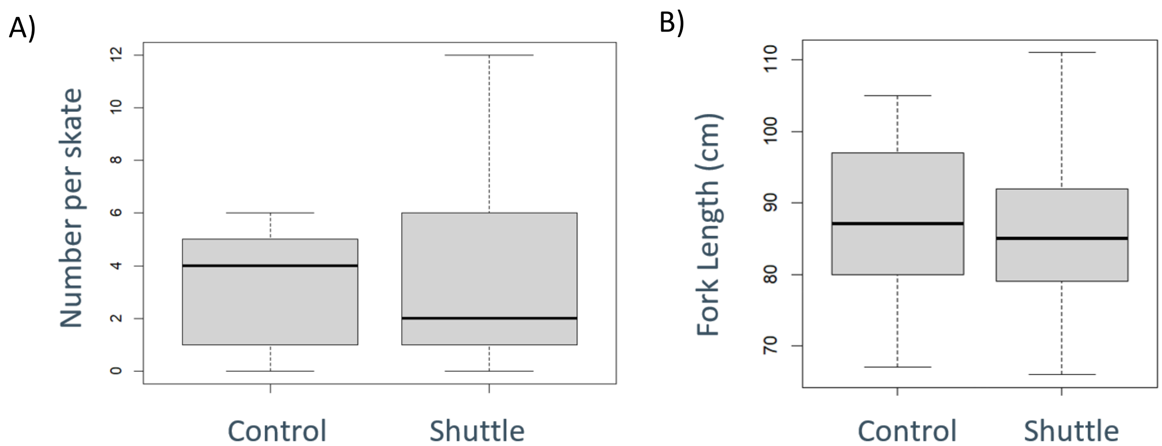


Figure 7. Number of individuals (A) and fork length (B; in cm) of Pacific halibut recovered per skate of control gear or retrieved by the underwater shuttle depicted in Figure 6.

RECOMMENDATION/S

That the Commission:

1) **NOTE** paper IPHC-2025-AM101-15, that provides a report on current and planned biological and ecosystem science and research activities contemplated in the IPHC's Five-Year Program of Integrated Research and Monitoring (2022-2026).

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APPENDICES

Appendix I: Biological research areas in the 5-Year Program of Integrated Research and Monitoring (2022-2026) and ranked relevance for stock assessment and management strategy evaluation (MSE).

Appendix II: List of ranked research priorities for stock assessment

Appendix III: List of ranked research priorities for management strategy evaluation (MSE)

Appendix IV: Summary of current competitive research grants awarded to IPHC

APPENDIX I

Biological research areas in the 5-Year Program of Integrated Research and Monitoring (2022-2026) and ranked relevance for stock assessment and management strategy evaluation (MSE)

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 research priorities for stock assessment

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	Migration and population dynamics	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		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	Fishing technology	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	Fishing technology	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 research priorities for management strategy evaluation (MSE)

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

APPENDIX IV

Summary of current competitive research grants awarded to IPHC

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Grant period	Research area	Management implications	Research prioritization
1	**Bycatch Reduction Engineering Program-NOAA**	Full scale testing of devices to minimize whale depredation in longline fisheries (NOAA Award Number NA23NMF4720414)	IPHC	Alaska Fisheries Science Center-NOAA	$199,870	November 2023 – April 2026	Fishing technology	Mortality estimations due to whale depredation	3
2	**Alaska Sea Grant (pending award)**	Development of a non-lethal genetic-based method for aging Pacific halibut (R/2024-05)	IPHC APU	Alaska Fisheries Science Center-NOAA (Juneau)	$60,374	January 2025-December 2026	Population dynamics	Stock structure	2
Total awarded ($)					**$260,244**				