INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC–2021–RAB022–00
Last Update: 28 October 2021

22nd Session of the IPHC Research Advisory Board (RAB022) – *Compendium of meeting documents*

29 November 2021, Seattle, WA, USA

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

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PROVISIONAL: AGENDA FOR THE 22nd SESSION OF THE IPHC RESEARCH ADVISORY BOARD (RAB022)

Date: 29 November 2021
Location: Seattle, Washington, USA
Venue: Grand Hyatt Seattle
Time: 09:00-17:00
Chairperson: Dr David T. Wilson (Executive Director)
Vice-Chairperson: Dr Josep V. Planas (Biological & Ecosystem Sciences Branch Manager)

1. **OPENING OF THE SESSION** (Chairperson)

2. **ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION** (Chairperson)

3. **IPHC PROCESS** (Chairperson)
   - 3.1 Update on the actions arising from the 21st Session of the RAB (RAB021)
   - 3.2 Outcomes of the 97th Session of the IPHC Annual Meeting (AM097)

4. **SEASON OVERVIEW - 2021: RAB MEMBERS**

5. **IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS)**
   - 5.1 2021 FISS season: Design and implementation (K. Ualesi & D. Wilson)
   - 5.2 2022-24 FISS design evaluation (R. Webster)
   - 5.3 Modelling of IPHC length-weight data (R. Webster)
   - 5.4 Review of IPHC hook competition standardization (R. Webster)
   - 5.5 Accounting for the effects of whale depredation on the FISS (R. Webster)

6. **DESCRIPTION OF IPHC RESEARCH ACTIVITIES** (J. Planas & Project leaders)
   - 6.1 Key updates: IPHC 5-year Biological and Ecosystem Sciences Research Plan (2017-21) (J. Planas)
     - 6.1.1 Whale depredation (C. Dykstra)
     - 6.1.2 Alterations of flesh characteristics: chalky Pacific halibut (L. Sadorus)
   - 6.2 Core research streams: Updates for key ongoing research activities (Project leaders)
     - 6.2.1 Migration: Larval and juvenile connectivity of Pacific halibut (L. Sadorus, T. Loher)
     - 6.2.2 Reproduction: Reproductive assessment of the Pacific halibut population (J. Planas)
     - 6.2.3 Growth: Factors affecting somatic growth in Pacific halibut (J. Planas)
     - 6.2.4 Discard mortality rates: Discard mortality rates and post-release survival in the longline and guided recreational Pacific halibut fisheries (C. Dykstra)

6.2.5 Genetic and Genomics: Application of genetics and genomics to improve our knowledge on population structure and distribution (A. Jasonowicz)

7. **GUIDANCE ON, AND DISCUSSION OF, OTHER POTENTIAL APPLIED RESEARCH PROJECTS** (Chairperson & Vice-Chairperson)

8. **OTHER BUSINESS**
   8.1 IPHC Meeting calendar (2022-24) (Chairperson)

9. **REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 22^nd^ SESSION OF THE IPHC RESEARCH ADVISORY BOARD (RAB022)** (Chairperson)

SCHEDULE FOR THE 22nd SESSION OF THE IPHC RESEARCH ADVISORY BOARD (RAB022)

Monday, 29 November 2021		
Time	**Agenda item**	**Lead**
09:00-09:05	1. Opening of the Session	D. Wilson
09:05-09:15	2. Adoption of the agenda and arrangements for the Session	D. Wilson
09:15-09:30	3. IPHC Process	D. Wilson
09:30-10:30	4. Season overview: RAB members	RAB Members
10:30-10:45	Break	
10:45-11:15	5. IPHC fishery-independent setline survey (FISS) 5.1 2021 FISS season: Design and implementation (K. Ualesi & D. Wilson) 5.2 2022-24 FISS design evaluation (R. Webster) 5.3 Modelling of IPHC length-weight data (R. Webster) 5.4 Review of IPHC hook competition standardization (R. Webster) 5.5 Accounting for the effects of whale depredation on the FISS (R. Webster)	K. Ualesi & R. Webster
11:15-11:30	6. Description of IPHC research activities 6.1 Key updates: IPHC 5-year Biological and Ecosystem Sciences Research Plan (2017-21) 6.1.1 Whale depredation 6.1.2 Alterations of flesh characteristics: chalky Pacific halibut	J. Planas & Project leaders
11:30-12:30	6.2 Core research streams: Updates for key ongoing research activities 6.2.1 Migration 6.2.2 Reproduction 6.2.3 Growth 6.2.4 Discard mortality rates 6.2.5 Genetic and Genomics	Project leaders
12:30-13:15	Lunch	
13:15-15:15	7. Guidance on, and discussion of, other potential applied research projects	RAB Members
15:15-15:30	Break	
15:30-16:15	7. Guidance on, and discussion of, potential applied research projects (cont.)	RAB Members

16:15-16:20	8. Other business 8.1 Date and place of the 23rd and 24th Sessions of the IPHC Research Advisory Board	D. Wilson
16:20-17:15	9. Review of the draft and adoption of the report of the 22nd Session of the IPHC Research Advisory Board (RAB022)	D. Wilson

LIST OF DOCUMENTS FOR THE 22nd SESSION OF THE IPHC RESEARCH ADVISORY BOARD (RAB022)

LAST UPDATED: 28 OCTOBER 2021

Document	Title	Availability
IPHC-2021-RAB022-01	Agenda & Schedule for the 22nd Session of the IPHC Research Advisory Board (RAB022)	✓ 31 Aug 2021
IPHC-2021-RAB022-02	List of Documents for the 22nd Session of the IPHC Research Advisory Board (RAB022)	✓ 21 Oct 2021 ✓ 28 Oct 2021
IPHC-2021-RAB022-03	Update on the actions arising from the 21st Session of the RAB (RAB021) (D. Wilson & J. Planas)	✓ 22 Oct 2021
IPHC-2021-RAB022-04	Outcomes of the 97th Session of the IPHC Annual Meeting (AM097) (IPHC Secretariat)	✓ 21 Oct 2021
IPHC-2021-RAB022-05	IPHC Fishery-independent setline survey (FISS) design and implementation in 2021: preliminary summary (K. Ualesi, D. Wilson, C. Jones & R. Rillera)	✓ 28 Oct 2021
IPHC-2021-RAB022-06	2022-24 FISS Design evaluation (R. Webster)	✓ 27 Oct 2021
IPHC-2021-RAB022-07	IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling (R. Webster)	✓ 27 Oct 2021
IPHC-2021-RAB022-08	Overview: IPHC 5-year biological and ecosystem sciences research program (2017-21) (J. Planas)	✓ 25 Oct 2021
IPHC-2021-RAB022-09	Migratory behavior and distribution of Pacific halibut (L. Sadorus & T. Loher)	✓ 25 Oct 2021
IPHC-2021-RAB022-10	Reproductive assessment of the Pacific halibut population (J. Planas)	✓ 25 Oct 2021
IPHC-2021-RAB022-11	Evaluating discard mortality rates and developing best management practices in the Pacific halibut charter recreational fisheries (C. Dykstra)	✓ 25 Oct 2021
IPHC-2021-RAB022-12	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries (C. Dykstra)	✓ 25 Oct 2021
IPHC-2021-RAB022-13	Population genomics (A. Jasonowicz & J. Planas)	✓ 25 Oct 2021

Update on actions arising from the 21st Session of the IPHC Research Advisory Board (RAB021)

PREPARED BY: IPHC SECRETARIAT (D. WILSON & J. PLANAS; 22 OCT 2021)

PURPOSE

To provide the RAB with an opportunity to consider the progress made during the inter-sessional period, in relation to the recommendations and requests of the 21st Session of the IPHC Research Advisory Board (RAB021).

BACKGROUND

At the RAB021 meeting, a series of actions were agreed upon for implementation by the IPHC Secretariat. These action items and progress made on their implementation are detailed in Appendix A.

DISCUSSION

Noting that best practice governance requires the prompt delivery of core tasks assigned by the Commission, at each subsequent session of the Commission and its subsidiary bodies, attempts will be made to ensure that any recommendations and requests for action are carefully constructed so that each contains the following elements:

1) a specific action to be undertaken (deliverable);
2) clear responsibility for the action to be undertaken (i.e. a specific Contracting Party, the IPHC Secretariat, a subsidiary body of the Commission or the Commission itself);
3) a desired time frame for delivery of the action (i.e. by the next session of an subsidiary body, or other date).

This involves numbering and tracking all action items (see Appendix A) from the RAB, as well as including clear progress updates and document reference numbers.

RECOMMENDATIONS

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-03, which provided the RAB with an opportunity to consider the progress made during the inter-sessional period, in relation to the recommendations and requests of the 21st Session of the IPHC Research Advisory Board (RAB021).
2) **AGREE** to consider and revise as necessary the actions, and for these to be combined with any new actions arising from RAB022.

APPENDICES

Appendix A: Update on actions arising from the 21st IPHC Research Advisory Board (RAB021)

APPENDIX A

Update on actions arising from the 21st Session of the Research Advisory Board (RAB021)

Action No.	Description	Update
RECOMMENDATIONS - Nil		
REQUESTS		
RAB021-Req.01 (para 14)	***Effect of hypoxia off the Oregon and Washington coast*** The RAB **REQUESTED** the IPHC Secretariat consider how environmental monitoring could continue in areas where FISS sampling is not taking place in a given year, in particular to help understand environmental trends in IPHC Regulatory Area 2A.	In progress: The IPHC Secretariat is evaluating current efforts towards environmental monitoring, and continues to review external sources of environmental information in IPHC Regulatory Area 2A.
RAB021-Req.02 (para 17)	***IPHC Fishery-Independent Setline Survey*** Recalling the hook standardization discussion from RAB020, the RAB **REQUESTED** that the IPHC Secretariat consider investigating the possible effects of hook differences on FISS results.	Pending: Although supportive of this investigation, the IPHC considers this to be a lower priority than current ongoing research.
RAB021-Req.03 (para 18)	The RAB **REQUESTED** the IPHC Secretariat consider the effect of different bycatch species on hook competition rates.	In progress: The IPHC is currently collaborating on a study of standard and modified circle hooks that will use hook timers to record the capture time of different species. It is hoped that data from this study will inform the hook competition standardization.
RAB021-Req.04 (para 20)	**NOTING** the increasing cost of the FISS, the RAB **REQUESTED** the IPHC Secretariat consider additional ways to incorporate commercial fishery data into stock assessment.	In progress: All available components of fishery-dependent data are currently included in the stock assessment. The rationalized FISS design-process now actively works to minimize costs through both station selection and skate deployment.

Action No.	Description	Update
RAB021-Req.05 (para 21)	The RAB **REQUESTED** that the IPHC Secretariat engage with stakeholders who have performed FISS work in the western regulatory areas to improve the design and feasibility of the FISS, including the possibility of multi-year FISS contracts.	In progress: The IPHC notes both the challenges and critical nature of sampling these areas. Guidance will be provided to vessels in 2022 on a prioritized order for stations within charter regions. The IPHC welcomes dual-vessel bidding, sharing of stations among vessels sampling the same area, multi-year proposals, and other accommodations to make these areas more logistically feasible.
RAB021-Req.06 (para 33)	***Migratory behavior and distribution of Pacific halibut*** **NOTING** that some commercial and recreational fishers may release IPHC-tagged fish without realizing that they do not count against any regulatory limits and should be kept, the RAB **REQUESTED** the IPHC Secretariat conduct outreach with fishers and enforcement agencies on this issue.	In progress: The IPHC Secretariat is continuing to inform stakeholders on the implications of catching IPHC-tagged fish.
RAB021-Req.07 (para 41)	***Guidance on, and discussion of, other potential applied research projects*** The RAB **REQUESTED** that the IPHC Secretariat consider migration studies specific to IPHC Regulatory Area 2A, given that it represents the southernmost range of Pacific halibut distribution.	In progress: The IPHC Secretariat is planning studies to investigate possible changes in distribution of Pacific halibut in latitudinal extremes of the species range through population genomic analyses.
RAB021-Req.08 (para 43)	The RAB **REQUESTED** that the IPHC Secretariat review the definition of "washed" fish and the weight deduction that is applied for washed fish.	In progress: The IPHC has been attempting to collect data from commercial sampling to estimate the deduction due to washing for several years. This effort has not been successful, but remains ongoing.

OUTCOMES OF THE 97TH SESSION OF THE IPHC ANNUAL MEETING (AM097)

PREPARED BY: IPHC SECRETARIAT (21 OCTOBER 2021)

PURPOSE

To provide the RAB with the outcomes of the 97th Session of the IPHC Annual Meeting (AM097) relevant to the mandate of the RAB.

BACKGROUND

The agenda of the Commission's Annual Meeting (AM097) included an agenda items dedicated to the IPHC's 5-year Biological and Ecosystem Science Research Program, and the Report of the RAB021.

The Report of the 97th Session of the IPHC Annual Meeting was adopted on 11 February 2021 and is available for download from the IPHC website: https://www.iphc.int/venues/details/97th-session-of-the-iphc-annual-meeting-am097

DISCUSSION

During the course of the Annual Meeting (AM097) the Commission made a number of specific requests and recommendations regarding the IPHC research programs. Relevant sections from the report of the meeting are provided in Appendix A for the RAB's consideration.

RECOMMENDATION

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-04 which provides the outcomes of the 97th Session of the IPHC Annual Meeting (AM097) relevant to the mandate of the RAB.

APPENDICES

Appendix A: Outcomes of the AM097 relevant to the mandate of the RAB

APPENDIX A
Outcomes of AM097 relevant to the mandate of the RAB

(paragraph numbering reflects the AM097 report)

6. IPHC Science and Research

6.1 IPHC 5-year Biological & Ecosystem Science Research Plan (2017-21): update

52. The Commission **NOTED** paper IPHC-2021-AM097-10 which provided a description of progress on the IPHC 5-year Biological and Ecosystem Science Research Plan (2017-21).

53. The Commission **NOTED** the main objectives of the Biological and Ecosystem Science Research at the IPHC are to:
    1) identify and assess critical knowledge gaps in the biology of the Pacific halibut;
    2) understand the influence of environmental conditions; and
    3) apply the resulting knowledge to reduce uncertainty in current stock assessment models.

54. The Commission **NOTED** that the primary biological research activities at the IPHC that follow Commission objectives are identified in the IPHC Five-Year Biological and Ecosystem Science Research Plan (2017-21). The various activities under within the plan are proposed, reviewed and approval internally at the IPHC Secretariat. These activities are summarized in five broad research areas designed to provide inputs into stock assessment and the management strategy evaluation processes, as follows:
    1) **Migration**. Studies are aimed at further understanding reproductive migration and identification of spawning times and locations as well as larval and juvenile dispersal.
    2) **Reproduction**. Studies are aimed at providing information on the sex ratio of the commercial catch and to improve current estimates of maturity.
    3) **Growth and Physiological Condition**. Studies are aimed at describing the role of some of the factors responsible for the observed changes in size-at-age and to provide tools for measuring growth and physiological condition in Pacific halibut.
    4) **Discard Mortality Rates (DMRs) and Survival**. Studies are aimed at providing updated estimates of DMRs in both the longline and the trawl fisheries.
    5) **Genetics and Genomics**. Studies are aimed at describing the genetic structure of the Pacific halibut population and at providing the means to investigate rapid adaptive changes in response to fishery-dependent and fishery-independent influences.

55. The Commission **NOTED** the progress that the IPHC Secretariat has made in the five key research areas contemplated in the IPHC 5-Year Biological and Ecosystem Science Research Plan (2017-21) and, in particular, in the promising use of genomic approaches to address important questions related to stock structure and distribution, migration, and the genetic basis of key life-history traits (e.g. weight-at-age, maturity- and fecundity-at-age).

7. Report of the 21st Session of the IPHC Research Advisory Board (RAB021)

56. The Commission **NOTED** the Report of the 21st Session of the IPHC Research Advisory Board (RAB021) (IPHC-2020-RAB021-R) which was presented by the Co-Chairperson, Dr Josep Planas.

57. The Commission **CONSIDERED** the recommendations made by the RAB021 and **AGREED** to take them into consideration when deliberating on relevant agenda items throughout the meeting.

8. Reports of the IPHC Scientific Review Board

58. The Commission **NOTED** the Reports of the 16th and 17th Sessions of the IPHC Scientific Review Board (SRB016 - IPHC-2020-SRB016-R; SRB017 - IPHC-2020-SRB017-R) which were presented by the Dr. David Wilson, Executive Director) on behalf of the Chairperson, Dr Sean Cox (Simon Fraser University, Vancouver, Canada).

59. The Commission **CONSIDERED** the recommendations made by the SRB in 2020 and **AGREED** to take them into consideration when deliberating on relevant agenda items throughout the meeting.

60. The Commission **RECALLED** the request from the SRB016 (SRB016-Req. 19, shown below) for the Commission to hire a life-history modeller, and the associated response from the IPHC Secretariat. The Commission had previously considered this request at AM096 via paper IPHC-2020-AM096-INF04, and decided not to proceed at this time.

SRB016–Req.19 (para. 52) "*NOTING that a common theme in programmatic studies is a need to understand growth, the maturation process and size and age at sexual maturity, and to incorporate this understanding into the assessment and MSE programs, the SRB reiterated its previous REQUEST that the IPHC Secretariat hire a PhD-level life history modeller with expertise in the areas that include life history and quantitative genetics. The SRB was advised that at this point in time, the hiring of a life-history modeller is not financially feasible unless either 1) additional contributions were appropriated by the Contracting Parties, or 2) a current FTE was replaced with a life-history modeller.*"

IPHC-2021-RAB022-05

IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2021

PREPARED BY: IPHC SECRETARIAT (K. UALESI , D. WILSON, C. JONES & R. RILLERA; 28 OCTOBER 2021)

PURPOSE

To provide a summary of the IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2021.

BACKGROUND

The annual IPHC Fishery-Independent Setline Survey (FISS) of the Pacific halibut stock was augmented from 2014-2019 with expansion stations that filled in gaps in coverage in the annual FISS. Prior to 2020, the standard grid of stations comprised 1,200 stations. Following the completion in 2019, expansion stations were added to the standard grid in all IPHC Regulatory Areas, now totaling 1,890 stations for the full FISS design (Fig. 1), within the prescribed depth range of 18 to 732 metres (10 to 400 fathoms).

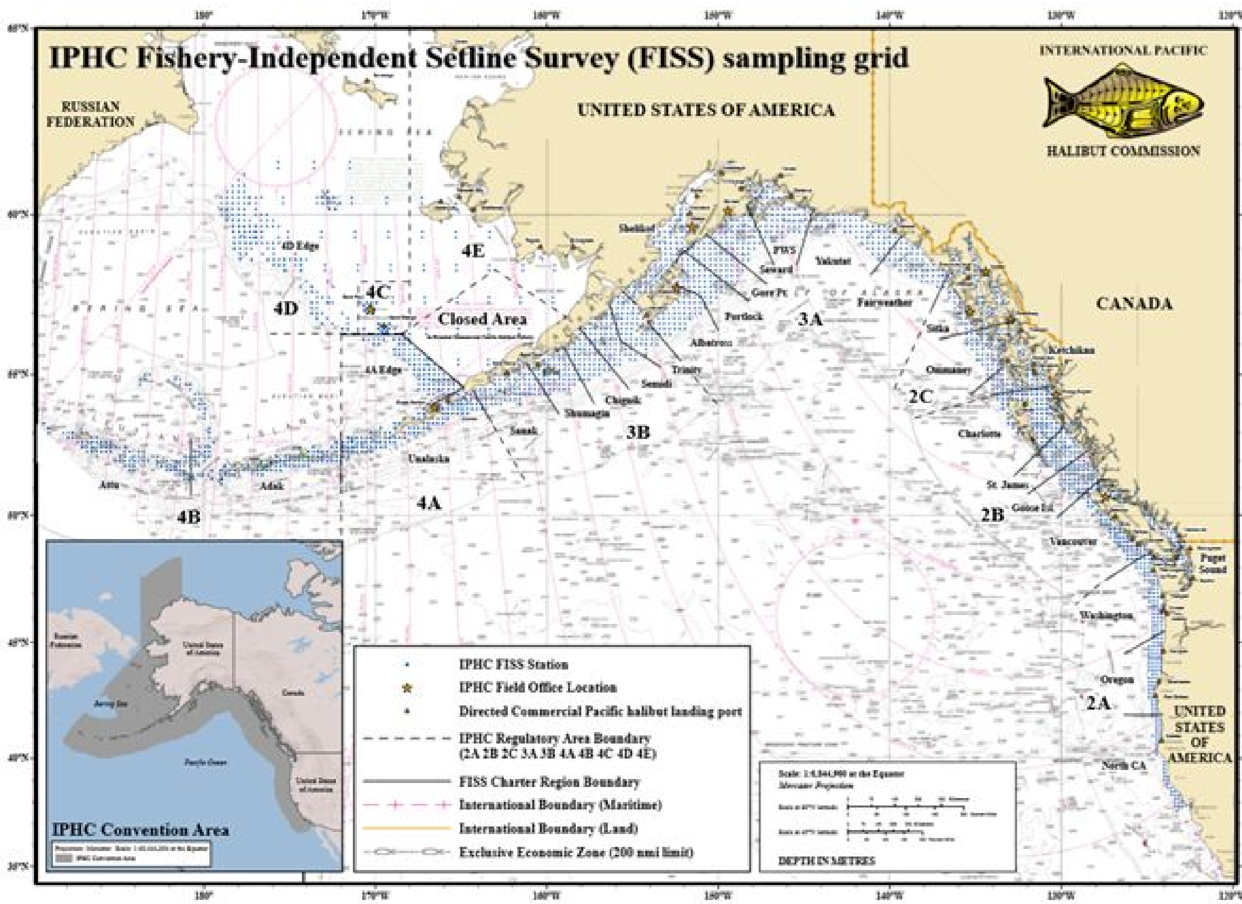

Figure 1. IPHC Fishery-Independent Setline Survey (FISS) with full sampling grid shown.

Prior to 2019, only fixed gear was used to fish FISS sets. With increasing use of snap gear in the commercial fishery, this restriction has limited the number of vessels available for the FISS. Further, any differences between snap and fixed gears (including catch rate differences and differences in fishing locations) may affect our understanding of trends in commercial fishery indices. This has motivated the need for a study comparing the two gear types with this work being done in 2019, 2020, and again in 2021.

Beginning in 2019, individual weight data were collected coastwide from Pacific halibut caught on the FISS to eliminate questions that have arisen regarding the accuracy of estimates that depend on these weights, including weight per unit effort (WPUE) indices of density. Data from IPHC collections from commercial landings and other sources had provided evidence that the current standard length-net weight curve used for estimating Pacific halibut weights on the FISS may have been over-estimating weights on average in most IPHC Regulatory Areas, and that the relationship between weight and length may vary spatially.

2021 FISS design

At the 9th Special Session of the Commission (SS09), the Commission recommended a FISS design for 2021 that included 1,346 stations coastwide (Fig. 2). The design comprised sampling of subareas within IPHC Regulatory Areas 2A, 4A, and 4B intended to reduce potential bias (relative to historical observed changes year-to-year) and to achieve a level of precision comparable to or better than recent setline surveys. 2021 sampling in IPHC Regulatory Areas 2B (except inside waters), and 3B included random subsampling from the full design to provide for unbiased estimates, while increasing precision relative to recent setline surveys. Sampling in IPHC Regulatory Area 4CDE included 100% of the full FISS design.

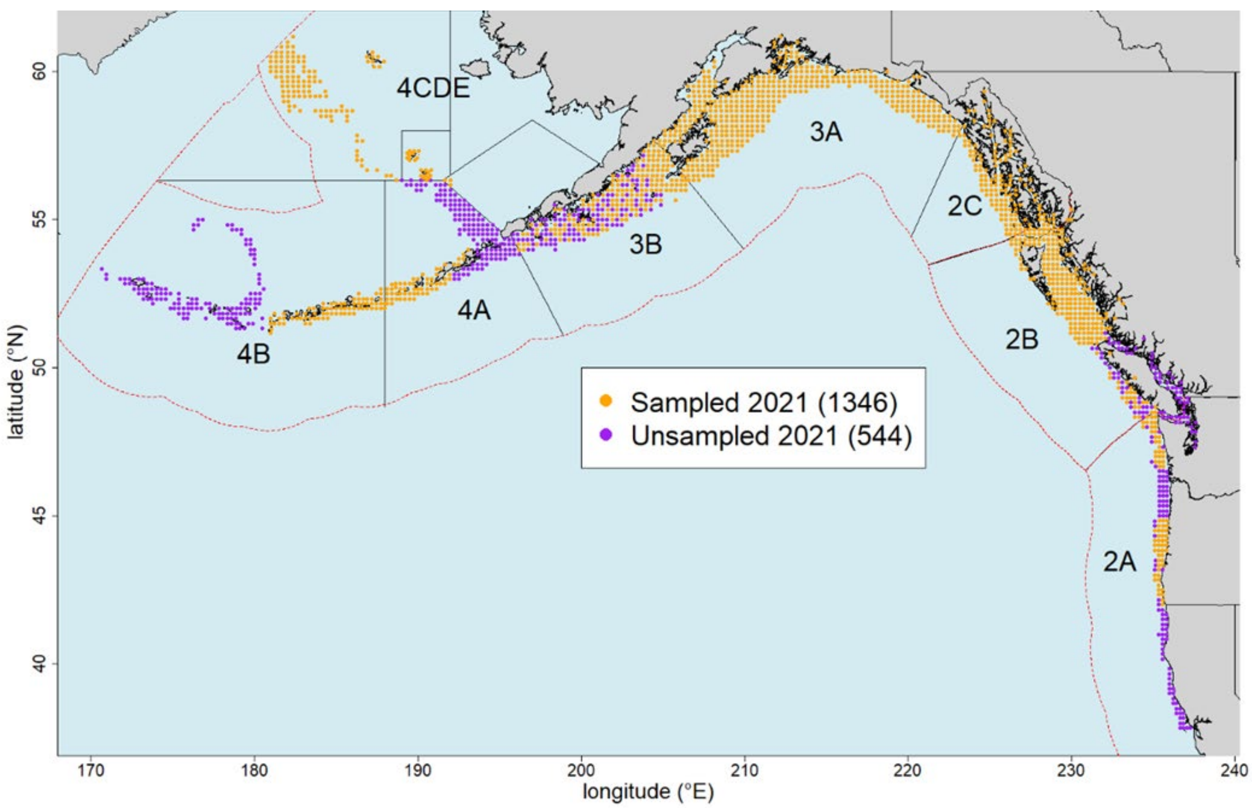

Figure 2. Map of the 2021 FISS design endorsed by the Commission on 8 December 2020 (IPHC-2020-SS09-R). Purple circles were not sampled in 2021.

MATERIALS AND METHODS

The IPHC's FISS design encompasses nearshore and offshore waters of the IPHC Convention Area (Fig. 1). The IPHC Regulatory Areas are divided into 29 charter regions, each requiring between 10 and 46 charter days to complete. FISS stations are located at the intersections of a 10 nmi by 10 nmi square grid within the depth range occupied by Pacific halibut during summer months (18 – 732 m [10 – 400 fm]). Figure 2 depicts the 2021 FISS station positions, and IPHC Regulatory Areas.

Fishing vessels are chosen through a competitive bid process where up to four (4) charter regions per vessel may be awarded and typically 10-15 vessels are chosen. In 2021, the process has been clearly documented on the IPHC website for accountability and transparency purposes: https://www.iphc.int/management/science-and-research/fishery-independent-setline-survey-fiss/62-fiss-vessel-recruiting.

In 2021, 13 vessels were chartered to complete the FISS, as detailed in Media Release 2021-019: Notification of IPHC Fishery-Independent Setline Survey (FISS) 2021 Contract Awards.

Sampling protocols - 2021

IPHC Setline Survey Specialists (Field) collected data according to protocols established in the 2021 FISS Sampling Manual (IPHC-2021-VSM01).

Sampling challenges - 2021

Of the 1,346 FISS stations planned for the 2021 FISS season, 1,167 (87%) were effectively sampled.

Not sampled: A total of 128 planned stations were not sampled in 2021. 75 of the 140 stations planned for Area 4CDE were not completed in 2021 due to mechanical issues and crew challenges aboard the vessel completing this area. In Adak, 36 of the 73 planned stations were not completed due to significant technological issues aboard the vessel. In Unalaska, the vessel faced several instances of lost gear and other logistical challenges at the end of the season, leaving 11 stations not sampled. In Yakutat, the presence of sea ice restricted the vessel's access and resulted in three (3) stations not being sampled and stations located in the Marine Protected Areas of IPHC charter regions St James and Charlotte prevented three (3) stations from being sampled.

Ineffective stations: Coastwide, fifty-nine (59) stations were deemed ineffective due to whale depredation (n=43), pinniped predation (n=1), gear soak time (n=3), shark predation (n=3), sand flea activity (n=2), station moved > 3nmi (n=1), and setting and gear issues (n=6).

Fixed versus Snap Gear comparison

A third comparison of the use of snap gear to the use of fixed gear on the FISS was conducted in IPHC Regulatory Area 3A (Seward charter region) in 2021 (Fig. 3). The design again featured each station being fished twice, once with fixed gear and once with snap gear. The comparison will provide data on any differences between catch (e.g. Pacific halibut catch rates, age and size distribution, bycatch species) on the two gears, and move the FISS closer to accommodating both data sources into its annual design in the near future.

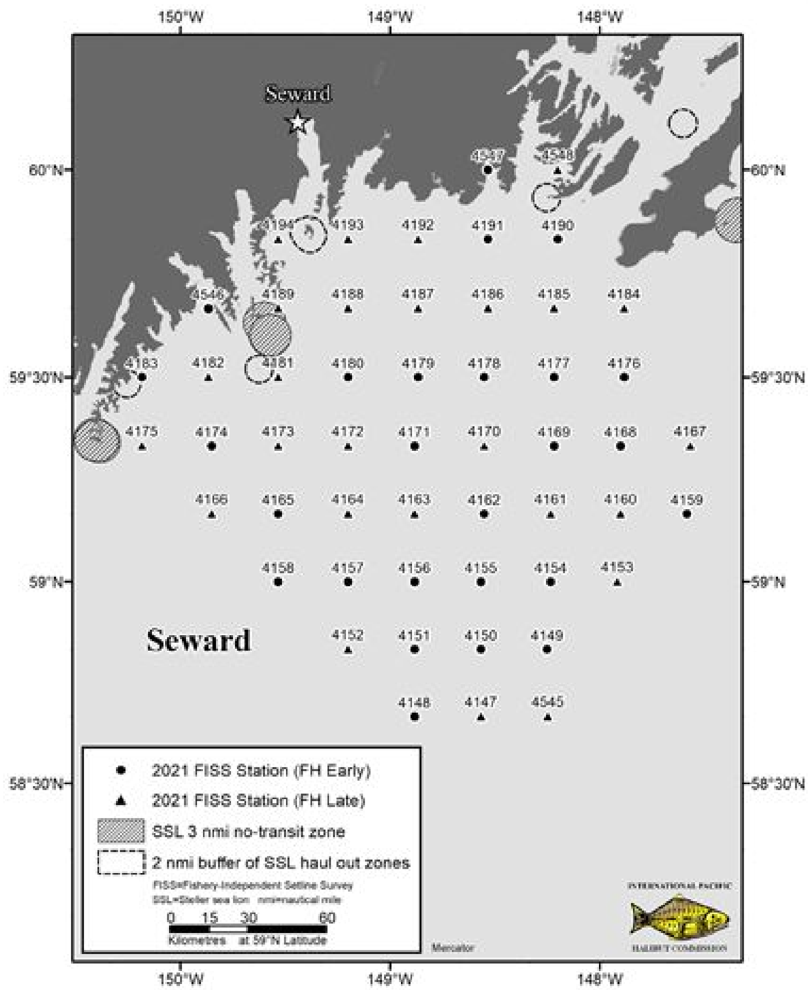

Figure 3. IPHC Fishery-Independent Setline Survey fixed-hook/snap gear comparison stations in the Seward region of IPHC Regulatory Area 3A. Early Fixed Hook stations equate to late Snap Gear stations and late Fixed Hook stations to early Snap Gear stations.

Bait (Chum salmon)

The minimum quality requirement for FISS bait is No. 2 semi-bright (Alaska Seafood Marketing Institute grades A through E), headed and gutted, and individually quick-frozen chum salmon. Bait usage is based on 0.17 kilograms (0.37 pounds) per hook resulting in approximately 136 kilograms (300 pounds) per eight skate station. Bait quality was monitored and documented throughout the season and found to meet the standard as described above.

Pre-season: In October 2020 (IPHC Media Release 2020-031), the Secretariat made pre-season bait purchases of approximately 90 tonnes (200,000 lbs) to ensure a smooth start to the 2021 FISS, and to take advantage of advance purchase prices.

In-season: In March 2021 the Secretariat made an in-season bait RFT (IPHC Media Release 2021-013) for approximately 77 tonnes (170,000 lbs) of bait, to supplement pre-season purchases and complete the 2021 FISS successfully.

RESULTS

Interactive views of the FISS results are provided via the IPHC website and can be found here:

https://www.iphc.int/data/setline-survey-catch-per-unit-effort
(published 29 October 2021)

As in previous years, legal-sized (O32) Pacific halibut that were caught on FISS stations and sacrificed in order to obtain biological data were retained and sold. In addition, beginning in 2020, sub-legal (U32) Pacific halibut that were caught and randomly selected for otolith sampling were also retained and sold. This helps to offset costs of the FISS. FISS vessels also retained for sale incidentally captured rockfish (*Sebastes spp.*) and Pacific cod (*Gadus macrocephalus*). These species were retained because they rarely survive the barotrauma resulting from capture. Most vessel contracts provided the vessel a lump sum payment, along with a 10% share of the Pacific halibut proceeds and a 50% share of the incidental catch proceeds.

The 2021 FISS chartered 13 commercial longline vessels (four Canadian and nine USA) during a combined 82 trips and 801 charter days (Tables 1). Otoliths were removed from 13,258 fish coastwide. Approximately 373 tonnes (823,000 pounds) of Pacific halibut, 33 tonnes (73,600 pounds) of Pacific cod, and 40 tonnes (87,250 pounds) of rockfish were landed from the FISS stations.

Table 1a. Effort and landing summary by FISS charter region and vessel for all 2021 stations and all Pacific halibut (sampled U32 and all O32).

IPHC Regulatory Area	Charter Region	Vessel	Vessel Number[1]	Charter Days[2]	Planned Stations	Effective Stations[3]	Pacific halibut Sold (t) [4]	Pacific halibut Sold (lb)[4]	Average Price USD/kg[5]	Average Price USD/lb[5]
2A	Oregon	*Pacific Surveyor*	947061	25	43	42	2	5,161	$11.94	$5.41
2A	Washington	*Pacific Surveyor*	947061	20	37	34	3	7,142	$11.06	$5.02
2B	Charlotte	*Vanisle*	21912	51	89	86	30	65,460	$18.01	$8.17
2B	Goose Island	*Vanisle*	21912	42	57	56	17	36,725	$17.87	$8.11
2B	St. James	*Pender Isle*	27282	34	60	59	17	37,493	$17.68	$8.02
2B	Vancouver	*Pender isle*	27282	14	29	29	2	3,792	$16.45	$7.46
2C	Ketchikan	*Bold Pursuit*	99997	26	43	43	16	34,885	$15.35	$6.96
2C	Ommaney	*Star Wars II*	99997	31	52	49	24	52,600	$14.41	$6.54
2C	Sitka	*Bold Pursuit*	27282	31	52	49	24	53,962	$14.66	$6.65
3A	Albatross	*Predator*	33133	26	49	46	22	47,980	$13.54	$6.14
3A	Fairweather	*Bold Pursuit*	99997	24	51	40	12	26,632	$14.35	$6.51
3A	Gore Point	*Kema Sue*	41033	26	48	47	13	28,642	$15.04	$6.82
3A	Portlock	*Kema Sue*	41033	33	51	49	19	42,168	$15.72	$7.13
3A	PWS	*Star Wars II*	99997	44	67	65	22	47,709	$16.09	$7.39
3A	Seward	*Kema Sue*	41033	27	52	52	17	38,398	$16.30	$7.39
3A	Seward (Snap)	*Star Wars II*	99997	37	52	49	15	33,907	$16.15	$7.32
3A	Shelikof	*Devotion*	42892	38	64	62	25	54,414	$15.00	$6.80
3A	Yakutat	*Seymour*	17530	35	64	57	23	51,141	$15.85	$7.19
3B	Chignik	*Polaris*	19266	18	31	30	7	16,250	$13.79	$6.25

3B	Sanak	*Allstar*	55922	14	25	24	4	8,052	$11.46	$5.20
3B	Semidi	*Polaris*	19266	18	32	31	5	10,522	$13.84	$6.28
3B	Shumagin	*Allstar*	55922	23	30	30	7	14,502	$12.30	$5.58
3B	Trinity	*Allstar*	55922	32	56	52	20	43,819	$13.63	$6.18
4A	Unalaska	*Devotion*	42892	31	59	33	14	30,257	$11.73	$5.32
4B	Adak	*Norcoaster*	38137	53	73	37	11	24,121	$12.14	$5.51
4C	4CDE	*Grant*	19262	12	57	20	2	5,487	$11.84	$5.37
4D	4CDE	*Norcoaster*	38137	30	80	42	1	1,583	$11.60	$5.26
Closed Area	4CDE	*Grant*	19262	6	3	3	0	112	$11.84	$5.37
Total		**13 Vessels**		**801**	**1,406**	**1,216**	**373**	**822,916**	**$15.13**	**$6.86**

[1] Canada: Vessel Registration Number and USA: ADF&G vessel number.
[2] Days are estimated - some vessels fished two charter regions in one day.
[3] Stations that did not meet setting parameters or deemed ineffective are excluded.
[4] Net weight (head-off, dressed, washed). May not sum to correct total due to rounding.
[5] Ex-vessel price.

Table 1b. Effort and landing summary by FISS charter region and vessel for all 2021 stations and O32 Pacific halibut.

IPHC Regulatory Area	Charter Region	Vessel	Vessel Number [1]	Charter Days[2]	Planned Stations	Effective Stations[3]	Pacific halibut Sold (t) [4]	Pacific halibut Sold (lb)[4]	Average Price USD/kg[5]	Average Price USD/lb[5]
2A	Oregon	*Pacific Surveyor*	947061	25	43	42	2	4,131	$12.57	$5.70
2A	Washington	*Pacific Surveyor*	947061	20	37	34	2	5,272	$12.64	$5.73
2B	Charlotte	*Vanisle*	21912	51	89	86	29	63,954	$18.06	$8.19
2B	Goose Island	*Vanisle*	21912	42	57	56	16	35,251	$17.97	$8.15
2B	St. James	*Pender Isle*	27282	34	60	59	17	36,970	$17.72	$8.04
2B	Vancouver	*Pender isle*	27282	14	29	29	2	3,615	$16.51	$7.49
2C	Ketchikan	*Bold Pursuit*	99997	26	43	43	16	34,268	$15.36	$6.97
2C	Ommaney	*Star Wars II*	99997	31	52	49	23	51,170	$14.43	$6.55
2C	Sitka	*Bold Pursuit*	27282	31	52	49	24	52,334	$14.70	$6.67
3A	Albatross	*Predator*	33133	26	49	46	21	46,454	$13.55	$6.15
3A	Fairweather	*Bold Pursuit*	99997	24	51	40	12	26,228	$14.37	$6.52
3A	Gore Point	*Kema Sue*	41033	26	48	47	13	28,067	$15.05	$6.83
3A	Portlock	*Kema Sue*	41033	33	51	49	19	41,840	$15.74	$7.14
3A	PWS	*Star Wars II*	99997	44	67	65	21	47,373	$16.11	$7.31
3A	Seward	*Kema Sue*	41033	27	52	52	17	38,039	$16.30	$7.39
3A	Seward (Snap)	*Star Wars II*	99997	37	52	49	15	33,727	$16.15	$7.33
3A	Shelikof	*Devotion*	42892	38	64	62	24	53,331	$15.02	$6.81
3A	Yakutat	*Seymour*	17530	35	64	57	23	50,314	$15.87	$7.20
3B	Chignik	*Polaris*	19266	18	31	30	7	14,365	$13.81	$6.27
3B	Sanak	*Allstar*	55922	14	25	24	3	7,109	$11.54	$5.23
3B	Semidi	*Polaris*	19266	18	32	31	4	9,355	$13.88	$6.29
3B	Shumagin	*Allstar*	55922	23	30	30	6	12,910	$12.37	$5.61
3B	Trinity	*Allstar*	55922	32	56	52	19	42,028	$13.63	$6.18
4A	Unalaska	*Devotion*	42892	31	59	33	12	25,446	$11.94	$5.42

4B	Adak	*Norcoaster*	38137	53	73	37	10	22,177	$12.15	$5.51
4C	4CDE	*Grant*	19262	12	57	20	2	4,966	$12.05	$5.46
4D	4CDE	*Norcoaster*	38137	30	80	42	1	1,362	$12.05	$5.46
Closed Area	4CDE	*Grant*	19262	6	3	3	0	101	$12.05	$5.46
Total		**13 Vessels**		**801**	**1,406**	**1,216**	**359**	**792,157**	**$10.51**	**$6.91**

[1] Canada: Vessel Registration Number and USA: ADF&G vessel number.
[2] Days are estimated - some vessels fished two charter regions in one day.
[3] Stations that did not meet setting parameters or deemed ineffective are excluded.
[4] Net weight (head-off, dressed, washed). May not sum to correct total due to rounding.
[5] Ex-vessel price.

Table 1c. Effort and landing summary by FISS charter region and vessel for all 2021 stations and sampled U32 Pacific halibut.

IPHC Regulatory Area	Charter Region	Vessel	Vessel Number[1]	Charter Days[2]	Planned Stations	Effective Stations[3]	Pacific halibut Sold (t) [4]	Pacific halibut Sold (lb)[4]	Average Price USD/kg[5]	Average Price USD/lb[5]
2A	Oregon	*Pacific Surveyor*	947061	25	43	42	0	1,030	$9.41	$4.27
2A	Washington	*Pacific Surveyor*	947061	20	37	34	1	1,870	$6.61	$3.00
2B	Charlotte	*Vanisle*	21912	51	89	86	1	1,506	$15.72	$7.13
2B	Goose Island	*Vanisle*	21912	42	57	56	1	1,474	$15.45	$7.01
2B	St. James	*Pender Isle*	27282	34	60	59	0	523	$14.62	$6.63
2B	Vancouver	*Pender isle*	27282	14	29	29	0	177	$15.13	$6.86
2C	Ketchikan	*Bold Pursuit*	99997	26	43	43	0	617	$14.47	$6.56
2C	Ommaney	*Star Wars II*	99997	31	52	49	1	1,430	$13.78	$6.25
2C	Sitka	*Bold Pursuit*	27282	31	52	49	1	1,628	$13.42	$6.09
3A	Albatross	*Predator*	33133	26	49	46	1	1,526	$13.23	$6.00
3A	Fairweather	*Bold Pursuit*	99997	24	51	40	0	404	$12.94	$5.87
3A	Gore Point	*Kema Sue*	41033	26	48	47	0	575	$14.12	$6.40
3A	Portlock	*Kema Sue*	41033	33	51	49	0	328	$12.27	$5.56
3A	PWS	*Star Wars II*	99997	44	67	65	0	336	$16.09	$7.30
3A	Seward	*Kema Sue*	41033	27	52	52	0	359	$16.20	$7.35
3A	Seward (Snap)	*Star Wars II*	99997	37	52	49	0	180	$15.86	$7.20
3A	Shelikof	*Devotion*	42892	38	64	62	0	1,083	$14.05	$6.37
3A	Yakutat	*Seymour*	17530	35	64	57	0	827	$14.37	$6.52
3B	Chignik	*Polaris*	19266	18	31	30	1	1,885	$13.57	$6.16
3B	Sanak	*Allstar*	55922	14	25	24	0	944	$10.86	$4.92
3B	Semidi	*Polaris*	19266	18	32	31	1	1,167	$13.58	$6.16
3B	Shumagin	*Allstar*	55922	23	30	30	1	1,591	$11.76	$5.34
3B	Trinity	*Allstar*	55922	32	56	52	1	1,791	$13.73	$6.23
4A	Unalaska	*Devotion*	42892	31	59	33	2	4,811	$10.58	$4.80
4B	Adak	*Norcoaster*	38137	53	73	37	1	1,944	$11.97	$5.43
4C	4CDE	*Grant*	19262	12	57	20	0	521	$9.92	$4.50
4D	4CDE	*Norcoaster*	38137	30	80	42	0	221	$8.82	$4.00
Closed Area	4CDE	*Grant*	19262	6	3	3	0	11	$9.92	$4.50

Total	**13 Vessels**	**801**	**1406**	**1216**	**14**	**30,759**	**$9.16**	**$5.66**

[1] Canada: Vessel Registration Number and USA: ADF&G vessel number.
[2] Days are estimated - some vessels fished two charter regions in one day.
[3] Stations that did not meet setting parameters or deemed ineffective are excluded.
[4] Net weight (head-off, dressed, washed). May not sum to correct total due to rounding.
[5] Ex-vessel price.

Vessels chartered by the IPHC delivered fish to 19 different ports (Tables 2). Fish sales were awarded based on obtaining a fair market price. When awarding sales, the Commission considered the price offered, the number of years that a buyer had been buying and marketing Pacific halibut, how fish were graded at the dock (including the determination of No. 2 and chalky Pacific halibut), and the promptness of settlements following deliveries. Individual sales were evaluated after each event to ensure that the buyer was meeting IPHC standards. Average prices increased from $10.49/kg in 2020 to $15.13/kg in 2021 (Tables 3). This represents a 44.2% increase in price.

Table 2a. FISS Pacific halibut landings by port for all Pacific halibut (sampled U32 and all O32), 2021[1,2].

Offload Port	Trips	Tonnes	Pounds	Total USD	Average Price (USD/kg)	Average Price (USD/lb)
Akutan	7	21	47,284	$258,146.09	$12.04	$5.46
Alitak	1	5	10,086	$52,382.27	$11.45	$5.19
Coos Bay	1	0	636	$3,808.75	$13.20	$5.99
Cordova	2	9	20,852	$150,976.65	$15.96	$7.24
Dutch Harbor	2	6	14,276	$73,972.26	$11.42	$5.18
Homer	4	22	49,592	$359,935.42	$16.00	$7.26
Juneau	3	17	37,244	$245,130.63	$14.51	$6.58
Ketchikan	4	19	42,205	$288,623.96	$15.08	$6.84
King Cove	2	4	8,965	$46,511.29	$11.44	$5.19
Kodiak	12	65	142,288	$895,636.20	$13.88	$6.29
Newport	2	2	4,525	$24,135.50	$11.76	$5.33
Petersburg	3	21	45,280	$298,141.46	$14.52	$6.58
Port Hardy	8	31	67,980	$539,792.38	$17.51	$7.94
Prince Rupert	7	34	75,490	$621,518.45	$18.15	$8.23
Sand Point	1	5	10,692	$57,773.76	$11.91	$5.40
Seward	16	76	167,098	$1,213,823.80	$16.01	$7.26
Sitka	2	16	34,732	$233,800.83	$14.84	$6.73
Westport	2	3	7,142	$35,830.80	$11.06	$5.02
Yakutat	3	17	36,549	$246,807.35	$14.89	$6.75
Grand Total	**82**	**373**	**822,916**	**$5,646,747.85**	**$15.13**	**$6.86**

[1] Net weight (head-off, dressed, washed).
[2] Prices based on net weight.

Table 2b. FISS Pacific halibut landings by port for O32 Pacific halibut, 2021[1,2].

Offload Port	Trips	Tonnes	Pounds	Total USD	Average Price (USD/kg)	Average Price (USD/lb)
Akutan	7	19	42,016	$232,426.29	$12.20	$5.53
Alitak	1	5	10,086	$52,382.27	$11.45	$5.19
Coos Bay	1	0	503	$3,143.75	$13.78	$6.25
Cordova	2	9	20,694	$150,151.65	$16.00	$7.26
Dutch Harbor	2	5	12,036	$62,772.26	$11.50	$5.22
Homer	4	22	49,063	$356,464.67	$16.02	$7.27
Juneau	3	16	36,080	$238,042.48	$14.55	$6.60
Ketchikan	4	19	40,904	$280,300.34	$15.11	$6.85
King Cove	2	4	7,889	$41,269.29	$11.53	$5.23
Kodiak	12	61	134,830	$849,719.36	$13.89	$6.30
Newport	2	2	3,628	$20,402.50	$12.40	$5.62
Petersburg	3	20	44,534	$293,478.96	$14.53	$6.59
Port Hardy	8	30	65,500	$522,701.69	$17.59	$7.98
Prince Rupert	7	34	74,290	$612,859.97	$18.19	$8.25
Sand Point	1	4	9,693	$52,778.76	$12.00	$5.45
Seward	16	75	165,430	$1,202,817.01	$16.03	$7.27
Sitka	2	15	34,013	$229,371.28	$14.87	$6.74
Westport	2	2	5,272	$30,220.80	$12.64	$5.73
Yakutat	3	16	35,696	$241,435.95	$14.91	$6.76
Grand Total	**82**	**359**	**792,157**	**$5,472,739.28**	**$15.23**	**$6.91**

[1] Net weight (head-off, dressed, washed).
[2] Prices based on net weight.

Table 2c. FISS Pacific halibut landings by port for sampled U32 Pacific halibut, 2021[1,2].

Offload Port	Trips	Tonnes	Pounds	Total USD	Average Price (USD/kg)	Average Price (USD/lb)
Akutan	7	2	5,268	$25,719.80	$10.76	$4.88
Alitak	1	0	0	$0.00	$0.00	$0.00
Coos Bay	1	0	133	$665.00	$11.02	$5.00
Cordova	2	0	158	$825.00	$11.51	$5.22
Dutch Harbor	2	1	2,240	$11,200.00	$11.02	$5.00
Homer	4	0	529	$3,470.75	$14.46	$6.56
Juneau	3	1	1,164	$7,088.15	$13.43	$6.09
Ketchikan	4	1	1,301	$8,323.62	$14.10	$6.40
King Cove	2	0	1,076	$5,242.00	$10.74	$4.87
Kodiak	12	3	7,458	$45,916.84	$13.57	$6.16
Newport	2	0	897	$3,733.00	$9.17	$4.16
Petersburg	3	0	746	$4,662.50	$13.78	$6.25
Port Hardy	8	1	2,480	$17,090.69	$15.19	$6.89
Prince Rupert	7	1	1,200	$8,658.48	$15.91	$7.22
Sand Point	1	0	999	$4,995.00	$11.02	$5.00
Seward	16	1	1,668	$11,006.79	$14.55	$6.60
Sitka	2	0	719	$4,429.55	$13.58	$6.16
Westport	2	1	1,870	$5,610.00	$6.61	$3.00
Yakutat	3	0	853	$5,371.40	$13.88	$6.30
Grand Total	**82**	**14**	**30,759**	**$174,008.57**	**$12.47**	**$5.66**

[1] Net weight (head-off, dressed, washed).
[2] Prices based on net weight.

Table 3a. FISS landings (total pounds and price) of all Pacific halibut (sampled U32 and all O32) by IPHC Regulatory Area in 2021[1].

IPHC Regulatory Area	2A	2B	2C	3A	3B	4A	4B	4C	4D	Closed Area	Combined
Tonnes	6	65	64	168	42	14	11	2	1	0	373
Pounds	12,303	143,470	141,447	370,991	93,145	30,257	24,121	5,487	1,583	112	822,916
Price USD/kg	$11.43	$17.85	$14.74	$15.35	$13.29	$11.73	$12.14	$11.84	$11.60	$11.84	$15.13
Price USD/lb	$5.18	$8.09	$6.69	$6.96	$6.03	$5.32	$5.51	$5.37	$5.26	$5.37	$6.86

[1] Net weight (head-off, dressed, washed).

Table 3b. FISS landings (total pounds and price) of O32 Pacific halibut by IPHC Regulatory Area in 2021[1].

IPHC Regulatory Area	2A	2B	2C	3A	3B	4A	4B	4C	4D	Closed Area	Combined
Tonnes	4	63	62	166	39	12	10	2	1	0	359
Pounds	9403	139,790	137,772	365,373	85,767	25,446	22,177	4,966	1,362	101	792,157
Price USD/kg	$12.61	$17.91	$14.77	$15.37	$13.32	$11.94	$12.15	$12.05	$12.05	$12.05	$15.23
Price USD/lb	$5.72	$8.12	$6.70	$6.97	$6.04	$5.42	$5.51	$5.46	$5.46	$5.46	$6.91

[1] Net weight (head-off, dressed, washed)

Table 3c. FISS landings (total pounds and price) of sampled U32 Pacific halibut by IPHC Regulatory Area in 2021[1].

IPHC Regulatory Area	2A	2B	2C	3A	3B	4A	4B	4C	4D	Closed Area	Combined
Tonnes	1	2	2	3	3	2	1	0	0	0	14
Pounds	2900	3,680	3,675	5,618	7,378	4,811	1,944	521	221	11	30,759
Price USD/kg	$7.61	$15.43	$13.73	$13.87	$12.87	$10.58	$11.97	$9.92	$8.82	$9.92	$12.47
Price USD/lb	$3.45	$7.00	$6.23	$6.29	$5.84	$4.80	$5.43	$4.50	$4.00	$4.50	$5.66

[1] Net weight (head-off, dressed, washed)

FISS timing

Each year, the months of June, July, and August are targeted for FISS fishing. In 2021, this activity took place from 29 May through 14 September. On a coastwide basis, FISS vessel activity was highest in intensity at the beginning of the FISS season and declined early in August as boats finished their charter regions (Figure 8). All FISS activity was completed by mid-September.

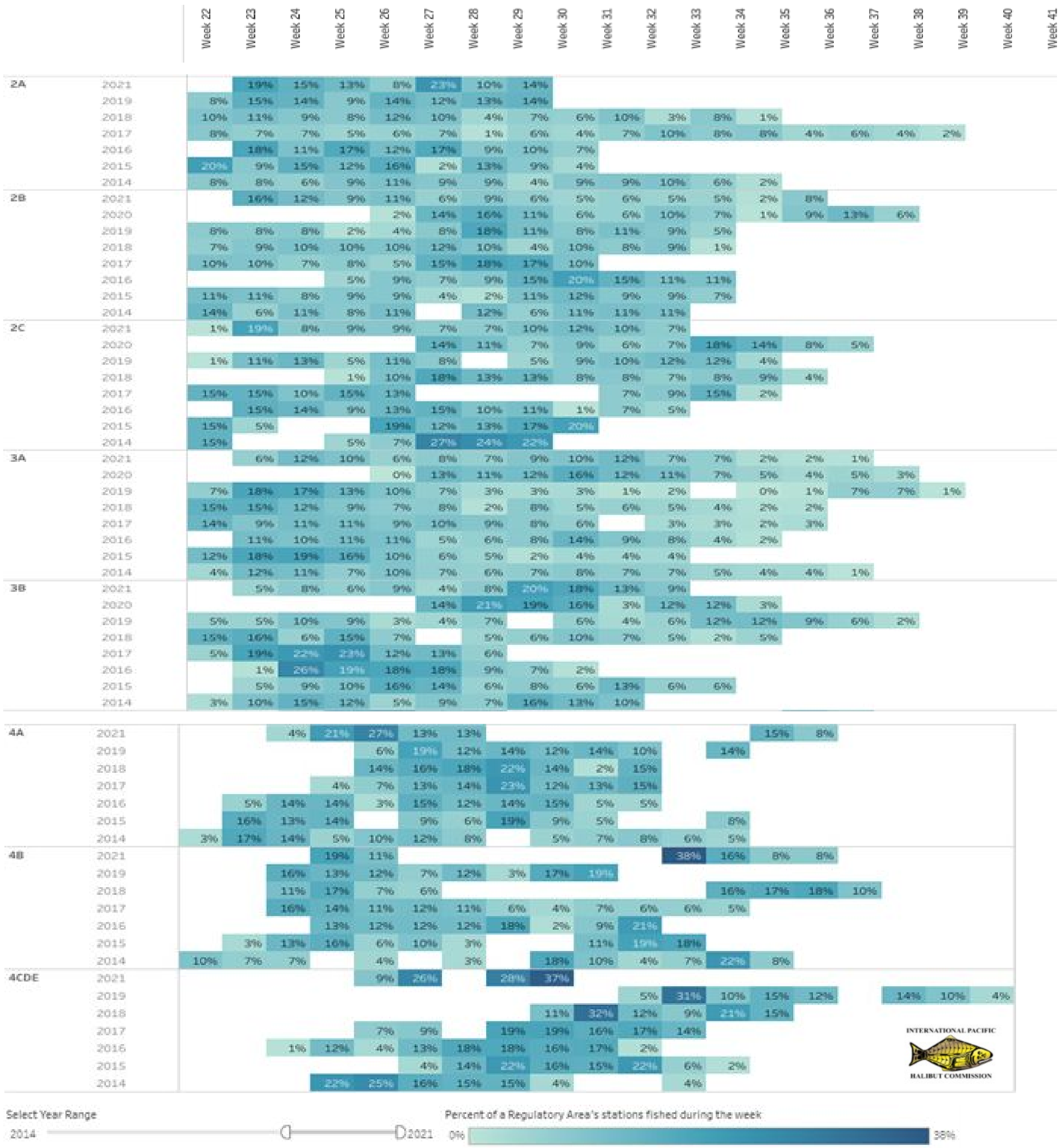

Figure 8. Percent of the total FISS stations completed by IPHC Regulatory Area during each week of the year (2014-2021). Week 22 begins in late May or early June depending on the year.

RECOMMENDATION/S

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-05 which provides a summary of the IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2021.

APPENDICES

Nil.

2022-24 FISS design evaluation

PREPARED BY: IPHC SECRETARIAT (R. A. WEBSTER; 27 OCTOBER 2021)

PURPOSE

To present proposed designs for the IPHC's Fishery-Independent Setline Survey (FISS) for the 2022-24 period, and an evaluation of those designs, as reviewed and endorsed by the Scientific Review Board in June 2021 (SRB018).

BACKGROUND

The IPHC's Fishery-Independent Setline Survey (FISS) provides data used to compute indices of Pacific halibut density for use in monitoring stock trends, estimating stock distribution, and as an important input in the stock assessment. Stock distribution estimates are based on the annual mean weight-per-unit effort (WPUE) for each IPHC Regulatory Area, computed as the average of WPUE of all Pacific halibut and for O32 (greater than or equal to 32" or 81.3cm in length) Pacific halibut estimated at each station in an area. Mean numbers-per-unit-effort (NPUE) is used to index the trend in Pacific halibut density for use in the stock assessment models.

FISS history 1993-2019

The IPHC has undertaken FISS activity since the 1960s. However, methods were not standardized to a degree (e.g., the bait and gear used) that allows for simple combined analyses until 1993. From 1993 to 1997, the annual design was a modification of a design developed and implemented in the 1960s, and involved fishing triangular clusters of stations, with clusters located on a grid (IPHC 2012). Coverage was limited in most years, and was generally restricted to IPHC Regulatory Areas 2B through 3B. The modern FISS design, based on a grid with 10 nmi (18.5 km) spacing, was introduced in 1998, and over the subsequent two years was expanded to include annual coverage in parts of all IPHC Regulatory Areas within the depth ranges of 20-275 fathoms (37-503 m) in the Gulf of Alaska and Aleutian Islands, and 75-275 fathoms (137-503 m) in the Bering Sea (IPHC 2012). Annually-fished stations were added around islands in the Bering Sea in 2006, and in the same year, a less dense grid of paired stations was fished in shallower waters of the southeastern Bering Sea, providing data for a calibration with data from the annual National Marine Fishery Service (NMFS) trawl survey (Webster et al. 2020).

Examination of commercial logbook data and information from other sources, it became clear by 2010 that the historical FISS design had gaps in coverage of Pacific halibut habitat that had the potential to lead to bias in estimates derived from its data. These gaps included deep and shallow waters outside the FISS depth range (0-20 fathoms and 275-400 fathoms), and unsurveyed stations on the 10 nmi grid within the 20-275 fathom depth range within each IPHC Regulatory Area. This led the IPHC Secretariat to propose expanding the FISS to provide coverage within the unsurveyed habitat with United States and Canadian waters. In 2011 a pilot expansion was undertaken in IPHC Regulatory Area 2A, with stations on the 10 nmi grid added to deep (275-400 fathoms) and shallow (10-20 fathoms) waters, the Salish Sea, and other, smaller gaps in coverage. (The 10 fathom limit in shallow waters was due to logistical difficulties in fishing longline gear in shallower waters.) A second expansion in IPHC Regulatory Area 2A was completed in 2013, with a pilot California survey between latitudes of 40-42°N.

The full expansion program began in 2014 and continued through 2019, resulting in the sampling of the entire FISS design of 1890 stations in the shortest time logistically possible. The FISS expansion program allowed us to build a consistent and complete picture of Pacific halibut density throughout its range in Convention waters. Sampling the full FISS design has reduced bias as noted above, and, in conjunction with space-time modelling of survey data (see below), has improved precision and fully quantified the uncertainty associated with estimates based on partial annual sampling of the species range. It has also provided us with a complete set of observations over the full FISS design (Figure 1) from which an optimal subset of stations can be selected when devising annual FISS designs. This station selection process began in 2019 for the 2020 FISS and continues with the current review of design proposals for 2022-24. Note that in the Bering Sea, the full FISS design does not provide complete spatial coverage, and FISS data are augmented with calibrated data from National Marine Fisheries Service (NMFS) and Alaska Department of Fish and Game (ADFG) trawl surveys (stations can vary by year – 2019 designs are shown in Figure 1). Both supplementary surveys are conducted approximately annually.

Space-time modelling

In 2016, a space-time modelling approach was introduced to estimate time series of weight and numbers-per-unit-effort (WPUE and NPUE), and to estimate the stock distribution of Pacific halibut among IPHC Regulatory Areas. This represented an improvement over the largely empirical approach used previously, as it made use of additional information within the survey data regarding the degree of spatial and temporal of Pacific halibut density, along with information from covariates such as depth (Webster et al. 2020). It also allowed a more complete accounting of uncertainty: for example, prior to the use of space-time modelling, uncertainty due to unsurveyed regions in each year was ignored in the estimation - these unsampled regions were either filled in using independently estimated scalar calibrations (if fished at least once), or catch-rates at unsampled stations were assumed to be equal to the mean for the entire Regulatory Area. The IPHC's Scientific Review Board (SRB) has provided supportive reviews of the space-time modelling approach (e.g., IPHC-2018-SRB013-R), and the methods were recently published in a peer-review journal (Webster et al. 2020). Similar geostatistical models are now routinely used to standardise fishery-independent trawl surveys for groundfish on the West Coast of the U.S. and in Alaskan waters (e.g., Thorson et al. 2015 and Thorson 2019).

FISS design objectives

The primary purpose of the annual FISS is to sample Pacific halibut to provide data for the stock assessment (abundance indices, biological data) and estimates of stock distribution for use in the IPHC's management procedure. The priority of a rationalised FISS is therefore to maintain or enhance data quality (precision and bias) by establishing baseline sampling requirements in terms of station count, station distribution and skates per station. Potential considerations that could add to or modify the design are logistics and cost (secondary design layer), and FISS removals (impact on the stock), data collection assistance for other agencies, and IPHC policies (tertiary design layer). These priorities are outlined in Table 1.

Table 1. Prioritization of FISS objectives and corresponding design layers.

Priority	**Objective**	**Design Layer**
Primary	Sample Pacific halibut for stock assessment and stock distribution estimation	Minimum sampling requirements in terms of: • Station distribution • Station count • Skates per station
Secondary	Long term revenue neutrality	Logistics and cost: operational feasibility and cost/revenue neutrality
Tertiary	Minimize removals, and assist others where feasible on a cost-recovery basis.	Removals: minimize impact on the stock while meeting primary priority Assist: assist others to collect data on a cost-recovery basis IPHC policies: ad-hoc decisions of the Commission regarding the FISS design

Review process

Since completion of the FISS expansions, a review process has been developed for annual FISS designs created according the above objectives:

- The Secretariat presents design proposals to the SRB for three subsequent years at the June meeting (recognizing that data from the current summer FISS will not be available for analysis prior to the September SRB meeting).
- The first review of design proposals by Commissioners will occur at the September work meeting, revised if necessary based on June SRB input;
- Presentation of proposed designs for 'endorsement' occurs at the November Interim Meeting;
- Ad-Hoc modifications possible at the Annual Meeting to the design for the current year (due to unforeseen issues arising);
- Endorsed design for current year modified for cost and logistical reasons prior to summer implementation in FISS (February-April).

Consultation with industry and stakeholders occurs throughout the FISS planning process, and particularly in finalizing design details as part of the FISS charter bid process, when stations can be added to provide for improved logistical efficiency. We also note the opportunities for stakeholder input during public meetings (Interim and Annual Meetings) and through the IPHC's Research Advisory Board.

Note that while the review process examines designs for the next three years, revisions to designs for the second and third years are possible during subsequent review periods. Having design proposals available for three years instead of the next year only assists the IPHC with medium-term planning of the FISS, and allows reviewers (SRB, IPHC Commissioners) and stakeholders to see more clearly the planning process for sampling the entire FISS footprint over multiple years. Extending the proposed designs beyond three years was not considered worthwhile, as we expect further evaluation undertaken following collection of data during the one to three-year time period to influence design choices for subsequent years.

PROPOSED DESIGNS FOR 2022-24

The designs proposed for 2022-24 (Figures 2 to 4) use efficient subarea sampling in IPHC Regulatory Areas 2A, 4A and 4B, and incorporate a randomized subsampling of FISS stations in IPHC Regulatory Areas 2B, 2C, 3A and 3B (except for the near-zero catch rate inside waters around Vancouver Island), with a sampling rate chosen to keep the sample size close to 1000 stations in an average year. This was also used to generate the designs originally proposed for 2020 (but modified as a result of the impact of COVID19 and cost considerations), and for those proposed and approved for 2021. In 2020, designs for 2022-23 were also approved subject to revision. We are proposing one change from that 2022 design, bringing forward by one year (from 2023 to 2022) the sampling of the central and western subareas of IPHC Regulatory Area 4B to reduce the risk of bias in estimates from that area. Thus, we propose that:

- In 2022 the lower-density western and central subareas of IPHC Regulatory Area 4B in sampled, followed by the higher-density eastern subarea in 2023-24
- The higher-density western subarea of IPHC Regulatory Area 4A be sampled in all three years, with the medium-density northern shelf edge subarea added in 2023 only
- The highest-density waters of IPHC Regulatory 2A in northern Washington and central/southern Oregon are proposed for sampling in each year of the 2022-24 period
- The near-zero density waters of the Salish Sea in IPHC Regulatory 2B are not proposed for sampling in 2022-24

Following this three-year period, it is expected that the remaining subareas will be included during the subsequent 3-5 years. These include the southeastern subarea of IPHC Regulatory 4A, and lower-density waters of IPHC Regulatory 2A (see below).

The design proposals again include full sampling of the standard FISS grid in IPHC Regulatory Area 4CDE. The Pacific halibut distribution in this area continues to be of particular interest, as it is a highly dynamic region with an apparently northward-shifting distribution of Pacific halibut, and increasing uncertainty regarding connectivity with populations adjacent to and within Russian waters.

While the proposed designs continue to rely on randomised subsampling of stations within the core IPHC Regulatory Areas (2B, 2C, 3A and 3B) and logistically efficient subarea designs elsewhere, other designs have been considered and remain as options. A discussion of these, adapted from previous reports, is in Appendix A.

We note that at SRB018, the SRB endorsed the final 2022 FISS design as presented in Fig. 2, and provisionally endorsed the 2023-24 designs (Figs. 3 and 4) (IPHC-2021-SRB018-R).

FISS DESIGN EVALUATION

Precision targets

In order to maintain the quality of the estimates used for the assessment, and for estimating stock distribution, the IPHC Secretariat has set a target range of less than 15% for the coefficient of variation (CV) of mean O32 and all sizes WPUE for all IPHC Regulatory Areas. We also established precision targets of IPHC Biological Regions and a coastwide target (IPHC-2020-AM096-07), but achievement of the Regulatory Area targets is expected to ensure that targets for the larger units will also be met.

Reducing the potential for bias

In IPHC Regulatory Areas in which stations are not subsampled randomly (IPHC Regulatory Areas 2A, 4A and 4B in the 2022-24 proposals), sampling a subset of the full data frame in any area or region brings with it the potential for bias. This is due to trends in the unsurveyed portion of a management unit (Regulatory Area or Region) potentially differing from those in the surveyed portion. To reduce the potential for bias, we also looked at how frequently part of an area or region ("subarea") should be surveyed in order to reduce the likelihood of appreciable bias. For this, we proposed a threshold of a 10% absolute change in biomass percentage: how quickly can a subarea's percent of the biomass of a Regulatory Area change by at least 10% (e.g., from 15 to 25% of the area's biomass)? By sampling each subarea frequently enough to reduce the chance of its percentage changing by more than 10% between successive surveys of the subarea, we minimize the potential for appreciable bias in the Regulatory Area's index.

We examined the effect of subsampling the FISS stations for a management unit on precision as follows:

- Where a randomised design is not used, identify logistically efficient subareas within each management unit and select priorities for future sampling
- Generate simulated data for all FISS stations based on the output from the most recent space-time modelling
- Fit space-time models to the observed data series augmented with 1 to 3 additional years of simulated data, where the design over those three years reflects the sampling priorities identified above
- Project precision estimates and quantify bias potential for comparison against threshold

Table 2 shows projected CVs following completion of the proposed 2022-24 FISS designs. With these designs, we are projected to maintain CVs within the target range. Estimates from the terminal year are most informative for management decisions, but they also typically have the largest CVs (all else being equal). The final column in Table 2 shows the CV projections immediately following the 2022 FISS, which are also within the target range.

The projected CV for 2024 for IPHC Regulatory Area 2A is close to exceeding the target, and in future revisions of the 2024 design, we may wish to consider adding stations from southern Washington/northern Oregon, and northern California to the design ("subarea 2" for this Regulatory Area). While historical data show this subarea to be highly stable over time in terms of its biomass proportion, by 2024 it will have been five years since any part of it was last sampled, and with no other lower-density subareas planned for sampling that year in IPHC Regulatory Areas 4A and 4B, this may be a logistically feasible year for fishing those stations. Should estimated CVs increase more rapidly than projected, future designs would be revised accordingly.

Table 2. Projected CVs (%) for 2021-24 for O32 WPUE estimated after completion of the proposed 2022-24 FISS designs, and (final column) after completion of the proposed 2022 FISS design only.

Reg. Area	2021	2022	2023	2024	2022 (Estimated in 2022)
2A	13	13	14	15	14
4A	10	9	9	10	10
4B	10	12	10	12	14

For maintaining low bias, we looked at estimates of historical changes in the proportion of biomass in each subarea, and used that to guide the sampling frequency in future designs. Thus subareas that have historically had rapid changes in biomass proportion need to be sampled most frequently, and those that are relatively stable can be sampled less frequently. For example, if a subarea's % of its Regulatory Area's biomass changed by no more than 8% over 1-2 years (in absolute terms) but by up to 12% over three years, we should sample it at least every three years based on the 10% criterion discussed above.

Based on estimates from the historical times series (1993-2020) of O32 WPUE, the proposed designs for 2022-24 would be expected to maintain low bias by ensuring that it is unlikely that biomass proportions for all subareas change by more than 10% since they were previously sampled (Table 3).

Table 3. Maximum expected absolute changes (%) in biomass proportion since previous sampling of subareas that are unsampled in a given year, based on estimated the 1993-2020 time series.

Reg. Area	2021	2022	2023	2024
2A	8	9	9	9
4A	8	10	6	6
4B	10	9	8	10

Post-sampling evaluation for 2020

The evaluation of precision of proposed designs above is based on using simulated sample data generated under the fitted space-time model for future years. If observed data are more (or less) variable than those generated under the model, actual estimates of precision may differ from those projected from models making use of the generated data. Table 4 compares the estimates of the CV for mean O32 WPUE for the implemented 2020 design based on using simulated data for 2020 and estimated from fitting the models including observed 2020 data. The projected CVs based on simulated data are essentially the same as those estimated when observed data are used for 2020 for the four IPHC Regulatory Areas sampled in 2020.

Table 4. Comparison of projected and estimated CVs (%) for 2020 by IPHC Regulatory Area. Note that FISS sampling in 2020 did not include Areas 2A, 4A, 4B or 4CDE due to unplanned survey reductions, therefore projected and estimated CVs are identical.

Regulatory Area	2020 projected CV (%)	2020 estimated CV (%)
2A		22
2B	6	6
2C	6	5
3A	4	4
3B	10	10
4A		25
4B		25
4CDE		12

CONSIDERATION OF COST

Ideally, the FISS design would be based only on scientific needs. However, some Regulatory Areas are consistently more expensive to sample than others, so for these the efficient subarea designs were developed. The purpose of factoring in cost was to provide a statistically efficient and logistically feasible design for consideration by the Commission. During the Interim and Annual Meetings and subsequent discussions, cost, logistics and tertiary considerations (Table 1) are also factored in developing the final design for implementation in the current year. It is anticipated that under most circumstances, cost considerations can be addressed by adding stations to the minimum design proposed in this report (2020 was an exceptional case). In particular, the FISS is funded by sales of captured fish and is intended to have long-term revenue neutrality, meaning that any design must also be evaluated in terms of the following factors:

- Expected catch of Pacific halibut
- Expected Pacific halibut sale price
- Charter vessel costs, including relative costs per skate and per station
- Bait costs
- IPHC Secretariat administrative costs

Balancing these factors may result in modifications to the design such as increasing sampling effort in high-density regions and decreasing effort in low density regions. At present, with stocks near historic lows and extremely low prices for fish sales, the current funding model may require that some low-density habitat be omitted from the design entirely (as occurred in 2020). This will have implications for data quality, particularly if such reductions in effort relative to proposed designs continue over multiple years. Note that this did not occur in the 2021 design, as it was sufficient to include additional stations in core IPHC Regulatory Areas to generate a revenue-neutral coastwide design.

RECOMMENDATION

That the Research Advisory Board:

1) **NOTE** paper IPHC-2021-RAB022-06 that presents the FISS design proposals for 2022-24 together with an evaluation of the proposed designs;

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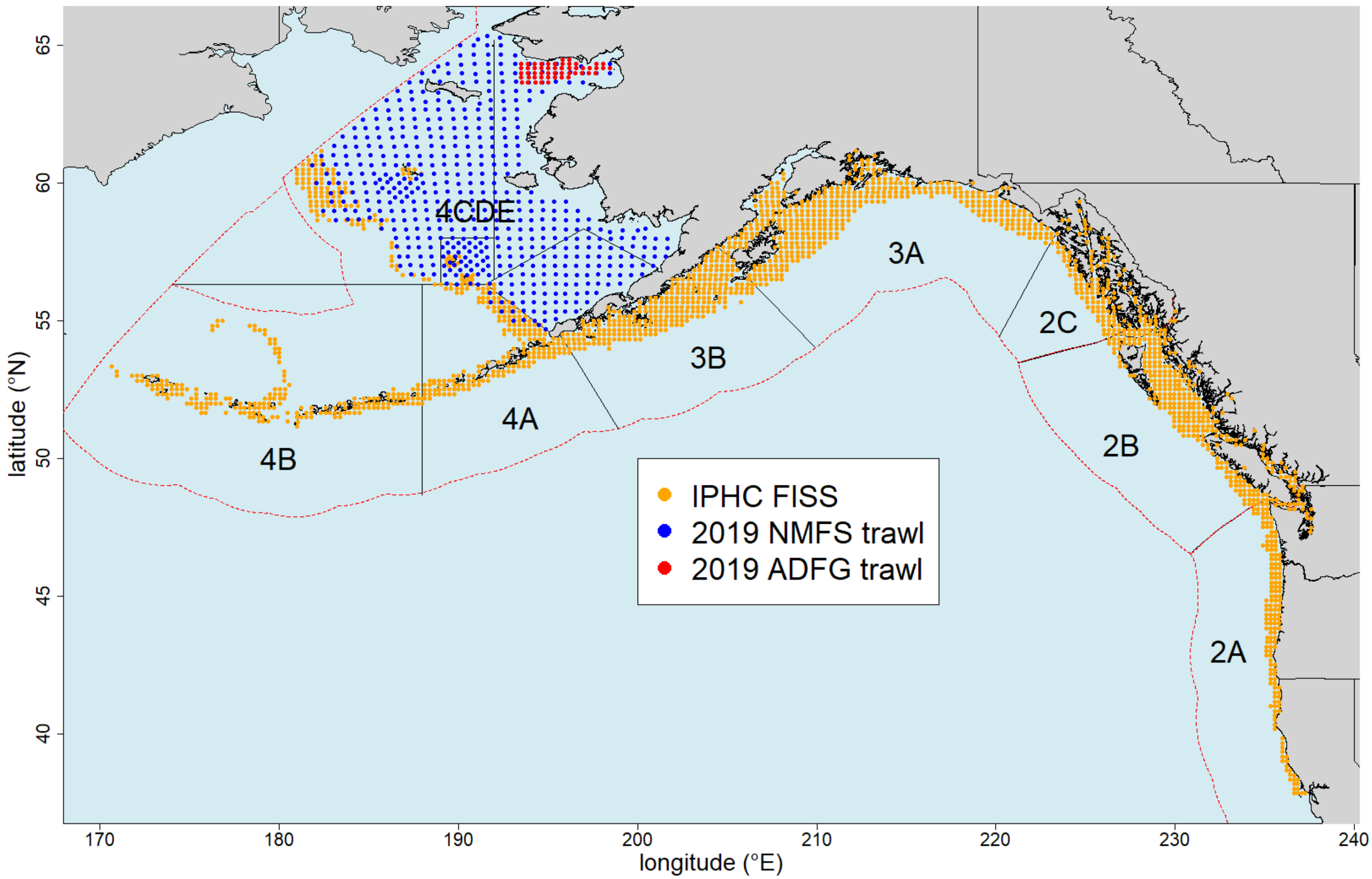
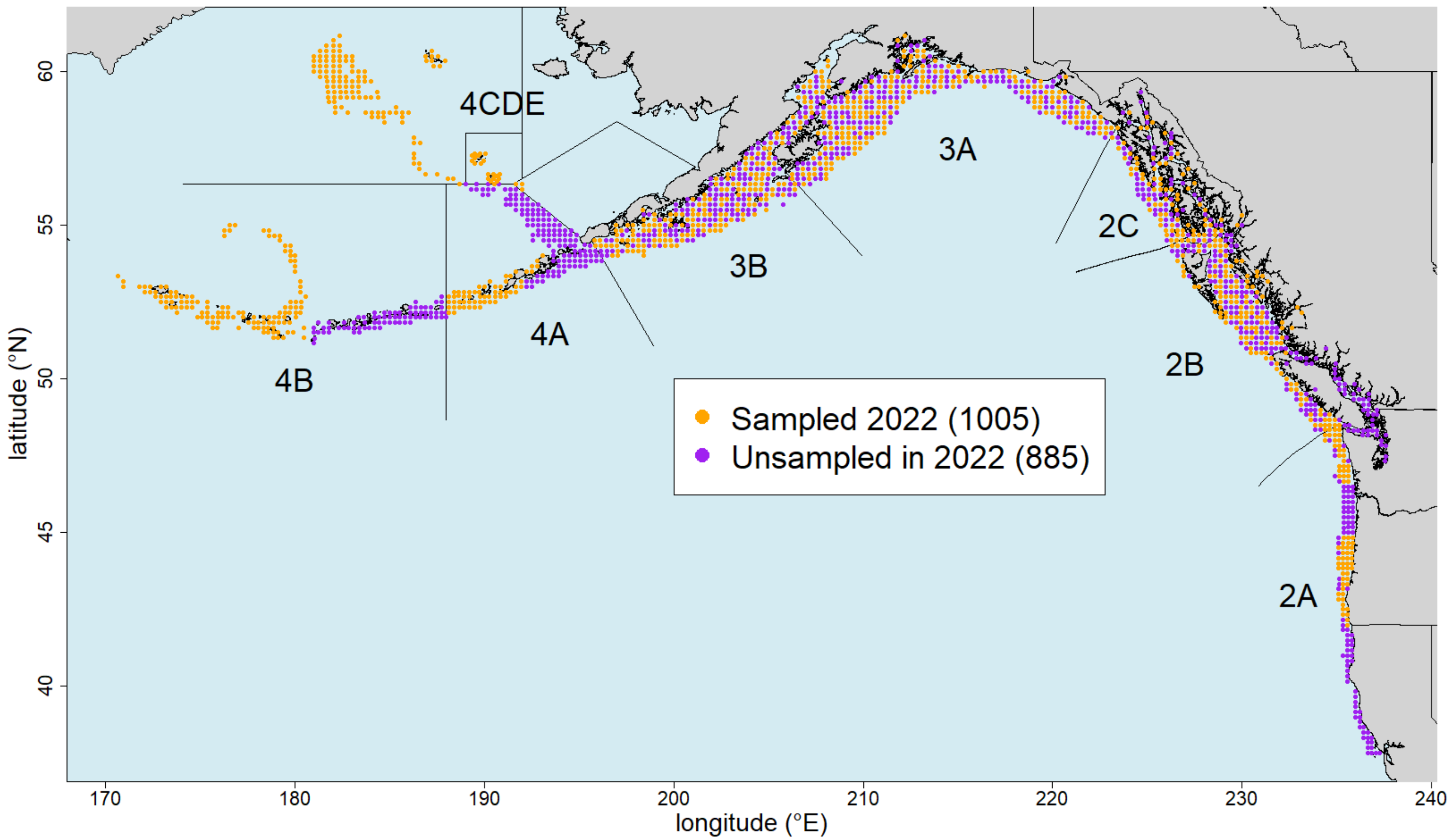
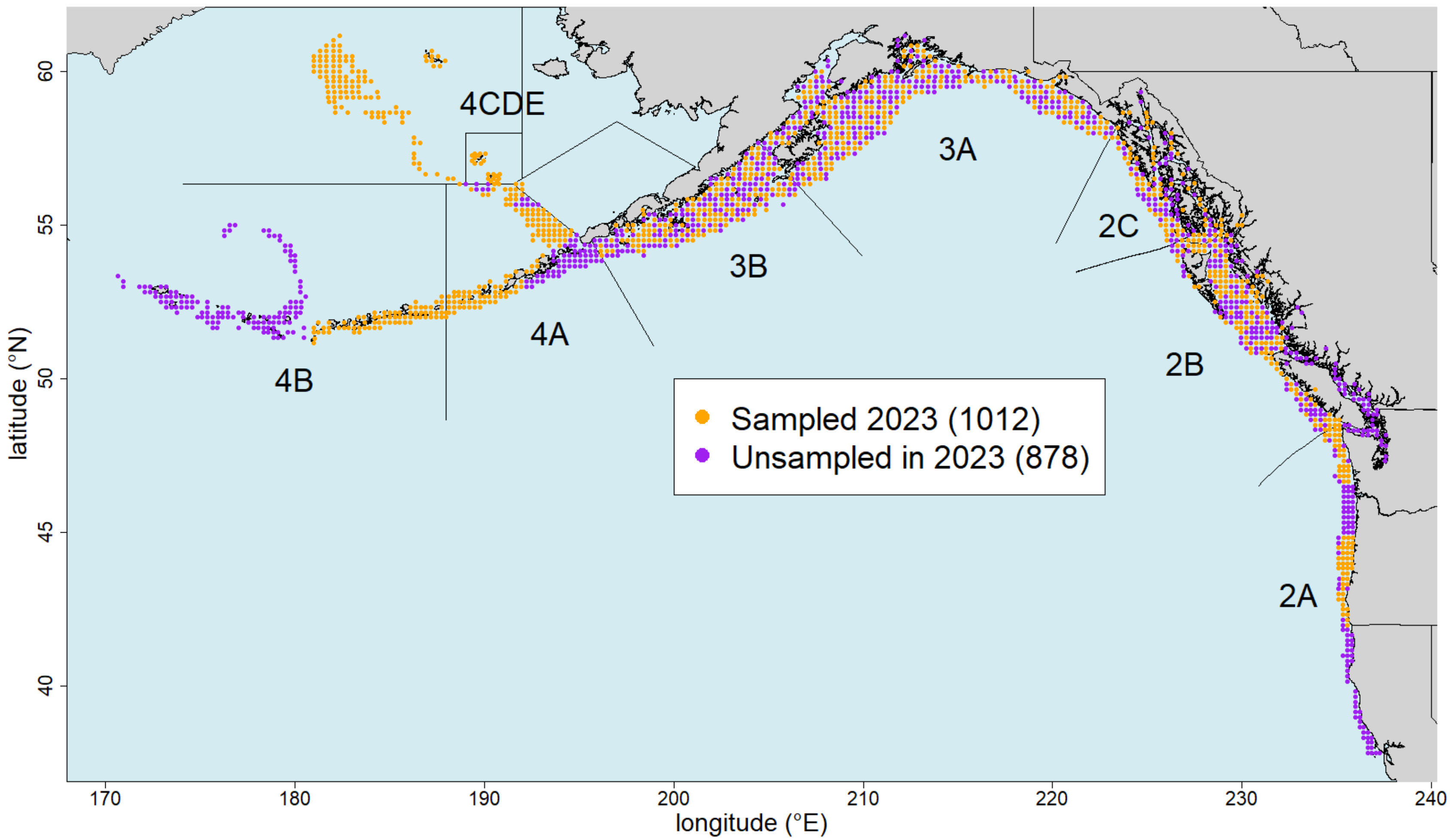


Figure 1. Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs, and other colours representing trawl stations from 2019 NMFS and ADFG surveys used to provide complementary data for Bering Sea modelling.



4CDE
4B
4A
3B
3A
2C
2B
2A
Sampled 2022 (1005)
Unsampled in 2022 (885)
latitude (°N)
longitude (°E)
40
45
50
55
60
170
180
190
200
210
220
230
240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3A
2C
3B
4A
4B
2B
2A
Sampled 2023 (1012)
Unsampled in 2023 (878)
latitude (°N)
longitude (°E)
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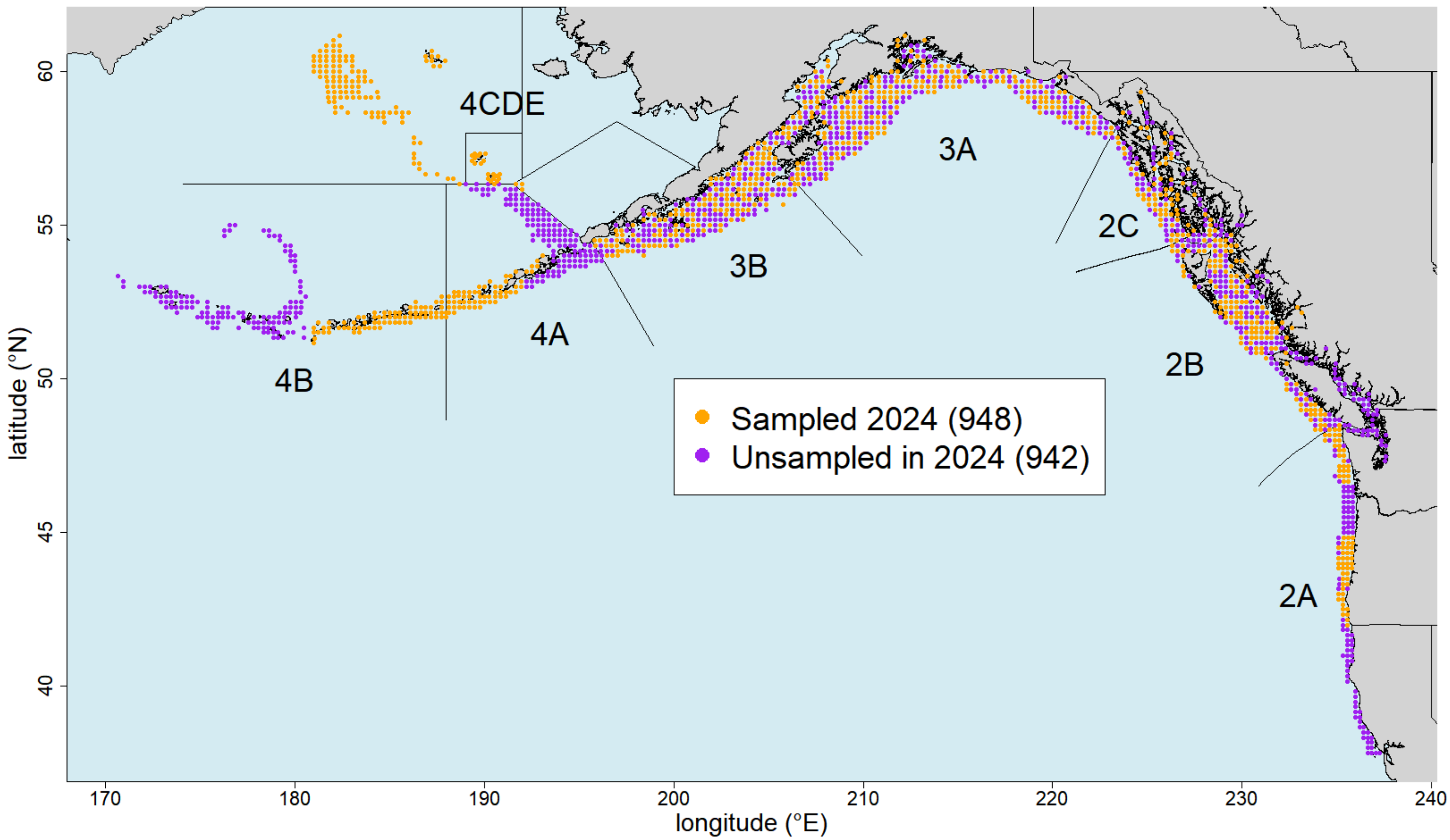
4CDE
4B
4A
3B
3A
2C
2B
2A
Sampled 2024 (948)
Unsampled in 2024 (942)
latitude (°N)
longitude (°E)
60
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IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling

PREPARED BY: IPHC SECRETARIAT (R. WEBSTER; 27 OCTOBER 2021)

Part 1: Modelling of IPHC length-weight data

PURPOSE

To present results of fitting models to IPHC length-weight data from FISS and commercial sampling, and make recommendations of revised length-net weight relationships for applications to non-IPHC data sources.

BACKGROUND/INTRODUCTION

Historical length-weight curve

The IPHC's standard length to net weight relationship was used in all commission work to convert length to net weight of halibut until 2015, when individual weights were added to standard commercial data collections. More recently, the IPHC's Fishery Independent Setline Survey (FISS) began collecting individual weights in 2017, and made such collections comprehensive in 2019. The parameters of this relationship were estimated in 1926 based on a relatively small sample of Pacific halibut (454 fish) collected off Masset in IPHC Regulatory Area 2B. Using 1989 data, Clark (1992) re-estimated the relationship's parameters and found good agreement with the earlier curve, and no changes to the historical IPHC relationship were made. While it was recognized that such a calculated relationship will not be consistently accurate when computing total or mean weights from small numbers of Pacific halibut, it was assumed that predictions should be accurate when data come from larger samples of fish (Clark 1992). However, when Courcelles (2012) estimated the relationship from data collected in 2011, she found significant differences between her estimated curve and that derived from the 1989 data, although inference was limited to a relatively small part of Area 3A and to the time of the FISS. Reports from staff working on the FISS, along with other anecdotal reports, suggested that the historical length-net weight relationship has been overestimating the weight of Pacific halibut on average in recent years.

Adjustments and conversion factors

Various adjustment and conversion factors have been used to account for Pacific halibut measured at different stages of processing following capture (Table 1.1).

Table 1.1 Definitions of types of weight measures used by the IPHC and multipliers used to convert to net weight.

Weight	Definition	Multiplier to convert to net weight	Notes
Round	Head-on, not gutted, no ice and slime	0.75	
Gross (vessel weight)	Head-on, gutted, with ice and slime	0.8624	Assumes 10% head weight and 2% shrinkage, or 12% head, and 2% ice and slime
Dressed (vessel weight)	Head-on, gutted, no ice and slime	0.88	Assumes 10% head weight and 2% shrinkage, or 12% head only
Gross (dock weight)	Head-on, gutted, with ice and slime	0.882 or 0.88	Assumes 10% head weight and 2% ice and slime; deductions either additive (10+2=12% in 2A and 2B) or multiplicative (1-0.9*0.98=0.118 or 11.8% in Alaska)
Dressed (dock weight)	Head-on, no ice and slime (washed)	0.9	Assumes 10% head weight
Net	Head-off, gutted, no ice and slime (washed)	1	

The historical relationship between fork length and net weight includes adjustments for the weight of the head, and of ice and slime (I/S): gross landed weight (gutted, with head, ice and slime) was assumed to include a proportion of 0.12 head weight and 0.02 ice and slime, which combine to give a multiplier of 0.8624 to convert gross to net weight. Clark (1992) noted that subsequent studies showed the head weighed less than 0.12 of gross weight, but that the adjustment factor worked well anyway, possibly because of additional shrinkage of fish after being weighed at sea (as they were in the 1926 study in which the relationship was estimated). In practice, combined deductions of 0.12 in Areas 2A and 2B, and 0.118 in Alaska, were applied to commercial landings to convert from gross to net weight. These both include the 0.02 deduction for ice and slime assumed in the IPHC length-net weight relationship, but use 0.1 as the proportion for the head. This head deduction has been required as part of IPHC regulations since 2008 (Leaman and Gilroy 2008, Gilroy et al. 2008). The way the two deductions are combined differs among areas. In Areas 2A and 2B, these deductions are simply added (0.1+0.02=0.12), while in Alaska, the corresponding multipliers (1 minus the deduction) are multiplied, leading to a multiplier of 0.882, and a deduction of 0.118.

Estimating and comparing length-net weight curves

The commercial sampling program and the FISS weight sampling provide us with two independent data sources to use in re-estimating length-net weight relationships. For estimating the relationship between fork length and net weight, only head-on fish (with the same standard head and I/S deductions assumed in the standard IPHC relationship, 0.10 and 0.02 respectively) are used to ensure a consistent comparison due to the high spatial variability in the proportion of the weight removed when cutting heads (see below). Function parameters are estimated by fitting linear models (on the log scale) using least squares.

Commercial catch sampling

In 2015, collection of weight data by IPHC staff began on randomly sampled fish in commercial landings. Sample weights were measured in all ports except Dutch Harbor and St Paul, which were added the following year. In 2017, weighing of fish was expanded to include all Pacific halibut selected for biological sampling (length measurement, fin clip for genetic analysis, and otolith collection). The addition of recording fish weights to commercial sampling was motivated by a desire for more accurate estimation of commercial landings, validation of adjustments for head weights and the weight of ice and slime, and validation or revision of the IPHC historical length-net weight relationship. Sample sizes by year and IPHC Regulatory Area are given in Table 1.2.

Table 1.2. Sample sizes of weighed commercial Pacific halibut by year and IPHC Regulatory Area.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE
2015	32	801	1431	1538	1133	798	192	147
2016	303	1943	1673	1470	1492	1574	1466	1270
2017	1118	1376	1367	1453	1381	997	1816	1632
2018	2253	1421	1612	1676	808	925	1307	1494
2019	1731	1076	1573	1751	1751	1322	968	960
2020	1318	1694	1717	1608	1606	937	1264	905

Head weight

Head weight was estimated from a subset of Pacific halibut that were weighed twice, before and after the head was cut in the plant. Data showed that head cuts were highly variable (Webster and Erikson 2017), and the proportion of the fish removed varied greatly among ports and plants. Because the head cut was so variable, the IPHC regulations were changed in 2018 (?) to require all catch to be offloaded and weighed with the head on to ensure consistent treatment of fish across ports and plants, and accurate accounting for the mortality in stock assessment and management analyses. Following the regulation change, commercial sampling for head weight was discontinued, and the 10% deduction for head is applied to all offloaded Pacific halibut as a standard part of the conversion to net weight. (With the requirement to land fish head on, the accuracy of that 10% adjustment became moot – it is simply part of the IPHC definition of net weight.)

Ice and slime

It was hoped that commercial sampling would yield estimates of the weight of ice and slime through the comparison of fish weight twice, before and after washing. Plant operations have not allowed for the collecting of such data, and therefore it has not been possible to validate the assumed 2% adjustment for ice and slime. In the absence of any updated information, that adjustment remains in use. The Commission considers this adjustment to be applicable only in the absence of any water used to remove ice from the unloaded fish prior to weighing. The 'plug' ice in the body cavity is assumed to be removed and not part of the 2% deduction for all fish.

Length-net weight curves

We estimated the length-net weight curve for each IPHC Regulatory Area and for each year from 2016-20, allowing us to assess variation in estimated curves over time and space, as well as make comparisons between estimated curves and the historical length-net weight relationship. Variation in space over the five-year period (Figures 1.1 to 1.5) was generally much greater than variation in time within each IPHC Regulatory Area (Figures 1.6 to 1.13). IPHC Regulatory Areas 2A and 4CDE showed much greater temporal variation in estimated curves (Figures 1.6 and 1.13) than other areas: timing and distribution of sampling is less consistent in these Regulatory Areas than elsewhere, which makes inference on changes in the relationship more difficult over short periods. Estimated curves for Regulatory Areas 2B (Figure 1.7) and 3B (Figure 1.10) are close to the historical curve in all years, while those for Regulatory Areas 2C, 3A, 4A and 4B and consistently below the historical curve, with the degree of difference varying among areas.

FISS sampling

Wide-scale weighing of Pacific halibut on the IPHC FISS commenced in 2019 and continued through 2020. In 2019, the intention was to record dressed weight of all legal-sized (O32) fish using motion-compensated scales, with the exception of some larger fish, that were weighed dockside. Due to technical issues, fish on some trips were unable to be weighed. Sample sizes by year and area are given in Table 1.3.

Table 1.3. Sample sizes of weighed FISS Pacific halibut by year and IPHC Regulatory Area.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE
2019	786	3889	10898	15460	4530	3758	495	1545
2020	0	8103	6392	24815	2642	0	0	0

A random subsample of sublegal (U32) fish had dressed weight recorded (those selected for otolith collection), along with round weight, to estimate the relationship between round and dressed weight for use in predicting weight of fish not selected for otolith sampling (and therefore with no dressed weight). Predictions of net weight from round weight (coastwide data) and from length (by IPHC Regulatory Area) were compared to determine which variable was the most accurate predictor of net weight. The approach we took was to model the relationship between the ratio of dressed to round weight and round weight, after applying the normalizing arcsin-square root transformation.

The resulting relationship estimated that as round weight increases, the corresponding dressed weight is a decreasing fraction of round weight, ranging from 88% for fish at 0.5 kg to 84% for 8 kg fish (the approximate weight range of fish in the data).

The estimated relationship with round weight was found to produce more accurate predictions (Figure 1.14), with much less variability from true net weight (scaled from dressed weight as per Table 1.1) and no constraint forced on maximum predicted weight by a strict relationship with length. This led to the recommendation that round weights of U32 Pacific halibut continue to be measured during the FISS, but that measurement of dressed weight for a subsample of such fish can be discontinued. From 2020 onwards, dressed weight (and hence net weight) is being predicted for each U32 fish from the relationship estimated from the 2019 data.

There was general consistency across years for each of the four IPHC Regulatory Area sampled in both 2019 and 2020 (Figures 1.15-1.18) in estimated length-net weight relationships, although differences for Regulatory Areas 2C and 3B (the latter having greatly reduced sampling in 2020) were somewhat larger than Regulatory Areas 2B and 3A. As with length-net weight relationships estimated from commercial sampling data, spatial variation in the estimated relationships among areas was much greater than temporal variation within areas (Figures 1.19-1.20).

Estimating shrinkage

As noted above, there is the assumption of 2% shrinkage when converting weights made on board a vessel to net weight. A subsample of Pacific halibut from FISS sampling was weighed both on the vessels and later at the dock during the 2016 and 2017 FISS seasons, providing data with which to estimate the shrinkage rate of fish. The data file recording at sea and dockside weights for the same individuals includes measurements on 562 fish, although 12 only have a single weight recorded. At sea weights were recorded as round weights, while dockside weights were of head-on and washed fish (i.e., dockside dressed, Table 1.1). To estimate shrinkage, round weights must first be converted into at-sea dressed weights, requiring multiplication of round weights by 0.85 (0.75/0.88 from Table 1.1). Without data to validate this assumed multiplier directly, we are in the problematic position of trying to estimate shrinkage based on values that may themselves be in error due to inaccuracy of the multiplier. While we were able to estimate a relationship between round weight and dressed weight for U32 fish above, the fish weighed twice are O32 fish, and therefore the estimated relationship may not apply. Given the assumed 0.85 multiplier, the average % shrinkage across all 550 fish with both weights is 1.9% (SE=0.2%), and is therefore consistent with a shrinkage multiplier of 2% as assumed in Table 1.1. Future FISS sampling should include a selection of O32 Pacific halibut weighed twice, before and after gutting, to validate the conversion from round weight to dressed at sea.

Commercial and FISS length-weight comparisons

The estimated length-net weight curves above can be used to predict net weight for Pacific halibut with missing direct measurements from both commercial and FISS sampling. With two independent sources of IPHC length-weight data since 2019, thought must be given to how (or whether) to combine the two sources for estimating length-weight curves for use outside of the IPHC when direct weight measurement is not available, i.e., for other survey data (e.g., NMFS and DFO surveys), commercial observer data, and data from recreational catch sampling. While the FISS data are typically collected in a spatially comprehensive manner within each IPHC Regulatory Area, they are temporally restricted to the May-September summer period.

Conversely, commercial samples are collected throughout the fishing season, but may more geographically limited due to the concentration of fishing effort in the most productive habitat within each area. In this section we assess the likely importance of any differences in estimated length-net weight curves that may be a result of such sampling differences when it comes to calculating statistics such as mean weight of sampled fish.

For 2019 and 2020 data, we fitted two length-net weight models to the combined commercial and FISS data for each IPHC Regulatory Area:

Model 1: Assume length-net weight relationships are the same for both data sources

Model 2: Allows parameters for length-net weight relationships to differ between the data sources

Table 1.4. Estimated model parameters (with standard errors) for Models 1 and 2 fitted to combined FISS and commercial data (with weight in kg), by IPHC Regulatory Area and year. Note that the historical length-net weight relationship has intercept of -12.57 and slope of 3.24.

Reg Area	Year	Model 1		Model 2			
		Intercept (SE)	Slope (SE)	FISS		Commercial	
				Intercept (SE)	Slope (SE)	Intercept (SE)	Slope (SE)
2A	2019	-13.51 (0.08)	3.42 (0.02)	-13.16 (0.11)	3.35 (0.02)	-13.43 (0.10)	3.40 (0.02)
2B	2019	-12.40 (0.03)	3.18 (0.01)	-12.40 (0.04)	3.18 (0.01)	-12.79 (0.09)	3.26 (0.02)
	2020	-12.69 (0.03)	3.24 (0.01)	-12.72 (0.03)	3.24 (0.01)	-12.57 (0.08)	3.21 (0.02)
2C	2019	-12.44 (0.02)	3.18 (0.00)	-12.46 (0.02)	3.19 (0.00)	-12.20 (0.07)	3.13 (0.01)
	2020	-12.56 (0.03)	3.21 (0.01)	-12.63 (0.03)	3.23 (0.01)	-12.33 (0.07)	3.16 (0.02)
3A	2019	-12.25 (0.02)	3.14 (0.00)	-12.26 (0.02)	3.14 (0.00)	-12.34 (0.07)	3.15 (0.02)
	2020	-12.15 (0.02)	3.11 (0.00)	-12.14 (0.02)	3.11 (0.00)	-12.38 (0.07)	3.16 (0.02)
3B	2019	-12.78 (0.03)	3.26 (0.01)	-12.75 (0.03)	3.26 (0.01)	-13.05 (0.07)	3.32 (0.02)
	2020	-12.59 (0.03)	3.21 (0.01)	-12.51 (0.04)	3.20 (0.01)	-13.16 (0.07)	3.34 (0.02)
4A	2019	-12.00 (0.03)	3.09 (0.01)	-12.07 (0.03)	3.11 (0.01)	-12.56 (0.08)	3.21 (0.02)
4B	2019	-12.13 (0.08)	3.10 (0.02)	-11.80 (0.10)	3.04 (0.02)	-12.72 (0.10)	3.23 (0.02)
4CDE	2019	-12.07 (0.04)	3.11 (0.01)	-12.04 (0.05)	3.10 (0.01)	-12.51 (0.08)	3.20 (0.02)

Model parameter estimates are given in Table 1.4. We compared the actual observed mean net weight of fish mean to net weights predicted from each model for each source (FISS and commercial), and to that predicted by the historical relationship. Only fish included in the modelling were used in the comparison, i.e., only data from fish with directly measured weights were included (some extreme outlying data were excluded). Results of the comparisons of mean net weights are presented in Table 1.5. Figures comparing the FISS and commercial data and estimated length-net weight curves for Model 2 are shown in Figures 1.21-1.32.

As might be expected, Model 2 produced estimated mean net weights closest to the observed values, with differences all within 1% (Table 1.5). In cases where estimated length-net weight curves differed between FISS and commercial data to some degree, this model accounts for such differences. Model 1, while less accurate in estimating observed mean net weights than Model 2, still performed well in almost all cases, with differences of less than 2% except for the FISS mean in IPHC Regulatory Area 2A, the commercial mean in IPHC Regulatory 3A, and the FISS mean in IPHC Regulatory Area 4B, all in 2019. We note that those three cases are ones in which there were differences between the FISS and commercial length-net weight curves when estimated separately (Figures 1.21, 1.24 and 1.27), but where one data source had much larger sample sizes and so had greater influence on the estimates of a single length-net weight curve in Model 1: for IPHC Regulatory Area 2A, 69% of the data came from commercial samples; for 3A in 2019, 90% of the data came from FISS samples; and for 4B, 66% of the data came from commercial samples.

Discussion

Analysis of the IPHC length-weight data has made it clear that currently there is a positive bias in weights predicted from the historical length-net weight relationship in most IPHC Regulatory Areas, especially (in absolute terms) for the largest Pacific halibut. that the IPHC recommends that this bias can best be eliminated by weighing individual fish directly. In the absence of sampling capability, the bias can be reduced through the use of relationships estimated from more contemporary IPHC FISS and commercial data. For IPHC data where there is no reliable direct weight measurement, the weight of a fish can be predicted from the length-net weight relationship estimated for its IPHC Regulatory Area and year of capture, and for its data source (commercial or FISS sampling). This change has already been made to the prediction of net weight for fish captured on the FISS with missing weight measurements.

For predicting weights for Pacific halibut sampled from non-IPHC data sources, Model 1 is of more practical use than Model 2, as it would not require a choice of which IPHC source was most likely to resemble the data source of interest (recreational, observer, etc). By combining data from the more temporally comprehensive commercial samples with data from the spatially extensive FISS, the resulting length-net weight represents an average that can be applied to a wide range of data sources.

Spatial differences in estimated length-net weight curves imply that area-specific curves should be used. On the other hand, the relative temporal stability of these curves suggests that curves could be estimated from multiple years' data, and only revised periodically. Following the 2021 FISS, three consecutive years of data from both IPHC sources will be available for core areas (2B, 2C, 3A and 3B), and two years (2019 and 2021) for other areas, providing a combined data set for estimation of curves for application to non-IPHC length data in 2021.

In fitting Model 1, we simply combined the data without weighting the two data sources, so each fish, no matter its source, was given equal weight. This resulted in instances where the estimated length-net weight equation was more influenced by data from one source than the other, typically the FISS in the core areas, and sometimes the commercial samples elsewhere. Generally, this did not matter much, as the two sources produced consistent estimated relationships most of the time (Figures 1.21 to 1.32). It may be desirable, however, to weight the data sources equally (i.e., down-weight data from the source with the larger sample size relative to the other source) to produce a relationship that better represents an average of the FISS and commercial data relationships, and thus one that is as widely applicable as possible for each IPHC Regulatory Area.

Therefore, the IPHC intends to produce a revised length-net weight relationship based on Model 1 (combined fitting) and including all data from 2019-2021. This relationship should be used in place of the historical relationships for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected for 2021 and until further notice. The Secretariat anticipates re-evaluating the relationship as additional years of data are collected and updating it accordingly.

Finally, we note that there remain two components to the estimation of weight from length that are not directly estimable from recent FISS and commercial sample data: the conversion from round to net weight (or round to dress weight), and the adjustment factors for ice and slime (conversion from unwashed to wash). The former only has data available for U32 fish, while there are no data available to estimate the latter. We recommend that future FISS sampling include a random sample of O32 fish weighed twice, before and after dressing, and that renewed efforts should be made to weigh a sample of fish twice dockside, before and after washing.

RECOMMENDATION

That the Research Advisory Board:

1) **NOTE** paper IPHC-2021-RAB022-07.1 that presents methods for revised the length-net weight relationships from FISS and commercial sampling data

References

Clark, W. G. 1992. Validation of the IPHC length-weight relationship for halibut. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 1991: 113–116.

Courcelles, D. 2012. Re-evaluation of the length-weight relationship of Pacific halibut (Hippoglossus stenolepis). Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2011: 459-470.

Gilroy, H. L., Hutton, L. M. and MacTavish, K. A. 2009. 2008 commercial fishery and regulation changes. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2008: 37-48.

Leaman, B. M. and Gilroy, H. L. 2008. IPHC staff regulatory proposals: 2008. Int. Pac. Halibut Comm. Annual Meeting Handout: 105-110.

Webster, R. A. and Erikson, L. M. 2017. Analysis of length-weight data from commercial sampling in 2016. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016: 101-109.

Table 1.5. Comparison of mean observed Pacific halibut net weight with mean nets weights predicted from Models 1 and 2 (see text) and the historical length-net weight relationship. Intensity of shading indicates magnitude of departures from observed mean, either negative (blue) or positive (orange/brown).

Reg Area	**Calculation method**	**2019**				**2020**			
		FISS		Commercial		FISS		Commercial	
		Mean (kg)	diff from Observed	Mean (kg)	diff from Observed	Mean (kg)	diff from Observed	Mean (kg)	diff from Observed
2A	Observed	9.9		7.6					
	Model 1	9.6	−3.1%	7.7	+1.1%				
	Model 2	9.9	−0.3%	7.6	−0.4%				
	Historical	9.9	−0.8%	8.0	+4.9%				
2B	Observed	9.4		11.0		10.7		11.0	
	Model 1	9.3	−1.4%	11.1	+1.3%	10.6	−0.7%	11.1	+1.0%
	Model 2	9.4	−0.7%	10.9	−0.3%	10.7	−0.3%	10.9	−0.5%
	Historical	9.5	+0.8%	11.4	+3.6%	11.0	+2.3%	11.4	+4.0%
2C	Observed	10.8		13.5		11.4		14.3	
	Model 1	10.8	−0.5%	13.5	−0.3%	11.3	−0.9%	14.4	+0.8%
	Model 2	10.8	−0.5%	13.5	−0.5%	11.3	−0.5%	14.3	−0.4%
	Historical	11.3	+4.3%	14.2	+4.9%	11.5	+0.5%	14.7	+2.4%
3A	Observed	8.5		8.7		8.6		9.1	
	Model 1	8.5	−0.7%	8.9	+2.1%	8.6	−0.6%	9.2	+1.0%
	Model 2	8.5	−0.4%	8.7	−0.5%	8.6	−0.5%	9.0	−0.5%
	Historical	8.9	+3.8%	9.3	+6.8%	9.1	+5.5%	9.7	+7.4%
3B	Observed	8.4		9.1		6.4		9.0	
	Model 1	8.3	−1.1%	9.2	+0.9%	6.3	−0.9%	9.0	−0.1%
	Model 2	8.3	−0.5%	9.1	−0.3%	6.3	−0.5%	8.9	−0.3%
	Historical	8.3	−1.0%	9.3	+1.0%	6.5	+2.1%	9.2	+3.3%
4A	Observed	6.0		9.9					
	Model 1	5.9	−1.4%	10.0	+1.0%				
	Model 2	5.9	−0.4%	9.3	−0.5%				
	Historical	5.9	−0.6%	10.3	+4.2%				
4B	Observed	8.7		9.0					
	Model 1	8.3	−3.7%	9.0	+0.7%				
	Model 2	8.6	−1.0%	9.0	−0.3%				
	Historical	9.2	+3.9%	9.9	+10.7%				
4CDE	Observed	6.9		11.0					
	Model 1	6.8	−1.2%	11.0	−0.0%				
	Model 2	6.9	−0.6%	11.0	−0.4%				
	Historical	6.8	−1.7%	11.2	+1.1%				

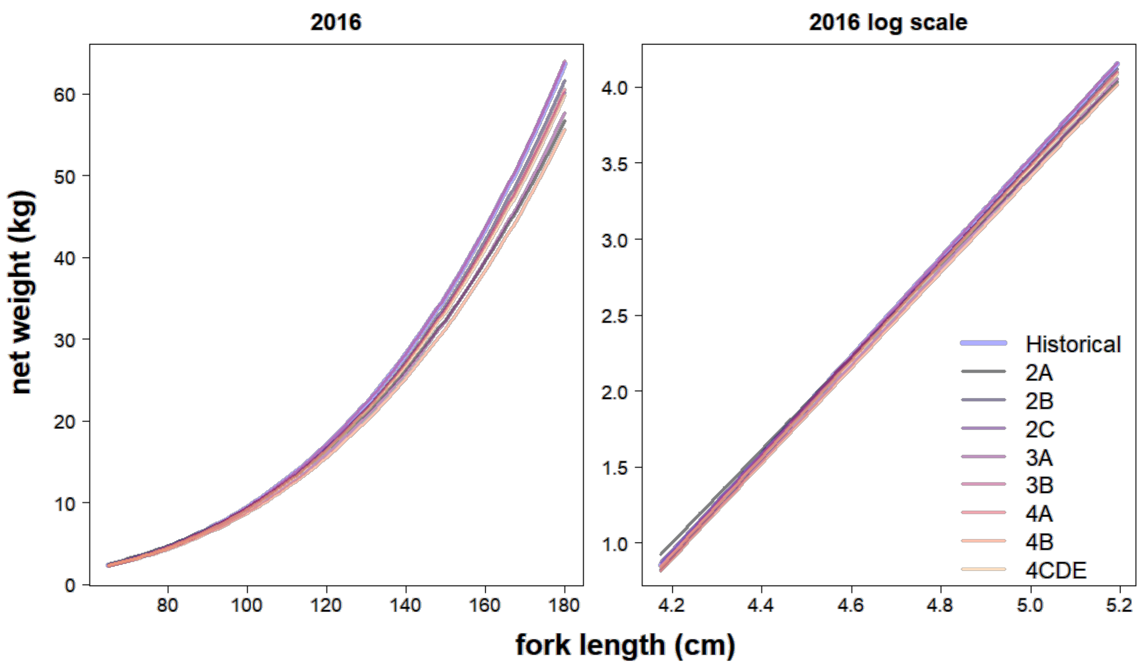

Figure 1.1 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2016.

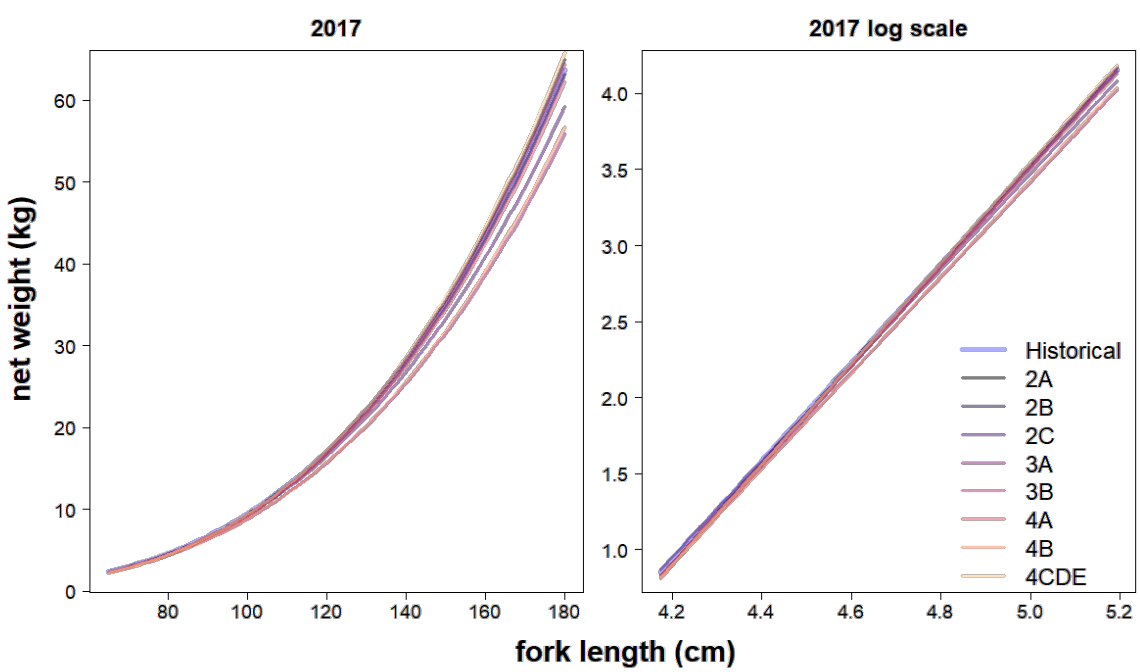

Figure 1.2 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2017.

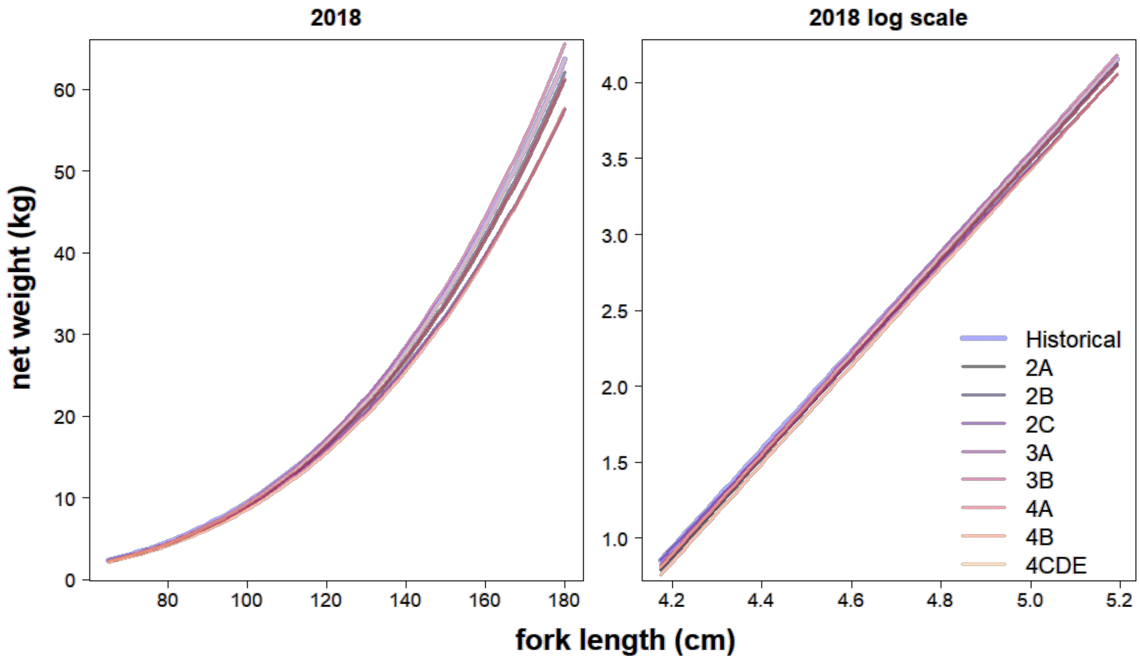

Figure 1.3 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2018.

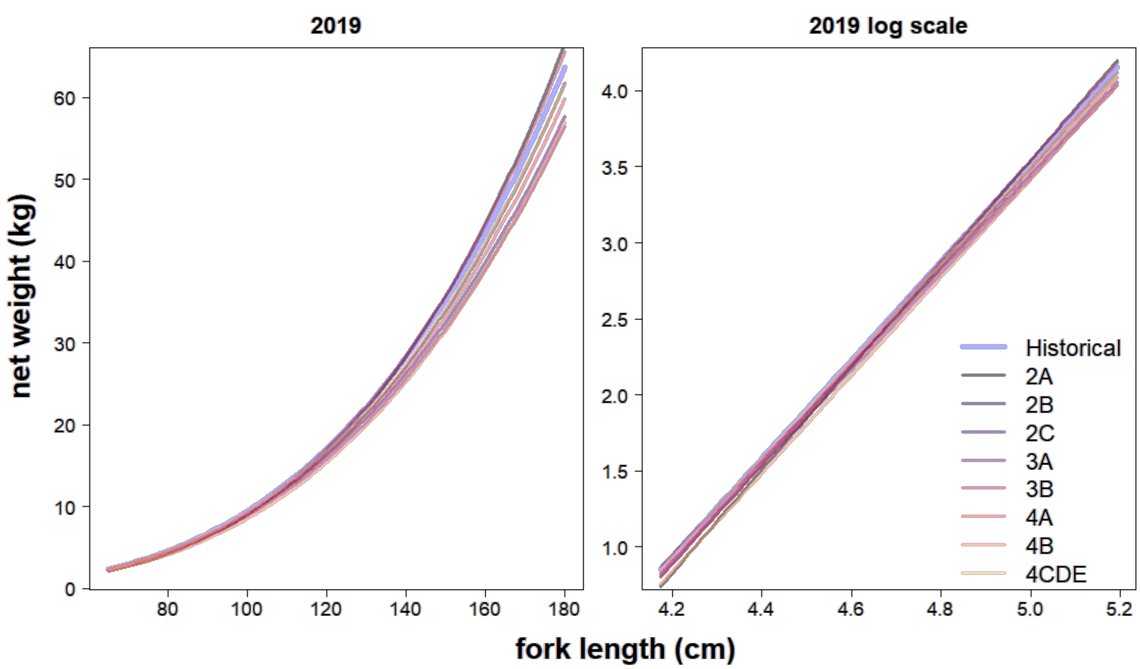

Figure 1.4 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2019.

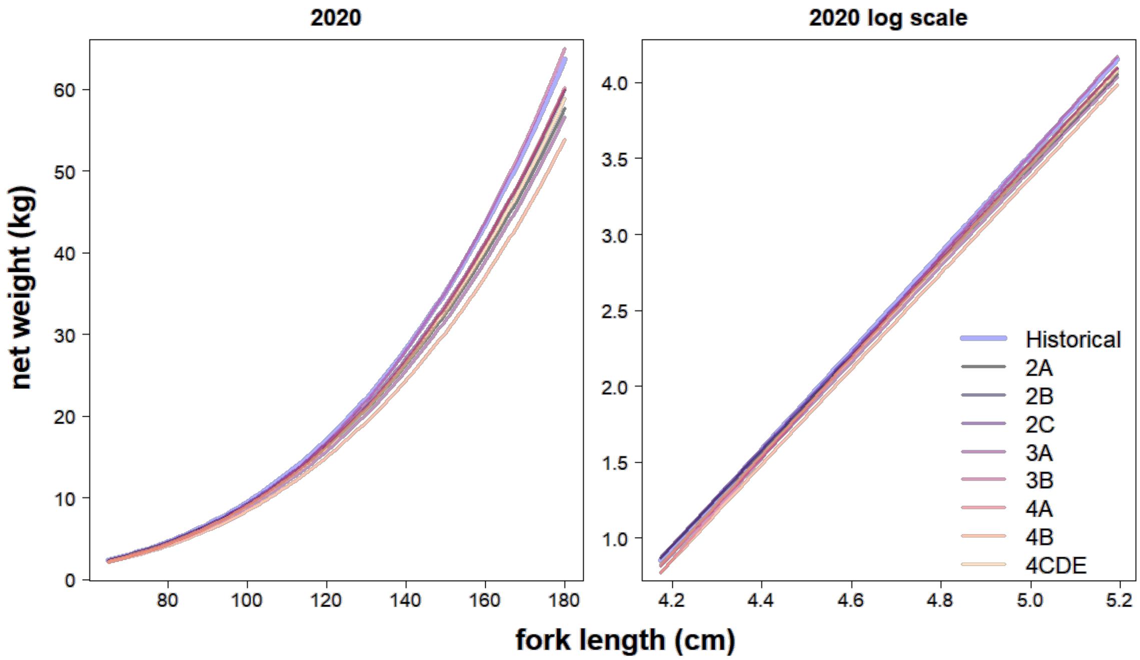

Figure 1.5 Comparison of estimated length-net weight curves from commercial data by IPHC Regulatory Area for 2020.

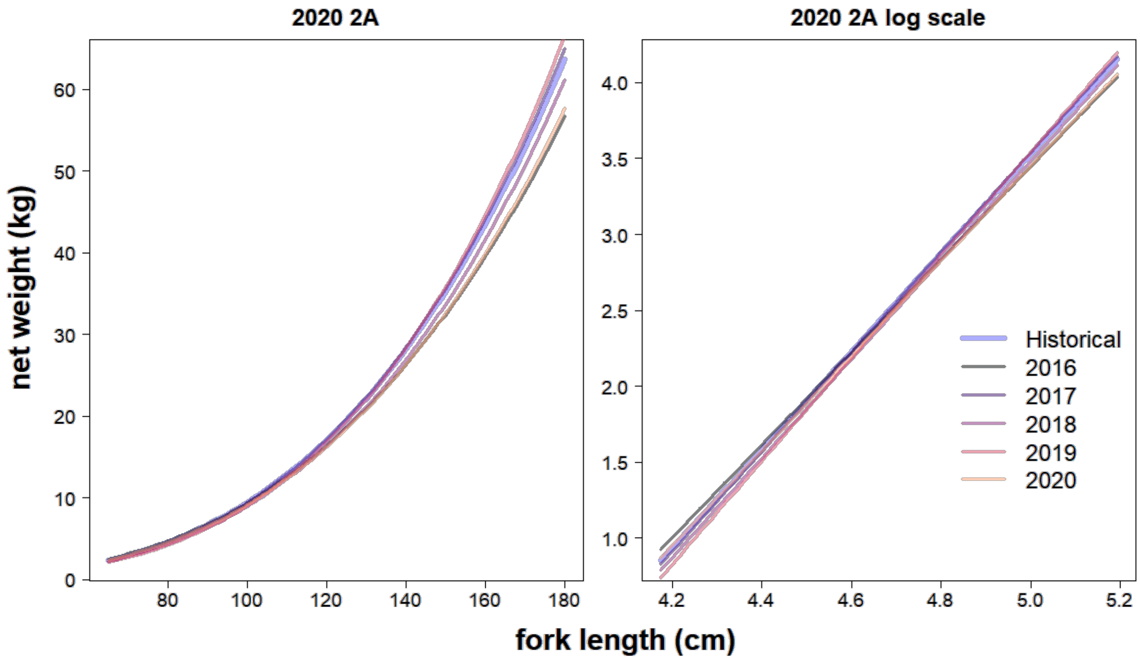

Figure 1.6 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 2A.

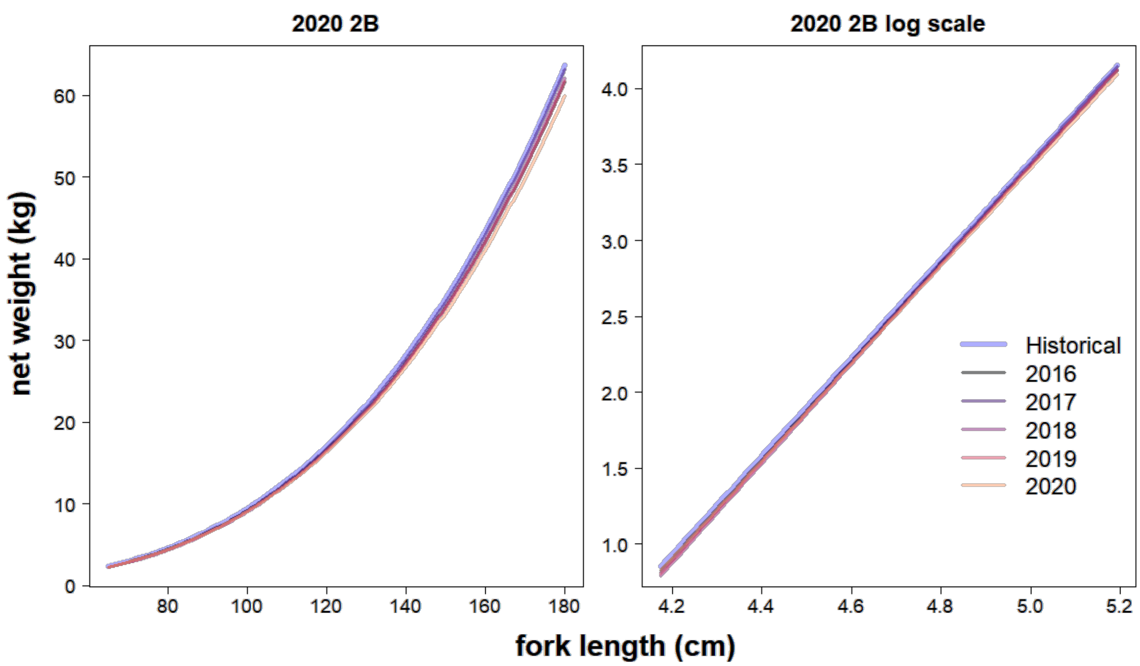

Figure 1.7 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 2B.

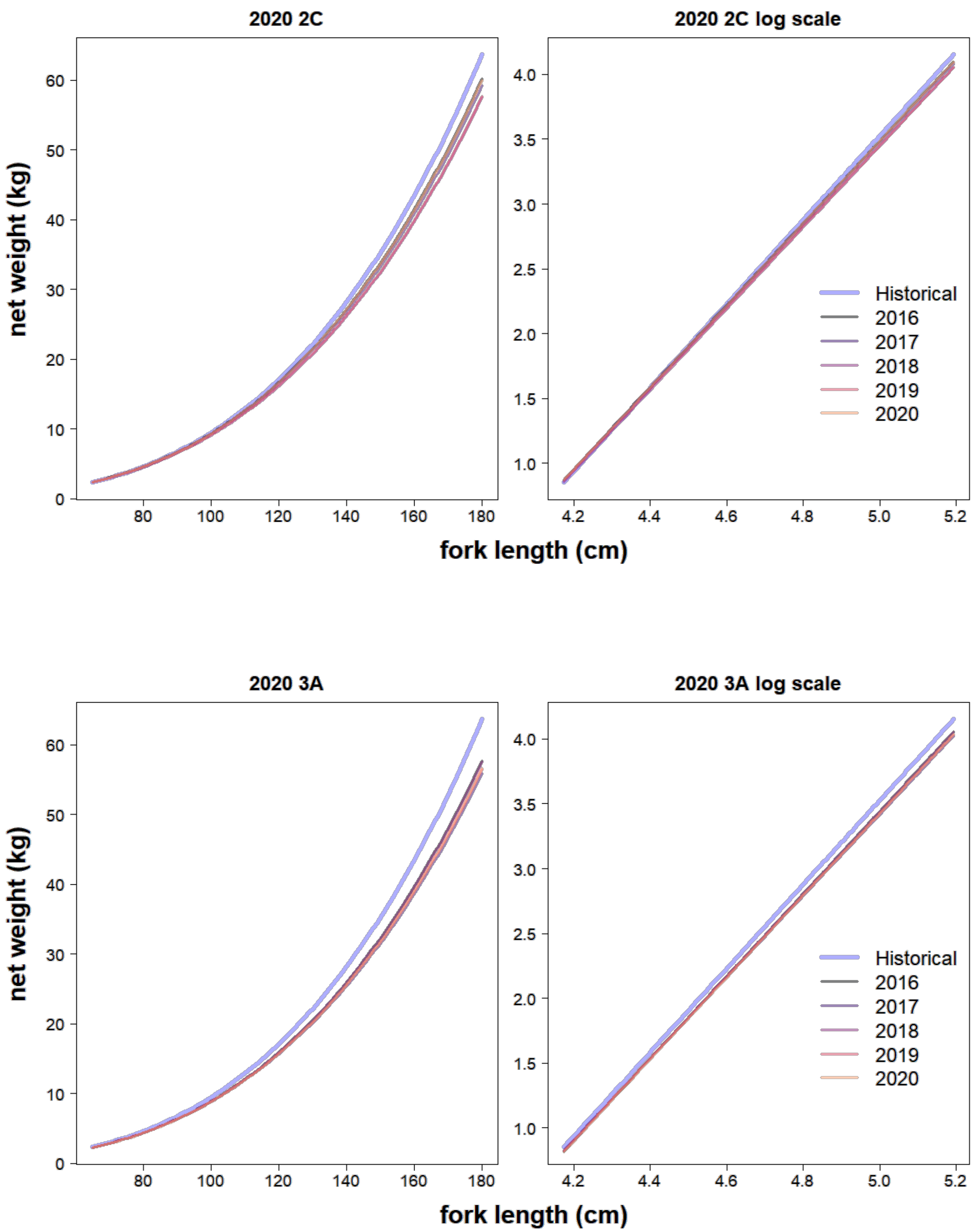

Figure 1.9 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 3A.

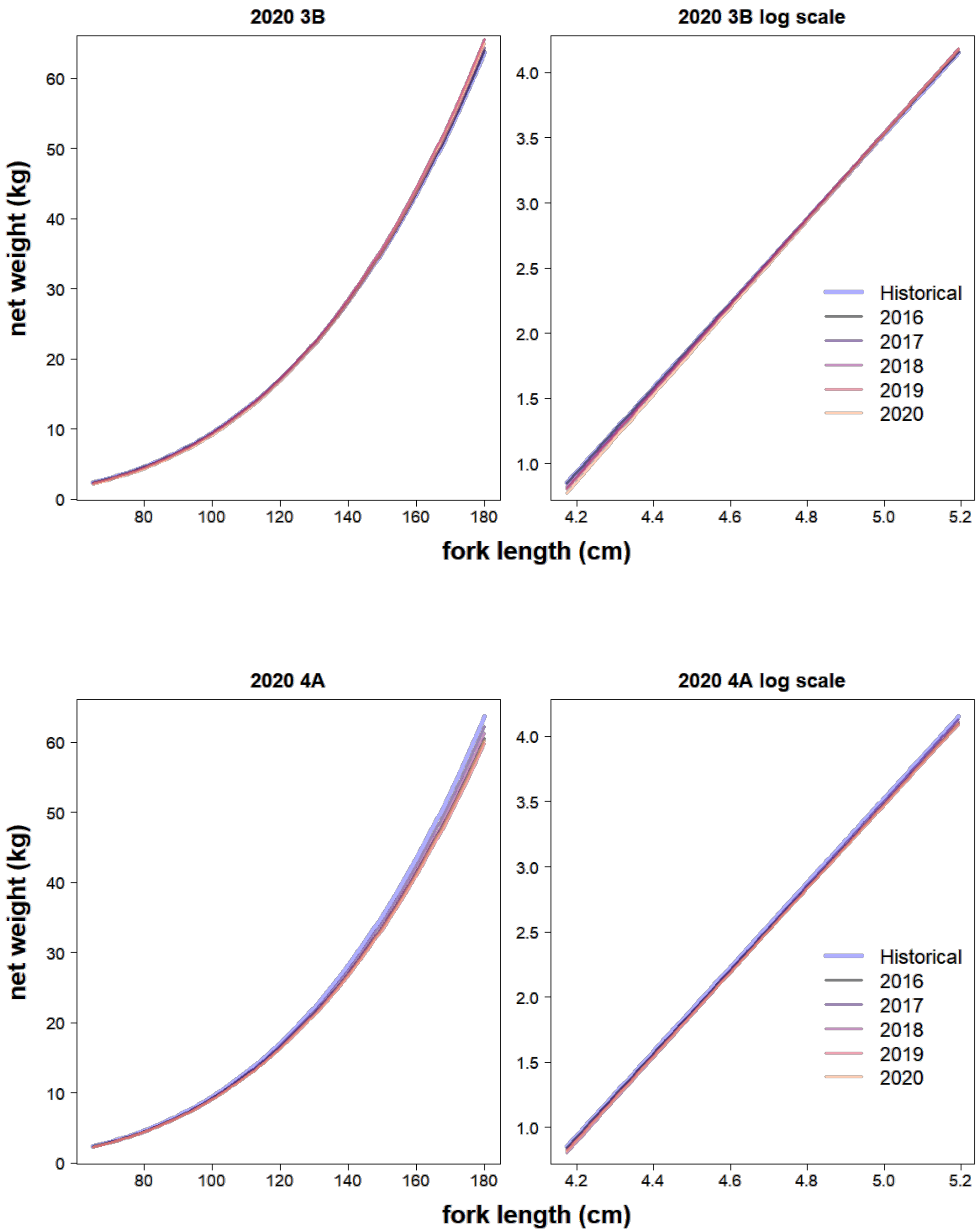

Figure 1.11 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 4A.

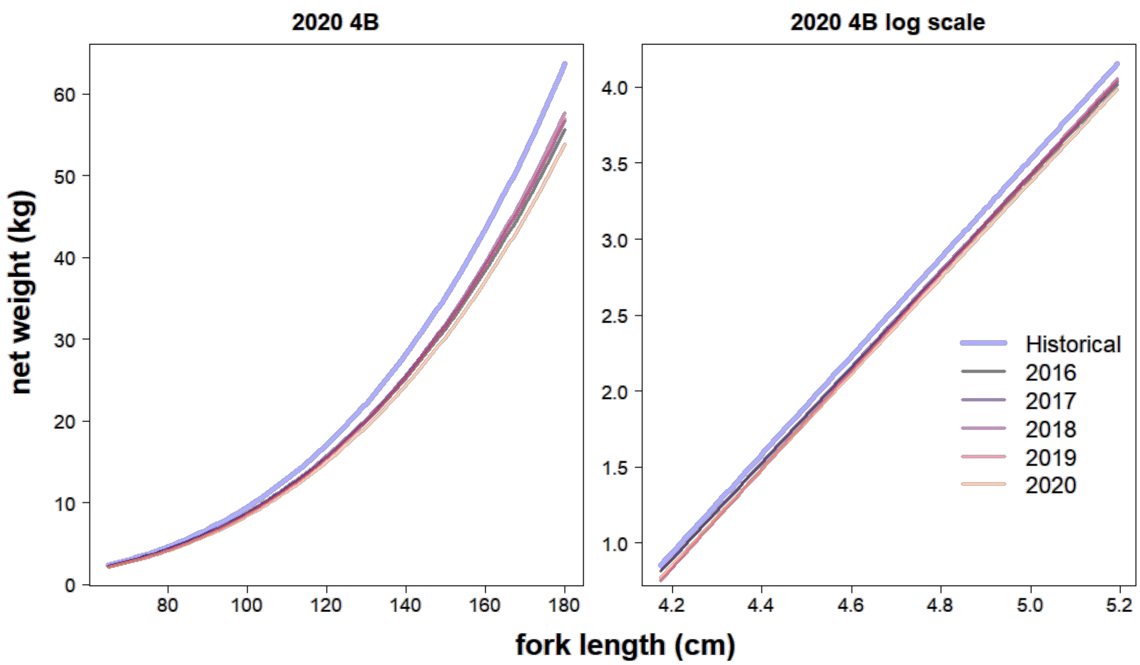

Figure 1.12 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 4B.

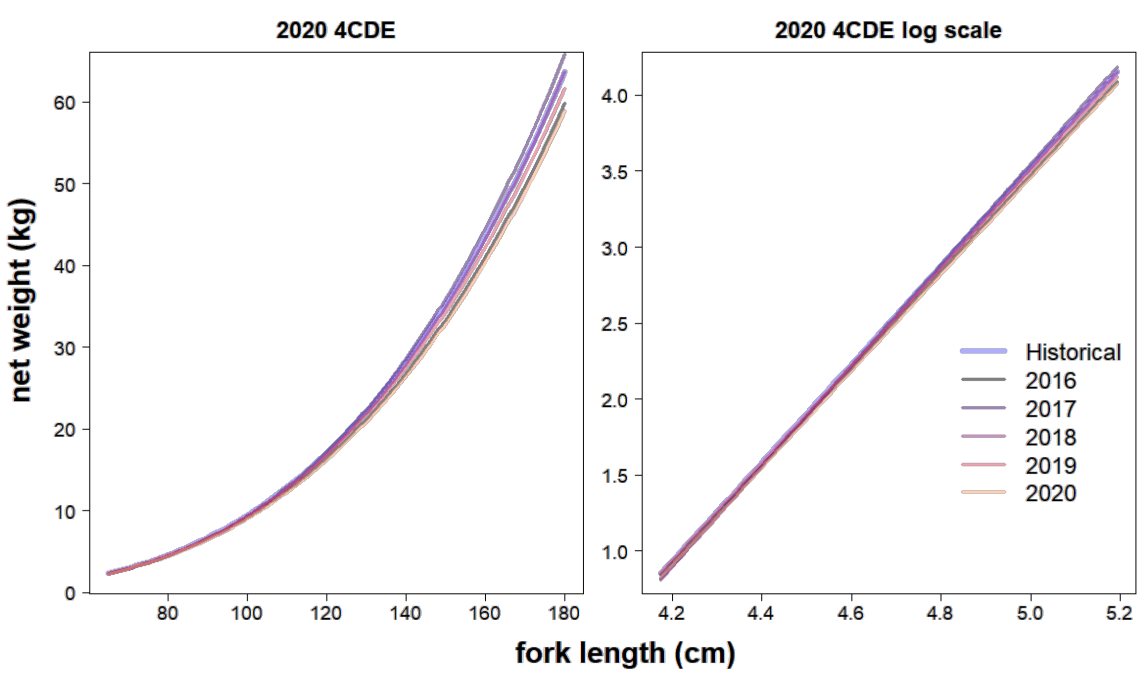

Figure 1.13 Comparison of estimated length-net weight curves from commercial data by year for IPHC Regulatory Area 4CDE.

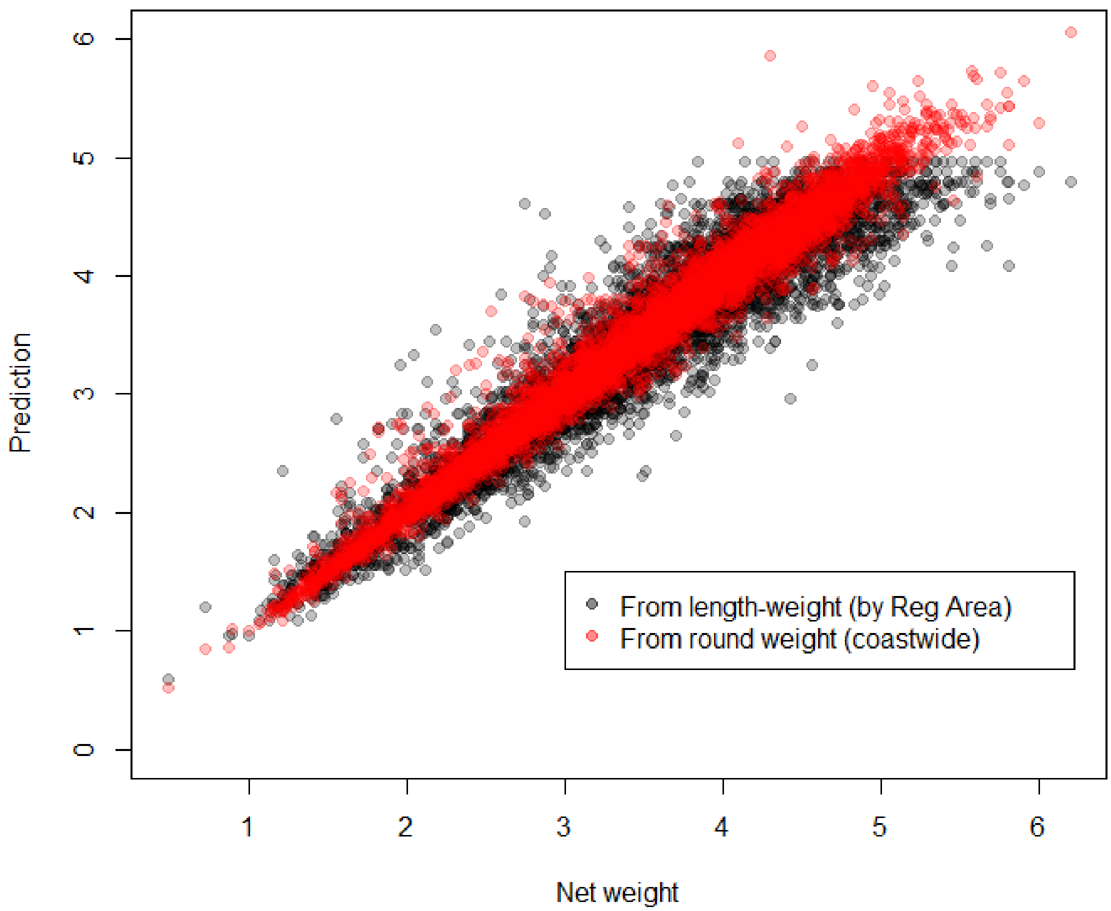

Figure 1.14 Model prediction of net weight from estimated length-net weight relationship (by IPHC Regulatory Area) and estimated coastwide relationship between net weight and round weight.

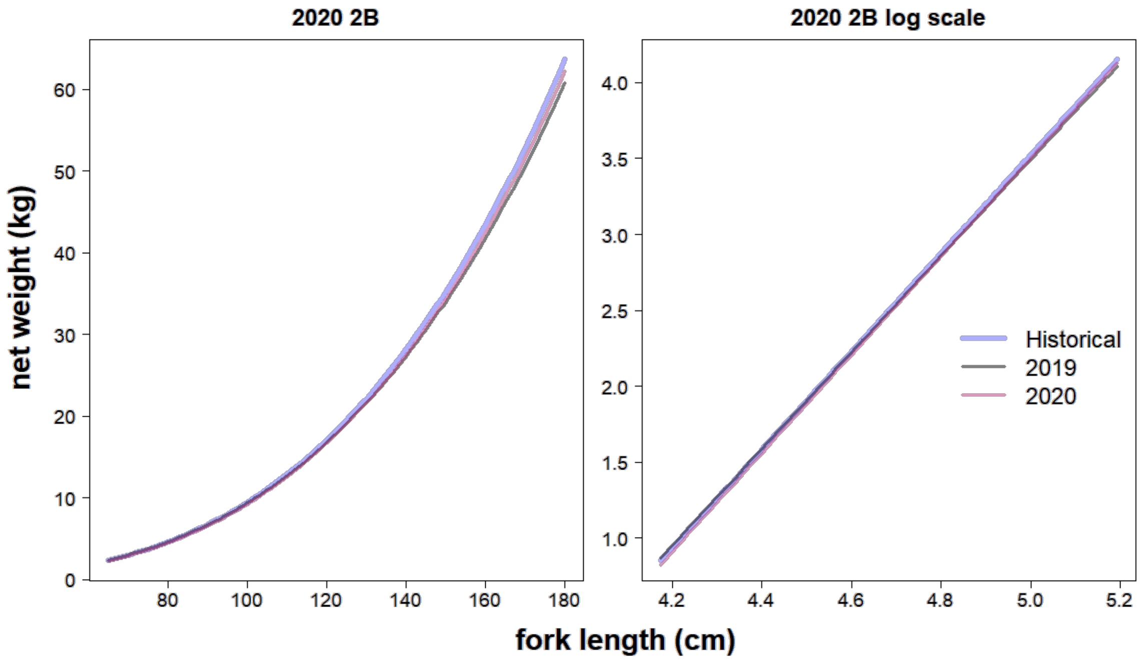

Figure 1.15 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 2B.

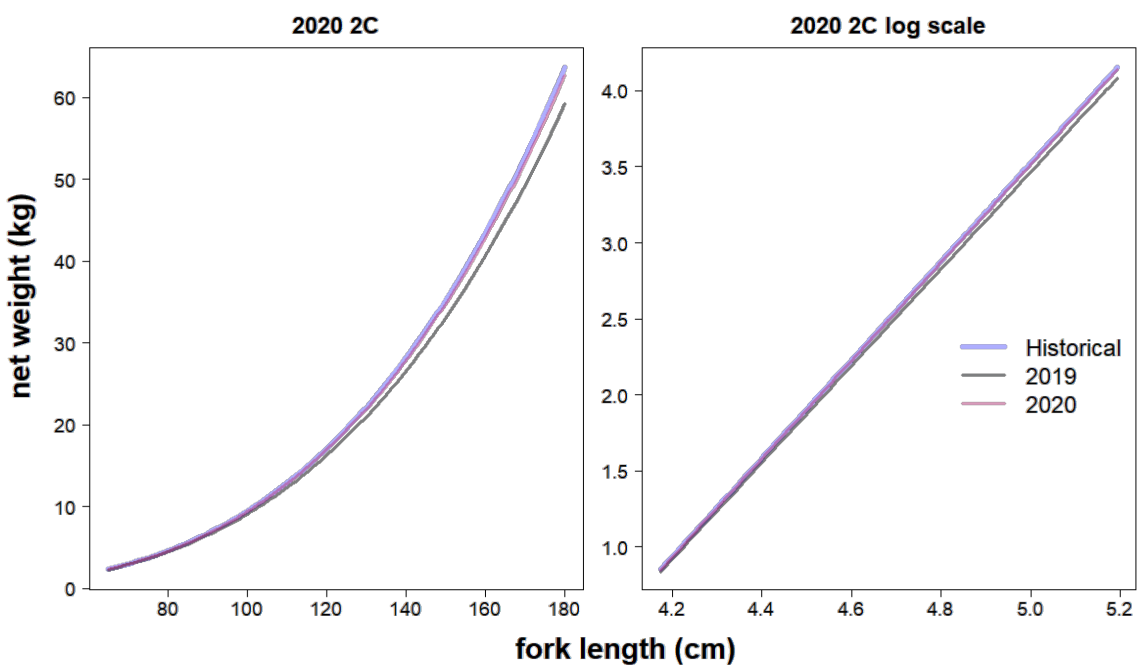

Figure 1.16 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 2C.

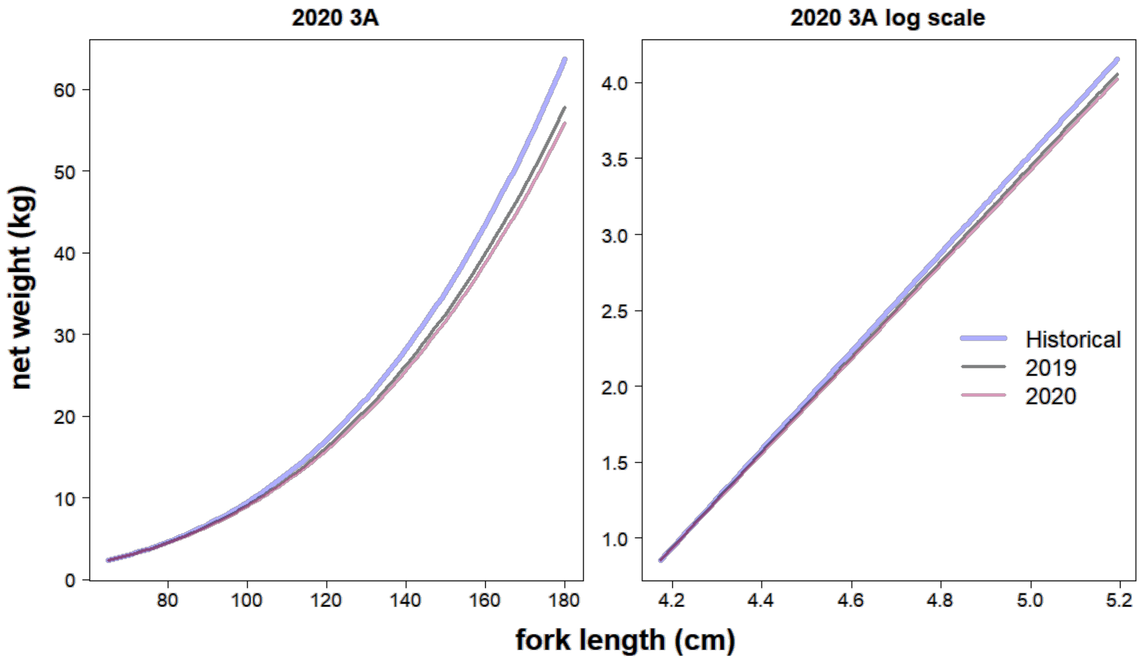

Figure 1.17 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 3A.

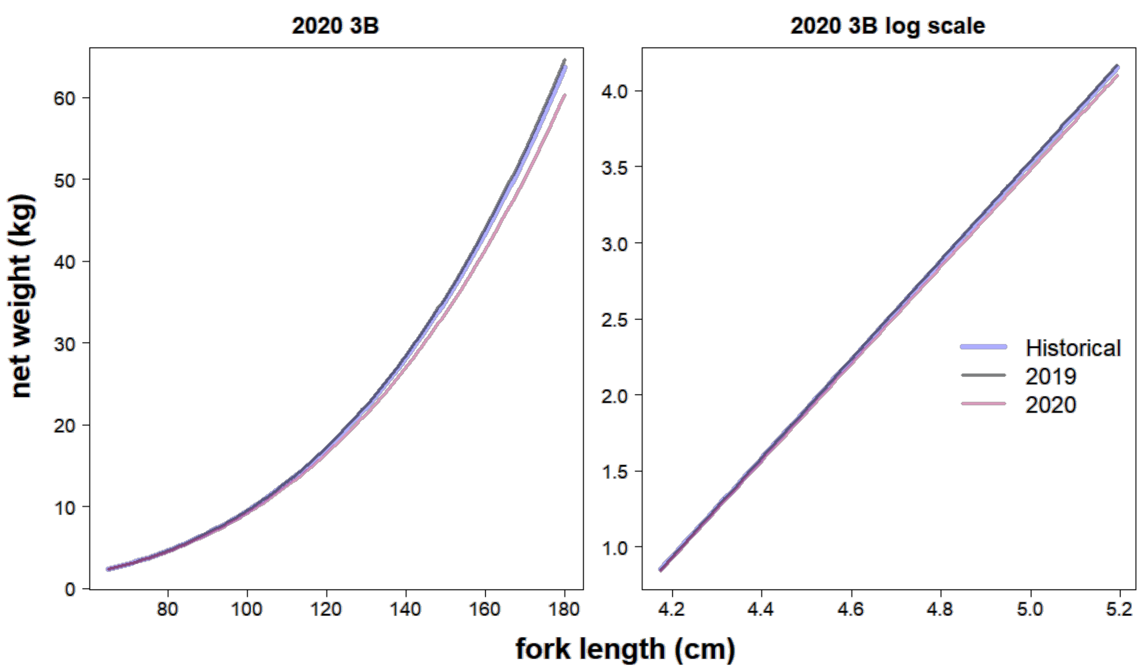

Figure 1.18 Comparison of estimated length-net weight curves from FISS data by year for IPHC Regulatory Area 3B.

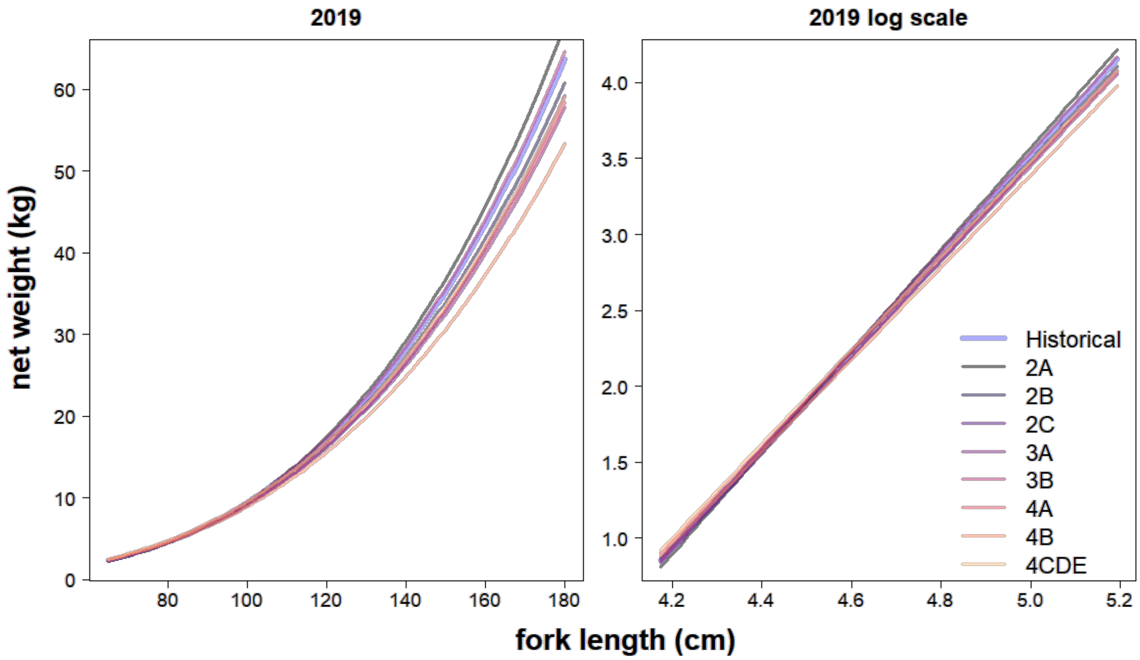

Figure 1.19 Comparison of estimated length-net weight curves from FISS data by IPHC Regulatory for 2019.

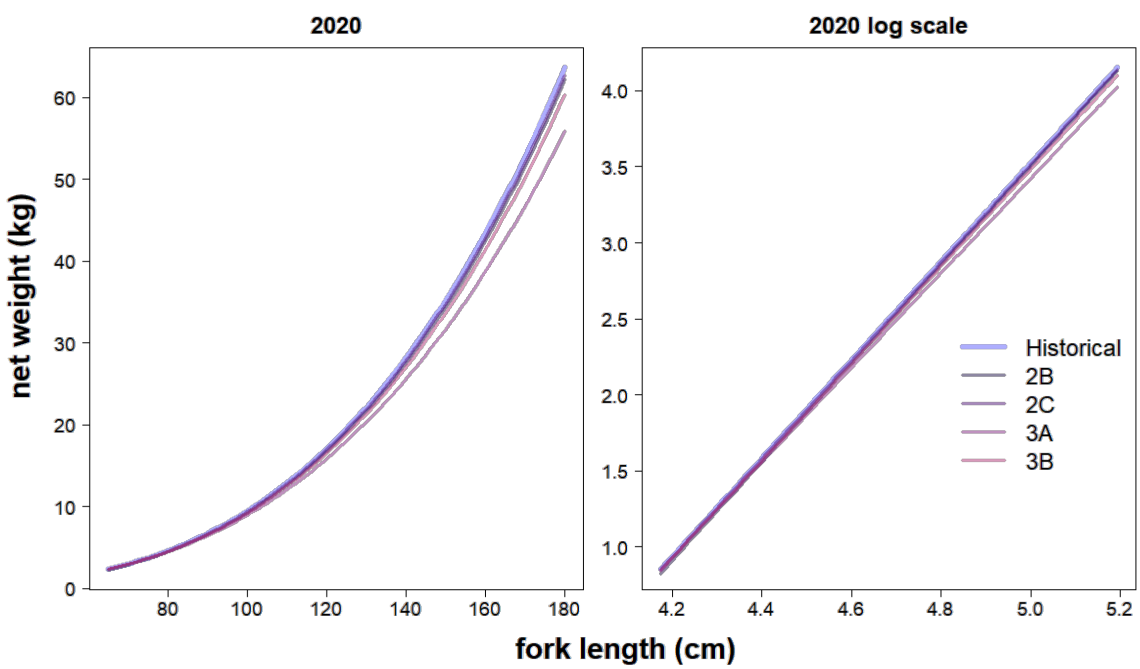

Figure 1.20 Comparison of estimated length-net weight curves from FISS data by IPHC Regulatory for 2020.

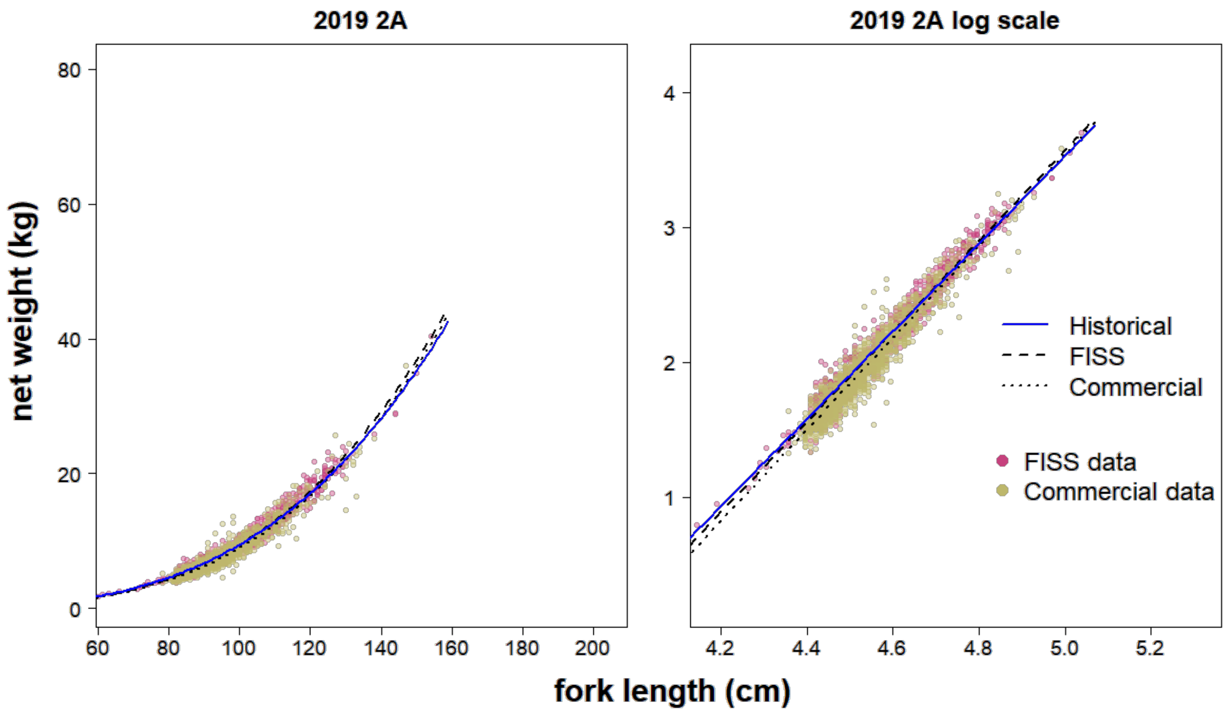

Figure 1.21 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2A in 2019.

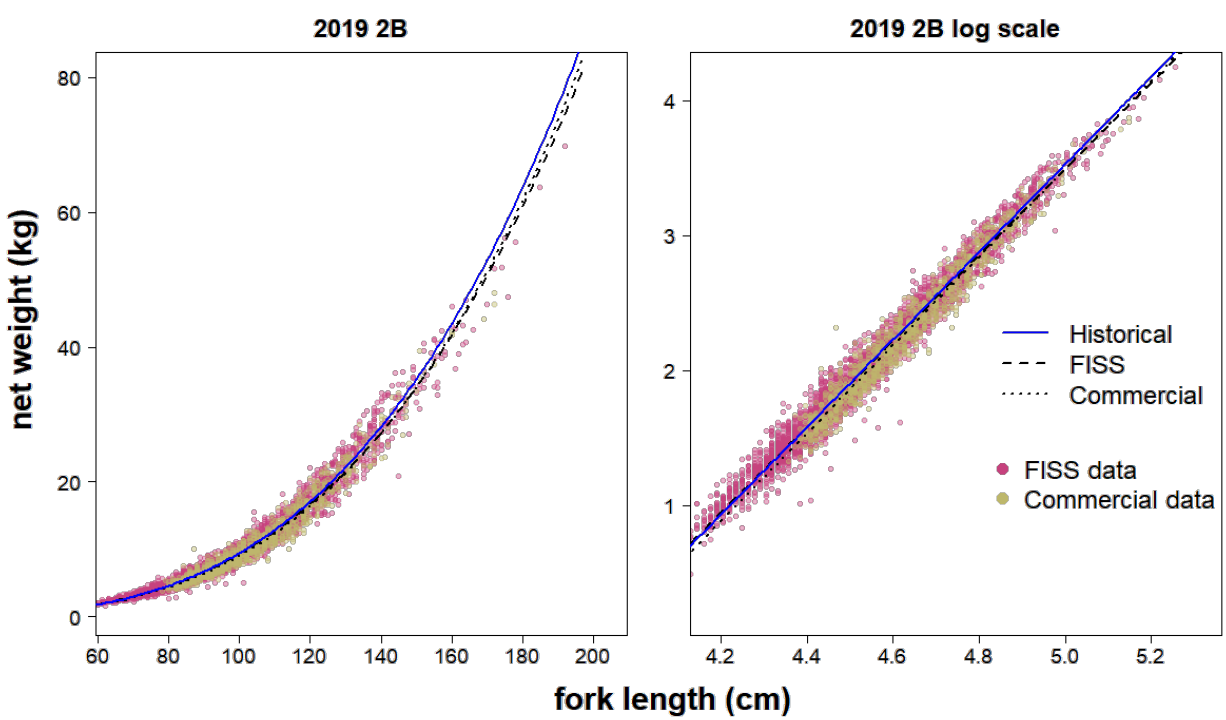

Figure 1.22 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2B in 2019.

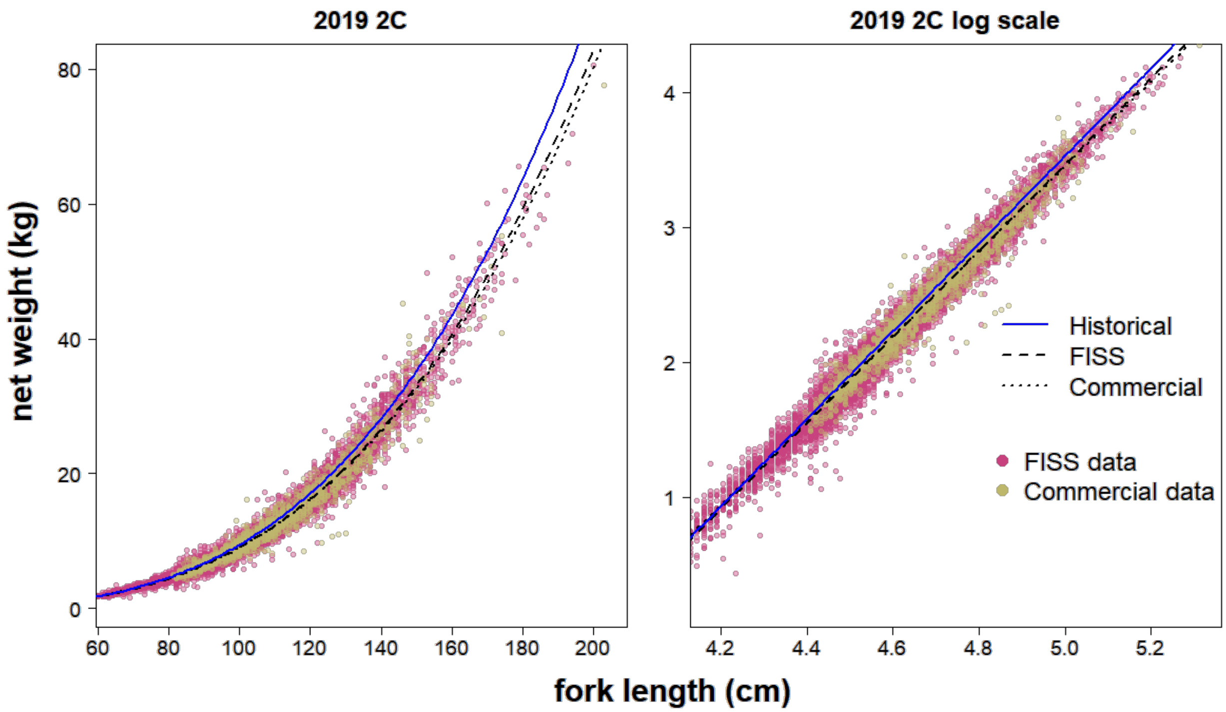

Figure 1.23 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2C in 2019.

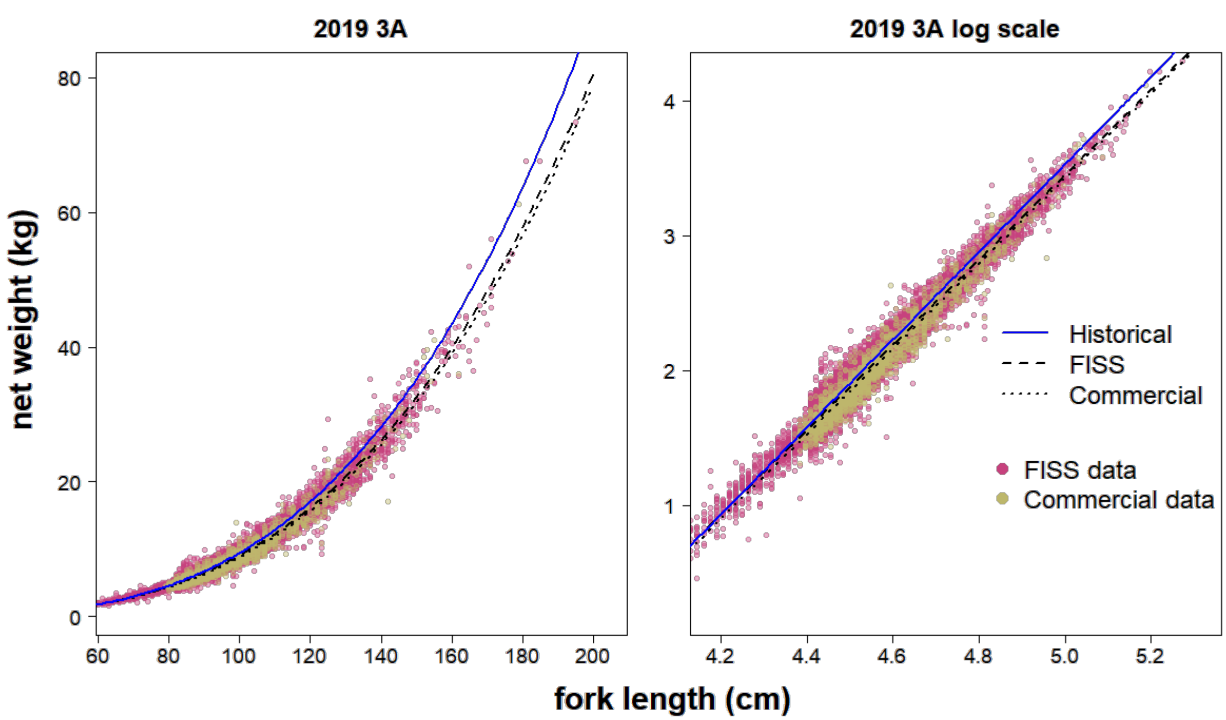

Figure 1.24 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3A in 2019.

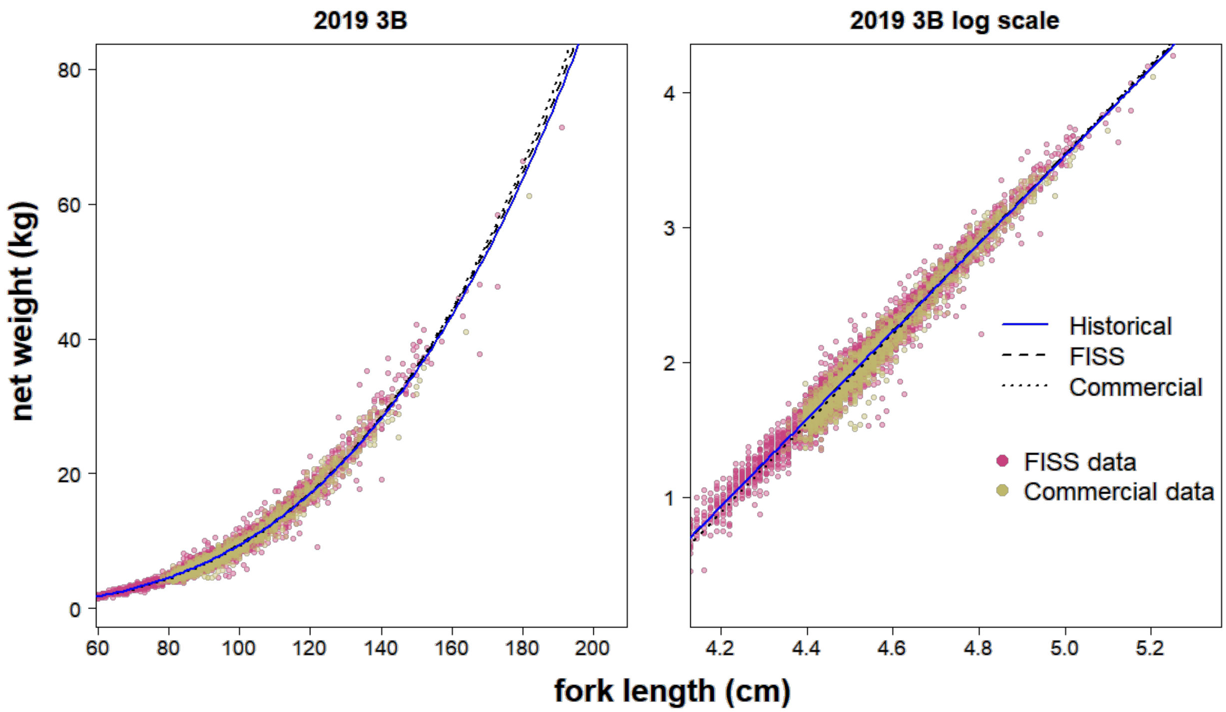

Figure 1.25 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3B in 2019.

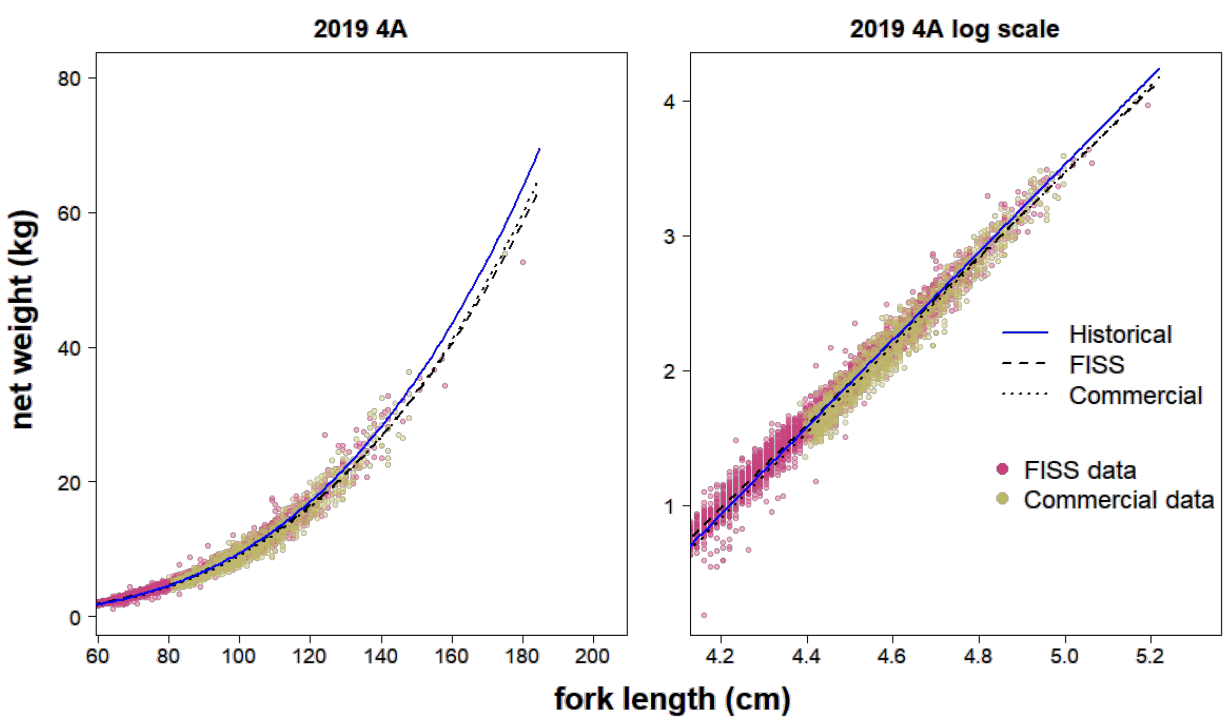

Figure 1.26 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 4A in 2019.

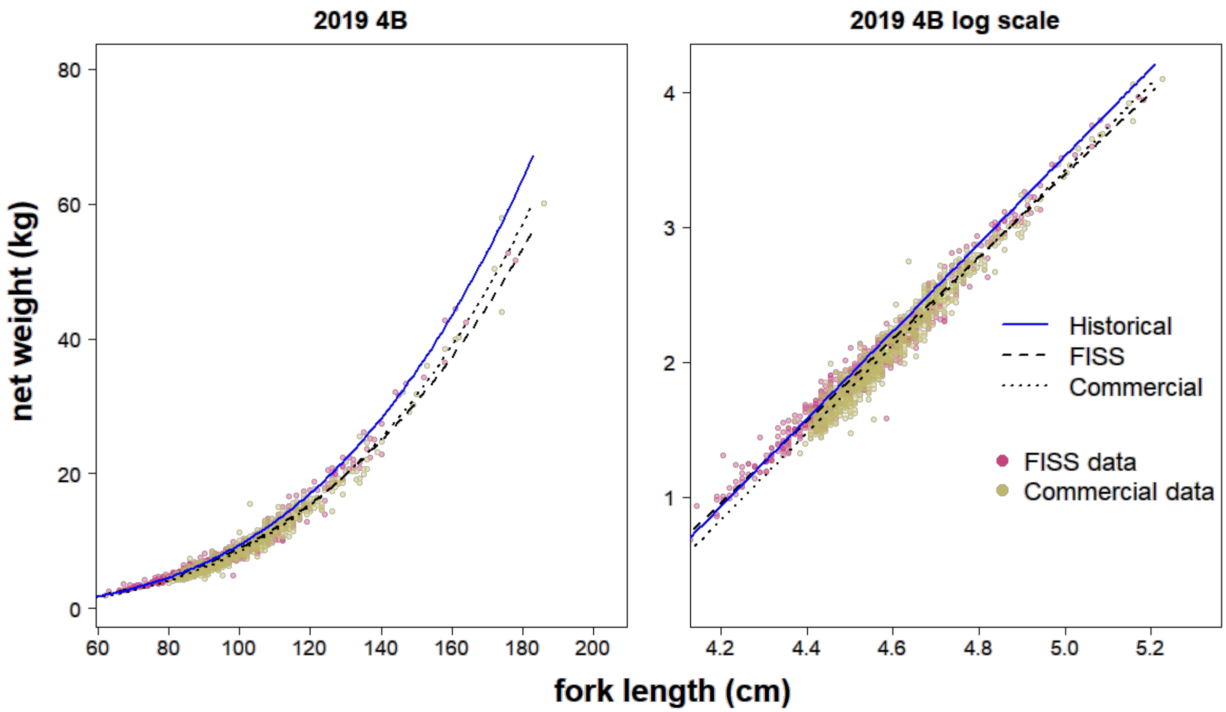

Figure 1.27 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 4B in 2019.

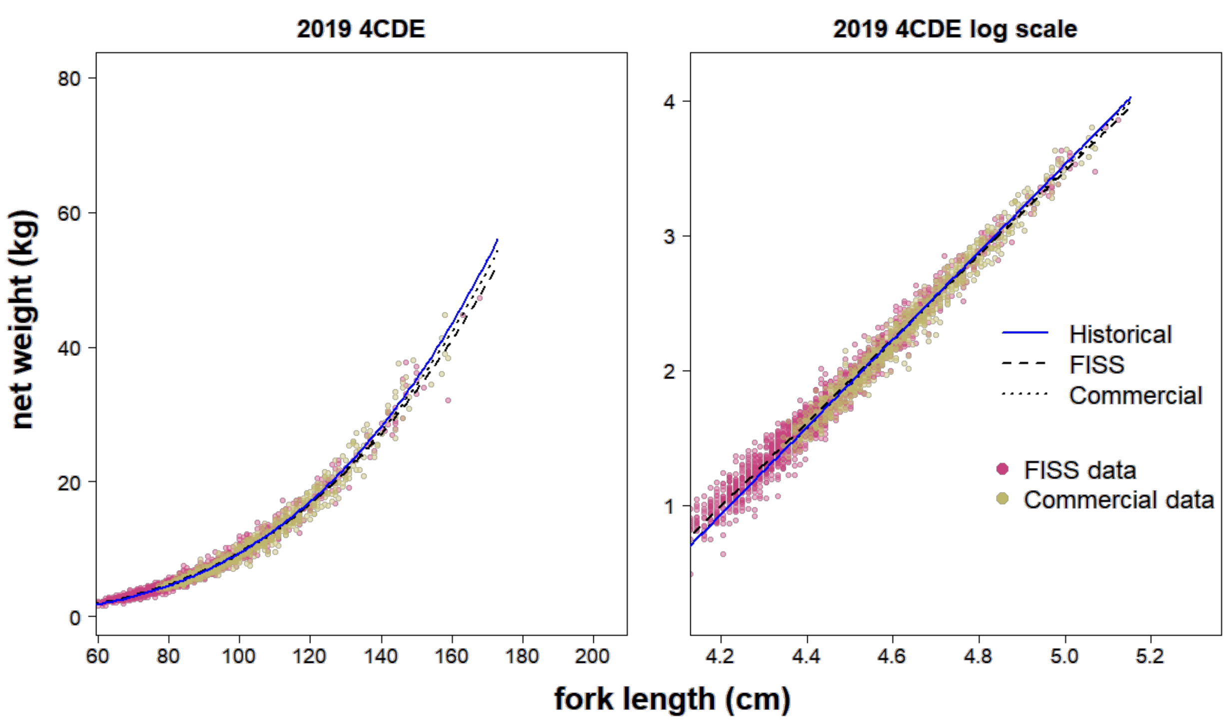

Figure 1.28 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 4CDE in 2019.

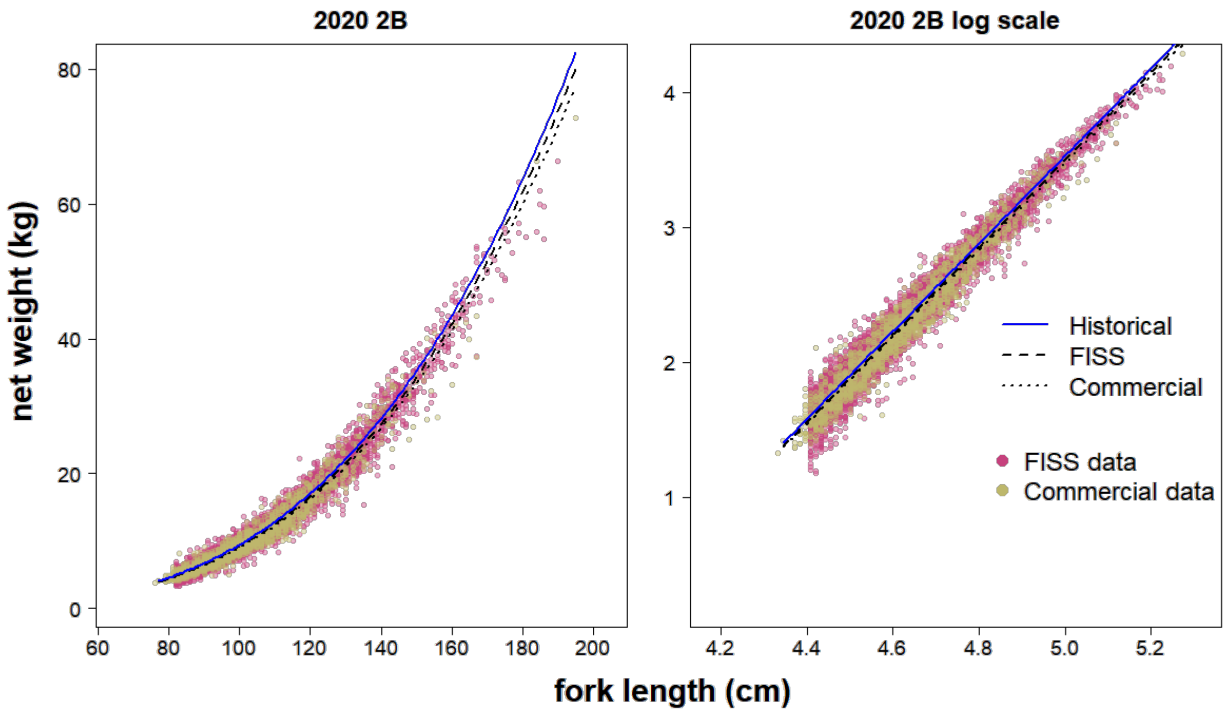

Figure 1.29 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2B in 2020.

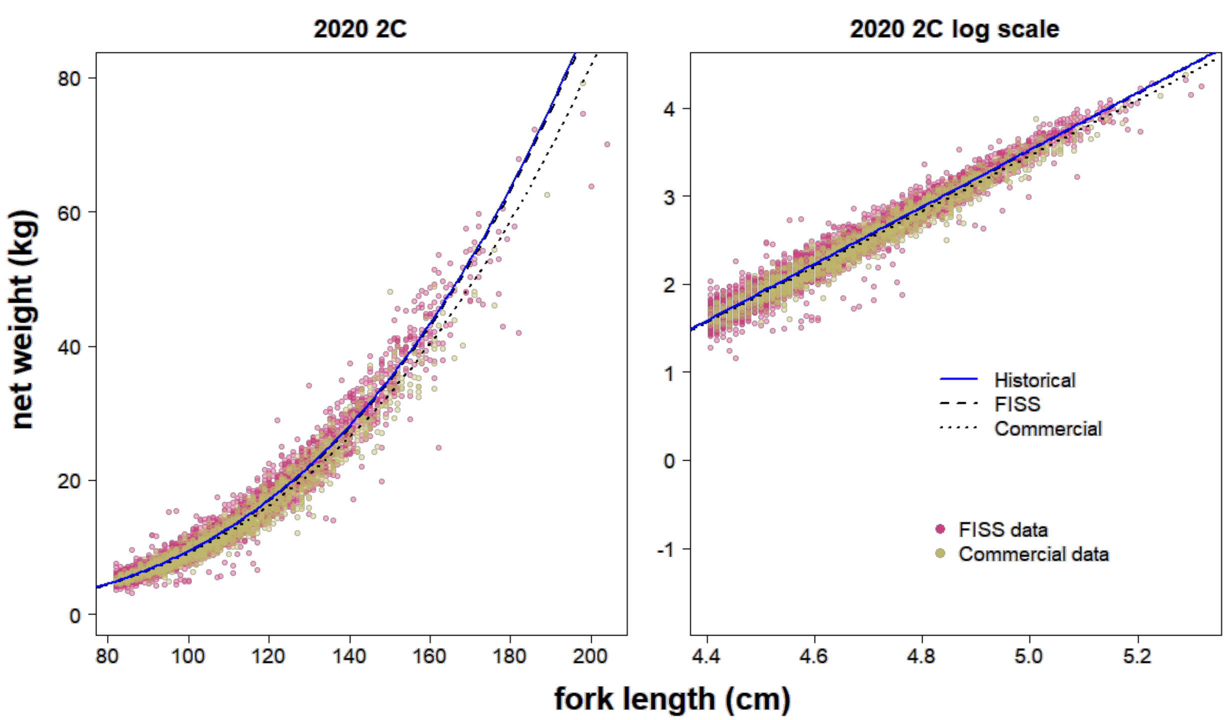

Figure 1.30 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 2C in 2020.

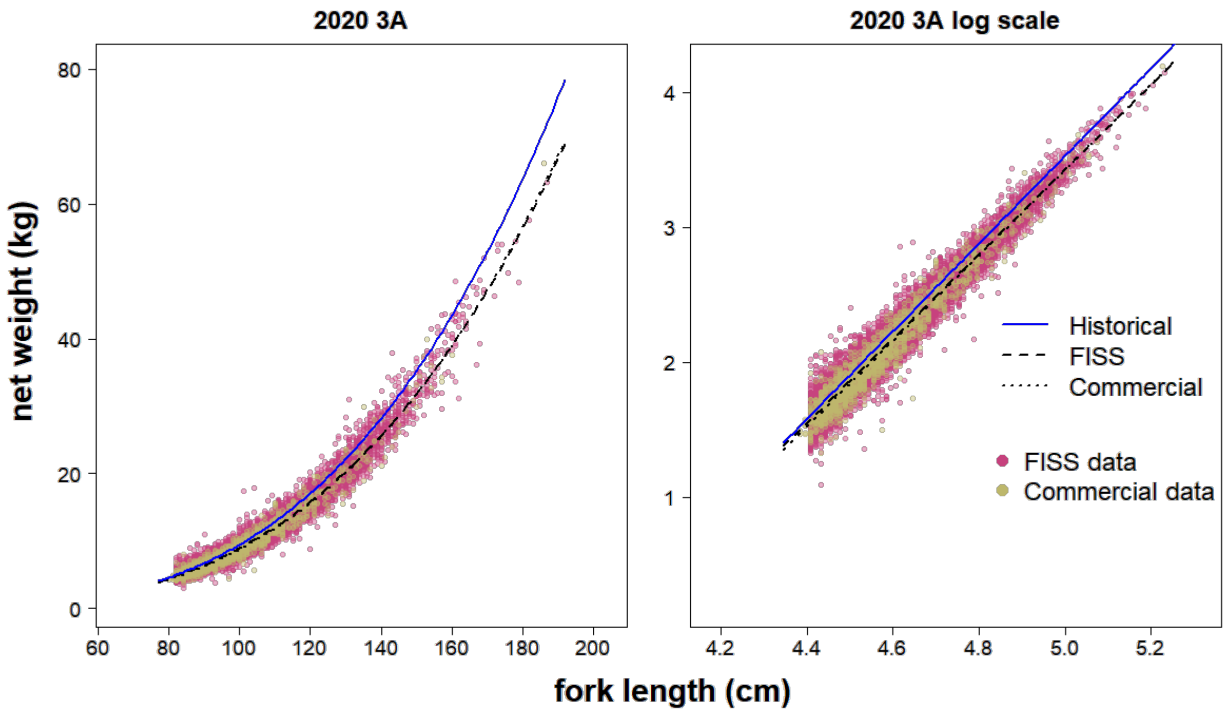

Figure 1.31 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3A in 2020.

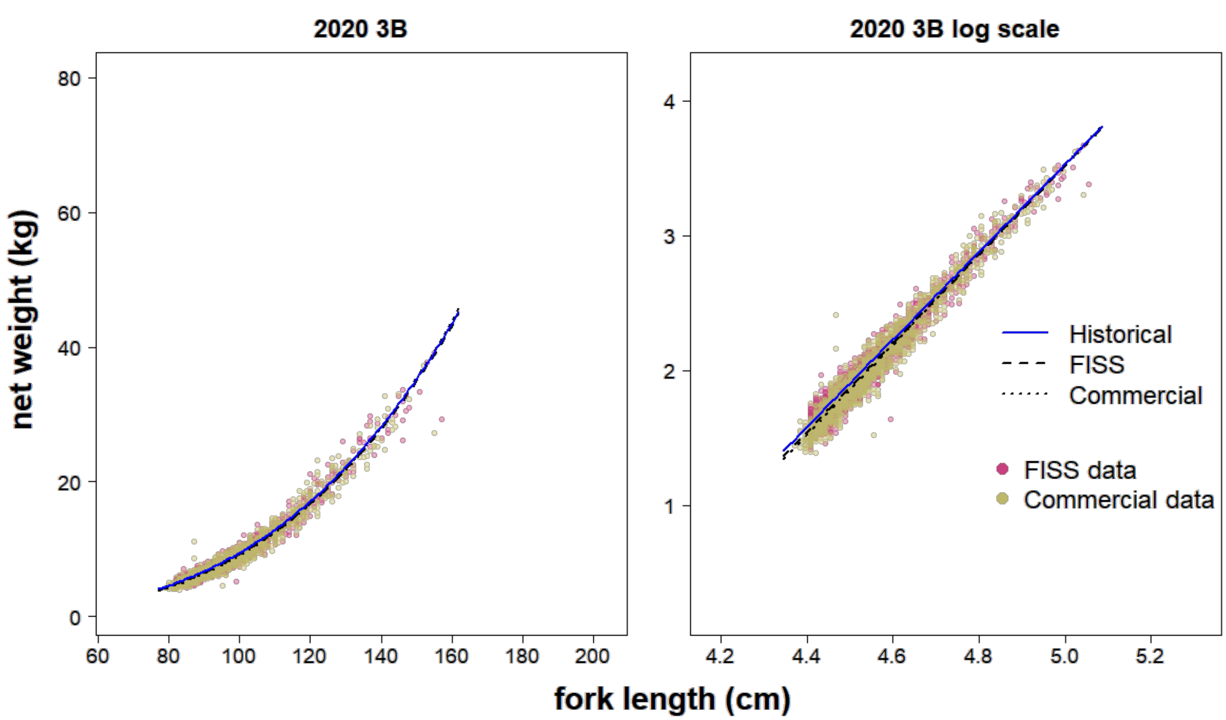

Figure 1.32 Comparison of estimated length-net weight curves from FISS and commercial data for IPHC Regulatory Area 3B in 2020.

Part 2: Review of IPHC hook competition standardization

PURPOSE

To provide a review of the IPHC approach to standardizing WPUE and NPUE for competition for baits on the Fishery-Independent Setline Survey (FISS). A short discussion of IPHC experiments with hook timers is also provided.

BACKGROUND/INTRODUCTION

In 2007, the IPHC transitioned from IPHC Regulatory Area-specific stock assessments to a coastwide stock assessment. At the same time, the IPHC began using the O32 WPUE index (including all fish over 32 inches, 81 cm, in length; this corresponds to the current directed commercial fishery minimum size limit for landings) from the FISS to estimate the distribution of the stock among IPHC Regulatory Areas. In order to address concerns that such an index can be affected by catchability differences among areas, Secretariat staff devised adjustments intended to standardise the index for at least some contributors to catchability differences. The most important of these, and one of only two standardisations still applied (along with an adjustment for FISS timing), is the hook competition standardisation. Originally devised as an average adjustment applied at the IPHC Regulatory Area level, with the introduction of the space-time model for estimating WPUE and NPUE indices, this was updated to a station-specific adjustment in 2016, as supported by the SRB (IPHC-2016-SRB09-R).

STANDARDIZATION FOR HOOK COMPETITION

Gear saturation is the process by which catch rates decrease disproportionately to abundance as the sampling gear becomes fully occupied. Although it may be present for many types of sampling gear, for longline gear, as deployed by the IPHC, gear saturation may be considered via competition for the finite number of hooks deployed. The IPHC method for standardisation for hook competition was developed by Clark (2008), and was based on the number of baits removed on FISS sets, B_i, by predator species *i*. The Baranov catch equation was used to model the B_i, the number of baits removed by predator *i* after a time period, *T*:

$$B_i = B_0 \frac{F_i}{Z}\left(1-e^{-ZT}\right)$$

Here F_i is the instantaneous rate of bait removal by predator *i*, B_0 is the initial number of baited hooks, and *Z* is the sum of the instantaneous rates applied by all bait takers. It follows that the expected catch (*C*) of halibut (*h*), which is one of the bait predators, is given by

$$C_h = B_0 \frac{F_h}{Z}\left(1-e^{-ZT}\right) \qquad (1)$$

For the FISS sets, soak time is assumed to be of sufficient length that catches of all species are unaffected by the exact value of *T*. For simplicity, we therefore set *T*=1 in the above equations. It is further assumed that empty hooks are due to bait taking by species other than halibut, and, therefore, halibut do not escape once captured. In these equations, $\left(1-e^{-Z}\right)$

therefore given by $\log\left(B_0/B_1\right)$, where B_1 is the number of baits remaining when the gear is hauled.

The IPHC approach to standardising for hook competition is to treat F_h as the standardised index for Pacific halibut at a given station, which is estimated by rearranging (1) and substituting in the estimate of Z:

$$F_h = \frac{C_h}{B_0}\log\left(\frac{B_0}{B_1}\right)\frac{B_0}{B_0 - B_1} \quad (2)$$

With C_h/B_0 representing catch per unit effort, the remaining part of the right-hand side of (2) is the hook competition adjustment factor. We note that the IPHC approach has the same mathematical derivation as the method developed contemporaneously by Etienne et al. (2013).

In practice, we substitute WPUE or NPUE for C_h/B_0 in (2), for which effort is measured by the number of effective skates, rather than the count of baits set. As the adjustment factor has a lower bound of 1, the result of the standardisation would be to increase average WPUE or NPUE, with larger positive adjustments made when fewer baits are returned. To maintain the indices on a scale familiar to stakeholders, all adjustment factors are divided by the same scalar, based on the coastwide mean adjustment factor for 1998. Importantly, this approach implicitly accounts for changes in predator density, not only among stations within a sampling year, but also across years, such that a long-term change in the level of competition would be accounted for.

Pacific halibut represents the most common species captured, and therefore the largest contribution to the hook competition correction. However, non-target species (commonly dogfish, Pacific cod and others depending on the geographical area) are frequently encountered in abundance at some FISS stations every year. Missing baits are attributed to hook competition, except where they are lost during setting, in which case they are recorded as such, and the baits deployed adjusted accordingly. Aggregating by area and year, generally 5-40% of baited hooks are returned with baits, with lowest rates of return in IPHC Regulatory Area 2A (typically less than 10%) and highest in IPHC Regulatory Area 4B (20-40% each year).

To avoid the adjustment going to infinity as the number of baits returned goes to zero, a small amount (B_0/100, for our 100-hook skates) is added to both the B_0 and B_1 when computing Z. Note also that when zero Pacific halibut are captured, the multiplicative adjustment leaves the value of WPUE or NPUE unchanged at zero.

As an example, Figures 2.1-2.3 demonstrate the effect of the standardisation on O32 WPUE from IPHC Regulatory Area 2B in 2018. This was a year in which dogfish captures were higher than normal in parts of the area, leading to lower bait returns and negatively impacting the observed survey catch of Pacific halibut. Figure 2.1 shows the hook competition adjustment factors for each station, while Figures 2.2 and 2.3 respectively plot O32 WPUE by station before and after application of the hook competition standardisation (i.e., before and after multiplication by the factors in Figure 2.1).

IPHC HOOK TIMER STUDIES

Historical work on hook timers (Kaimmer 2011, Parma et al. 1995) was intended to produce data on the rate of bait capture by Pacific halibut and competing species. However, the timers in use in those studies were not tripped most of the time, and it appears they were not sensitive to the capture of smaller fish or to smaller fish taking the bait without being captured (Parma et al. 1995).

The IPHC is currently collaborating on a study of standard and modified circle hooks that will use hook timers to record the capture time of different species. Modern hook timers are expected to be more sensitive than those used in historical studies, and it is therefore hoped that this study will yield data that will help inform the calculation of the hook competition standardisation.

RECOMMENDATION

That the Research Advisory Board:

1) **NOTE** paper IPHC-2021-RAB022-07.2 that presents an overview of the IPHC standardization for hook competition on FISS sets.

References

Clark, W.G. 2008. Effect of hook competition on survey CPUE. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 2007: 211-215.

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IPHC 2016. Report of the 9th Session of the IPHC Scientific Review Board (SRB) IPHC-2016-SRB09-R. 5 p.

Kaimmer, S. M. 2011. Special setline experiments 1985-1994 objectives, data formats, and collections. IPHC Technical Report 53.

Parma, A. M., Kaimmer, S. M. and Sullivan, P. J. 1995. A progress report on the use of hook timers and underwater observations to assess the effect of bait competition on CPUE. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 1994: 211-221.

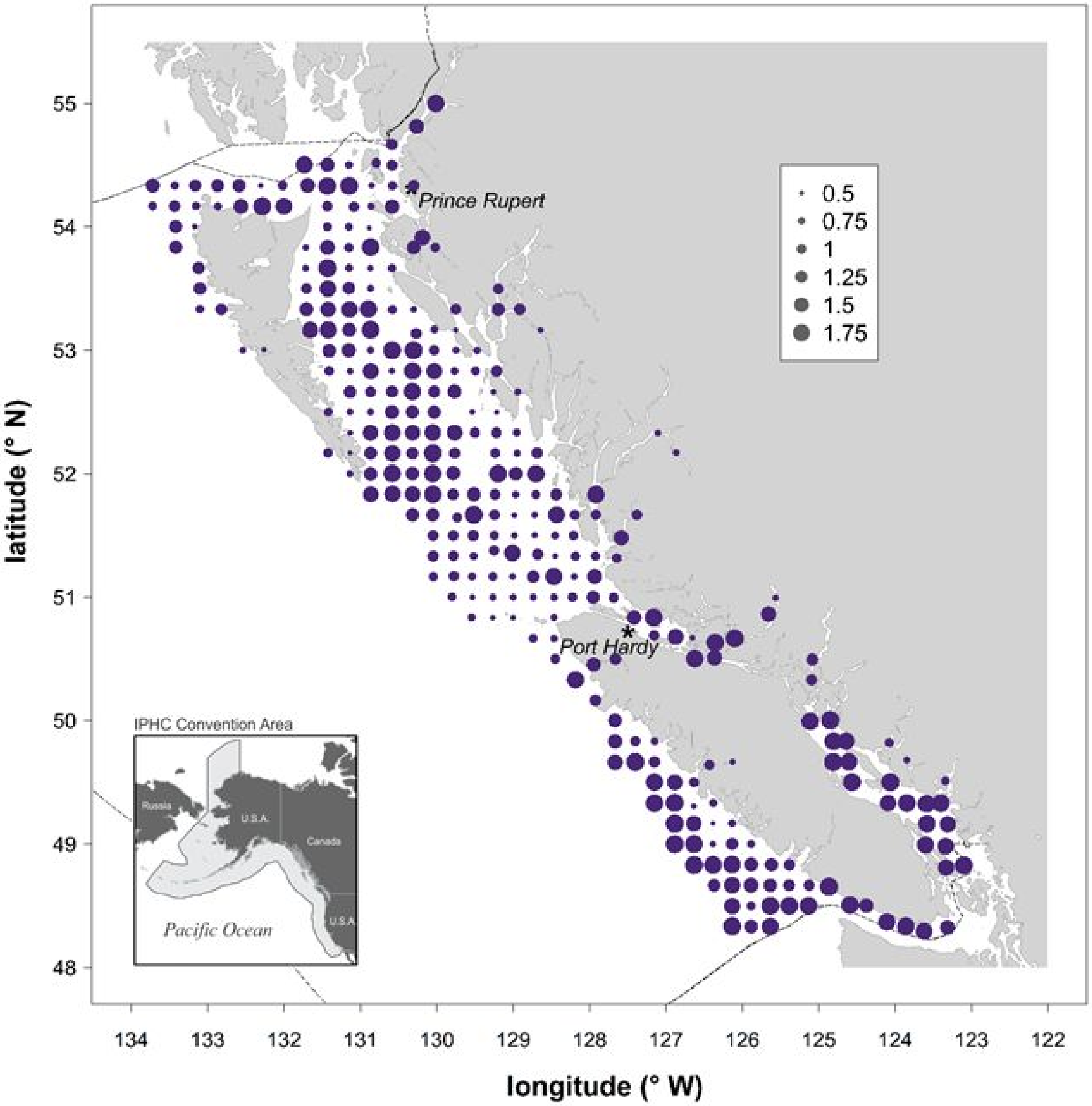


Figure 2.1. Hook competition adjustment factors for each station in IPHC Regulatory Area 2B in 2018. Larger circles are due to greater competition for baits (fewer baits returned), while smaller circles are a result of lower levels of competition.

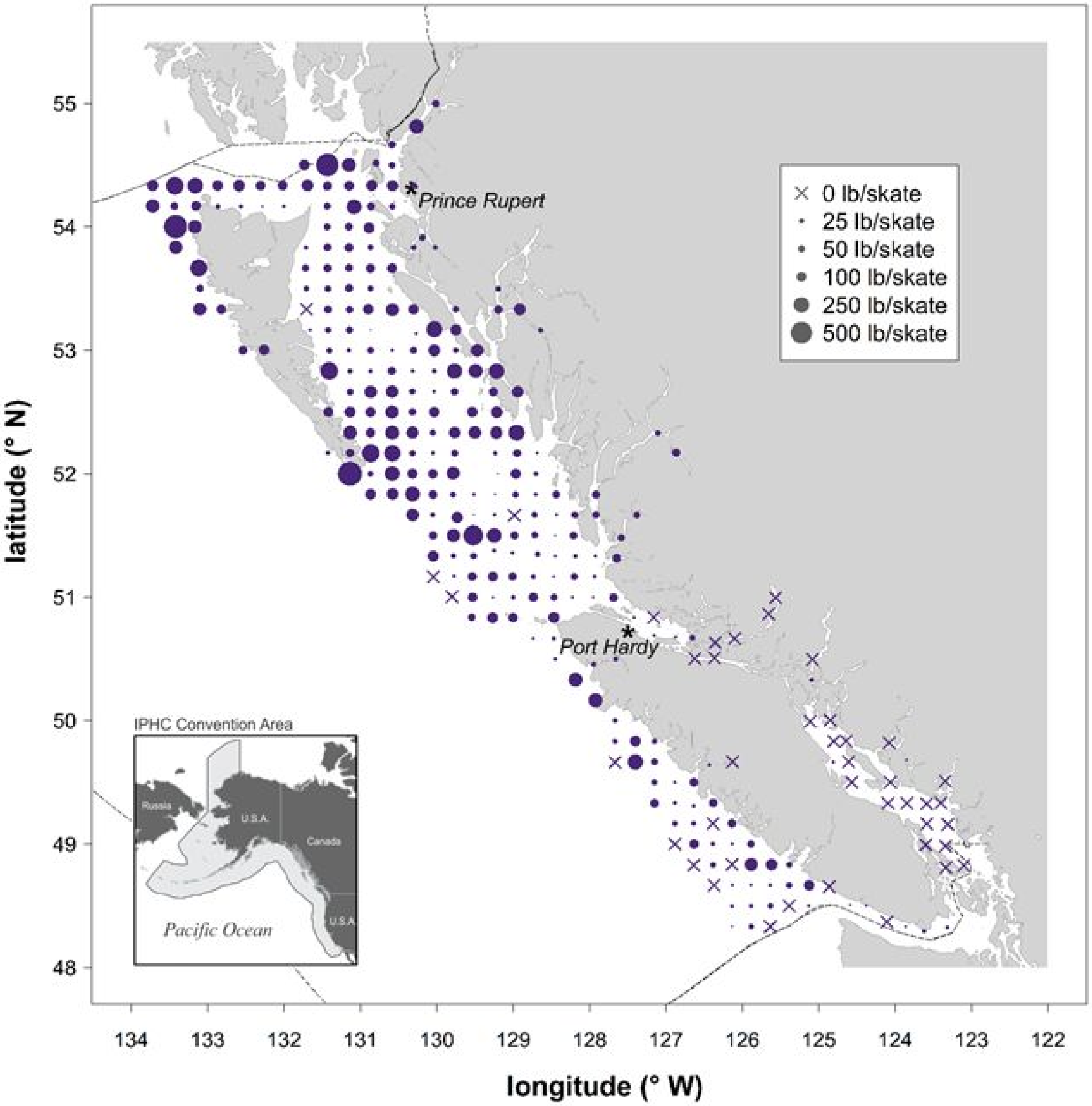


Figure 2.2. Raw O32 WPUE (lb/skate) for each station in IPHC Regulatory Area 2B in 2018.

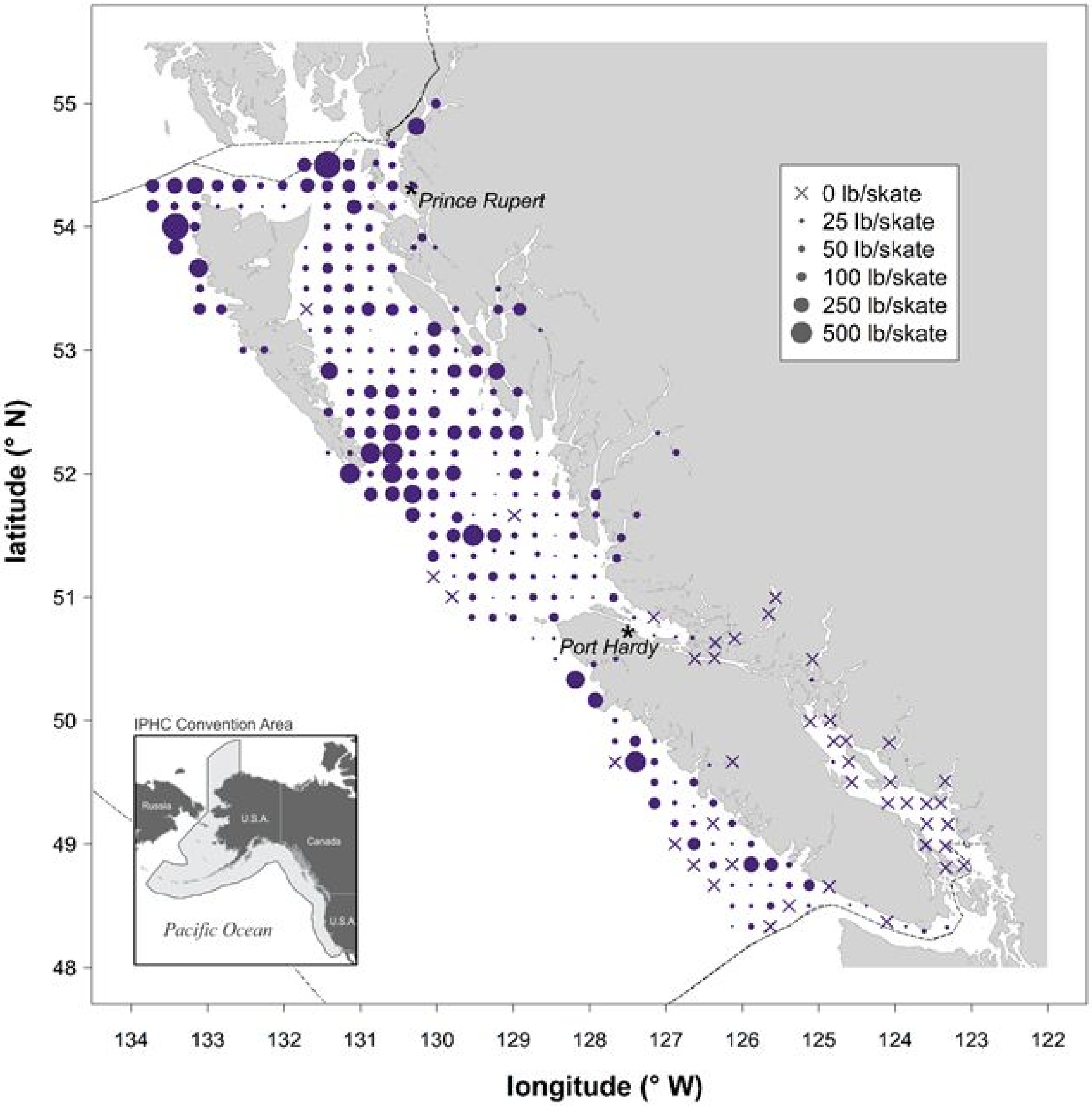


Figure 2.3. O32 WPUE (lb/skate) for each station standardized for hook competition in IPHC Regulatory Area 2B in 2018.

Part 3: Estimating the effects of whale depredation on the FISS

PURPOSE

To estimate the effects of whale depredation on FISS catch rates within the space-time model.

BACKGROUND/INTRODUCTION

The presence of sperm whales and orcas during the fishing and hauling of FISS sets can lead to such sets being designated as ineffective for the use in analyses due to the potential impact on recorded catch rates Pacific halibut of depredation by these marine mammals (IPHC-2021-VSM01, page 18). The criteria for ineffectiveness, which were tightened in 2019, are as follows:

- Sperm whales: a sperm whale is spotted within 3 nmi of the boat while hauling gear
- Orcas: a set has more than 1 lips-only Pacific halibut or a set has other observations of orca feeding on Pacific halibut

These criteria were designed to minimize the potential for including biased data in the annual indices. Sperm whales have been found to depredate cryptically on the gear at large distances from the vessel, while orcas generally leave clear evidence of depredation or are observed in the act. Coastwide, relatively few sets are designated as ineffective due to sperm whale and orca depredation each year: from 2010-2020, 1.4-3.0% of all sets fished included sperm whales or orcas as a reason for ineffectiveness. However, the impacts can be greater for a given area and year. For example, IPHC Regulatory Area 3A has had up to 6% of sets affected by whales (mainly sperm whales), while IPHC Regulatory Area 4A is the area most affected by orca encounters, with over 10% of sets affected in some years.

We used the IPHC's space-time model to estimate a parameter for the difference between affected and unaffected sets for IPHC Regulatory Areas 4A and 3A.

IPHC REGULATORY AREA 4A

As noted above, IPHC Regulatory Area 4A is the area with the greatest proportion of sets affected by whale interactions, almost all of which are interactions with orcas (139 orca sets from 1993-2020 and three sperm whale sets). We refitted the space-time model (see IPHC-2021-SRB018-05 Rev_1, Appendix B for details) to the O32 WPUE 1993-2020 data series, including sets with ineffectiveness codes for either orca or sperm whale interactions but omitting whale-affected sets that also included another ineffectiveness reason (e.g., both orcas and gear issues).

We estimated that affected sets have an average O32 WPUE of 51% (95% CI: 43-60%) of the average for unaffected sets in IPHC Regulatory Area 4A.

IPHC Regulatory Area 3A

Both sperm whales and orcas interact with FISS sets in IPHC Regulatory Area 3A, but with 116 sets affected by sperm whales over the 1993-2020 period vs 29 orca sets (and 18 with both), the former species provides a large majority of recorded whale interactions.

The model estimates a much smaller effect of whale interactions than in IPHC Regulatory Area 4A, with orca-affected estimated to have 84% (68-104%) of the O32 WPUE of unaffected sets, and sperm whale-affected sets having 86% (75-99%) of the O32 WPUE of unaffected sets.

Discussion

A goal of these analyses was to determine if we could include data from sets affected by marine mammals in the space-time modelling of FISS catch rates by accounting for the effect of depredation in the model, rather than excluding the sets as ineffective. The impact on estimates of WPUE of including these sets in the analyses was small. In its report (IPHC-2021-SRB019-R), the Scientific Review Board, noting the limited impact, "**REQUESTED** that the IPHC Secretariat continue to monitor the influence of whale depredation on the FISS and the stock assessment." For 2021, sets affected by marine mammals continue to considered ineffective and are excluded from data analyses.

RECOMMENDATION

That the Research Advisory Board:

1) **NOTE** paper IPHC-2021-RAB022-07.3 that presents estimates of the effects of whale interactions on FISS catch rates through the space-time modelling.

References

IPHC 2021. International Pacific Halibut Commission Fishery-Independent Setline Survey Sampling Manual (2021). IPHC-2021-VSM01.

IPHC 2021. Report of the 19th Session of the IPHC Scientific Review Board (SRB019). IPHC-2021-SRB019-R.

Webster, R. A. 2021. 2022-24 FISS design evaluation. IPHC-2021-SRB018-05 Rev_1.

Overview: IPHC 5-year Biological and Ecosystem Sciences Research Program (2017-21)

PREPARED BY: IPHC SECRETARIAT (J. PLANAS, 25 OCTOBER 2021)

PURPOSE

To provide the RAB with a description of the research projects proposed by IPHC Secretariat and contemplated within the Five-year Biological and Ecosystem Science Research Program (2017-21).

BACKGROUND

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

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

The primary biological research activities at IPHC that follow Commission objectives are identified and described in the IPHC Five-Year Biological and Ecosystem Science Research Plan (2017-21). These activities are summarized in five broad research areas designed to provide inputs into stock assessment and the management strategy evaluation processes (Appendix I), as follows:

1) Migration and Distribution. Studies are aimed at further understanding reproductive migration and identification of spawning times and locations as well as larval and juvenile dispersal.
2) Reproduction. Studies are aimed at providing information on the sex ratio of the commercial catch and to improve current estimates of maturity.
3) Growth and Physiological Condition. Studies are aimed at describing the role of some of the factors responsible for the observed changes in size-at-age and to provide tools for measuring growth and physiological condition in Pacific halibut.
4) Discard Mortality Rates (DMRs) and Survival. Studies are aimed at providing updated estimates of DMRs in both the longline and the trawl fisheries.
5) Genetics and Genomics. Studies are aimed at describing the genetic structure of the Pacific halibut population and at providing the means to investigate rapid adaptive changes in response to fishery-dependent and fishery-independent influences.

DISCUSSION ON THE MAIN RESEARCH ACTIVITIES

1. Migration and Distribution.

   Research activities in this Research Area aim at improving existing knowledge on Pacific halibut larval and juvenile distribution. The relevance of research outcomes from these activities for stock assessment (SA) is in the improvement of estimates of productivity. These research outcomes will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region and represent one of the top three biological inputs into SA (Appendix II). The relevance of these research outcomes for the management and strategy evaluation (MSE) process is in the improvement of the parametrization of the Operating Model and represent the top ranked biological input into the MSE (Appendix III).

1.1. Larval distribution and connectivity between the Gulf of Alaska and Bering Sea.
Principal Investigator: Lauri Sadorus (M.Sc.)
Objective: To investigate larval and juvenile connectivity of Pacific halibut within and between the Gulf of Alaska and the 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. The results of this study have been published in the journal *Fisheries Oceanography* (Sadorus et al., 2021). A full description of this project is included in paper IPHC-2021-RAB022-09.

2. Reproduction.

Research activities in this Research Area aim at providing information on key biological processes related to reproduction in Pacific halibut (maturity and fecundity) and to provide sex ratio information of Pacific halibut commercial landings. The relevance of research outcomes from these activities for stock assessment (SA) is in the scaling of Pacific halibut biomass and in the estimation of reference points and fishing intensity. These research outputs will result in a revision of current maturity schedules and will be included as inputs into the SA (Appendix II), and represent the most important biological inputs for stock assessment. The relevance of these research outcomes for the management and strategy evaluation process is in the improvement of the simulation of spawning biomass in the Operating Model (Appendix III).

Recent sensitivity analyses have shown the importance of changes in spawning output due to skip spawning and/or changes in maturity schedules for stock assessment (Stewart and Hicks, 2018). Information of these key reproductive parameters provides direct input to stock assessment. For example, information on fecundity-at-age and –at-size could be used to replace spawning biomass with egg output as the metric of reproductive capability in the stock assessment and management reference points. This information highlights the need for a better understanding of factors influencing reproductive biology and reproductive success of Pacific halibut. In order to fill existing knowledge gaps related to the reproductive biology of female Pacific halibut, research efforts are devoted to characterize female maturity in this species. Specific objectives of current studies include: 1) histological assessment of the temporal progression of female developmental stages and reproductive phases throughout an entire reproductive cycle; 2) investigation of skip-spawning in females; and 3) fecundity estimations. A full description of this project is included in paper IPHC-2021-RAB022-10.

3. Growth.
Principal Investigator: Josep Planas (Ph.D.)
Objective: To investigate somatic growth variation as a driver for changes in size-at-age.

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 (Appendix II). 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 (Appendix III).

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 (SA). Bycatch and wastage of Pacific halibut, as defined by the incidental catch of fish in non-target fisheries and by the mortality that occurs in the directed fishery (i.e. fish discarded for sublegal size or for regulatory reasons), respectively, represent important sources of mortality that can result in significant reductions in exploitable yield in the directed fishery. Given that the incidental

mortality from the commercial Pacific halibut fisheries and bycatch fisheries is included as part of the total removals that are accounted for in the SA, changes in the estimates of incidental mortality will influence the output of the SA and, consequently, the catch levels of the directed fishery. Research activities conducted in this Research Area aim at providing information on discard mortality rates and producing guidelines for reducing discard mortality in Pacific halibut in the longline and recreational fisheries. The relevance of research outcomes from these activities for SA resides in their ability to improve trends in unobserved mortality in order to improve estimates of stock productivity and represent the most important inputs in fishery yield for SA (Appendix II). The relevance of these research outcomes for the management and strategy evaluation process is in fishery parametization (Appendix III).

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

4.1. Evaluation of the effects of hook release techniques on injury levels and association with the physiological condition of captured Pacific halibut and estimation of discard mortality using remote-sensing techniques in the directed longline fishery.
Principal Investigator: Claude Dykstra (B.Sc.)
Objective: To provide estimates of discard mortality and best-handling practices in the Pacific halibut directed fishery.

The IPHC Secretariat, with funding by a grant from the Saltonstall-Kennedy Grant Program NOAA (NA17NMF4270240; 2017-2020), has recently 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 discard mortality rate (DMR) in the directed longline fishery. The initial results on individual survival outcomes for Pacific halibut released in excellent condition as the viability category assigned to the fish following capture 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%. A manuscript describing these results has been accepted for publication in the *Journal of North American Fishery Management* (Loher et al., in press).

The IPHC Secretariat is currently conducting modeling analyses of potential relationships between individual physiological characteristics of discarded Pacific halibut, environmental conditions and handling practices, as well as on the ability of electronic monitoring systems to capture release methods and individual lengths of captured fish.

4.2. Discard mortality rates of Pacific halibut in the charter recreational fishery.
Principal Investigator: Claude Dykstra (B.Sc.)
Objective: To provide estimates of discard mortality and best-handling practices in the Pacific halibut guided 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) (Appendix IV). A full description of this project is included in paper IPHC-2021-RAB022-11.

5. Genetics and genomics.
   Principal Investigator: Andy Jasonowicz (M.Sc.)
   Objective: To investigate the genetic structure of the Pacific halibut population and to conduct genetic analyses to inform on Pacific halibut movement and distribution in the Convention Waters.

   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. The relevance of research outcomes from these activities for stock assessment (SA) resides (1) in the introduction of possible changes in the structure of future stock assessments, as separate assessments may be constructed if functionally isolated components of the population are found (e.g. IPHC Regulatory Area 4B), and (2) in the improvement of productivity estimates, as this information may be used to define management targets for minimum spawning biomass by Biological Region. These research outcomes provide the second and third top ranked biological inputs into SA (Appendix II). Furthermore, the relevance of these research outcomes for the management and strategy evaluation process is in biological parametization and validation of movement estimates, on one hand, and of recruitment distribution, on the other hand (Appendix III). This project has received funding from the North Pacific Research Board (NPRB Project No. 2110) (Appendix IV). A full description of this project is included in paper IPHC-2021-RAB022-13.

6. Other research.

   The IPHC Secretariat (PI's: Mr. Claude Dykstra and Dr. Ian Stewart) has been successful in securing funding from NOAA's 2021 Bycatch Reduction Engineering Program (BREP) for a project entitled "Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries" (Appendix IV). This study seeks to identify potential methods for protecting hook captured fish from whale depredation and to develop and field-test several simple low-cost catch-protection designs that can be deployed effectively using current longline fishing techniques. The proposed work entails conducting a workshop with industry (affected fishers, gear researchers, scientists) in late 2021 to identify methods to protect fishery catches from depredation. The top two or three catch protection design outcomes from the workshop will be incorporated into functional prototypes and field tested in 2022 on longline sea trials targeting flatfish. A full description of this project is included in paper IPHC-2021-RAB022-12.

RECOMMENDATION/S

1) That the RAB **NOTE** IPHC-2021-RAB022-08, which outlined the research projects proposed by the IPHC Secretariat to the Commission and provided an overview of the 5-year research program (2017-21).

APPENDICES

Appendix I: Integration of ongoing biological research activities, stock assessment and management strategy evaluation.

Appendix II: List of ranked biological uncertainties and parameters for stock assessment and their links to potential research areas and research activities (2017-21)

Appendix III: List of ranked biological uncertainties and parameters for management strategy evaluation and their potential links to research areas and research activities (2017-21)

Appendix IV: Summary of awarded research grants current in 2021

APPENDIX I

Integration of ongoing biological research activities, stock assessment and management strategy evaluation

Research areas	Research activities	Research outcomes	Relevance for stock assessment	Relevance for MSE	Specific analysis input	SA Rank (Top 3)	MSE Rank (Top 3)
Migration	Larval and juvenile connectivity and early life history studies	Improved understanding of larval and juvenile distribution	Improve estimates of productivity	Improve parametization of the Operating Model	Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	3. Biological input	1. Biological parameterization and validation of movement estimates
Reproduction	Histological maturity assessment	Updated maturity schedule	Scale biomass and reference point estimates	Improve simulation of spawning biomass in the Operating Model	Will be included in the stock assessment, replacing the current schedule last updated in 2006	1. Biological input	
	Examination of potential skip spawning	Incidence of skip spawning			Will be used to adjust the asymptote of the maturity schedule, if/when a time-series is available this will be used as a direct input to the stock assessment		
	Fecundity assessment	Fecundity-at-age and -size information			Will be used to move from spawning biomass to egg-output as the metric of reproductive capability in the stock assessment and management reference points		
	Examination of accuracy of current field macroscopic maturity classification	Revised field maturity classification			Revised time-series of historical (and future) maturity for input to the stock assessment		
	Sex ratio of current commercial landings	Sex ratio-at-age	Scale biomass and fishing intensity		Annual sex-ratio at age for the commercial fishery fit by the stock assessment	1. Assessment data collection and processing	
	Historical sex ratios based on archived otolith DNA analyses	Historical sex ratio-at-age			Annual sex-ratio at age for the commercial fishery fit by the stock assessment		
	Recruitment strength and variability	Establishment of temporal and spatial maturity and spawning patterns	Improve stock-recruitment curve for more precise assessment	Improve simulation of recruitment variability and parametization of recruitment distribution in the Operating Model	May be used to provide a weighted spawning biomass calculation and or inform targets for minimum spawning biomass by Biological Region		2. Biological parameterization and validation of recruitment variability and distribution
Growth	Evaluation of somatic growth variation as a driver for changes in size-at-age	Identification and application of markers for growth pattern evaluation	Scale stock productivity and reference point estimates	Improve simulation of variability and allow for scenarios investigating climate change	May inform yield-per-recruit and other spatial evaluations of productivity that support mortality limit-setting		3. Biological parameterization and validation for growth projections
		Environmental influences on growth patterns			May provide covariates for projecting short-term size-at-age. May help to delineate between effects due to fishing and those due to environment, thereby informing appropriate management response		
Mortality and survival assessment	Discard mortality rate estimate: longline fishery	Experimentally-derived DMR	Improve trends in unobserved mortality	Improve estimates of stock productivity	Will improve estimates of discard mortality, reducing potential bias in stock assessment results and management of mortality limits		1. Fishery parameterization
	Discard mortality rate estimate: recreational fishery				Will improve estimates of discard mortality, reducing potential bias in stock assessment results and management of mortality limits		2. Fishery parameterization
	Best handling practices: longline fishery	Guidelines for reducing discard mortality			May reduce discard mortality, thereby increasing available yield for directed fisheries		
	Best handling practices: recreational fishery	Guidelines for reducing discard mortality			May reduce discard mortality, thereby increasing available yield for directed fisheries		
Genetics and genomics	Population structure	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area	Altered structure of future stock assessments	Improve parametization of the Operating Model	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	2. Biological input	1. Biological parameterization and validation of movement estimates.
	Distribution	Assignment of individuals to source populations and assessment of distribution changes			Will be used to define management targets for minimum spawning biomass by Biological Region	3. Biological input	2. Biological parameterization and validation of recruitment distribution

APPENDIX II

List of ranked biological uncertainties and parameters for stock assessment and their links to potential research areas and research activities (2017-21)

SA Rank	Research outcomes	Relevance for stock assessment	Specific analysis input	Research Area	Research activities
1. Biological input	Updated maturity schedule	Scale biomass and reference point estimates	Will be included in the stock assessment, replacing the current schedule last updated in 2006	Reproduction	Histological maturity assessment
	Incidence of skip spawning		Will be used to adjust the asymptote of the maturity schedule, if/when a time-series is available this will be used as a direct input to the stock assessment		Examination of potential skip spawning
	Fecundity-at-age and -size information		Will be used to move from spawning biomass to egg-output as the metric of reproductive capability in the stock assessment and management reference points		Fecundity assessment
	Revised field maturity classification		Revised time-series of historical (and future) maturity for input to the stock assessment		Examination of accuracy of current field macroscopic maturity classification
2. Biological input	Stock structure of IPHC Regulatory Area 4B relative to the rest of the Convention Area	Altered structure of future stock assessments	If 4B is found to be functionally isolated, a separate assessment may be constructed for that IPHC Regulatory Area	Genetics and Genomics	Population structure
3. Biological input	Assignment of individuals to source populations and assessment of distribution changes	Improve estimates of productivity	Will be used to define management targets for minimum spawning biomass by Biological Region		Distribution
	Improved understanding of larval and juvenile distribution		Will be used to generate potential recruitment covariates and to inform minimum spawning biomass targets by Biological Region	Migration	Larval and juvenile connectivity studies
1. Assessment data collection and processing	Sex ratio-at-age	Scale biomass and fishing intensity	Annual sex-ratio at age for the commercial fishery fit by the stock assessment	Reproduction	Sex ratio of current commercial landings
	Historical sex ratio-at-age		Annual sex-ratio at age for the commercial fishery fit by the stock assessment		Historical sex ratios based on archived otolith DNA analyses
2. Assessment data collection and processing	New tools for fishery avoidance/deterence; improved estimation of depredation mortality	Improve mortality accounting	May reduce depredation mortality, thereby increasing available yield for directed fisheries. May also be included as another explicit source of mortality in the stock assessment and mortality limit setting process depending on the estimated magnitude	Mortality and survival assessment	Whale depredation accounting and tools for avoidance
1. Fishery yield	Physiological and behavioral responses to fishing gear	Reduce incidental mortality	May increase yield available to directed fisheries	Mortality and survival assessment	Biological interactions with fishing gear
2. Fishery yield	Guidelines for reducing discard mortality	Improve estimates of unobserved mortality	May reduce discard mortality, thereby increasing available yield for directed fisheries	Mortality and survival assessment	Best handling practices: recreational fishery

APPENDIX III

List of ranked biological uncertainties and parameters for management strategy evaluation (MSE) and their potential links to research areas and research activities (2017-21)

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

APPENDIX IV

Summary of awarded research grants

Project #	Grant agency	Project name	PI	Partners	IPHC Budget ($US)	Management implications	Grant period
1	**National Fish & Wildlife Foundation**	Improving the characterization of discard mortality of Pacific halibut in the recreational fisheries (NFWF Award No. 61484)	IPHC Dr J. Planas and Mr Claude Dykstra	Alaska Pacific University, U of A Fairbanks, charter industry	$98,902	Bycatch estimates	1 April 2019 – 1 November 2021
2	**North Pacific Research Board**	Pacific halibut discard mortality rates (NPRB Award No. 2009)	IPHC Dr. J. Planas	Alaska Pacific University	$210,502	Bycatch estimates	1 January 2021 – 31 March 2022
3	**Bycatch Reduction Engineering Program-NOAA**	Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries (NOAA Award Number NA21NMF4720534)	IPHC Mr. Claude Dykstra and Dr. I. Stewart	Deep Sea Fishermen's Union, Alaska Fisheries Science Center-NOAA, industry representatives	$99,700	Whale depredation	1 November 2021 – 30 April 2022
4	**North Pacific Research Board**	Pacific halibut population genomics (NPRB Award No. 2110)	IPHC Dr. J. Planas	Alaska Fisheries Science Center-NOAA	$193,685	Stock structure	1 February 2022 – 31 January 2024
		Total awarded ($)			**$602,789**		

INTERNATIONAL PACIFIC HALIBUT COMMISSION

Migratory behavior and distribution of Pacific halibut

PREPARED BY: IPHC SECRETARIAT (L. SADORUS & T. LOHER; 25 OCTOBER 2021)

PURPOSE

To provide the RAB with a description of the studies designed to improve our knowledge on distribution and migration of Pacific halibut in the northeast Pacific Ocean and eastern Bering Sea.

BACKGROUND

The IPHC is currently investigating Pacific halibut distribution and migration at early and juvenile life-stages.

Unlike juvenile Pacific halibut which are demersal, larvae are pelagic for approximately the first six months of life and are distributed largely based on where they originated (i.e. where they were spawned) and where the currents carry them during their pelagic life stage. Of interest to the IPHC Secretariat is the connectivity of larvae to nursery areas, particularly for larvae spawned in the Gulf of Alaska that settle in the Bering Sea, as well between the eastern and western sides of each basin, and the environmental drivers that may affect the magnitude of this connectivity. Also of interest are the geographic differences in larval dispersal and distribution of settled Pacific halibut related to environmental conditions. For example, it has been established that the counter-clockwise Alaska Coastal Current in the Gulf of Alaska flows into the Bering Sea via Aleutian Island passes, primarily Unimak Pass. The IPHC does not conduct larval surveys, but National Oceanic and Atmospheric Administration (NOAA) icthyoplankton (larval) surveys are conducted annually, and IPHC teamed with NOAA to examine these data spanning from 1972 to 2015 and model possible dispersal pathways, both at the larval and early demersal stages.

DISCUSSION

The research project investigating larval and juvenile connectivity between the Gulf of Alaska (GOA) and Bering Sea (BS), 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 GOA and BS and within each of these two ocean basins. The first of these two models was a combination physical oceanography and larval recruitment model and the second model was a spatio-temporal model. Results from the larval recruitment model indicate that the Aleutian Islands constrain connectivity between GOA and BS, but that large island passes serve as pathways between these ecosystems. The degree of connectivity between GOA and BS is influenced by spawning location such that up to 50-60% of simulated larvae from the westernmost GOA spawning location arrive in the BS with progressively fewer larvae arriving proportional to distance from spawning grounds further east. There is also a large degree of connectivity between eastern and western GOA and between eastern and western BS. Spatial modeling of 2-6 year old fish shows ontogenetic migration from the inshore settlement areas of eastern BS towards Unimak Pass and GOA by age 4. The pattern of larval dispersal from GOA to BS, and subsequent post-settlement migrations back from BS toward GOA, provides evidence of circular, multiple life-stage, connectivity between these ecosystems, regardless of temperature stanza or year class strength. The study showed annual variations in dispersal, but there was no clear signal between warm and cold stanza years identified. The results of these studies will improve estimates of productivity by contributing to the generation of potential recruitment covariates and by informing minimum spawning biomass targets by Biological Region. In addition, these results will assist in the biological parameterization and validation of movement estimates in the MSE Operating Model (Appendix I). The results of this study have been published in the journal *Fisheries Oceanography* (Sadorus et al., 2021).

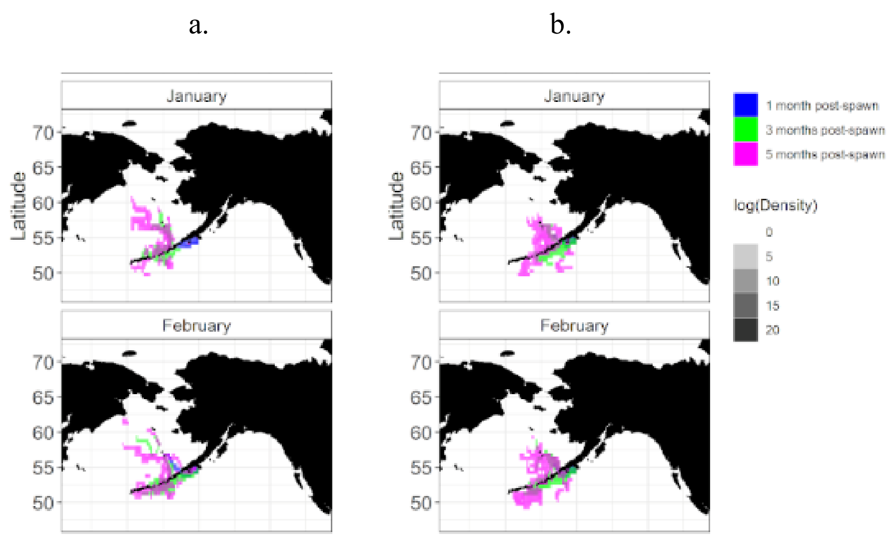


Figure 1. A sample of larval advection modelling results for Pacific halibut spawned in January (top) or February (bottom) in the western Gulf of Alaska during a) 2005 (a warm year) and b) 2009 (a cold year).

RECOMMENDATION

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-09, which described studies designed to improve our knowledge on Pacific halibut connectivity at early and juvenile stages.

Reproductive assessment of the Pacific halibut population

PREPARED BY: IPHC SECRETARIAT (J. PLANAS, 25 OCTOBER 2021)

PURPOSE

To provide the RAB with a description of the studies designed to improve our knowledge on reproductive development in female and male Pacific halibut.

BACKGROUND

Each year, the fishery-independent setline survey (FISS) collects biological data on the maturity of female Pacific halibut that are used in the stock assessment. In particular, the female maturity schedule is used to estimate spawning stock biomass. Currently used estimates of maturity at age indicate that the age at which 50% of female Pacific halibut are sexually mature is 11.6 years on average. However, maturity is estimated with the use of macroscopic visual criteria, implying a relative level of uncertainty associated with the employed semi-quantitative assessment, and the maturity schedules for both sexes have not been revised in recent years and may be outdated. For this reason, research efforts are needed to improve our understanding of reproductive maturity in female Pacific halibut. Unfortunately, relatively little is known regarding the physiological changes that take place in the ovary during reproductive development leading to spawning in this species. The objective of this study is to understand and report the progression of reproductive development in female Pacific halibut during an entire annual reproductive cycle.

DISCUSSION

Biological samples and biological information from female and male Pacific halibut were successfully collected on a monthly basis for an entire year, from September 2017 through August 2018, in the Portlock region in the Central Gulf of Alaska (Appendix I). The period of sample collection covered an entire annual reproductive cycle in female Pacific halibut and therefore included all maturity stages from post-spawning and early gonadal growth and development until spawning. Biological information and biological samples collected included: maturity stage (classified according to current maturity scales), fork length, otoliths for aging, round weight, gonad weight, liver weight, photographic images of gonads, ovarian and testicular samples for histology, ovarian, testicular and pituitary samples for gene expression, blood samples, fin clips, and fat content.

Photographic images of all staged gonads will be contrasted with gonadosomatic index (GSI; gonad weight/round weight X 100) determinations and histological examination of ovarian and testicular staging. This will allow us to revise the morphological criteria currently used for staging the maturity status of the gonads (ovary and testis). Blood samples were collected on all fish in order to conduct a thorough endocrinological assessment of reproductive status and development in order to correlate levels of reproductive hormones and reproductive genetic markers with morphological and histological assessment of the gonads. Finally, the collected data on fat content will provide functional data on the energy stored in the fish in order to relate energy storage to sexual maturity. Energy storage will be determined by the hepatosomatic index (HSI; liver weight/round weight X 100) and the muscle fat content as measured with the Fatmeter device.

The completed collection of morphological, histological, endocrine, and functional data from female and male Pacific halibut throughout an entire annual cycle will provide us with a better understanding of the temporal and spatial progression of sexual maturation in Pacific halibut, and will allow for a better estimation of maturity for stock assessment purposes.

Analysis of the data analyzed to date indicate that macroscopic (field) maturity staging captures changes in the maturity schedule of female Pacific halibut that are consistent with the expected peak time of spawning (January-February) and that are correlated with the changes in the gonadosomatic index (Figure 1).

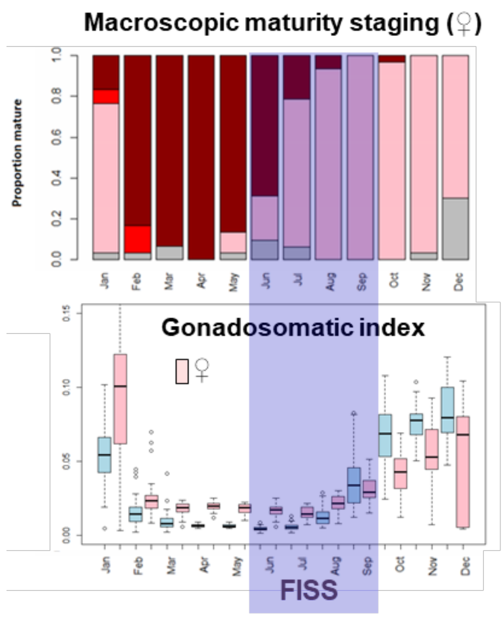


Figure 1. Top, temporal progression of macroscopic maturity stages (grey: immature; pink: maturing; red: ripe; purple: spent) during an entire annual reproductive cycle. Bottom, temporal changes in the gonadosomatic index (gonad weight/round weight X 100) during an entire annual reproductive cycle (pink: females; blue: males). Highlighted over the two graphs is the period during which macroscopic maturity stages used in stock assessment are collected in IPHC's fishery-independent setline survey (FISS).

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. This information is contained in a manuscript that has been recently published in the *Journal of Fish Biology* (Fish et al., 2020). In brief, 8 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 7 different microscopic maturity stages were established. Analysis of oocyte size frequency distribution among the seven different maturity stages provided the first direct evidence for the group-synchronous pattern of oocyte development and for determinate fecundity as the reproductive strategy in female Pacific halibut. The results of this study will allow us to establish a comparison of the microscopic/histological and macroscopic/field classification criteria that are currently used to assign the maturity status of females that is used in stock assessment. The results of this study set the stage for and in-depth study on temporal changes in reproductive development, as assessed by microscopic observations of ovarian samples collected throughout an entire annual reproductive cycle, that is currently underway. Preliminary 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. 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).

Furthermore, the IPHC Secretariat is also establishing a comparison of the microscopic (e.g. histological) and macroscopic (e.g. visual) maturity classification criteria to determine whether field classification criteria that are currently used to assign the maturity status of females that is used in stock assessment needs to be revised in light of the improved knowledge on ovarian development.

RECOMMENDATION

That the RAB:

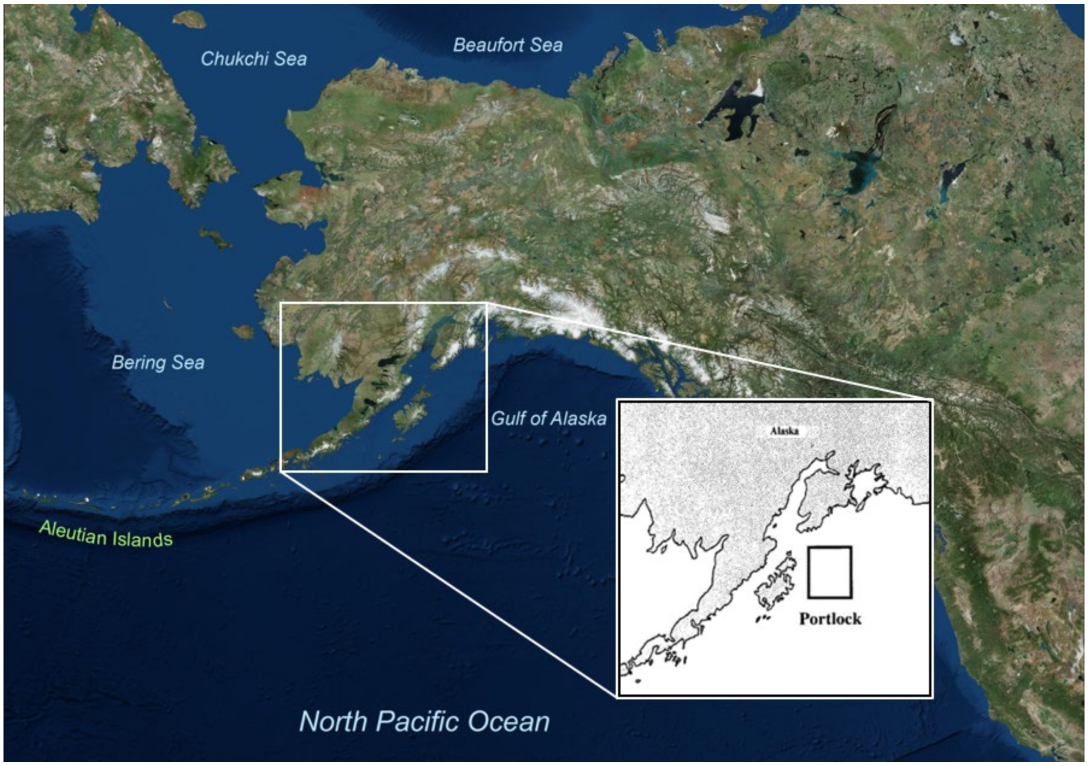
1) **NOTE** paper IPHC-2021-RAB022-10 which outlined the research project describing studies designed to improve our knowledge on reproductive development in female Pacific halibut.

APPENDICES

Appendix I: Geographic location of the sample collection efforts (2017-2018): the Portlock region in the Central Gulf of Alaska.

APPENDIX I

Geographic location of the sample collection efforts (2017-2018): the Portlock region in the Central Gulf of Alaska



Evaluating discard mortality rates and developing best management practices in the Pacific halibut charter recreational fisheries

PREPARED BY: IPHC SECRETARIAT (C. DYKSTRA, 25 OCTOBER 2021)

PURPOSE

To provide the RAB with a description of an ongoing study designed to improve our knowledge on discard mortality rates in the Pacific halibut charter recreational fishery.

BACKGROUND

The Pacific halibut recreational fishery (combined guided and unguided) is an important contributor (19%) to the total fishery-induced mortality, with 2,767 metric tons (6.1 million pounds) of removals in 2019. The Gulf of Alaska (IPHC Regulatory Areas 2C and 3A) accounts for more than 78% of the recreational mortalities coastwide. Under current regulations, the number of fish captured, handled and discarded by the Pacific halibut recreational fisheries is significant. Capture-related events impose stress and injury to the fish and, consequently, decrease the survival of discarded fish. In contrast to the trawl and longline Pacific halibut fisheries, discard mortality rates (DMRs) have not been determined experimentally in the recreational fisheries and are currently based on DMR information generated from commercial gear using J-hooks combined with rates derived for other sport fisheries, and coarsely applied to recreational hook type and creel census data. This project aims at better understanding the role of fishing practices and capture conditions on injury profile, physiological stress levels and survival in the Pacific halibut recreational fisheries in order to estimate DMRs. Recent reductions in Pacific halibut catch limits places added importance for improved DMR estimates applied to the recreational fishery.

The primary components of this project are to: 1) collect information on hook types and sizes and handling practices used in the guided recreational Pacific halibut fisheries of the central and eastern Gulf of Alaska; 2) quantify relationships between gear types employed and the size composition of captured Pacific halibut; 3) characterize injury profiles and physiological stress levels in relation to commonly-employed capture and handling protocols, and; 4) to quantify and characterize survival of the discarded Pacific halibut in order to evaluate the relative accuracy of currently-employed DMRs. Funding for these projects was provided by the National Fish and Wildlife Foundation (components 1-4) and the North Pacific Research Board (component 4).

DISCUSSION

The first component of the existing project was initiated in May of 2019 and was composed of fleet outreach exercises that were conducted in the Alaskan ports of Homer and Seward in IPHC Regulatory Area 3A, and in Juneau and Sitka in IPHC Regulatory Area 2C. Working directly with each port's charter association and the ADF&G, stakeholder meetings were conducted in order to explain project objectives, solicit the involvement of local guided recreational fishing captains, receive feedback with respect to project logistics, and answer questions and concerns that fleet members might have regarding the work. This was followed by the distribution of a voluntary survey – developed in collaboration with the University of Alaska, Fairbanks – soliciting detailed information regarding gear configurations (hook types and sizes) employed and fish handling practices (e.g., fish manipulated by hand or net, hook-release method, time out of water), that was administered to guided recreational fishing captains via the IPHC's commercial port sampling program over the course of the 2019 fishing season. Results show that the guided recreational fleet predominantly uses circle hooks (75-100%), followed by jigs. Predominant hook release methods included reversing the hook (54%) or twisting the hook out with a gaff (40%), and the fish were generally handled by supporting both the head and tail (65%), while other common techniques included handling by the operculum (10%) or by the tail alone (10%). The data obtained from the 2019 guided recreational fleet survey provided the basis for structuring field work which was conducted during the summer of 2021.

In order to conduct the proposed field studies, the IPHC Secretariat chartered the guided recreational vessel F/V High Roller (operated by Alaska Premier Charters) from 21-27 May 2021 in IPHC Regulatory Area 2C (out of Sitka, AK). The research charter in IPHC Regulatory Area 3A (out of Seward, AK) was conducted on the fishing vessel Gray Light (operated by Graylight Fisheries) on 11-16 June 2021. The fishing vessels were required to fish 6 rods at a time, three (3) rigged with 12/0 circle hooks and three (3) rigged with 16/0 circle hooks in order to establish a comparison of the two most common gear types used in the Pacific halibut recreational fishery.

In IPHC Regulatory Area 2C, we captured, sampled and released 243 Pacific halibut that were on average 80.1 ± 19.0 cm in fork length (range from 52 to 149 cm) and 7.4 ± 7.5 Kg in weight (range from 1.5 to 49.75 Kg). In IPHC Regulatory Area 3A (Seward, AK), we captured, sampled and released 118 Pacific halibut that were on average 72.5 ± 14.1 cm in fork length (range from 42 to 110 cm) and 5.0 ± 3.3 Kg in weight (range from 0.55 to 17 Kg). Therefore, a total of 361 Pacific halibut were captured, sampled and released in the two research charters conducted.

For all Pacific halibut captured in IPHC regulatory area 2C, we recorded the time from hooking to release, length and weight, the injury code and release viability category using the standard IPHC criteria, and air and fish temperature. In addition, from each fish we collected a blood sample, measured somatic fat content with the use of a Distell Fat Meter, took a picture of the hooking injury, collected a fin clip for genetic sexing and tagged the fish with an opercular wire tag prior to release. Pacific halibut captured in IPHC Regulatory Area 3A were subjected to the same sampling protocol except for 80 fish that were tagged with acceleration-logging survivorship pop-up archival transmitting (sPAT) tags. sPAT-tagged fish were selected only among those fish that were classified in the "excellent" viability category and did not have a blood sample taken to minimize handling-related stress). The deployed sPAT tags were programmed to be released after 96 days.

As of October 2021, tags have reported in, and blood sample processing and data analysis are underway.

RECOMMENDATION

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-11, which described studies designed to improve our estimates of discard mortality rates in the directed Pacific halibut longline fishery.

Gear-based approaches to catch protection as a means for minimizing whale depredation in longline fisheries

PREPARED BY: IPHC SECRETARIAT (C. DYKSTRA, 25 OCTOBER 2021)

PURPOSE

To provide the RAB with a description of an ongoing study designed to identify and test new tools to minimize marine mammal depredation of hook captured Pacific halibut.

BACKGROUND

Removal of captured fish from fishing gear (known as depredation) is a growing problem among many hook-and-line fisheries worldwide. In the north Pacific Ocean, both Killer (*Orcinus orca*) and Sperm (*Physeter macrocephalus*) whales are involved in depredation behavior in Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*), and Greenland turbot (*Reinhardtius hippoglossooides*) longline fisheries. In 2011 and 2012, fisheries observers estimated that 21.4% of sablefish sets, 9.9% of Greenland turbot sets, and 6.9% of Pacific halibut sets were affected by whale depredation in the Bering Sea (Peterson et al. 2014). Reductions in catch per unit effort (CPUE) when whales were present ranged across geographic regions from 55%-69% for sablefish, 54%-67% for Greenland turbot, and 15-57% for Pacific halibut (Peterson et al., 2014). These impacts also incur significant time, fuel, and personnel costs to fishing operations. From a fisheries management perspective, depredation creates an additional and highly uncertain source of mortality, loss of data (e.g. compromised survey activity), and reduces fishery efficiency. Stock assessments of both Pacific halibut and sablefish have adjusted their analysis of fishery-independent data to account for the effects of whale depredation on catch rates. In the sablefish assessment, fishery limits are also adjusted downward to reflect expected depredation during the commercial fishery. In recent years, whale depredation has been limiting fishers' ability to harvest their Greenland turbot allocations and they have been well below (35-78% in the last 5 years) the total allowable catch for that fishery. Meanwhile, potential risks to the whales include physical injury due to being near vessels and gear, disruption of social structure and developing an artificial reliance on food items that can be affected by fishery dynamics.

Many efforts have been made over the years to mitigate this problem, with fishers generally limited to simple methods that can be constructed, deployed, or enacted without significantly disrupting normal fishing operations, or without violating gear regulations. Existing approaches include catch protection, physical and auditory deterrents, and spatial or temporal avoidance. These approaches have had variable degrees of success and ease of adoption in each fishery but none have solved the problem. Terminal gear modification and catch protection have been identified as an avenue with the highest likelihood of 'breaking the reward cycle' in depredation behaviors.

Pacific halibut and Greenland turbot are prohibited in trawl fisheries, are difficult to capture efficiently in pots, and therefore new approaches to protection of longline catch are necessary.

This project focuses on investigating strategies aimed at protecting longline-caught fish, through low cost, easy to adopt gear modifications. Recent developments in physical catch protection methods include: development of underwater shuttles that unhook and transport catch to the surface (e.g. Patagonian toothfish: Sago Solutions), light and expandable spring coils (e.g., the underlying mechanism of ‘slinky’ pots used in the Alaska sablefish fishery: Cod Coil), and triggerable spokes or mesh panels attached to the gear to obscure catches of tuna (Paradep). Some of these approaches may have elements that are suitable to be adapted for the protection of longline captured Pacific halibut.

Discussion

This project will be structured in two parts. First, in early 2022 we will conduct a virtual workshop with industry (affected fishers, gear researchers, scientists) to identify methods to protect fishery catches from depredation. Participants have been identified to highlight their work on underwater shuttles, expandable coils, and “umbrella like” shrouding devices. Each research group will outline what their product is, it’s mode of action, method of interaction with the gear, functionality, costs (catch rates, money, time, safety, storage), modifications to consider, critical considerations, and ease of modification for flatfish fisheries. Brainstorming exercises will be used to fully develop these ideas and come up with designs for initial trials. Secondly, the top two or three catch protection design outcomes from the workshop will be incorporated into functional prototypes and field-tested in longline sea trials targeting flatfish in the summer of 2022.

Recommendation

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-12, which described studies designed to investigate whale depredation mitigation strategies through catch-protection in longline fisheries.

Population genomics

PREPARED BY: IPHC SECRETARIAT (A. JASONOWICZ & J. PLANAS, 25 OCTOBER 2021)

PURPOSE

To provide the RAB with a description of the studies conducted by IPHC Secretariat on population genomics.

BACKGROUND

Understanding population structure is imperative for sound management and conservation of natural resources. Pacific halibut in US and Canadian waters are managed as a single, panmictic population on the basis of tagging studies and historical (pre-2010) analyses of genetic population structure that failed to demonstrate significant differentiation in the eastern Pacific. However, two studies published within this decade have reported significant genetic population structure suggesting that Pacific halibut residing in the Aleutian Islands may be genetically distinct from other regions. Recent advances in genomic technology now enable researchers to examine entire genomes at unprecedented resolution. While genetic techniques previously employed in fisheries management have generally used a small number of markers (~10-100), whole-genome scale approaches can now be conducted with lower cost and provide orders of magnitude more data (millions of markers). By studying the genomic structure of spawning populations, genetic signatures of geographic origin can be established and, consequently, could be used to identify the geographic origin of individual Pacific halibut and, therefore, inform on the movement and distribution of Pacific halibut.

DISCUSSION

The main purpose of the present study on population genomics is to conduct an analysis of Pacific halibut population structure in IPHC Convention waters using genomic techniques. Recent studies have reported significant genetic population structure that suggest Pacific halibut residing in the Aleutian Islands may be genetically distinct from other regions. In particular, differentiation of the population on either side of Amchitka Pass was indicated, suggesting a possible basis for separating IPHC Regulatory Area 4B into two management subareas. However, these results were confounded by (1) the use of a small number of genetic markers and (2) the use of samples collected outside of the spawning season (i.e. winter) in some areas. In particular, previous analyses employed summer-collected (i.e., non-spawning season) samples west of Amchitka Pass which may not be representative of the local spawning population, but rather a mixture of spawning groups on the feeding grounds. Therefore, it is advisable to re-assess those conclusions using samples collected during the spawning season and modern, high-resolution genomic techniques.

In January and February of 2020, the IPHC Secretariat conducted sample collections on either side of Amchitka Pass (IPHC Regulatory Area 4B) during the spawning season to address the limitations of previous studies. These samples, in combination with previous samples collected during the spawning season (i.e. Bering Sea, Central Gulf of Alaska and waters off British Columbia) (Figure 1) will be used to re-evaluate stock structure of Pacific halibut in IPHC Convention waters. The temporal replicates at many of these locations will enable the IPHC

Secretariat to evaluate the stability of genetic structure over time, ensuring confidence in the results. Given that the IPHC Secretariat completed the sequencing of the Pacific halibut genome in 2020, low-coverage whole-genome resequencing (lcWGR) will be used to obtain genomic sequences from 600 Pacific halibut (50 per collection). lcWGR offers a cost-effective way to develop a large number (~millions) of single nucleotide polymorphisms (SNPs) that can be used as genetic markers to evaluate population structure, identify potentially adaptive regions of the genome, and used in other management applications. For example, a panel of SNPs could be developed to estimate the contribution of different spawning groups to a mixed sample or identify the geographic origin of individual Pacific halibut.

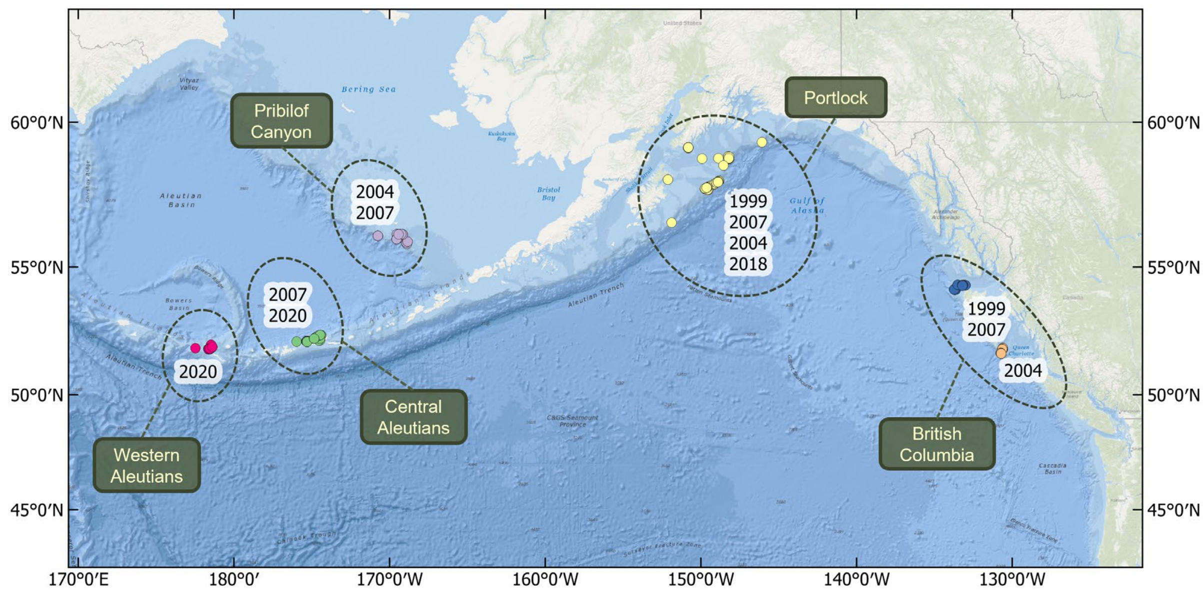


Figure 1. Map of sample collections made during the spawning season used for genomic analysis of population structure in Pacific halibut in the northeast Pacific Ocean.

RECOMMENDATION

That the RAB:

1) **NOTE** paper IPHC-2021-RAB022-13, which outlined the studies on population genomics by the IPHC Secretariat.