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

PREPARED BY: IPHC SECRETARIAT (D. WILSON, J. PLANAS, I. STEWART, A. HICKS, R. WEBSTER, & B. HUTNICZAK); 29 OCTOBER 2021)

PURPOSE

To provide the Commission with the current draft of the IPHC 5-Year program of integrated research and monitoring (2022-26), which remains in development.

BACKGROUND

The IPHC has a long-standing history (since 1923) of collecting data, undertaking research, and stock assessment, devoted to describing and understanding the Pacific halibut (*Hippoglossus stenolepis*) stock and the fisheries that interact with it.

The IPHC Secretariat conducts activities to address key issues identified by the Commission, its subsidiary bodies, the broader stakeholder community, and the IPHC Secretariat. The process of identifying, developing, and implementing our science-based activities involves several steps that are circular in nature, but result in clear project activities and associated deliverables. The process includes developing and proposing projects based on direct input from the Commission, the experience of the IPHC Secretariat given our broad understanding of the resource and its associated fisheries, and concurrent consideration by relevant IPHC subsidiary bodies, and where deemed necessary, additional external peer review.

An overarching goal of the IPHC 5-Year Program of integrated research and monitoring (2021-26) is therefore to promote integration and synergies among the various research and support activities of the IPHC Secretariat in order to improve our knowledge of key inputs into the Pacific halibut stock assessment, economic impact assessment of the resource, and Management Strategy Evaluation (MSE) processes, thereby providing the best possible advice for management decision making processes.

The program builds on the outcomes and experiences of the Commission arising from the implementation of the 2017-21, 5-Year Biological and Ecosystem Science Research Plan (IPHC–2019–BESRP-5YP).

RECOMMENDATIONS

That the Commission **NOTE** paper IPHC-2021-IM097-12 which provided the current draft of the IPHC 5-Year program of integrated research and monitoring (2022-26), which remains in development.

APPENDICES

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

INTERNATIONAL PACIFIC HALIBUT COMMISSION

5-YEAR PROGRAM OF INTEGRATED RESEARCH AND MONITORING

(January 2022 - June 2026)

INTERNATIONAL PACIFIC

HALIBUT COMMISSION

Commissioners

Canada	United States of America
Paul Ryall	Glenn Merrill
Neil Davis	Robert Alverson
Peter DeGreef	Richard Yamada

Executive Director

David T. Wilson, Ph.D.

BIBLIOGRAPHIC ENTRY

IPHC 2021. International Pacific Halibut Commission 5-Year program of integrated research and monitoring (2022-26). Seattle, WA, U.S.A. *IPHC–2021–5YPIR, 33 pp.*

INTERNATIONAL PACIFIC
HALIBUT COMMISSION

Contact details:

International Pacific Halibut Commission
2320 W. Commodore Way, Suite 300
Seattle, WA, 98199-1287, U.S.A.
Phone: +1 206 634 1838
Fax: +1 206 632 2983
Email: secretariat@iphc.int
Website: http://www.iphc.int/

ACRONYMS

<<<To be completed>>>

DEFINITIONS

A set of working definitions are provided in the IPHC Glossary of Terms and abbreviations: https://iphc.int/the-commission/glossary-of-terms-and-abbreviations

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EXECUTIVE SUMMARY

To be developed once draft below is finalised

1. Introduction

The International Pacific Halibut Commission (IPHC) is a public international organization so designated via Presidential Executive Order 11059, and established by a Convention between Canada and the United States of America. The IPHC Convention was concluded in 1923 and entered into force that same year. The Convention has been revised several times since, to extend the Commission's authority and meet new conditions in the fishery. The most recent change occurred in 1979 and involved an amendment to the 1953 Halibut Convention. The amendment, termed a "protocol", was precipitated in 1976 by Canada and the United States of America extending their jurisdiction over fisheries resources to 200 miles. The 1979 Protocol along with the U.S. legislation that gave effect to the Protocol (Northern Pacific Halibut Act of 1982) has affected the way the fishery is conducted, and redefined the role of IPHC in the management of the fishery during the 1980s. Canada does not require specific enabling legislation to implement the protocol.

The basic texts of the Commission are available on the IPHC website: https://www.iphc.int/the-commission, and prescribe the mission of the organization as:

*"..... **to develop the stocks of [Pacific] halibut in the Convention waters to those levels which will permit the optimum yield from the fishery and to maintain the stocks at those levels**. ....." IPHC Convention*, Article I, sub-article I, para. 2). The IPHC Convention Area is detailed in Fig. 1.

The IPHC Secretariat, formed in support the Commission's activities, is based in Seattle, WA, USA. As its shared vision, ***the IPHC Secretariat aims to deliver positive economic, environmental, and social outcomes for the Pacific halibut resource for Canada and the U.S.A. through the application of rigorous science, innovation, and the implementation of international best practice.***

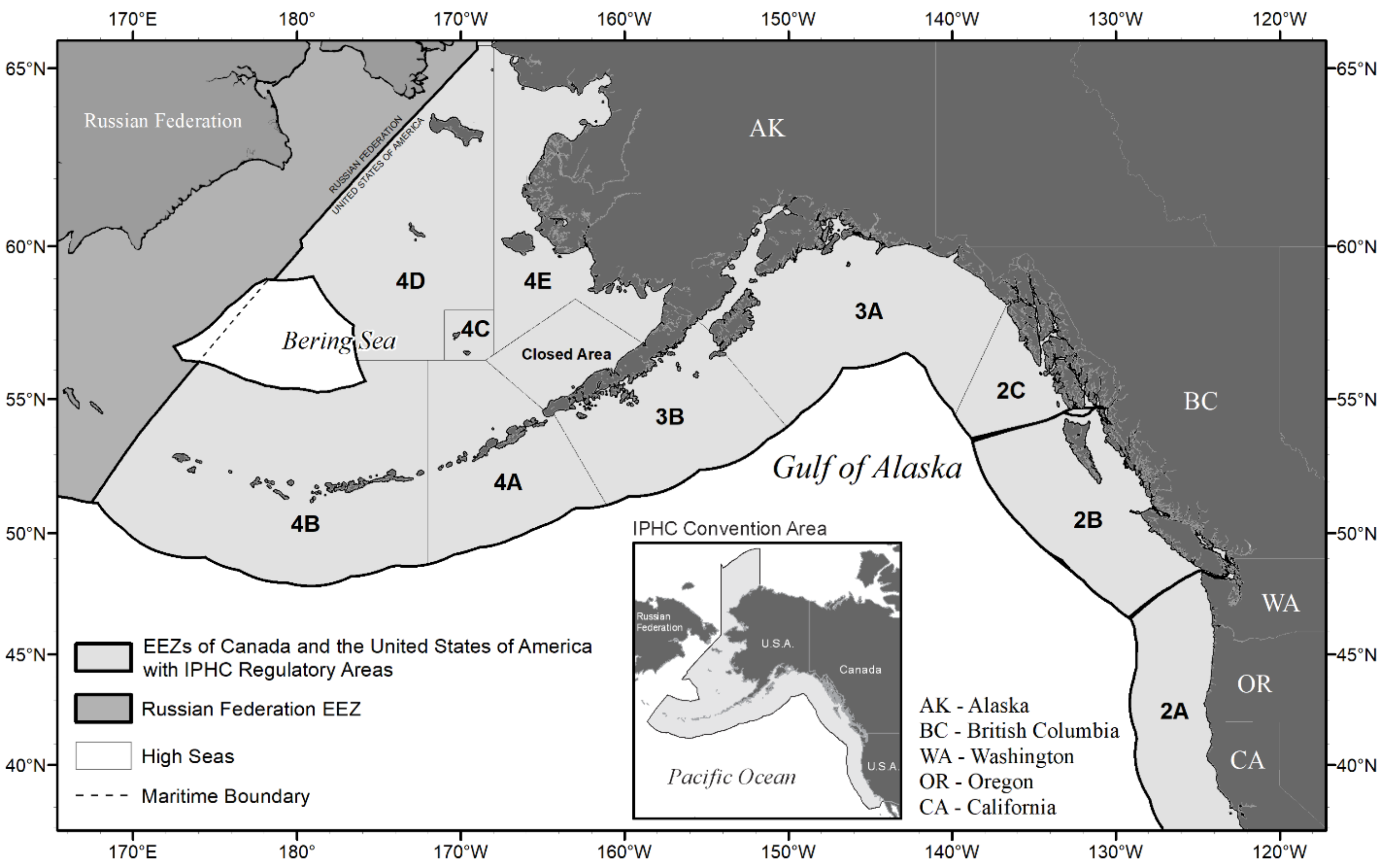

Figure 1. Map of the IPHC Convention Area (map insert) and IPHC Regulatory Areas.

2. *Objectives*

The IPHC has a long-standing history (since 1923) of collecting data, undertaking research, and stock assessment, devoted to describing and understanding the Pacific halibut (*Hippoglossus stenolepis*) stock and the fisheries that interact with it.

The IPHC Secretariat conducts activities to address key issues identified by the Commission, its subsidiary bodies, the broader stakeholder community, and of course, the IPHC Secretariat itself. The process of identifying, developing, and implementing our science-based activities involves several steps that are circular in nature, but result in clear project activities and associated deliverables. The process includes developing and proposing projects based on direct input from the Commission, the experience of the IPHC Secretariat given our broad understanding of the resource and its associated fisheries, and concurrent consideration by relevant IPHC subsidiary bodies, and where deemed necessary, additional external peer review.

[To be added: SRB recommendations arising from the implementation of the 2017-21, 5-Year Biological and Ecosystem Science Research Plan (IPHC–2019–BESRP-5YP), including climate change linkages]

[To be added: 2nd Performance Review of the IPHC process and relevant recommendations]

An **overarching goal** of the *IPHC 5-Year Program of integrated research and monitoring (2021-26)* is therefore to promote integration and synergies among the various research and support activities of the IPHC Secretariat in order to improve our knowledge of key inputs into the Pacific halibut stock assessment, economic impact assessment of the resource, and Management Strategy Evaluation (MSE) processes, thereby providing the best possible advice for management decision making processes.

The research and monitoring activities conducted by the IPHC Secretariat are directed towards fulfilling the following five (5) **objectives** within areas of data collection, biological and ecological research, stock assessment, MSE, and fisheries economics, with the overall aim of proving an integrated program of research and monitoring (Fig 2):

Research

1) **Stock assessment**: apply the resulting knowledge to reduce uncertainty in current stock assessment models and the stock management advice provided to the Commission;
2) **Management Strategy Evaluation (MSE)**: to provide inputs that inform the MSE process, which will evaluate the consequences of alternative management options, known as harvest strategies;
3) **Fishery socioeconomics**: to provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource in Canada and the United States of America.
4) **Biology and Ecology**: identify and assess critical knowledge gaps in the biology and ecology of Pacific halibut within its known range, including the influence of environmental conditions on population and fishery dynamics;

Monitoring

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

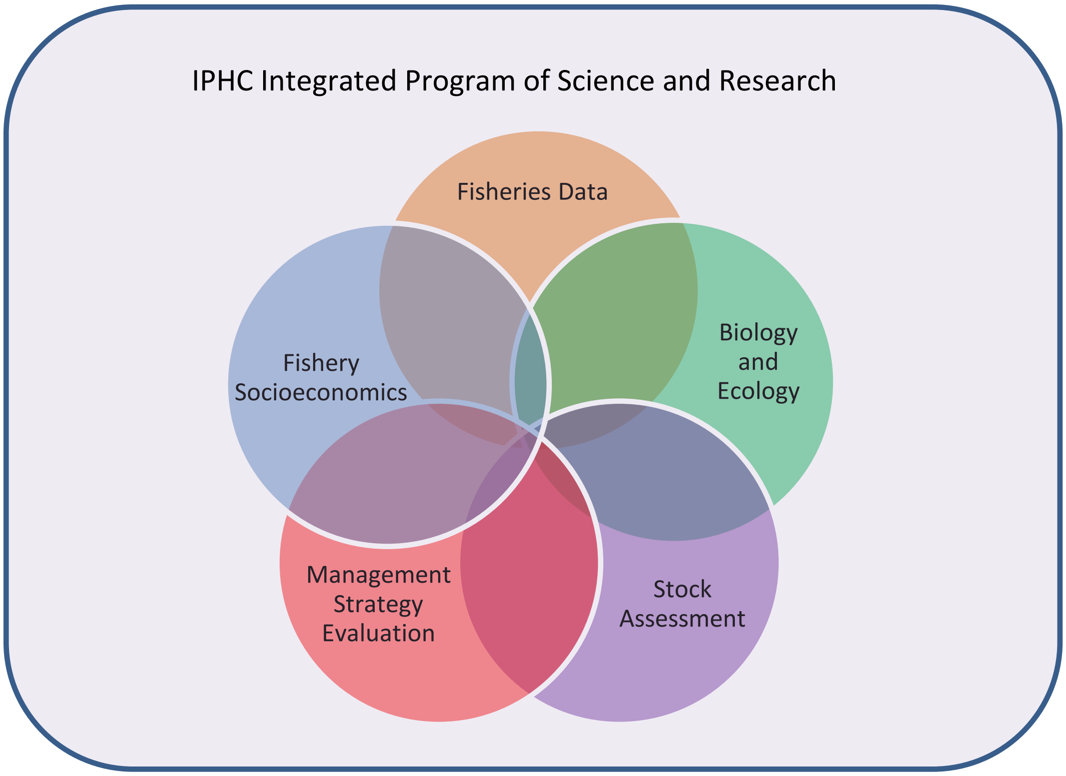

Figure 2. Core areas of the IPHC's integrated program of research and monitoring.

3. *Strategy*

The IPHC Strategic Plan (2019-23) (the Plan) contains five (5) enduring strategic goals in executing our mission, including our overarching goal and associated science and research objectives. Although priorities and tasking will change over time in response to events and developments, the Plan provides a framework to standardise our approach when revising or setting new priorities and tasking. The Strategic goals as they apply to the science and research activities of the IPHC Secretariat, will be operationalised through a multi-year tactical activity matrix (Appendix I) at the organisational and management unit (Branch) level (Fig. 3). The tactical activity matrix is described in the sections below, and has been developed based on the core needs of the Commission, in developing and implementing robust, scientifically-based management decisions on an annual, and multi-year level. Relevant IPHC subsidiary bodies will be involved in project development and ongoing review.

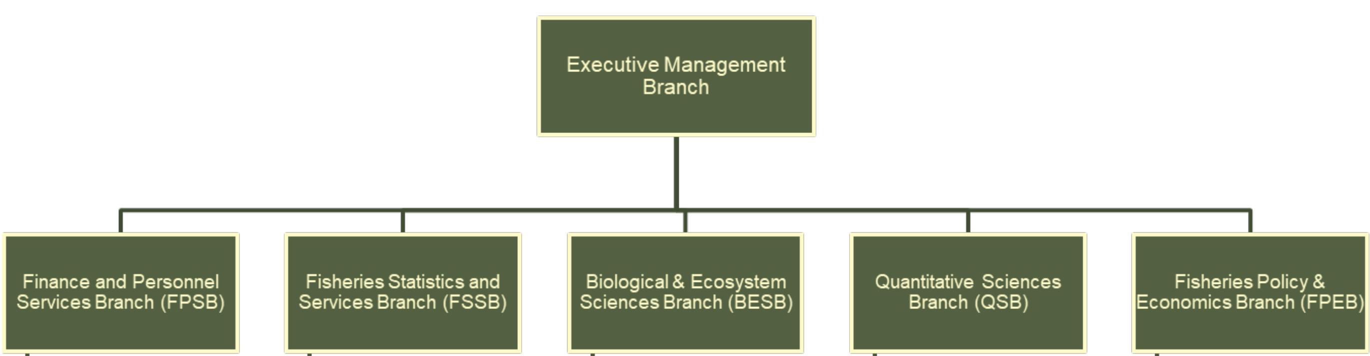

Figure 3. IPHC Secretariat organisation chart (2021).

4. *Measures of Success*

The Secretariat's success in the implementing the *IPHC 5-Year Program of Integrated Research and Monitoring (2022-26)* will be measured according to the following criteria:

4.1 Delivery of specified products

Each project line item will contain specific deliverables that constitute useful inputs into the stock assessment and the management strategy evaluation process, as well as support their implementation in the decision making process at the level of the Commission.

4.2 Communication

[In development]

4.3 External research funding

The Secretariat has set a funding goal of at least 20% of the funds for this program to be sourced from external funding bodies on an annual basis.

4.4 Peer-reviewed journal publication

Publication of research outcomes in peer-reviewed journals will be clearly documented and monitored as a measure of success. This may include single publications at the completion of a particular project, or a series of publications throughout the project as well as at its completion. Each sub-project shall be published in a timely manner, and shall be submitted no later than 12 months after the end of the research.

4.5 Future Strategic Science and Research Activities

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

1) Cutting-edge research programs in fisheries research in support of fisheries management of Pacific halibut;
2) Groundbreaking methodological research;
3) High impact and applied research;
4) Establish new collaborative agreements and interactions with research agencies and academic institutions;
5) To promote the international involvement of the IPHC by continued and new participation in international scientific organizations and by leading international science and research collaborations.
6) To incorporate talented students and early researchers in research activities contemplated.

5. *Core focal areas - Background*

The goals of the main activities of the *5-Year program of integrated research and monitoring (2022-26)* are integrated across the organisation, involving 1) monitoring (fisheries-dependent and –independent data collection), and 2) research (biological, ecological), modelling (FISS and stock assessment), Management Strategy Evaluation (MSE), and fishery socioeconomic analysis, as outlined in the following sub-sections. These components are closely linked to one another, and all feed into management decision making (Fig. 4). The current program builds on the outcomes and experiences of the Commission arising from the implementation of the 2017-21 5-Year Biological and Ecosystem Science Research Plan (IPHC–2019–BESRP-5YP), and which is summarized in Appendix II.

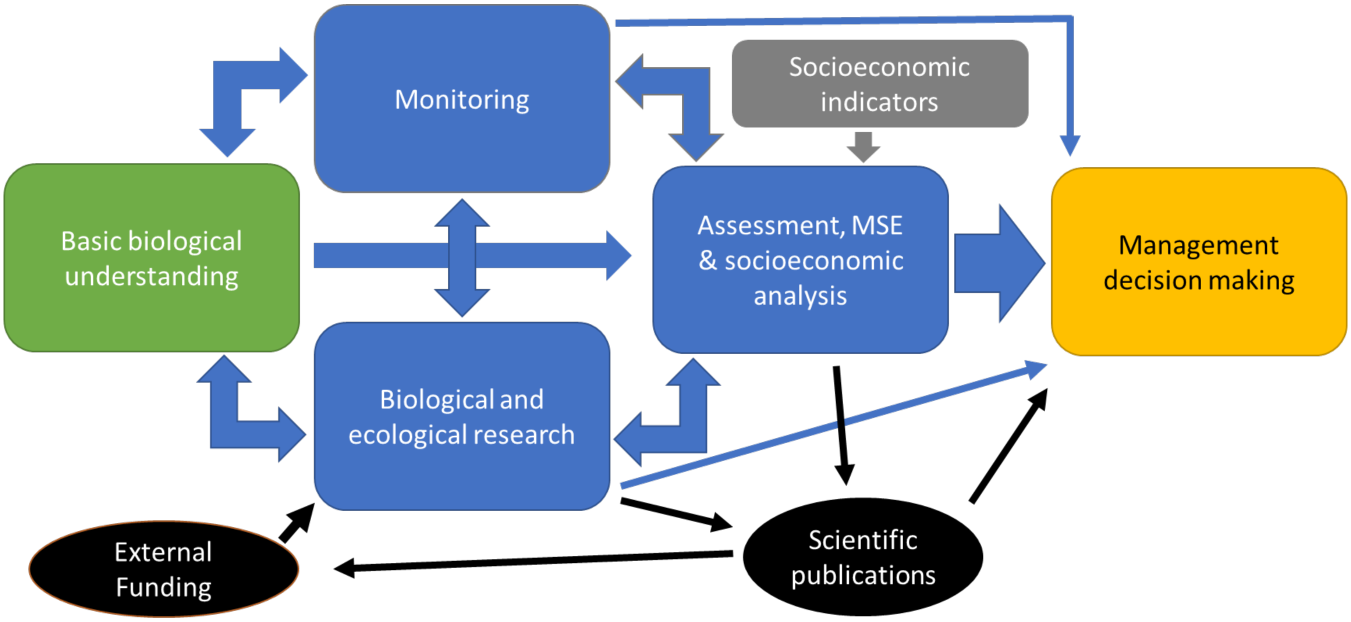

Figure 4. Flow of information from basic biological understanding of the Pacific halibut resource, through IPHC research components (monitoring, biological and ecological research, and assessment, MSE and socioeconomic analysis to management decision-making. Socioeconomic indicators (grey) provide another source of information beyond current monitoring programs. Arrows indicate the strength (size of the arow) and direction of information exchange. Also identified (in black) are the external links from funding and scientific publications which supplement the IPHC's internal process.

5.1 Research

Focal Area Objective	To reduce uncertainty in the current stock assessment and the resultant stock management advice provided to the Commission.
IPHC Website portal	https://www.iphc.int/management/science-and-research/stock-assessment

The IPHC conducts an annual stock assessment, using data from the fishery-independent setline survey (FISS), the commercial Pacific halibut and other fisheries, as well biological information from its research program. The assessment includes the Pacific halibut resource in the IPHC Convention Area, covering the Exclusive Economic Zones of Canada and the United States of America. Data sources are updated each year to reflect the most recent scientific information available for use in management decision making.

The 2020 stock assessment relied on an ensemble of four population dynamics models to estimate the probability distributions describing the current stock size, trend, and demographics. The ensemble is designed to capture both uncertainty related to the data and stock dynamics (due to estimation) as well as uncertainty related to our understanding of the way in which the Pacific halibut stock functions and is best approximated by a statistical model (structural uncertainty).

Stock assessment results are used as inputs for harvest strategy calculations, including mortality projection tables for the upcoming year that reflect the IPHCs harvest strategy policy and other considerations, as well as the harvest decision table which provides a direct tool for the management process. The harvest decision table uses the probability distributions from short-term (three year) assessment projections to evaluate the trade-offs between alternative levels of potential yield (catch) and the associated risks to the stock and fishery.

The stock assessment research priorities have been subdivided into four categories:

1) Assessment data collection and processing;
2) technical development
3) biological inputs; and
4) fishery yield.

It is important to note that ongoing monitoring, including the annual FISS and directed commercial landings sampling programs is not considered research and is therefore not included in this research priority list despite the critical importance of these collections. These are prescribed in the sections below.

5.1.2 Management Strategy Evaluation (MSE)

Focal Area Objective	To provide inputs that inform the MSE process, which will evaluate the consequences of alternative management options, known as harvest strategies.
IPHC Website portal	https://www.iphc.int/management/science-and-research/management-strategy-evaluation

Management Strategy Evaluation (MSE) is a process to evaluate the consequences of alternative management options, known as harvest strategies. MSE uses a simulation tool to determine how alternative harvest strategies perform given a set of pre-defined fishery and conservation objectives, taking into account the uncertainties in the system and how likely candidate harvest strategies are to achieve the chosen management objectives.

MSE is a simulation technique based on modelling each part of a management cycle. The MSE uses an operating model to simulate the entire population and all fisheries, factoring in management decisions, the monitoring program, the estimation model, and potential ecosystem effects using a closed-loop simulation.

Undertaking an MSE has the advantage of being able to reveal the trade-offs among a range of possible management decisions. Specifically, to provide the information on which to base a rational decision, given harvest strategies, preferences, and attitudes to risk. The MSE is an essential part of the process of developing, evaluating and agreeing to a harvest strategy.

The MSE process involves:

- Defining fishery and conservation objectives with the involvement of stakeholders and managers;
- Identifying harvest strategies (a.k.a. management procedures) to evaluate;
- Simulating a Pacific halibut population using those harvest strategies;
- Evaluating and presenting the results in a way that examines trade-offs between objectives;
- Applying a chosen harvest strategy for the management of Pacific halibut;
- Repeating this process in the future in case of changes in objectives, assumptions, or expectations.

There are many tasks that would improve the MSE framework and the presentation of future results to the Commission. The tasks can be divided into five general categories, which are common to MSE in general:

1. **Objectives**: The goals and objectives that are used in the evaluation.

2. **Management Procedures (MPs)**: Specific, well-defined management procedures that can be coded in the MSE framework to produce simulated TCEYs for each IPHC Regulatory Area.
3. **Framework**: The specifications and computer code for the closed-loop simulations including the operating model and how it interacts with the MP.
4. **Evaluation**: The performance metrics and presentation of results. This includes how the performance metrics are evaluated (e.g. tables, figures, and rankings), presented to the Commission and its subsidiary bodies, and disseminated for outreach.
5. **Application**: Specifications of how an MP may be applied in practice and re-evaluated in the future, including responses to exceptional circumstances.

All of these categories provide inputs and outputs of the MSE process, but the Framework category benefits most from the integration of biological and ecosystem research because the operating model, the simulation of the monitoring program, the estimation model, and potential ecosystem effects are determined from this knowledge.

Outcomes of the MSE process will not only inform the Commission on trade-offs between harvest strategies and assist in choosing an optimal strategy for management of the Pacific halibut resource, but will inform the prioritization of research activities related to fisheries monitoring, biological and ecological research, stock assessment, and fishery socio-economics.

5.1.3 Fishery socioeconomics

Focal Area Objective	To provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource in Canada and the United States of America.
IPHC Website portal	https://www.iphc.int/management/economic-research

Under the Convention, the IPHC's mandate is optimum management of the Pacific halibut resource, which necessarily includes a socioeconomic dimension. Fisheries economics is an active field of research around the world in support of fisheries policy and management. Adding the economic expertise to the Secretariat, the IPHC has become the first regional fishery management organization (RFMO) in the world to do so.

The goal of the IPHC economic study is 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 of America. The economic effects of changes to harvest policies can be far-reaching. Altered catch limits have an impact on the direct users of the stock (commercial harvesters, recreational anglers, subsistence fishers), but at the same time, there is a ripple effect through the economy. Fisheries operations create demand for inputs from other sectors while at the same time support industries further along the value chain that rely on the supply of fish, such as seafood processors. The viability of the Pacific halibut sectors is vital to the prosperity of fisheries-dependent households, having a considerable impact on coastal communities. The economic impacts are transmitted cross-regionally through business-to-business transactions (trade in commodities), labor commuting patterns, and the dissemination of profits along the value chain. There is also an inflow of economic benefits to the local economies from outside when non-residents partake in local leisure activities that would not attract the same number of visitors if not for the opportunity to catch this iconic fish of the Pacific Northwest. Understanding the formation of the price paid for Pacific halibut products by final consumers (end-users) is an important step in assessing the contribution of Pacific halibut to the Gross Domestic Product (GDP) along the entire value chain. Pacific halibut's value is also in its contribution to the diet through subsistence fisheries and importance to the traditional users of the resource. To native people, traditional fisheries constitute a vital aspect of local identity and a major factor in cohesion.

Understanding such a broad scope of regional impacts is essential for designing policies with desired effects depending on regulators' priorities. The ability to trace the socioeconomic impacts cross-regionally is particularly important in the context of shared resources and joint management, such as the case of collective management of Pacific halibut by the IPHC. Moreover, the study informs on the community impacts of the Pacific halibut resource throughout its range, highlighting communities particularly dependent on economic activities that rely on Pacific halibut. A good understanding of the localized effects is pivotal to policymakers who are often concerned about community impacts, particularly in terms of impact on employment opportunities and households' welfare. Integrating economic approaches with stock assessment and MSE can assist fisheries in bridging the gap between the current and the optimal economic performance without compromising the stock biological sustainability. Moreover, the study can also inform on socioeconomic drivers (human behavior, human organization) that affect the dynamics of fisheries, and thus contribute to improved accuracy of the stock assessment and the MSE. As such, it can provide a complementary resource for the development of harvest control rules, thus directly contributing to Pacific halibut management.

5.1.4 Biology and Ecology

Focal Area Objective	To identify and assess critical knowledge gaps in the biology and ecology of Pacific halibut within its known range, including the influence of environmental conditions on population and fishery dynamics.
IPHC Website portal	https://www.iphc.int/management/science-and-research/biological-and-ecosystem-science-research-program-bandesrp

Since its inception, the IPHC has had a long history of research activities devoted to describe and understand the biology of the Pacific halibut (*Hippoglossus stenolepis*). At present, the main objectives of the Biological and Ecosystem Science Research Program at IPHC are to: 1) identify and assess critical knowledge gaps in the biology of the Pacific halibut; 2) understand the influence of environmental conditions in the biology of the Pacific halibut and its fishery; and 3) apply the resulting knowledge to reduce uncertainty in current stock assessment models.

The primary biological research activities at the IPHC that follow Commission objectives and selected for their important management implications are identified and described in the proposed 5-Year Research Plan for the period 2022-2026. An overarching goal of the 5-Year Research Plan is to promote integration and synergies among the various research activities led by the IPHC in order to improve our knowledge of key biological inputs that feed into the stock assessment and MSE process. The goals of the main research activities of the 5-Year Research Plan are therefore aligned and integrated with the IPHC stock assessment and MSE processes. The IPHC Secretariat conducts research activities to address key biological issues based on the IPHC Secretariat's own input as well as input from the IPHC Commissioners, stakeholders and particularly from specific subsidiary bodies to the IPHC such, including the Scientific Review Board (SRB) and the Research Advisory Board (RAB).

The biological research activities contemplated in the 5-Year Research Plan and their specific aims are detailed in Section 6. Overall, the biological research activities at IPHC aim at providing information on factors that influence the biomass of the Pacific halibut population (e.g. distribution and movement of fish among IPHC Regulatory Areas, growth patterns and environmental influences on growth in larval, juvenile and adult fish, drivers of changes in size-at-age) and, specifically, of the spawning (female) population (e.g. reproductive maturity, skipped spawning, reproductive migrations) and resulting changes in population dynamics. Furthermore, the research activities of IPHC also aim, on one hand, at providing information on the survival of regulatory-discarded Pacific halibut in the directed fisheries with the objective to refine current estimates of discard mortality rates and develop best handling practices, and, on the other hand, at reducing whale depredation and Pacific halibut bycatch through gear modifications and through a better understanding of behavioral and physiological responses of Pacific halibut to fishing gear.

5.2 Monitoring

5.2.1 Fisheries data collection

Focal Area Objective	To collect fishery-dependent and fishery-independent data on the distribution and abundance of Pacific halibut, as well as other key biological data, through ongoing monitoring activities.
IPHC Website portal	***Fishery-dependent data:*** • https://www.iphc.int/datatest/commercial-fisheries • https://www.iphc.int/data/datatest/non-directed-commercial-discard-mortality-fisheries • https://www.iphc.int/data/datatest/pacific-halibut-recreational-fisheries-data • https://www.iphc.int/datatest/subsistence-fisheries • https://www.iphc.int/data/time-series-datasets ***Fishery-independent data:*** • https://www.iphc.int/management/science-and-research/fishery-independent-setline-survey-fiss • https://www.iphc.int/data/datatest/fishery-independent-setline-survey-fiss

5.2.1.1 ***Fishery-dependent data***. The IPHC estimates all Pacific halibut removals taken in the IPHC Convention Area and uses this information in its yearly stock assessment and other analyses. The data are compiled by the IPHC Secretariat and include data from Federal and State agencies of each Contracting Party. Specific activities in this area include:

- **Directed commercial fisheries data**: The IPHC Secretariat collects logbooks, otoliths, tissue samples, and associated sex-length-weight data from directed commercial landings coastwide (Fig. 5). A sampling rate is determined for each port by IPHC Regulatory Area. The applicable rate is calculated from the current year's mortality limits and estimated percentages of weight of fish landed, and estimated percentages of weight sampled in that port to allow for collection of the target number of biological samples by IPHC Regulatory Area. An example of the data collected and the methods used are provided in the annually updated directed commercial sampling manual (e.g. IPHC Directed Commercial Landings Sampling Manual 2021). Directed commercial fishery landings are recorded by the Federal and State agencies of each Contracting Party and summarized each year by the IPHC. Discard mortality for the directed commercial fishery is currently estimated using a combination of research survey (USA) and observer data (Canada).
    - Quality control and sampling rate estimations: [To be developed: QC practices, protocol references, and most recent sampling rate/design evaluation]
- **Non-directed commercial discard mortality data**: The IPHC accounts for non-directed commercial discard mortality by IPHC Regulatory Area and sector. Non-directed commercial discard mortality estimates are provided by State and Federal agencies of each Contracting Party, and compiled annually for use in the stock assessment and other analysis. https://www.iphc.int/data/datatest/non-directed-commercial-discard-mortality-fisheries.
- Non-directed commercial discard mortality of Pacific halibut is estimated because not all fisheries have 100% monitoring and not all Pacific halibut that are discarded are assumed to

die. The IPHC relies upon information supplied by observer programs run by Contracting Party agencies for non-directed commercial discard mortality estimates in most fisheries. Non-IPHC research survey information or other sources are used to generate estimates of non-directed commercial discard mortality in the few cases where fishery observations are unavailable. Trawl fisheries off Canada British Columbia are monitored and non-directed commercial discard mortality information is provided to IPHC by DFO. NOAA Fisheries operates observer programs off the USA West Coast and Alaska, which monitor the major groundfish fisheries. Data collected by those programs are used to estimate non-directed commercial discard mortality.

  - Quality control and sampling rate estimations: [To be developed: QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Subsistence fisheries data**: Subsistence fisheries are non-commercial, customary, and traditional use of Pacific halibut for direct personal, family, or community consumption or sharing as food, or customary trade. The primary subsistence fisheries are the treaty Indian Ceremonial and Subsistence fishery in IPHC Regulatory Area 2A off northwest Washington State (USA), the First Nations Food, Social, and Ceremonial (FSC) fishery in British Columbia (Canada), and the subsistence fishery by rural residents and federally-recognized native tribes in Alaska (USA) documented via Subsistence Halibut Registration Certificates (SHARC). Subsistence fishery removals of Pacific halibut, including estimated subsistence discard mortality, are provided by State and Federal agencies of each Contracting Party, estimated, and compiled annually for use in the stock assessment and other analysis. https://www.iphc.int/datatest/subsistence-fisheries.
  - Quality control and sampling rate estimations: [To be developed: QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Recreational fisheries data**: Recreational removals of Pacific halibut, including estimated recreational discard mortality, are provided by State agencies of each Contracting Party, estimated, and compiled annually for use in the stock assessment and other analysis. https://www.iphc.int/data/datatest/pacific-halibut-recreational-fisheries-data.

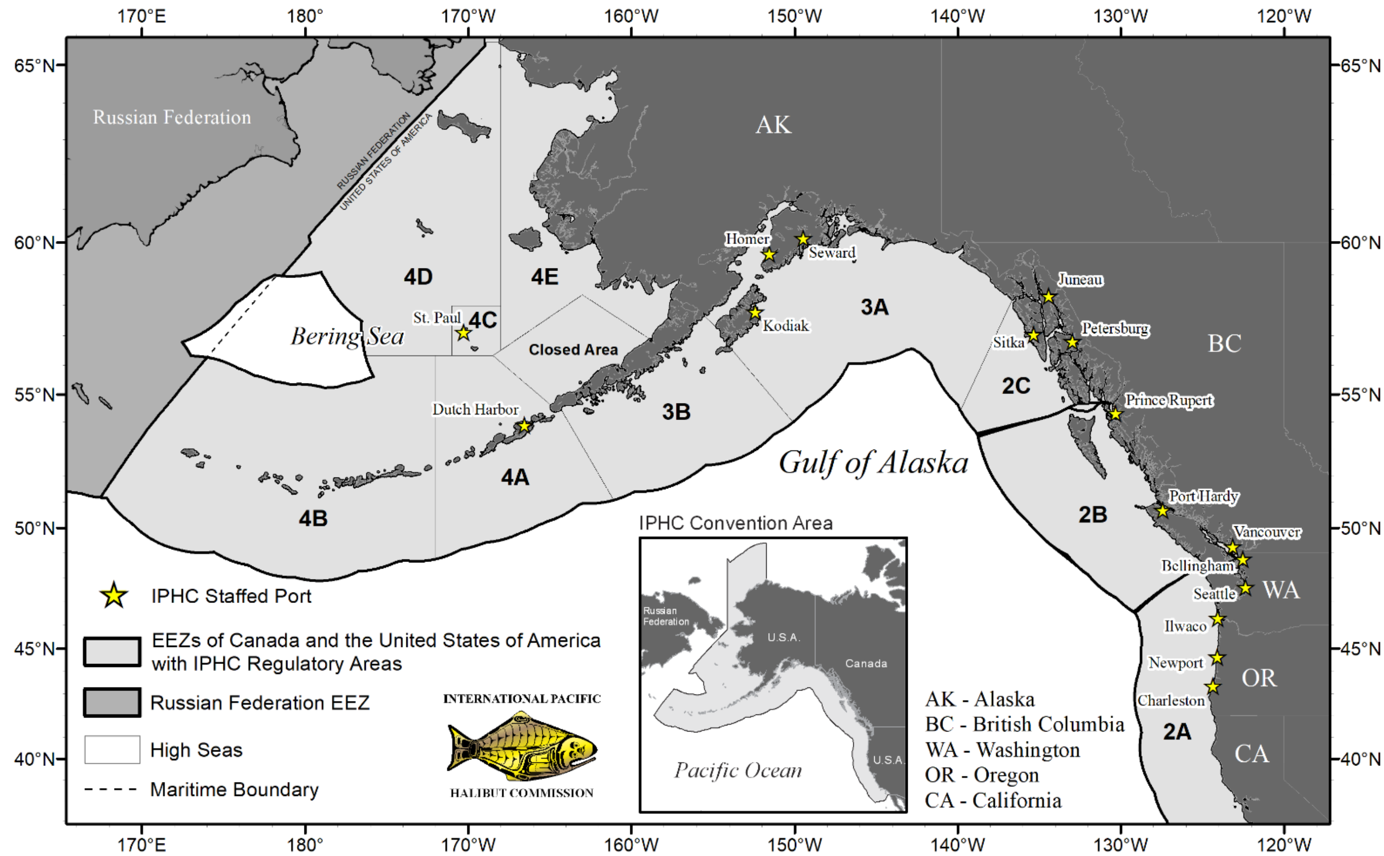

Figure 5. Ports where the IPHC has sampled directed commercial landings throughout the fishing period in recent years (note: ports sampled in a given year may change for operational reasons).

- Quality control and sampling rate estimations: [To be developed: QC practices, protocol references, and most recent sampling rate/design evaluation]

5.2.1.2 Fishery-independent data. Data collection and monitoring activities aimed at providing a standardised time-series of biological and ecological data that is independent of the fishing fleet.

- **Fishery-independent setline survey (FISS)**: The IPHC Fishery-Independent Setline Survey (FISS) provides catch-rate information and biological data on Pacific halibut that are independent of the fishery. These data, collected using standardized methods, bait, and gear during the summer of each year, are used to estimate the primary index of population abundance used in the stock assessment. The FISS is restricted to the summer months, but encompasses nearly all of the commercial fishing grounds in the Pacific halibut fishery, and almost all known Pacific halibut habitat in Convention waters outside the Bering Sea. The standard FISS grid totals 1,890 stations (Fig. 6). Biological data collected on the FISS (e.g. the length, weight, age, and sex composition of Pacific halibut) are used to monitor changes in biomass, growth, and mortality of the Pacific halibut population. In addition, records of non-target species caught during FISS operations provide insight into bait competition, and serve as an index of abundance over time, making them valuable to the potential management and avoidance of non-target species. An example of the data collected and the methods used are provided in the annually updated FISS sampling manual (e.g. IPHC FISS Sampling Manual 2021).

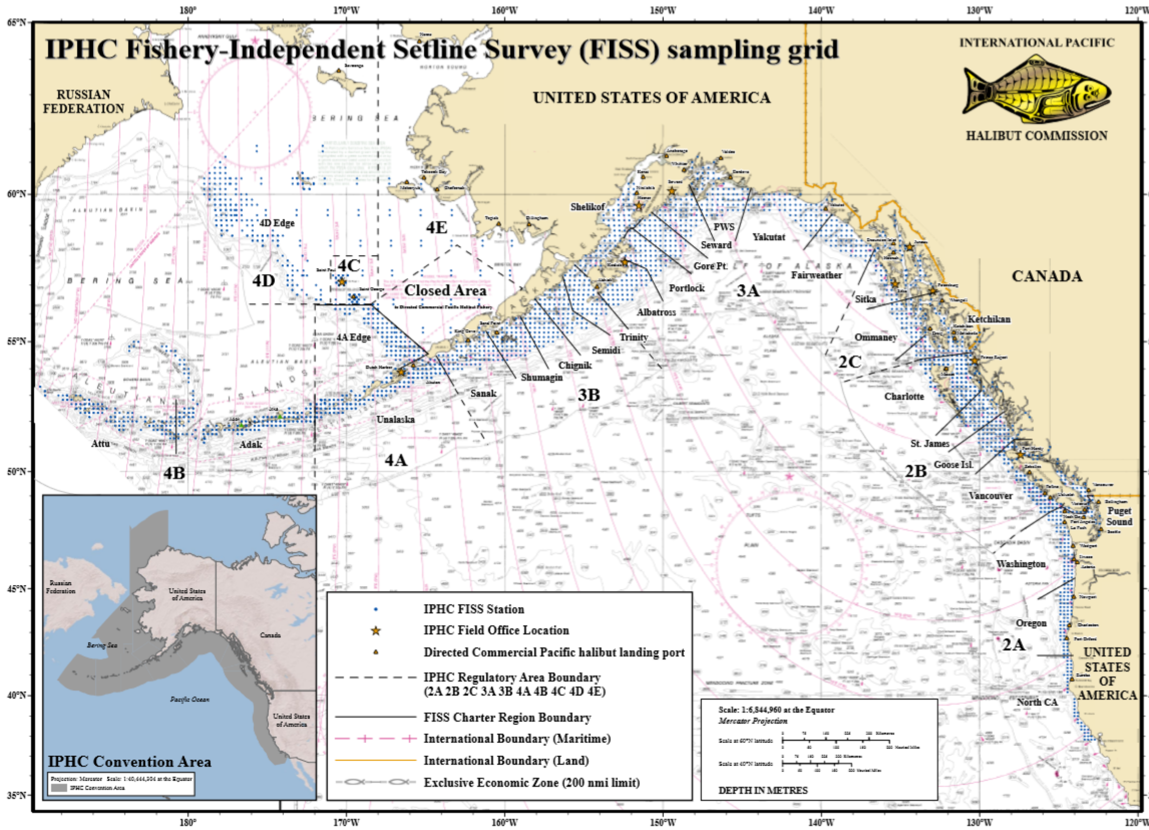

Figure 6. IPHC Fishery-Independent Setline Survey (FISS) with full sampling grid shown.

- Quality control and sampling rate estimations: Following a program of planned FISS expansions from 2014-19, a process of rationialisation of the FISS was undertaken. The goal was to ensure that, given constraints on resources available for implementing the FISS, station selection was such that precise density indices would be estimated with high precision and low bias. An annual design review process has been developed during which potential FISS designs for the subsequent three years are evaluated according to precision and bias criteria. The resulting proposed designs and their evaluation are presented for review at the June Scientific Review Board meeting (IPHC-2021-SRB018-R), and potentially modified following SRB input before presentation to the Commissioners at the Work Meeting and Interim Meeting. Annual biological sampling rates for each IPHC Regulatory Area are calculated based on the previous year's catch rates and an annual target of 2000 sampled fish (with 100 additional archive samples) ().
    - [To be developed: QC practices, protocol references, and most recent sampling rate/design evaluation]

- **Fishery-independent Trawl Survey (FITS)**: Since 1996, the IPHC has participated annually in the NOAA Fisheries trawl surveys operating in the Bering Sea (Fig. 7) and Aleutian Islands (Fig. 8) and Gulf of Alaska (Fig. 9). The information collected from Pacific halibut caught on these surveys, together with data from the IPHC Fishery-Independent Setline Survey (FISS) and commercial Pacific halibut data, are used directly in estimating indices of abundance and in the stock assessment and to monitor population trends, growth/size, and to supplement understanding of recruitment, and age composition of young Pacific halibut.

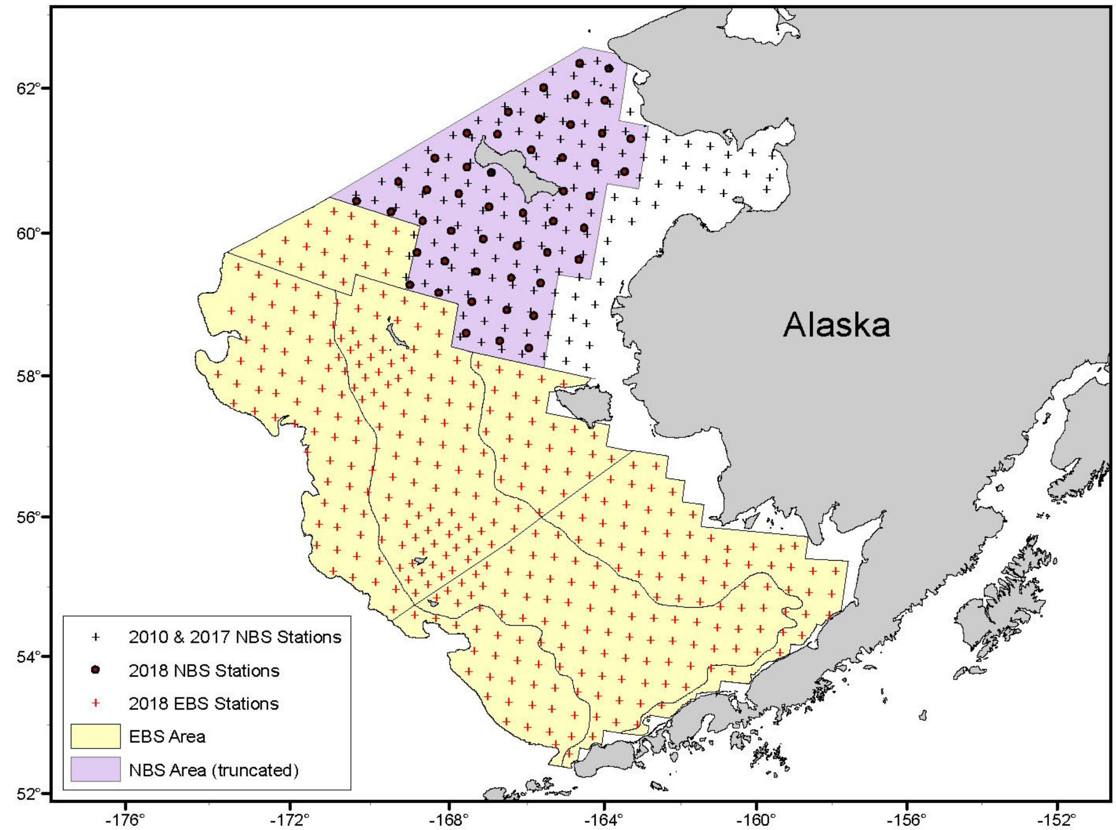

Figure 7. Sampling station design for the 2018 NOAA Bering Sea bottom trawl survey. Black dots are stations sampled in the 2018 "rapid-response" NBS trawl survey and black plus signs are stations sampled in the 2010 and 2017 standard NBS trawl surveys.

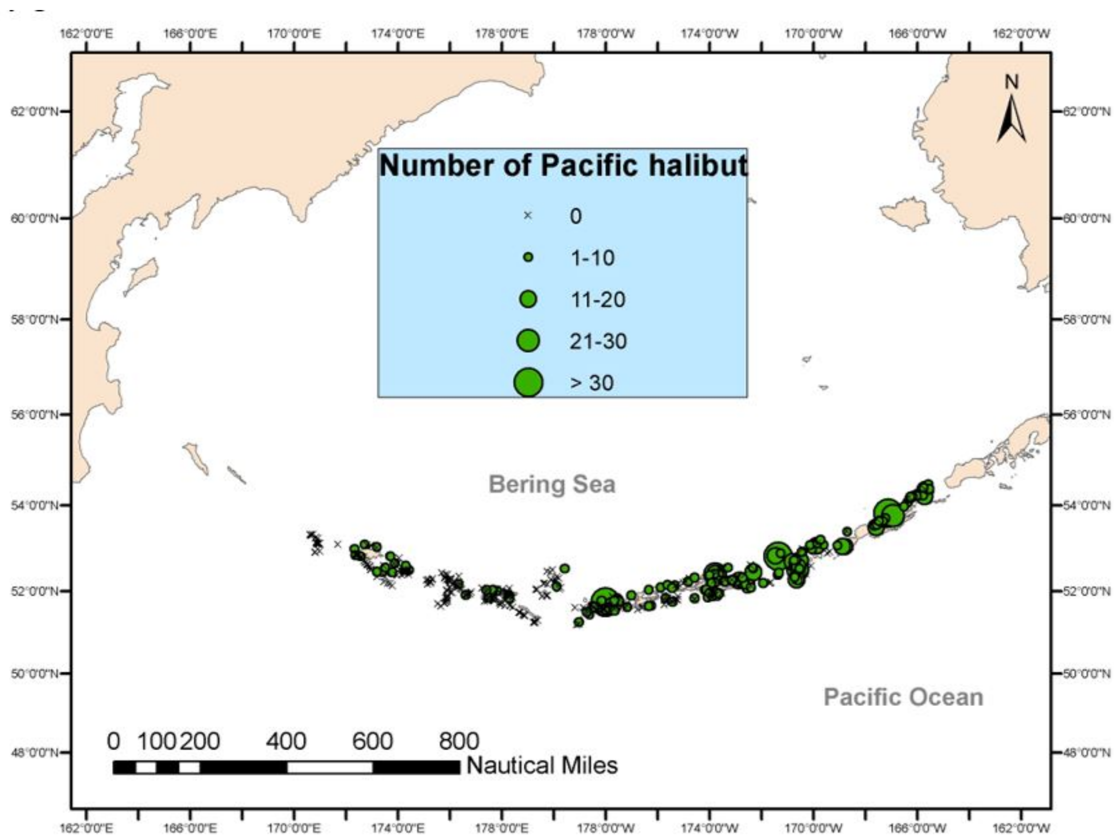

Figure 8. Sampling stations and catch for the 2018 NOAA-Fisheries Aleutian Islands bottom trawl survey.

[2021 Map to be added]

Figure 9. Sampling stations and catch for the yyyy NOAA-Fisheries Gulf of Alaska bottom trawl survey.

- Quality control and sampling rate estimations: [To be developed: QC practices, protocol references, and most recent sampling rate/design evaluation]

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

[In development – addition of the IPHC Scientific process – meeting schedule/linkages]

Research at IPHC can be classified as "use-inspired basic research" (Stokes 1997) which combines knowledge building with the application of existing and emerging knowledge to provide for the management of Pacific halibut. The four core focal areas: stock assessment, management strategy evaluation, fishery socioeconomics, and biology & ecology, all interact with each other as well as with fisheries monitoring activities in the IPHC integrated program of research and monitoring. Progress and knowledge building in one focal area influences and informs application in other core focal areas, also providing insight into future research priorities. The circular feedback loop is similar to the scientific method of observing a problem, creating a hypothesis, testing that hypothesis through research and analysis, drawing conclusions, and refining the hypothesis. The IPHC Secretariat has been working with IPHC advisory bodies, such as the Scientific Review Board (SRB), and the Commission to conduct scientific research in a way that utilizes the scientific method. Problems are often identified by an advisory body or Commission and hypotheses are developed by the IPHC Secretariat. Research is reviewed by the SRB and refined hypotheses are presented to advisory bodies and the Commission.

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

6.1 Research

6.1.1 Stock Assessment

Within the four assessment research categories, the following topics have been identified as top priorities in order to focus attention on their importance for the stock assessment and management of Pacific halibut. A brief narrative is provided here to highlight the specific use of products from these studies in the stock assessment.

6.1.1.1 Stock Assessment data collection and processing:

6.1.1.1.1 Commercial fishery sex-ratio-at-age via genetics and development of methods to estimate historical sex-ratios-at-age

Commercial fishery sex-ratio information has been found to be closely correlated with the absolute scale of the population estimates in the stock assessment, and has been identified as the greatest source of uncertainty since 2013. With only three years (2017-19) of commercial sex-ratio-at-age information available for the 2020 stock assessment, the annual genetic assay of fin clips sampled from the landings remains critically important. When the time series grows longer, it may be advantageous to determine the ideal frequency at which these assays need to be conducted. Development of approaches to use archived otoliths, scales or other samples to derive historical estimates (if possible) could provide valuable information on earlier time-periods (with differing fishery and biological properties), and therefore potentially reconcile some of the considerable historical uncertainty in the present stock assessment.

6.1.1.1.2 Whale depredation accounting and tools for avoidance

Whale depredation currently represents a source of unobserved and unaccounted-for mortality in the assessment and management of Pacific halibut. A logbook program has been phased in over the last several years, in order to record whale interactions observed by commercial fishermen. Estimation of depredation mortality, from logbook records and supplemented with more detailed data and analysis from the FISS represents a first step in accounting for this source of mortality; however, such estimates will likely come with considerable uncertainty. Reduction of depredation mortality through improved fishery avoidance and/or catch protection would be a preferable extension and/or solution to basic estimation. As such, research to provide the fishery with tools to reduce depredation is considered a closely-related high priority.

6.1.1.2 Stock Assessment technical development:

6.1.1.2.1 Maintaining coordination with the MSE

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

6.1.1.2.2 Data weighting

The stock assessment currently relies on iterative "Francis" weighting of the age compositional data using a multinomial likelihood formulation (Francis 2011). Exploration of alternative likelihoods, possibly including options that are estimable (rather than iterated), such as the Dirichlet-multinomial or the Logistic-normal has been ongoing since the full assessment analysis conducted in 2019. Use of alternative likelihoods could increase computational efficiency and better represent the uncertainty in data weighting.

6.1.1.2.3 Environmental covariates to recruitment

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

6.1.1.2.4 'Leading' parameter estimation

Stock assessments are generally very sensitive to the estimates of leading parameters (stock-recruitment parameters, natural mortality, etc.). For Pacific halibut some of these are fully integrated into the estimation uncertainty (average unexploited recruitment), or partially integrated (e.g., estimation of natural mortality in two of the four models). As time-series of critically informative data sources like the FISS and the sex-ratio of the commercial landings grow longer it may be possible to integrate additional leading parameters directly in the assessment models and/or include them as nested models within the ensemble. Evaluation of several such alternatives was provided in the 2019 full assessment and should be continued to be explored.

6.1.1.3 Stock Assessment biological inputs:

6.1.1.3.1 Maturity, skip-spawning and fecundity

Management of Pacific halibut is currently based on reference points that rely on relative female spawning biomass. Therefore, any changes to our understanding of reproductive output – either across age/size (maturity), over time (skip spawning) or as a function of body mass (fecundity) are crucially important. Each of these components directly affects the annual reproductive output estimated in the assessment. Ideally, the IPHC would have a program in place to monitor each of these three reproductive traits over time and use that information in the estimation of the stock-recruitment relationship, and the annual reproductive output relative to reference points. This would reduce the potential for biased time-series estimates created by non-stationarity in these traits (illustrated via sensitivity analyses in several of the recent assessments). However, at present we have only historical time-aggregated estimates of maturity and fecundity schedules. Therefore, the current research priority is to first update our estimates for each of these traits to reflect current environmental and biological conditions. After current stock-wide estimates have been achieved, a program for extending this information to a time-series via transition from research to monitoring can be developed.

6.1.1.3.2 Stock structure of IPHC Regulatory Area 4B relative to the rest of the convention area

The current stock assessment and management of Pacific halibut assume that IPHC Regulatory Area 4B is functionally connected with the rest of the stock, i.e., that recruitment from other areas can support harvest in Area 4B and that biomass in Area 4B can produce recruits that may contribute to other Areas. Tagging (Webster et al. 2013) and genetic (Drinan et al. 2016) analyses have indicated the potential for Area 4B to be demographically isolated. An alternative to current assessment and management structure would be to treat Area 4B separately from the rest of the coast. This would not likely have a large effect on the coastwide stock assessment as Area 4B represents only approximately 5% of the surveyed stock (Stewart et al. 2021b). However, it would imply that the specific mortality limits for Area 4B could be very important to local dynamics and should be separated from stock-wide trends. Therefore, information on the stock structure for Area 4B has been identified as a top priority.

6.1.1.3.3 Meta-population dynamics (connectivity) of larvae, juveniles and adults

The stock assessment and current management procedure treat spawning output, juvenile Pacific halibut abundance, and fish contributing to the fishery yield as equivalent across all parts of the Convention Area. Information on the connectivity of these life-history stages could be used for a variety of improvements to the assessment and current management procedure, including: investigating recruitment covariates, structuring spatial assessment models, identifying minimum or target spawning biomass levels in each Biological Region, refining the stock-recruitment relationship to better reflect source-sink dynamics and many others. Spatial dynamics have been highlighted as a major source of uncertainty in the Pacific halibut assessment for decades, and will continue to be of high priority until they are better understood.

6.1.1.4 Stock Assessment fishery yield:

6.1.1.4.1 Biological interactions with fishing gear

In 2020, 16% of the total fishing mortality of Pacific halibut was discarded (Stewart et al. 2021b). Discard mortality rates can vary from less than 5% to 100% depending on the fishery, treatment of the catch and other factors (Leaman and Stewart 2017). A better understanding of the biological underpinnings for discard mortality could lead to increased precision in these estimates, avoiding potential bias in the stock assessment. Further, improved biological understanding of discard mortality mechanisms could allow for reductions in this source of fishing mortality, and thereby increased yield available to the fisheries.

6.1.1.4.2 Guidelines for reducing discard mortality

Much is already known about methods to reduce discard mortality, in non-directed fisheries as well as the directed commercial and recreational sectors. Promotion and adoption of best handling practices could reduce discard mortality, lead to greater retained yield, and reduce the potential uncertainty associated with large quantities of estimated mortality due to discarding.

Looking forward, the IPHC has recently considered adding close-kin genetics (e.g. Bravington et al. 2016) to its ongoing research program. Close-kin mark-recapture can potentially provide estimates of the absolute scale of the spawning output from the Pacific halibut population. This type of information can be fit directly in the stock assessment, and if estimated with a reasonable amount of precision, even a single data point could substantially reduce the uncertainty in the scale of total population estimates. Further, close-kin genetics may provide independent estimates of total mortality (and therefore natural mortality conditioned on catch-at-age), relative fecundity-at-age, and the spatial dynamics of spawning and recruitment. All of these quantities could substantially improve the structure of the current assessment and reduce uncertainty. Data collection of genetic samples from 100% of the sampled commercial landings has been in place since 2017 (as part of the sex-ratio monitoring) and routine comprehensive genetic sampling of FISS catch will begin in 2021. The genetic analysis required to produce data allowing the estimation of reproductive output and other population parameters from close-kin mark-recapture modelling is both complex and expensive, and it could take several years for this project to get fully underway.

6.1.2 Management Strategy Evaluations

MSE priorities have been subdivided into three categories: 1) biological parameterisation, 2) fishery parameterization, and 3) technical development. Research provides specifications for the MSE simulations, such as inputs to the OM, but another important outcome of the research is to define the range of plausibility to include in the MSE simulations as a measure of uncertainty. The following topics have been identified as top priorities.

6.1.2.1 MSE Biological and population parameterization

6.1.2.1.1 Distribution of life stages and stock connectivity

Research topics in this category will mainly inform parameterization of movement in the OM, but will also provide further understanding of Pacific halibut movement, connectivity, and the temporal variability. This knowledge may also be used to refine specific MSE objectives to reflect reality and plausible outcomes.

This research includes examining larval and juvenile distribution which is a main source of uncertainty in the OM that is currently not fully incorporated. Outcomes will assist with conditioning the OM, verify patterns simulated from the OM, and provide information to develop reasonable sensitivity scenarios to test the robustness of MPs.

Also included in this number one priority is stock structure research, especially with regard to IPHC Regulatory Area 4B. The dynamics of this IPHC Regulatory Area are not fully understood and it is useful to continue research on the connectivity of IPHC Regulatory Area 4B with other IPHC Regulatory Areas.

Finally, genomic analysis of population size is also included in this ranked category because that would help inform development of the OM as well as the biological sustainability objective related to maintaining a minimum spawning biomass in each IPHC Regulatory Area. An understanding of the spatial distribution of population size will help to inform this objective as well as the OM conditioning process.

6.1.2.1.2 Spatial spawning patterns and connectivity between spawning populations

An important parameter that can influence simulation outcomes is the distribution of recruitment across Biological Regions. Continued research in this area will improve the OM and provide justification for parameterising temporal variability. Research includes assigning individuals to spawning areas and establishing temporal and spatial spawning patterns. Outcomes may also provide information on recruitment strength and the relationship with environmental factors. For example, recent work by Sadorus et al (2020) used a biophysical and spatio-temporal models to examine connectivity across the Bering Sea and Gulf of Alaska. Furthermore, close-kin mark-recapture (Bravington et al. 2016) may provide insights into spatial relationships between juveniles and adults as well as abundance in specific regions.

6.1.2.1.3 Understanding growth variation

Changes in the average weight-at-age of Pacific halibut is one of the major drivers of changes in biomass over time. The OM currently simulates temporal changes in weight-at-age via a random autocorrelated process which is unrelated to population size or environmental factors. Ongoing research in drivers related to growth in Pacific halibut will help to improve the simulation of weight-at-age.

6.1.2.2 MSE fishery parameterization

The specifications of fisheries and their parameterizations involved consultation with Pacific halibut stakeholders but some aspects of those parameterizations benefit from targeted research. One specific example is knowledge of discarding and discard mortality rates in directed and non-directed fisheries. Discard mortality can be a significant source of fishing mortality in some IPHC Regulatory Areas and appropriately modelling that mortality will provide a more robust evaluation of MPs.

6.1.2.1 MSE technical development

Technical improvements to the MSE framework will allow for rapid development of alternative operating models and efficient simulation of management strategies for future evaluation.

6.1.2.1.1 Alternative migration scenarios

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

6.1.2.1.1 Realistic simulations of estimation error

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

6.1.2.1.2 Incorporate additional sources of implementation uncertainty

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

6.1.2.2 MSE Program of Work for 2021–2023

Following the 11th Special Session of the IPHC, an MSE program of work for 2021–2023 was developed. Seven tasks were identified that pertained to further developments of the MSE framework, evaluation of alternative MPs, and improvements in evaluation and presentation of results. Table 1 lists these tasks and provides a brief description. Additional details can be found in the program of work available on the MSE webpage.

Table 1. Tasks recommended by the Commission at SS011 (IPHC-2021-SS011-R para 7) for inclusion in the IPHC Secretariat MSE Program of Work for 2021–23.

ID	Category	Task	Deliverable
F.1	Framework	Develop migration scenarios	Develop OMs with alternative migration scenarios
F.2	Framework	Implementation variability	Incorporate additional sources of implementation variability in the framework
F.3	Framework	Develop more realistic simulations of estimation error	Improve the estimation model to more adequately mimic the ensemble stock assessment
F.5	Framework	Develop alternative OMs	Code alternative OMs in addition to the one already under evaluation.
M.1	MPs	Size limits	Identification, evaluation of size limits
M.3	MPs	Multi-year assessments	Evaluation of multi-year assessments
E.3	Evaluation	Presentation of results	Develop methods and outputs that are useful for presenting outcomes to stakeholders and Commissioners

6.1.3 Fishery socioeconomics

The priorities of the IPHC fisheries socioeconomics program can be subdivided into four categories. These are described below.

6.1.3.1 Primary economic data collection

In order to accurately capture the economic impact of the Pacific halibut, the IPHC designed a series of surveys to gather information from the sectors relying on the Pacific halibut resource, intended to fill identified socioeconomic data gaps. The survey target groups are commercial fishers, processing plant operators, and charter business owners. The goal of the survey is to improve the understanding of each sector's production structure (i.e., data on the distribution of revenue between profit and expenditure items), profitability (including the viability of the sector depending on the stock condition), and distribution of earnings. The compiled survey data, together with secondary data from various governmental and non-governmental sources, serve as an input to the economic impact assessment model.

6.1.3.2 Development of the Pacific halibut multiregional economic impact assessment (PHMEIA)

Pacific halibut multiregional economic impact assessment (PHMEIA) model is a multiregional model based on a social accounting matrix (SAM) framework that describes the economic interdependencies between sectors and regions developed to assess the economic contribution of Pacific halibut resource to the economy of the United States and Canada. The model describes 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. In addition, the PHMEIA model traces the flow of earnings from the harvest stage to the beneficial owners of the resource, accounting for cross-regional income spillovers, which represent economic stimulus in the regions other than the one in which the harvest occurs.

It is important to note that accurate characterization of the Pacific halibut sectors in the PHMIA model requires active participation of IPHC stakeholders, including commercial fishers, processing plant operators, and charter business owners in developing the necessary data for analysis (see section 6.1.3.1).

The following components have been identified as priorities for improving the PHMEIA model for it to better serve management decisions.

6.1.3.2.1 Expanding the static SAM model to a computable general equilibrium model

Relaxing the assumption of fixed technical coefficients by specifying these coefficients econometrically as a function of relative prices of inputs is one of the most compelling extensions to the static SAM model. Such models, generally referred to as computable general equilibrium (CGE) models, require research to develop credible functional relationships between prices and consumption that would guide economic agents' behavior in the model. The CGE approach is a preferred way forward when expanding the model usability and applying it in conjunction with the Pacific halibut management strategy evaluation. In addition, the dynamic model is well suited to analyze the impact of a broad suite of policies or external factors that would affect the stock over time.

6.1.3.2.2 Improving the spatial granularity of the SAM model

Extending the community analysis beyond a simplified approach relying on the calculated multiplier effects and local exposure to the region's Pacific halibut economic impact (as described in the IPHC-2021-SRB018-09, section *Community impacts in Alaska*) to a full community level (or any other spatial scale) SAM-based model requires identifying the economic relationships between different sectors or industries (including both seafood and non-seafood industries) within each broader-defined region, this including deriving estimates on intra-regional trade in commodities and flow of earnings. This extension of the current model has a great potential for more accurate estimates of the community effects. Detailing the geography of impacts of the Pacific halibut fisheries, paying particular attention to quantifying leakage of economic benefits from communities strongly dependent on fisheries, will provide a coherent picture of the exposure of fisheries-dependent households by location to changes in resource availability.

6.1.3.2.3 Study of recreational demand

It is important to note that while it is reasonable to assume that changes in harvest limits have a relatively proportional impact on production by commercial fishers (unless these are dramatic and imply fleet restructure or a significant shift in prices), the effects on the recreational sector are not so straightforward. A separate study estimating changes in saltwater recreational fishing participation as a response to the changing recreational harvest limits applicable to Pacific halibut is necessary to assess policy impacts in the recreational sector rather than provide an economic impact snapshot. Such studies typically require surveying recreational fishers, but adoption of alternative approaches will be also assessed.

6.1.3.2.4 Study of demand for Pacific halibut products

Catches can be converted to revenues, but one has to determine what price to multiply harvests by. Since price fluctuates with harvest levels, pragmatic assessment of harvest limits changes needs to be supplemented with a model of demand for Pacific halibut. The demand-adjusted prices provide more economics-sound projections of gross revenues in the sector. The demand model (e.g. Synthetic Inverse Demand System) can also be used to estimate final consumer benefits from changing Pacific halibut harvests and prices (i.e., consumer surplus).

6.1.3.2.5 Study of demand for Pacific halibut products

In 2021, fresh Alaskan Pacific halibut fillets routinely sold for USD 24-28 a pound, and often more, downtown Seattle (e.g. USD 38 at Pike Place Market). Pacific halibut dishes at the restaurants typically sell for USD 37-43 for a dish including a 6oz fish portion. The complete path of landed fish, from the hook to the plate, includes, besides harvesters, processors, and wholesalers, also retailers, and services. Pacific halibut is primarily sold to upscale retail outlets and white-tablecloth restaurants, resulting in a high price markup in the supply chain.

Understanding the formation of the price paid by final consumers (end-users) is an important step in assessing the contribution of Pacific halibut to the Gross Domestic Product (GDP) along the entire value chain. However, it is important to note that there are many seafood substitutes available to buyers. Thus, including economic impacts beyond processors and wholesalers in the economic impact assessment (as opposed to assessing the snapshot contribution to the GDP) would be misleading when considering that it is unlikely that supply shortage would result in a noticeable change in retail or services level gross revenues.

6.1.3.2.6 Uncertainty in the PHMEIA model

The PHMEIA model results focus on the magnitude of the Pacific halibut contribution to the economy and its spatial distribution. To increase confidence in the PHMEIA results, the model needs to consider sources of input variations and the cumulative effect of interactions among them. The natural next step is to conduct sensitivity analysis to account for the uncertainties in the system. The current framework would benefit from proposing methods for calculating the range (confidence intervals) of impacts from input variations within a PHMEIA framework, explicitly accounting for multiple sources of input variations.

6.1.3.2.7 Assessment of the economic impact of other sources of Pacific halibut mortality

All-sectors-encompassing quantitative assessment of the economic impact of the Pacific halibut resource necessitates the development of a methodological approach for the remaining sources of Pacific halibut mortality, including subsistence fishing, bycatch, and research catch. Methods adopted for the commercial and charter sector are not adequate for this portion of the harvest.

As a part of the socioeconomic program, the IPHC established a collaboration with the Alaska Fisheries Science Center (AFSC) and the Alaska Department of Fish and Game (ADF&G), and will be participating in the following project: Fish, Food, and Fun: Exploring the Nexus of Subsistence, Personal Use, and Recreational Fisheries in Alaska (SPURF project). The SPURF project aims to understand the intersection of Alaska subsistence, personal use, and marine recreational fisheries in fulfilling household food needs and contribute to an improved understanding of the economic and social values of non-commercial Alaska fisheries. The project is scheduled to commence in Fall 2021.

6.1.3.3 Provide stakeholders with a user-friendly tool visualizing the spatial distribution of socioeconomic impacts

The complexity of Pacific halibut supply-side restriction in the form of region-based allocations suggests the need for a tool enabling regulators to assess various combinations of quota allocations easily. To address this, the results of the PHMEIA model are complemented by an interactive web-based application allowing users to estimate and visualize joint economic impacts based on custom changes simultaneously applied to all IPHC-managed Pacific halibut producing areas. In addition, the app highlights the spatial variation of the economic impacts and the importance of cross-regional flows in assessing the dependence of fishing communities on the Pacific halibut resource.

The application will be continuously updated and expanded as the project evolves along the lines described in section 6.1.3.2.

6.1.3.4 Provide input to the management strategy evaluation

MSE implementation has been generally oriented towards biological target reference points despite socioeconomic objectives being prevalent in the legislation of the USA and Canada. The PHMIA model may be used alongside the Pacific halibut MSE framework to translate alternative management options (harvest strategies) and resulting harvest allocations by IPHC Regulatory Area directly to socioeconomic performance metrics by region. Socioeconomic performance metrics presented alongside already developed biological/ecological performance metrics will bring the human dimension to the MSE framework, adding to the IPHC's portfolio of tools for assessing policy-oriented issues for the Pacific halibut throughout the Convention Area.

6.1.4 Biology and Ecology

6.1.4.1 Migration and Population Dynamics. Genetic and genomic studies aimed at improving current knowledge of Pacific halibut migration and population dynamics throughout all life stages in order to achieve a complete understanding of stock structure and distribution across the entire distribution range of Pacific halibut in the North Pacific Ocean and the biotic and abiotic factors that influence it (specifically excluding satellite tagging). Specific objectives in this area include:

- Improve current knowledge of the genetic structure of the Pacific halibut population through the use of state-of-the-art low-coverage whole genome resequencing approaches. Establishment of genetic signatures of spawning sites.
- Improve our understanding of the mechanisms and magnitude of larval connectivity in the North Pacific Ocean. Identification of environmental and biological predictors of larval abundance and recruitment.
- Improve our understanding of spawning site contributions to nursery/settlement areas in relation to year-class, recruit survival and strength, and environmental conditions in the North Pacific Ocean. Measure of genetic diversity of Pacific halibut juveniles from the eastern Bering Sea and the Gulf of Alaska.
- Improve our understanding of the relationship between nursery/settlement origin and adult distribution and abundance over temporal and spatial scales. Genomic assignment of individuals to source populations and assessment of distribution changes.

- Integrate analyses of Pacific halibut connectivity and distribution changes by incorporating genomic approaches.
- Improve estimates of population size, migration rates among geographical regions, and demographic parameters (e.g. fecundity-at-age, survival rate), through the application of close-kin mark-recapture-based approaches.
- Improve our understanding of the influences of oceanographic and environmental variation on connectivity, population structure and adaptation at a genomic level using seascape genomics approaches.

6.1.4.2 ***__Reproduction__***. Studies aimed primarily at addressing two critical issues for stock assessment analysis based on estimates of female spawning biomass: 1) the sex ratio of the commercial catch and 2) maturity estimations. Specific objectives in this area include:

- Continued improvement of genetic methods for accurate sex identification of commercial landings from fin clips and otoliths in order to incorporate recent and historical sex-at-age information into the stock assessment process.
- Improve our understanding of the temporal progression of reproductive development and gamete production during an entire annual reproductive cycle in female and male Pacific halibut.
- Update current maturity-at-age estimates.
- Provide estimates of fecundity-at-age and fecundity-at-size.
- Investigate the possible presence of skip spawning in Pacific halibut females.
- Improve accuracy in current staging criteria of maturity status used in the field.
- Investigate possible environmental effects on the ontogenetic establishment of the phenotypic sex and their influence on sex ratios in the adult Pacific halibut population.
- Improve our understanding of potential temporal and spatial changes in maturity schedules and spawning patterns in female Pacific halibut and possible environmental influences.
- Improve our understanding of the genetic basis of variation in age and/or size-at-maturity, fecundity, and spawning timing, by conducting genome-wide association studies.

6.1.4.3 ***__Growth__***. Studies aimed at describing the role of factors responsible for the observed changes in size-at-age and at evaluating growth and physiological condition in Pacific halibut. Specific objectives in this area include:

- Evaluate possible variation in somatic growth patterns in Pacific halibut as informed by physiological growth markers, physiological condition, energy content and dietary influences.
- Investigate the effects of environmental and ecological conditions that may influence somatic growth in Pacific halibut. Evaluate the relationship between somatic growth and temperature and trophic histories in Pacific halibut through the integrated use of physiological growth markers.
- Improve our understanding of the genetic basis of variation in somatic growth and size-at-age by conducting genome-wide association studies.

6.1.4.4 ***Mortality and Survival Assessment***. Studies aimed at providing updated estimates of discard mortality rates (DMRs) for Pacific halibut in the guided recreational fisheries and at evaluating methods for reducing mortality of Pacific halibut. Specific objectives in this area include:

- Provide information on the types of fishing gear and fish handling practices used in the Pacific halibut recreational (charter) fishery as well as on the number and size composition of discarded Pacific halibut in this fishery.
- Establish best handling practices for reducing discard mortality of Pacific halibut in recreational fisheries.
- Investigate new methods for whale avoidance and/or deterrence for the reduction of Pacific halibut depredation by whales and for improved estimation of depredation mortality.
- Investigate physiological and behavioral responses of Pacific halibut to fishing gear in order to reduce Pacific halibut bycatch.

6.1.4.5 ***Fishing Technology Studies aimed …***

<<In development>>>

6.2 Monitoring

6.2.1 ***Fishery-dependent data***. …………………

- **Directed commercial fisheries data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………
- **Non-directed commercial discard mortality data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………
- **Subsistence fisheries data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………
- **Recreational fisheries data**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………

6.2.2 ***Fishery-independent data***. Data collection and monitoring activities aimed at providing a standardised time-series of biological and ecological data that is independent of the fishing fleet.

- **Fishery-independent setline survey (FISS)**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development……….
- **Fishery-independent Trawl Survey (FITS)**: ………In development…………
- FUTURE Quality control and sampling rate estimations: ………In development…………

7. Conclusion and future review/amendments

<<In development>>>

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Clark, W.G., Hare, S.R., Parma, A.M., Sullivan, P.J., and Trumble, R.J. 1999. Decadal changes in growth and recruitment of Pacific halibut (*Hippoglossus stenolepis*). Canadian Journal of Fisheries and Aquatic Sciences 56: 242-252.

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APPENDICES

Appendix I: Multi-year tactical activity matrix

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

Appendix III: Proposed schedule of outputs

Appendix IV: Proposed schedule with funding and staffing indicators

APPENDIX I

Multi-year tactical activity matrix

<<In development>>

APPENDIX II

Outcomes of the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21) (IPHC–2019–BESRP-5YP)

A. Outcomes by Research Area:

1. Migration and Distribution.

1. Larval and juvenile connectivity and early life history studies. Planned research outcomes: improved understanding of larval and juvenile distribution.

Main results:

- Larval connectivity between the Gulf of Alaska and the Bering Sea occurs through large island passes across the Aleutian Island chain.
- The degree of larval connectivity between the Gulf of Alaska and the Bering Sea is influenced by spawning location.
- Spawning locations in the western Gulf of Alaska significantly contribute Pacific halibut larvae to the Bering Sea.
- Pacific halibut juveniles counter-migrate from inshore settlement areas in the eastern Bering Sea into the Gulf of Alaska through Unimak Pass.
- Elemental signatures of otoliths from juvenile Pacific halibut vary geographically at a scale equivalent to IPHC regulatory areas.

Integration with Stock Assessment and MSE: [In development]

Publications:

- Sadorus, L.; Goldstein, E.; Webster, R.; Stockhausen, W.; Planas, J.V.; Duffy-Anderson, J. Multiple life-stage connectivity of Pacific halibut (*Hippoglossus stenolepis*) across the Bering Sea and Gulf of Alaska. Fisheries Oceanography. 2021. 30:174-193. doi: https://doi.org/10.1111/fog.12512.
- Loher, T., Bath, G. E., Wischniowsky, S. The potential utility of otolith microchemistry as an indicator of nursery origins in Pacific halibut (*Hippoglossus stenolepis*) in the eastern Pacific: the importance of scale and geographic trending. Fisheries Research. 243: 106072. https://doi.org/10.1016/j.fishres.2021.106072.

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

- Evaluate the level of genetic diversity among juvenile Pacific halibut in the Gulf of Alaska and the Bering sea due to admixture.
- Assignment of individual juvenile Pacific halibut to source populations.

2. **Reproduction**.
    1. Sex ratio of commercial landings. Planned research outcomes: sex ratio information.

Main results:

- Establishment of TaqMan-based genetic assays for genotyping Pacific halibut in the IPHC Biological Laboratory.
- Sex ratio information for the 2017-2020 commercial landings.
- Transfer of genotyping efforts for sex identification to IPHC monitoring program.

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

- Monitoring effort.

    2. Histological maturity assessment. Planned research outcomes: updated maturity schedule.

Main results:

- Oocyte developmental stages have been characterized and fully described in female Pacific halibut for the first time.
- Oocyte developmental stages have been used for the classification of female developmental stages and to be able to characterize female Pacific halibut as group synchronous with determinate fecundity.
- Female developmental stages have been used for the classification of female reproductive phases and to be able to characterize female Pacific halibut as following an annual reproductive cycle with spawning in January and February.
- Female developmental stages and reproductive phases of females collected in the central Gulf of Alaska have been used to identify the month of August as the time of the transition between the Vtg2 and Vtg3 developmental stages marking the beginning of the spawning capable reproductive phase.
- Future gonad collections for revising maturity schedules and estimating fecundity can be conducted in August during the FISS.

Publications:

- Fish, T., Wolf, N., Harris, B.P., Planas, J.V. A comprehensive description of oocyte developmental stages in Pacific halibut, *Hippoglossus stenolepis*. Journal of Fish Biology. 2020. 97: 1880-1885. doi: 10.1111/jfb.14551.
- Fish et al. 2021. In Preparation.

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

- Revision of maturity schedule by gonad collection during the FISS, as informed by previous studies on reproductive development.
- Estimation of fecundity by age and size, as informed by previous studies demonstrating determinate fecundity.

3. **Growth**.

    1. Identification of physiological growth markers and their application for growth pattern evaluation. Planned research outcomes: informative physiological growth markers.

Main results:

- Transcriptomic profiling by RNAseq of white skeletal muscle from juvenile Pacific halibut subjected to growth suppression and to growth stimulation resulted in the identification of a number of genes that change their expression levels in response to growth manipulations.
- Proteomic profiling by LC-MS/MS of white skeletal muscle from juvenile Pacific halibut subjected to growth suppression and to growth stimulation resulted in the identification of a number of proteins that change their abundance in response to growth manipulations.
- Genes and proteins that changed their expression levels in accordance to changes in the growth rate in juvenile Pacific halibut were selected as putative growth markers for future studies on growth pattern evaluation.

Publications:

- Planas et al. 2021. In Preparation.

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

- Application of identified growth markers in studies aiming at investigating environmental influences on growth patterns and at investigating dietary influences on growth patterns and physiological condition.

    2. Environmental influences on growth patterns. Planned research outcomes: information on growth responses to temperature variation.

Main results:

- Laboratory experiments under controlled temperature conditions have shown that temperature affects the growth rate of juvenile Pacific halibut through changes in the expression of genes that regulate growth processes.

Publications:

- Planas et al. 2021. In Preparation.

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

- Identification of temperature-specific responses in skeletal muscle through comparison between transcriptomic responses to temperature-induced growth changes and to density- and stress-induced growth changes.
- Application of growth markers for additional studies investigating the link between environmental variability and growth patterns and the effects of diet (prey quality and abundance) on growth and physiological condition.

4. **Mortality and Survival Assessment**.
    1. Discard mortality rate estimation in the longline Pacific halibut fishery. Planned research outcomes: experimentally-derived DMR.

Main results:

- Different hook release methods used in the longline fishery result in specific injury profiles and viability classification.
- Plasma lactate levels are high in Pacific halibut with the lowest viability classification.
- Survival of discarded fish with the highest viability classification is estimated to be between 4.2 and 8.4%.

Publications:

- Kroska, A.C., Wolf, N., Planas, J.V., Baker, M.R., Smeltz, T.S., Harris, B.P. Controlled experiments to explore the use of a multi-tissue approach to characterizing stress in wild-caught Pacific halibut (*Hippoglossus stenolepis*). 2021. Conservation Physiology 9(1):coab001; doi:10.1093/conphys/coab001.
- Loher, T., Dykstra, C.L., Hicks, A., Stewart, I.J., Wolf, N., Harris, B.P., Planas, J.V. Estimation of post-release longline mortality in Pacific halibut (*Hippoglossus stenolepis*) using acceleration-logging tags. North American Journal of Fisheries Management (In Review).

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

- Integration of information on capture and handling conditions, injury and viability assessment and physiological condition will lead to establishing a set of best handling practices in the longline fishery.

    2. Discard mortality rate estimation in the guided recreational Pacific halibut fishery. Planned research outcomes: experimentally-derived DMR.

Main results:

- Field experiments testing two different types of gear types (i.e. 12/0 and 16/0 circle hooks) resulted in the capture, sampling and tagging of 243 Pacific halibut in IPHC Regulatory Area 2C (Sitka, AK) and 118 in IPHC Regulatory Area 3A (Seward, AK).
- The distributions of fish lengths by regulatory area and by hook size were similar.

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

- Estimation of discard mortality rate in the guided recreational fishery.
- Integration of information on capture and handling conditions, injury and viability assessment and physiological condition linked to survival.
- Establishment of a set of best handling practices in the guided recreational fishery.

5. **Genetics and genomics**.
    1. Generation of genomic resources for Pacific halibut. Planned research outcomes: sequenced genome and reference transcriptome.

Main results:

- A first draft of the chromosome-level assembly of the Pacific halibut genome has been generated.
- The Pacific halibut genome has a size of 586 Mb and contains 24 chromosome-size scaffolds covering 98.6% of the complete assembly with a N50 scaffold length of 25 Mb at a coverage of 91x.
- The Pacific halibut genome has been annotated by NCBI and is available as NCBI Hippoglossus stenolepis Annotation Release 100 (https://www.ncbi.nlm.nih.gov/genome/annotation_euk/Hippoglossus_stenolepis/100/).
- Transcriptome (i.e. RNA) sequencing has been conducted in twelve tissues in Pacific halibut and the raw sequence data have been deposited in NCBI's Sequence Read Archive (SRA) under the bioproject number PRJNA634339 (https://www.ncbi.nlm.nih.gov/bioproject/PRJNA634339) and with SRA accession numbers SAMN14989915 - SAMN14989926.

Publications:

- Jasonowicz et al. 2021. In Preparation.
- Jasonowicz et al. 2022. In Preparation.

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

- Genome-wide analysis of stock structure and composition.

    2. Determine the genetic structure of the Pacific halibut population in the Convention Area. Planned research outcomes: genetic population structure.

Main results:

- The collection of winter genetic samples in the Aleutian Islands completed the winter sample collection needed to conduct studies on the genetic population structure of Pacific halibut in the Convention Area.
- Initial results of low coverage whole genome resequencing of winter samples indicate that an average of 26.5 million raw sequencing reads per obtained per sample that provided average individual genomic coverages for quality filtered alignments of 3.2x.

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

- Fine-scale delineation of population structure, with particular emphasis on IPHC Regulatory 4B structure.

B. External funding received:

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	**Saltonstall-Kennedy NOAA**	Improving discard mortality rate estimates in the Pacific halibut by integrating handling practices, physiological condition and post-release survival (NOAA Award No. NA17NMF4270240)	IPHC	Alaska Pacific University	$286,121	Bycatch estimates	September 2017 – August 2020
2	**North Pacific Research Board**	Somatic growth processes in the Pacific halibut (*Hippoglossus stenolepis*) and their response to temperature, density and stress manipulation effects (NPRB Award No. 1704)	IPHC	AFSC-NOAA-Newport, OR	$131,891	Changes in biomass/size-at-age	September 2017 – February 2020
3	**Bycatch Reduction Engineerin g Program - NOAA**	Adapting Towed Array Hydrophones to Support Information Sharing Networks to Reduce Interactions Between Sperm Whales and Longline Gear in Alaska	Alaska Longline Fishing Association	IPHC, University of Alaska Southeast, AFSC-NOAA	-	Whale Depredation	September 2018 – August 2019
4	**Bycatch Reduction Engineerin g Program - NOAA**	Use of LEDs to reduce Pacific halibut catches before trawl entrainment	Pacific States Marine Fisheries Commission	IPHC, NMFS	-	Bycatch reduction	September 2018 – August 2019
5	**National Fish & Wildlife Foundation**	Improving the characterization of discard mortality of Pacific halibut in the recreational fisheries (NFWF Award No. 61484)	IPHC	Alaska Pacific University, U of A Fairbanks, charter industry	$98,902	Bycatch estimates	April 2019 – November 2021
6	**North Pacific Research Board**	Pacific halibut discard mortality rates (NPRB Award No. 2009)	IPHC	Alaska Pacific University,	$210,502	Bycatch estimates	January 2021 – March 2022
		Total awarded ($)			**$727,416**		

C. Publications in the peer-reviewed literature:

2020:

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

2021:

- Carpi, P., Loher, T., Sadorus, L., Forsberg, J., Webster, R., Planas, J.V., Jasonowicz, A., Stewart, I. J., Hicks, A. C. Ontogenetic and spawning migration of Pacific halibut: a review. Rev Fish Biol Fisheries. 2021. https://doi.org/10.1007/s11160-021-09672-w.

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- Lomeli, M.J.M., Wakefield, W.W., Herrmann, B., Dykstra, C.L., Simeon, A., Rudy, D.M., Planas, J.V. Use of Artificial Illumination to Reduce Pacific Halibut Bycatch in a U.S. West Coast Groundfish Bottom Trawl. Fisheries Research. 2021. 233: 105737. doi: 10.1016/j.fishres.2020.105737.
- Sadorus, L.; Goldstein, E.; Webster, R.; Stockhausen, W.; Planas, J.V.; Duffy-Anderson, J. Multiple life-stage connectivity of Pacific halibut (*Hippoglossus stenolepis*) across the Bering Sea and Gulf of Alaska. Fisheries Oceanography. 2021. 30:174-193. doi: https://doi.org/10.1111/fog.12512.

APPENDIX III

Proposed schedule of outputs

<<In development>>

APPENDIX IV

Proposed schedule of funding and staffing indicators

<<In development>>