TSC Agency Reports – IPHC 2022

Contents

I. Agency Overview

Management of the Pacific halibut resource and fishery has been the responsibility of the International Pacific Halibut Commission (IPHC) since its creation in 1923, see Figure 1 for a map of the IPHC Convention Area. Assessing, forecasting, and managing the resource and fishery requires accurate assessments, continuous monitoring, and research responsive to the needs of managers and stakeholders. The fishery for Pacific halibut (*Hippoglossus stenolepis*) is one of the most valuable and geographically largest in the northeast Pacific Ocean. Industry participants from Canada and the United States of America have prosecuted the modern fishery and have depended upon the resource since the 1880s. Annual removals have been as high as 100 million pounds, and the long-term average of removals is 64 million pounds.

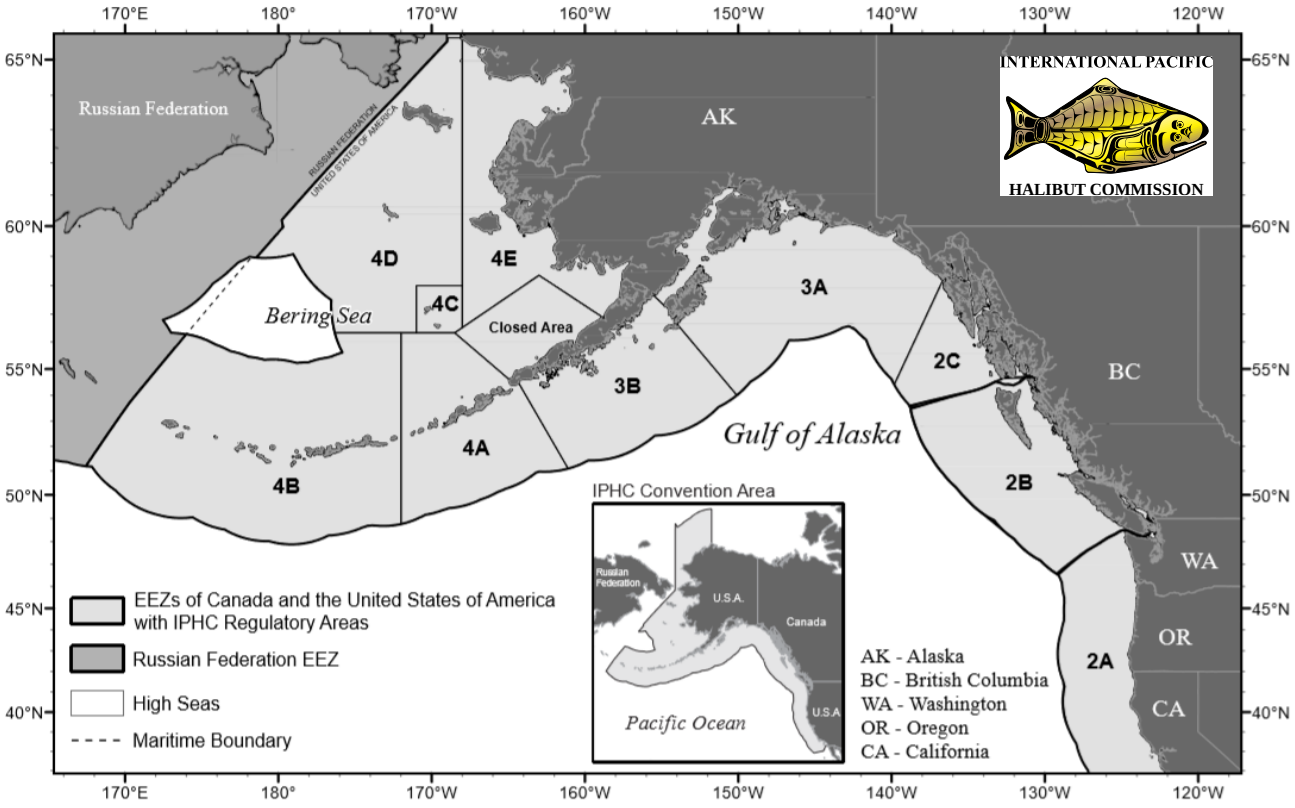

Figure 1. Map of the IPHC Convention Area and IPHC Regulatory Areas.

Staffing Updates: see https://www.iphc.int/locations/map.

II. Fishery-Independent Setline Survey (FISS)

The IPHC's Fishery-Independent Setline Survey (FISS) provides catch information and biological data on Pacific halibut (*Hippoglossus stenolepis)* that are collected independently of the commercial fishery. These data, which are collected using standardized methods, bait and gear during the summer of each calendar year, provide an important comparison with data collected from the commercial fishery. The directed commercial fishery is variable in its gear composition and distribution of fishing effort over time, and presents a broad spatial and temporal sampling of the stock. Pacific halibut biological data collected on the FISS (e.g. the size, age, and sex composition) are used to monitor changes in biomass, growth, and mortality in adult and sub-adult components of the Pacific halibut population. In addition, records of non-target species caught during FISS operations provide insight into bait competition, rate of bait attacks, and serve as an index of abundance over time, making them valuable to the assessment, management, and avoidance of non-target species. In addition, oceanographic data is collected at each station (please see section in Other Ongoing Data Collection Programs).

For details on FISS work conducted in 2021, please refer to the following paper *IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2021*.

III. Reserves – N/A

IV. Review of Agency Groundfish Research, Assessment, and Management

A. Pacific halibut and IPHC activities

1. Research

The primary biological research activities at the IPHC that follow Commission objectives and selected for their important management implications are identified and described in the IPHC Five-Year Biological and Ecosystem Science Research Plan for the period 2017-21:

Overview of research activities in 2021 and planned for 2022

1. Migration. Knowledge of Pacific halibut migration throughout all life stages is necessary in order to gain a complete understanding of stock distribution and the factors that influence it.

   1.1. Larval distribution and connectivity between the Gulf of Alaska and Bering Sea. Knowledge of the dispersal of Pacific halibut larvae and subsequent migration of young juveniles has remained elusive because traditional tagging methods are not effective on these life stages due to the small size of the animals. This larval connectivity project, in cooperation with NOAA EcoFOCI, used two recently developed modeling approaches to estimate dispersal and migration pathways of larval and young juvenile Pacific halibut in order to better understand the connectivity of populations between the Gulf of Alaska and Bering Sea and within each of these two ocean basins (Sadorus et al. *Fish Oceanogr.* 2021. 30:174-193). Additional studies are currently planned to investigate the potential of Pacific halibut larvae to be successfully delivered from offshore spawning sites to potential inshore settlement habitats identified by the IPHC Secretariat, under different climatic regimes.

   1.2. Wire tagging of U32 Pacific halibut. The patterns of movement of Pacific halibut among IPHC Regulatory Areas have important implications for management of the Pacific halibut fishery. The IPHC Secretariat has undertaken a long-term study of the migratory behavior of Pacific halibut through the use of externally visible tags (wire tags) on captured and released fish that must be retrieved and returned by workers in the fishing industry. In 2015, with the goal of gaining additional insight into movement and growth of young Pacific halibut (less than 32 inches [82 cm]; U32), the IPHC began wire-tagging small Pacific halibut encountered on the National Marine Fisheries Service (NMFS) groundfish trawl survey and, beginning in 2016, on the IPHC FISS. In 2021, 2,534 Pacific halibut were tagged and released on the IPHC FISS but no tagging was conducted in the NMFS groundfish trawl surveys. Therefore, a total of 6,111 U32 Pacific halibut have been wire tagged and released on the IPHC FISS and 126 of those have been recovered to date. In the NMFS groundfish trawl surveys through 2019, a total of 6,536 tags have been released and, to date, 76 tags have been recovered.

2. Reproduction. Efforts at IPHC are currently underway to address two critical issues in stock assessment: updated maturity estimations and new fecundity estimations.

   2.1. Maturity estimations. 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, 2020). These results highlight the need for a better understanding of factors influencing reproductive biology and success for 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) accurate description of oocyte developmental stages and their use to classify female maturity stages; 2) characterization of seasonal changes in female reproductive development; 3) revision of current estimates of female age-at-maturity; 4) comparison of macroscopic (based on field observations) and microscopic (based on histological assessment) maturity stages and revision of maturity criteria, and 5) investigations on female fecundity.

   The IPHC Secretariat has described for the first time the different oocyte stages that are present in the ovary of female Pacific halibut and how these are used to classify females histologically to specific maturity stages (Fish et al. *J. Fish Biol.* 2020. 97:1880-1885). In brief, eight different oocyte developmental stages have been described, from early primary growth oocytes until preovulatory oocytes, and their size and morphological characteristics established. Maturity classification was determined by assigning maturity status to the most advanced oocyte developmental stage present in ovarian tissue sections and seven different microscopic maturity stages were established. Analysis of oocyte size frequency distribution among the seven different maturity stages provided evidence for the group-synchronous pattern of oocyte development and for the determinate fecundity reproductive strategy in female Pacific halibut. The results of this study set the stage for recently completed study on temporal changes in maturity through histological assessment of ovarian samples collected over an entire annual reproductive cycle. Our results confirm that the peak period of spawning for Pacific halibut in the central Gulf of Alaska takes place in January and February. Analysis of the temporal changes in female reproductive phase shows that spawning capable females are detected as early as August, therefore marking the beginning of the spawning capable reproductive phase (Fish et al. *Front. Mar. Sci*. 2022. doi: 10.3389/fmars.2022.801759). For stock assessment purposes, the spawning capable reproductive phase comprises females that are considered mature. Importantly, the detection of spawning capable females in July-August is conducive to conducting routine histological assessments of female maturity during the IPHC's FISS sample collection period (i.e. June to late August) that will take place in 2022.

   2.2. Fecundity assessment. The IPHC Secretariat is planning the collection of ovarian samples in 2023 for fecundity assessment using the auto-diametric method.

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

   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 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. The IPHC Secretariat has 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 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. Discard Mortality Rates (DMRs) and Survival Assessment. Information on all Pacific halibut removals is integrated by the IPHC Secretariat, providing annual estimates of total mortality from all sources for its stock assessment. Bycatch and wastage of Pacific halibut, as defined by the incidental catch of fish in non-target fisheries and by the mortality that occurs in the directed fishery (i.e. fish discarded for sublegal size or for regulatory reasons), respectively, represent 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. For this reason, the IPHC Secretariat is conducting investigations on the effects of capture

and release on survival and on providing experimentally-derived 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 and survival of longline-caught Pacific halibut. The IPHC Secretariat, with funding by a grant from the Saltonstall-Kennedy Grant Program NOAA (NA17NMF4270240; 2017-2020), has conducted studies to evaluate the effects of hook release techniques on injury levels, their association with the physiological condition of captured Pacific halibut and, importantly, has generated experimentally-derived estimates of DMR in the directed longline fishery. Results on individual survival outcomes for Pacific halibut released in excellent viability condition indicate a range of DMRs between 4.2% (minimum) and 8.4% (maximum), that is consistent with the currently-applied DMR value of 3.5% (Loher et al. *North Am. J. Fish. Manage*. 2022. 42:37-49).

4.2. Discard mortality rates of Pacific halibut in the charter recreational fishery. The IPHC Secretariat is conducting a research project to better characterize the nature of charter recreational fisheries with the ultimate goal of better understanding discard practices relative to that which is employed in the directed longline fishery. This project has received funding from the National Fish and Wildlife Foundation (NFWF Project No. 61484) and the North Pacific Research Board (NPRB Project No. 2009). The experimental field components of this research project took place in Sitka, Alaska (IPHC Regulatory Area 2C) from 21-27 May 2021, and in Seward, Alaska (IPHC Regulatory Area 3A) from 11-16 June 2021. In brief, Pacific halibut were captured with the use of 12/0 and 16/0 circle hooks that best reflect the gear currently used and fish sizes were targeted to cover the Pacific halibut size distribution recorded by ADFG on an annual basis. All injuries were documented, along with length, weight, somatic fat measurements (using the Distell Fatmeter), and a blood sample (for measuring the levels of physiological stress indicators in plasma) was collected for each fish, before they were tagged and released. Environmental information on temperature (bottom/surface) and time (fight time, time on deck) was also tracked. Eighty (80) Pacific halibut of Excellent release viability were fitted with satellite pop-up archival tags (sPAT) for near-term survival estimation in IPHC Regulatory Area 3A. Analyses of survival data and levels of blood stress indicators are currently underway.

5. Genetics and genomics. The IPHC Secretariat is conducting studies that incorporate genomics approaches in order to produce useful information on population structure and distribution and connectivity of Pacific halibut.

5.1. Investigate the genetic structure of the Pacific halibut population in the North-eastern Pacific Ocean. Understanding population structure is imperative for sound management and conservation of natural resources. Pacific halibut in Canadian and USA waters are managed by the IPHC as a single coastwide unit stock since 2006. The rationale behind this management approach is based on our current knowledge of the highly migratory nature of Pacific halibut as assessed by tagging studies and of past analyses of genetic population structure that failed

to demonstrate significant differentiation in the North-eastern Pacific Ocean population of Pacific halibut by allozyme and small-scale microsatellite analyses. However, more recent studies have reported slight genetic population structure on the basis of genetic analysis conducted with larger sets of microsatellites suggesting that Pacific halibut captured in the Aleutian Islands may be genetically distinct from other areas. These findings of subtle genetic structure in the Aleutian Island chain area are attributed to limited movement of adults and exchange of larvae between this area and the rest of the stock due to the presence of oceanographic barriers to larval and adult dispersal (i.e. Amchitka Pass) that could represent barriers to gene flow. Unfortunately, previous genetic studies suggesting subtle genetic structure were conducted based on a relatively limited set of microsatellite markers and, importantly, using genetic samples collected in the summer (i.e. non-spawning season) that may not be representative of the local spawning population. With the collection of winter (i.e. spawning season) genetic samples in the Aleutian Islands by the IPHC in early 2020, a collection of winter samples from 5 different geographic areas across the North-eastern Pacific Ocean (i.e. British Columbia, Central Gulf of Alaska, Bering Sea, Central and Western Aleutian Islands) is now being used to re-examine the genetic structure of the Pacific halibut population at an unprecedented detail using a low-coverage whole genome resequencing approach and the recently sequenced Pacific halibut genome. The results from these ongoing genomic studies will provide important information on spawning structure and, consequently, on the genetic baselines of source populations. Importantly, the results from these studies will provide management advice regarding the relative justifiability for considering the western Aleutians as a genetically-distinct substock. This work has recently received funding from the North Pacific Research Board (NPRB Project No. 2110).

Other ongoing data collection projects

In addition to specific research projects, the IPHC collects data each year through ongoing data collection projects that are funded separately, either as part of the FISS or as part of the directed commercial fishery data collection program. Ongoing data collections projects include the following:

IPHC Secretariat aboard National Marine Fisheries Service groundfish trawl surveys in the Gulf of Alaska, Bering Sea and Aleutian Islands

The National Oceanic and Atmospheric Administration (NOAA) Fisheries has conducted annual bottom trawl surveys on the eastern Bering Sea continental shelf since 1979 and the IPHC has participated in the survey on an annual basis since 1998 by directly sampling Pacific halibut from trawl survey catches. The IPHC has participated in the NOAA Fisheries Aleutian Islands trawl survey, which takes place every two years, since 2012. Alternating year by year with the Aleutian Islands trawl survey is the NOAA Fisheries Gulf of Alaska trawl survey, which IPHC has participated in since 1996. The IPHC uses the NOAA Fisheries trawl surveys to collect information on Pacific halibut that are not yet vulnerable to the gear used for the IPHC FISS or directed commercial fishery, and as an additional data source and verification tool for stock analysis. In addition, trawl

survey information is useful as a forecasting tool for cohorts approaching recruitment into the FISS or directed commercial fishery.

Sampling of directed commercial landings

The IPHC positions Secretariat to sample the directed commercial landings for Pacific halibut in Alaska, British Columbia, Washington, and Oregon. Sampling of commercial landings involves collecting Pacific halibut otoliths, tissue samples (fin clips) for genetic sexing, fork lengths, weights, logbook information, and final landing weights.

The collected data are used in the stock assessment and other research. The collected otoliths provide age composition data and the tissue samples provide sex composition. Lengths and weight data, in combination with age data and sex data, provide size-at-age analyses by sex. Mean weights are combined with final landing weights to estimate catch in numbers. Logbook information provides weight per unit effort data, fishing location for the landed weight, and data for research projects. Finally, tags are collected to provide information on migration, exploitation rates, and natural mortality.

In addition to sampling the catch, other objectives include collecting recovered tags, and copying information from fishing logs along with the respective landed weights, for as many Pacific halibut trips as possible throughout the entire season.

Environmental data collection in the IPHC FISS

Since 2009, the IPHC has been collecting environmental data as water column profiles in each station sampled as part of the IPHC FISS. The data collected includes surface to depth profiles of pressure (depth), temperature, conductivity (salinity), dissolved oxygen, pH, and chlorophyl a concentration. For each year from 2009 until 2021 containing, environmental data, related metadata and maps of profiled FISS stations are publicly available on the IPHC website (https://www.iphc.int/datatest/data/water-column-profiler-data).

2. Assessment

The 2021 stock assessment produced the following scientific advice regarding the Pacific halibut stock:

> ***Sources of mortality**: In 2021, total Pacific mortality due to fishing increased to 37.66 million pounds (17,084 t) but remained below the 5-year average of 38.48 million pounds (17,456 t). Of that total, 88% comprised the retained catch, up from 84% in 2020.*
>
> ***Fishing intensity**: The 2021 fishing mortality corresponded to a point estimate of SPR = 46%; there is a 47% chance that fishing intensity exceeded the IPHC's current reference level of F43%. The Commission does not currently have a coastwide fishing intensity limit reference point.*
>
> ***Stock status** (spawning biomass): Current (beginning of 2022) female spawning biomass is estimated to be 191 million pounds (86,600 t), which corresponds to an 45% chance of being below the IPHC trigger reference point of SB30%, and less*

than a 1% chance of being below the IPHC limit reference point of SB20%. The stock is estimated to have declined by 17% since 2016 but is currently at 33% of the unfished state. Therefore, the stock is considered to be 'not overfished'. Projections indicate that mortality consistent with the interim management procedure reference fishing intensity (F43%) is likely to result in further declining biomass levels in the near future.

***Stock distribution**: The proportion of the coastwide stock represented by Biological Region 3 has increased sharply over 2020-21, reversing over a decade of steady decline. This trend occurs in tandem with declines in Biological Regions 2 and 4; however, all regions remain within the historical range observed from 1993-2021. These estimates have been updated and strongly informed by the comprehensive FISS design implemented in 2021.*

***Outlook**:* The projections for this assessment are more optimistic than those from the 2019 and 2020 assessments due to the increasing projected maturity of the 2012 year-class. This translates to a lower probability of stock decline for 2022 than in recent assessments as well as a decrease in this probability through 2023-24. There is greater than a 50% probability of stock decline in 2023 (55-64/100) for the entire range of SPR values from 40-46%, which include the status quo TCEY and the F43% reference level. The 2022 "3-year surplus" alternative, corresponds to a TCEY of 38.0 million pounds (~17,240 t), and a projected SPR of 48% (credible interval 32-63%). At the reference level (a projected SPR of 43%), the probability of spawning biomass decline from 2022 to 2023 is 59%, decreasing to 55% in three years, as the 2012 cohort matures. The one-year risk of the stock dropping below SB30% ranges from 43% at the F46% level to 45% at the F40% level of fishing intensity.*

** TCEY stands for Total Constant Exploitation Yield*

For more information on the 2020 stock assessment and the fishery status, please refer to paper IPHC-2022-AM098-10 at the IPHC website.

3. Management

The IPHC completed the 98th Session of the IPHC Annual Meeting (AM098) on 28 January 2022 with decisions on total mortality limits, fishery limits, fishing period dates, and other fishery regulation changes. A total of 199 individuals attended the meeting via the electronic platform.

Meeting documents, presentations, recordings of the sessions, and the report of the meeting are available on the AM097 meeting page at the IPHC website: 98th Session of the IPHC Annual Meeting (AM098). Decisions arising from this meeting, including management decisions, are documented in the following report: Report of the 98th Session of the IPHC Annual Meeting (AM098).

Mortality limits

Mortality limits adopted for 2022 added up to a 5.7% increase in comparison with the last year (Table 1).

Table 1: Mortality limits for 2021 and 2022.

IPHC Regulatory Area	2021 TCEY (Mlbs)	2022 TCEY (Mlbs)	Change
2A	1.65	1.65	0
2B	7.00	7.56	8.0%
2C	5.80	5.91	1.9%
3A	14.00	14.55	3.9%
3B	3.12	3.90	25.0%
4A	2.05	2.10	2.4%
4B	1.40	1.45	3.6%
4CDE	3.98	4.10	3.0%
IPHC Convention Area	**39.00**	**41.22**	**5.7%**

Other Actions

Management Strategy Evaluation: https://www.iphc.int/the-commission/harvest-strategy-policy

The Management Strategy Evaluation (MSE) at the IPHC completed an evaluation in 2021 of management procedures (MPs) relative to the coastwide scale and distribution of the TCEY to IPHC Regulatory Areas for the Pacific halibut fishery using a recently developed framework. The development of this MSE framework supports the evaluation of the trade-offs between fisheries management scenarios.

Economic research: https://www.iphc.int/management/science-and-research/economic-research

The goal of the IPHC economic research was to provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource that includes the full scope of Pacific halibut's contribution to regional economies of Canada and the United States. This research contributes to a wholesome approach to Pacific halibut management that is optimal from both biological and socioeconomic perspective, as mandated by the Convention.

Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) is a core product of the IPHC economic research. PHMEIA model describes economic interdependencies between sectors and regions to bring a better understanding of the role and importance of Pacific halibut resource in a regions' economies. The model details the within-region production structure of the Pacific halibut sectors (fishing, processing, charter) and accounts for economic activity generated through sectors that supply fishing vessels, processing plants, and charter businesses with inputs to production, by embedding Pacific halibut sectors into the model of the entire economy of Canada and the USA.

The PHMEIA results suggest that the revenue generated by Pacific halibut at the harvest stage accounts for only a fraction of economic activity that would be forgone if the resource was not available to fishers in the Pacific Northwest. In a typical year (based on 2019 data), one USD/CAD of Pacific halibut commercial landings was found to be linked

to over four USD/CAD-worth economic activity in Canada and the United States and contributed USD/CAD 1.3 to households. In the recreational sector, one USD/CAD spent by recreational anglers was linked to USD/CAD 4.9 circulating in the economy and USD/CAD 0.7 impact on households. The total economic activity linked to assessed Pacific halibut sectors is estimated at about USD 1.0 billion (CAD 1.3 billion), and contribution to households at over USD 300 million (CAD 400 million), highlighting how important Pacific halibut is to regional economies. However, the 2020 results suggest that Pacific halibut contribution to households' income dropped by a quarter throughout the pandemic, demonstrating Pacific halibut sectors' exposure to external factors beyond stock condition.

V. Ecosystem Studies

[See details in the Research section on ongoing IPHC data collection projects above.]

VI. Publications

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

Fish, T., Wolf, N., Smeltz, T.S., Harris, B.P., Planas, J.V. (2022). Reproductive biology of female Pacific halibut (Hippoglossus stenolepis) in the Gulf of Alaska. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2022.801759.

Loher, T., Dykstra, C.L., Hicks, A.C., Stewart, I.J., Wolf, N., Harris, B.P. and Planas, J.V. (2022). Estimation of Postrelease Longline Mortality in Pacific Halibut Using Acceleration-Logging Tags. North American Journal of Fisheries Management. 42:37-49. https://doi.org/10.1002/nafm.10711

Sadorus, L., Goldstein, E., Webster, R., Stockhausen, W., Planas, J.V., Duffy-Anderson, J. (2021). Multiple life-stage connectivity of Pacific halibut (Hippoglossus stenolepis) across the Bering Sea and Gulf of Alaska. Fisheries Oceanography. 30:174-193. doi: https://doi.org/10.1111/fog.12512

Stewart, I., Hicks, A. (2020). Assessment of the Pacific halibut (Hippoglossus stenolepis) stock at the end of 2019. Meeting Doc. IPHC-2020-SA-01, 32 p. Int. Pac. Halibut Comm., Seattle, Washington, USA. [Available from https://iphc.int/uploads/pdf/sa/2020/iphc-2020-sa-01.pdf]